Tufts University

Cummings School of Veterinary Medicine

Wind Turbine Feasibility Study

Power Engineers, LLC

Boreal Renewable Energy Development

Saratoga Associates

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0 Executive Summary

This study analyzes the feasibility of installing a single utility scale wind turbine at the Tufts University Cummings School of Veterinary Medicine (hereafter referred to as Cummings School). The results of the investigation determined that wind energy can provide the Cummings School with noteworthy economic and environmental benefits to their operations.

Significant findings regarding the project's feasibility are listed below:

Site Layout

- The 594 acre site is located in a thinly populated semi-rural area, and appears to have sufficient buffer to site a wind turbine.
- The Cummings School property falls in both the towns of Grafton and Westborough. The primary turbine site would be located in Grafton.
- There is sufficient space for turbine laydown and erection, though some tree removal may be necessary depending on location. Property line and fall zone issues will require civil engineering review before a final turbine location is determined.

Wind Resources

- Three months of wind resource data were logged by a Triton Sonic Wind Profiler manufactured by Second Wind Inc.
- For the August 5, 2009 through November 19, 2009 time period, wind speeds at the Tufts Triton averaged 5.16 meters/second (m/s) at 80m.
    - These wind data were leveraged to the Cummings School site through the utilization of long-term weather station data from the Worcester Regional Airport. Being 10 miles away from the Cummings School, Worcester data offer an acceptable, however imperfect, correlation for long-term forecasting.
    - The estimated long-term average wind speed at 60m is 6.25 m/s. This is 0.25 m/s faster than predicted by publicly-available meso-scale wind maps.

Environmental Resource Assessment

- Sensitive habitat exists within the vicinity of the Tufts project. Because the turbine is not within the habitat, such a designation should not cause major issues to the project. Further communication with state and federal wildlife officials is suggested.
- State GIS resources indicate a small stream near the primary turbine location. Further wetland research is warranted.
- Tufts must engage relevant regulatory officers and stakeholders to address the permitting issues that would permit installation of a wind turbine of the recommended size.

Engineering and Interconnection Requirements

- A standard spread foundation design will most likely be feasible. Further subsurface exploration will be required to finalize the design of the foundation.
- Electrical interconnection plans were developed for a turbine up to 1.5 MW (1,500kW), although the interconnection would be similar for all turbines in the range of 100-1500kW.
- The final configuration of the wind turbine generator interconnection facilities will be determined on the basis of the National Grid generator interconnection application and system impact study process.

Permitting

- The Town of Grafton currently has a 70 foot (21.3 meter) limit on wind turbine height
    - All turbines analyzed in this study far exceed this limit, as acceptable wind speeds will occur in the 50-80 meter range.
    - A special permit from the Town will be required if the turbine is to comply with local regulations.
- The Town of Westborough does not explicitly mention wind turbines in its bylaws
- Wetlands and wildlife issues need to be further addressed at the state and/or federal level.

- All other applicable state and federal permits are expected to be obtainable for the project.

Economic Feasibility Analysis

- The Cummings School consumes approximately 8,400,000 kWh / year, and spent roughly $1,000,000 between September 2007 and September 2008 on the kWh portion of their electric bill.
- Recent State net metering legislation is being put into place that will allow excess turbine generation to be credited to the Cummings School account even if it is not used simultaneously onsite
- We recommend the installation of a 1.5 MW turbine. Based on estimated cost figures, the Fuhrländer FL 1500 turbine demonstrates the best economic payback of the turbines in this range.
- A FL 1500 turbine would produce an estimated 3,100,000 kWh per year (a 23.5% net capacity factor).
- The estimated installed project cost of a Fuhrländer FL 1500 is $4,400,000.
- It is estimated that the installation of a Fuhrländer FL 1500 will have a net present value of 2,500,000 over the 20 year project life with the installation becoming cash flow positive in 10.5 years.
- Table 0-1 provides summary results for various turbine configurations that may be considered by the Cummings School. The results assume that the Cummings School receives the maximum Design & Construction grant from the Massachusetts Renewable Energy Trust (MRET) but is capped at $380,000 for wind turbines 600 kW and larger.

Table 0-1
Financial Results for Various Turbine Installations Assuming Maximum MTC Grant

Turbine Configuration	NPV-10 Years	NPV-20 Years	IRR-10 Years	IRR-20 Years	Years to Cash Flow Positive
Norwin 29 225[1]	($521,994)	($386,021)	N/A	N/A	N/A

[1] All turbines assume a 20 year installation lifetime. The N/A values for the Norwin 29 225 signify that turbine costs will not have been recovered at the 20 year point of the project.

Turbine Configuration	NPV-10 Years	NPV-20 Years	IRR-10 Years	IRR-20 Years	Years to Cash Flow Positive
Elecon 600	($746,670)	($61,838)	-11%	4%	15.8
Directwind 900	($573,563)	$889,495	-2%	10%	11.9
FL 1500/77	($511,241)	$2,523,291	1%	12%	10.5

1 Site Evaluation

1.1 Background

The Cummings School of Veterinary Medicine is one of eight schools that make up Tufts University. In addition to a handful of collaborative and multidisciplinary degrees, the school is the only institution in New England to offer a Doctorate in Veterinary Medicine.

The Cummings School is located in the towns of Grafton and Westborough, MA on a campus that is comprised of approximately 594 acres. It has a student population of 340 and includes a large and small animal hospital, as well as research facilities, administrative buildings, and livestock and food operations. The hospitals treat over 28,000 animals annually.

1.2 Geography

1.2.1 Campus

The Cummings School campus houses more than 40 building on its campus defined by gentle rolling pastures and forested hills. Campus buildings are largely clustered to the south of Route 30, mostly sited between Wildlife Drive (a campus owned road) and Willard Street on the west and east respectively. Figure 1-1 shows the campus layout and proposed turbine location. Campus greenspace extends eastward along the Route 30 into Westborough. This is denoted by the large green lawn to the north of the turbine location in Figure 1-1. To the south and east of its buildings and lawns, the campus becomes forest; to the south of the campus is primarily low-density residential properties.

Figure 1-1
Aerial View of the Cummings School

In all, Tufts owns a handful of large parcels that offer ample space for wind turbine development. A map that includes many campus building locations and names is included as Appendix A.

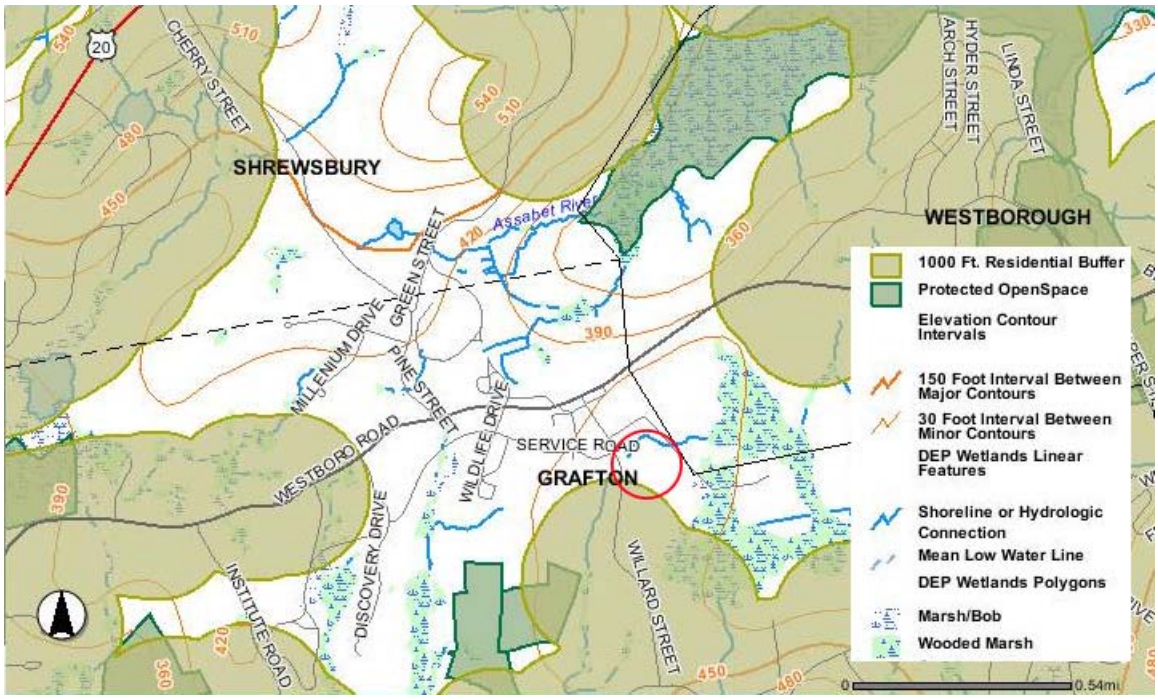
1.2.2 Vicinity

Immediate abutters to the Cummings School are MBTA tracks to the north, Commonwealth of Massachusetts Department of Capital Asset Management to the west and residential properties to the south and east. Other notable parcels in the vicinity are Grafton Job Corporation Center to the north of the MBTA tracks, Centech Park to the northwest, and the Willard House and Clock Museum about 0.5 miles to the south. These are all buffered significantly by the large cumulative size of Tufts' parcels.

North Grafton is marked by a variety of land uses. Grafton's central business district lies 2.8 miles to the south of the Cummings School campus while downtown Westborough is located 3.3 miles to the northeast.

As shown in Figure 1-2, a Cummings School wind turbine has more than 1,000 feet of separation from all nearby residences. Furthermore, the only nearby residences are in low-density developments and are concentrated along Willard Street.

Figure 1-2
Cummings School Vicinity



1.2.3 Potential Site Constraints

1.2.3.1 *Telecommunications*

Most radio, microwave and TV signals are unaffected by the operation of wind turbines. However, in some instances, AM radio signals can be impacted. Microwave signals also can be blocked by the wind turbine if it is in a direct line between a transmitter and receiver.

A review of all communication devices within a three mile radius of the turbine site was conducted via the Federal Communications Commission (FCC) web database. A handful of omni-directional communication facilities exist within 5 miles of the project location, the closest of which (off-campus) is a cellular tower 1.9 miles west-northwest of

the Cummings School on Route 140 in Shrewsbury. The next closest towers are 2.3 miles to the southeast and 2.5 miles to the southwest.[2]

Given the separation from these towers and the lack of particularly sensitive telecommunication nodes in the area, a wind turbine should not have an adverse impact on communications networks in the area, including the on-campus cell tower.

1.2.3.2 *Aviation*

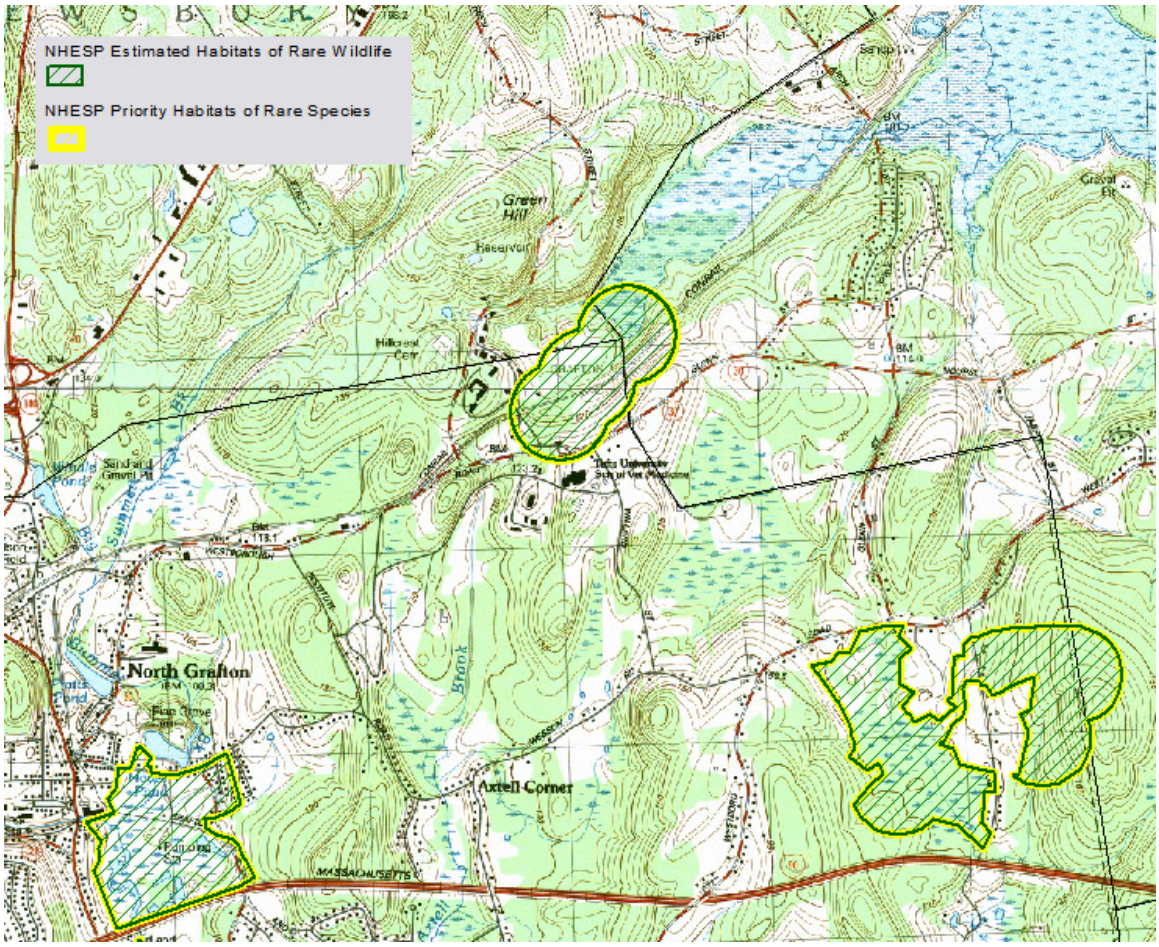
There are no airports within 10 miles of the Cummings School campus. Consequently, a turbine of any commercially-available size should receive FAA approval.

1.2.3.3 *Wildlife*

Significant wildlife resources are present in the vicinity of the project site. Figure 1-3 shows state-listed important habitats located on the campus, though largely north of Route 30. The Massachusetts Natural Heritage and Endangered Species Program (NHESP) has designated these estimated areas as habitats of rare wildlife and species. The Project Team recommends contacting the NHESP for more information on the species present in the vicinity of the proposed turbine site.

[2] There is an on campus cell tower of approximately 100' in height. It is unclear what impact a wind turbine would have on this tower. It is recommended a more in-depth study of potential impacts be conducted during the early design stage.

Figure 1-3
Wildlife Resources in the Vicinity of the Cummings School



1.2.4 Turbine Siting

The Project Team conducted a site assessment and received input from Cummings School community members to identify potential turbine locations. The School has many open fields that are used for animal grazing and haying, and other farming operations. These activities would be temporarily interrupted by a wind turbine installation. The turbine would be sited well away from academic and clinical facilities. Among our specific considerations were the following:

1.2.4.1 *Physical*

1. Sufficient real estate for staging, construction, fall zone and buffer?

{The campus has suitable land resources in multiple locations. The fall zone of the preliminary recommended turbine location extends beyond Willard Street and into Westborough.}

2. Accessibility – Can equipment be transported to the site?

   {Route 30 provides good access to the campus. Civil engineering during the detailed design phase will confirm transportation logistics.}

3. Does not interfere with the existing operations.

   {Delivery can be scheduled not to interfere with operations. Construction can be scheduled in order to not interfere with campus operations.}

1.2.4.2 *Operational*

1. Electrical engineering feasibility and interconnection issues (minimize wiring runs where possible).

   {Interconnection of a utility scale wind turbine is technically feasible. See Section 1.4.4 for full analysis. The site chosen is nearby the campus connection to the Tufts-owned 13.8kV distribution, which is connected to National Grid distribution lines}

2. Review of wind speed data, electrical usage.

   {There is adequate load at the Cummings School, and a fair wind resource is present. Details on wind resources is provided in Section 1.3}

3. Modeling run of financial pro-forma with multiple turbine configurations providing first estimate of economic feasibility.

   {A wind turbine provides substantial economic returns. It will be up to the University to determine if such returns are sufficient.}

1.2.4.3 *Community*

1. Compliance with local zoning regulations.

   {Permitting for the chosen location is achievable, but will require amendments to both the master plan and local zoning by-law. The Project Team recommends consultation with local legal counsel, Town of Grafton Planner, Planning Board and other civic leader, based on previously submitted Campus Master Plans.}

2. Significant buffer from nearest property line to assure Massachusetts noise policy can be met.

   {Turbine-based noise will not significantly impact nearby residences.}

3. Aesthetic impacts.

   {The wind turbine may have an impact on the nearby viewshed. However, it should not be visible from most locations in Grafton or Westborough because of topography and vegetation.}

1.2.5 Photo Simulation

The following are scaled depictions of turbine visual impact generated by Saratoga Associates through the use of sophisticated simulation software. Base photographs (see Figure 1-5, Figure 1-7, Figure 1-9, Figure 1-11, and Figure 1-13) accompanying site data were supplied to Saratoga Associates by Boreal as recommended by Cummings School representatives.

Photo renderings were developed by superimposing a rendering of a three-dimensional computer model of the proposed project into the base photograph taken from each corresponding location. The three-dimensional computer model, covering the regional terrain within the project area, were developed in AutoDesk Civil 3D 2009 and Autodesk® 3ds Max Design® 2009 (MAX) software.

Simulated perspectives were matched to the corresponding base photograph for each simulated view by matching the precise X, Y and Z coordinates of the field camera position (as recorded by GPS) and the focal length of the camera lens used. The camera's target position was established by aligning common elements visible in both the digital model and actual photograph (e.g., cell tower within view).

The proposed condition model was rendered at the same output size/digital resolution as the base photograph, and using the base photograph as a background environment map. The 3D model was rendered using sunlight settings matching the date and time of day the base photograph was taken. To the extent practicable, design details (e.g., precise dimension and form of the selected wind turbine, color, etc.) of the proposed turbine was built into the 3D model and incorporated into the rendering. Consequently, the scale, alignment, elevations and location of the visible elements of the proposed facilities are true to the proposed design. The rendered view was then superimposed

into a digital version of the base photograph using Adobe Photoshop CS2® software for post-production editing.

Potential visibility is dependent on final location and actual size of the proposed turbine. A 1.5 MW Fuhrländer FL 1500 is illustrated in Figure 1-6, Figure 1-8, Figure 1-10, Figure 1-12, and Figure 1-14 with a 77m rotor diameter atop an 80m tower. Despite prevailing southwesterly winds, turbine blades are, at times, rotated towards the viewer in order to illustrate full rotor breadth. The wind turbine is at least partially visible from all the locations, except for the simulation from the MBTA station, where high trees obstructed the view. A partial view of the wind turbine likely could be made from alternative locations at the station.

Figure 1-4
Map of Photo Simulation Sites

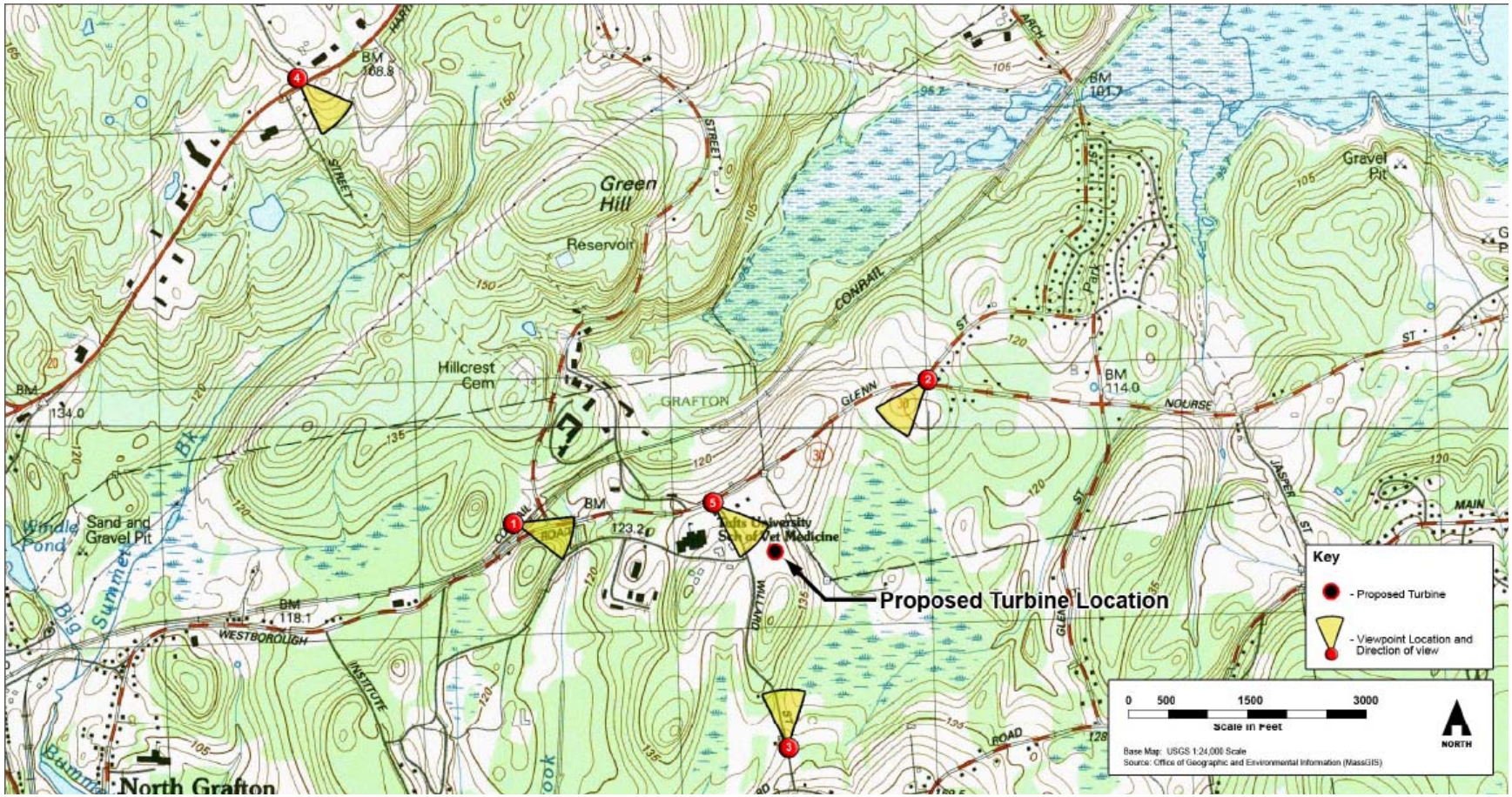


Figure 1-5
Photo Simulation from Site #1 – Existing View from Grafton MBTA Station

Figure 1-6
Photo Simulation from Site #1 – FL 1500 from Grafton MBTA Station

Figure 1-7
Photo Simulation from Site #2 – Existing View from Route 30 and Glen Street

Figure 1-8
Photo Simulation from Site #2 – FL 1500 from Route 30 and Glen Street

Figure 1-9
Photo Simulation from Site #3 – Existing View from Willard House

Figure 1-10
Photo Simulation from Site #3 – FL 1500 Turbine from Willard House

Figure 1-11
Photo Simulation from Site #4 – Existing View from Route 20 and Cherry Street

Figure 1-12
Photo Simulation from Site #4 – FL 1500 Turbine from Route 20 and Cherry Street

Figure 1-13
Photo Simulation from Site #5 – Existing View from School Entrance

Figure 1-14
Photo Simulation from Site #5 – FL 1500 Turbine from School Entrance

1.3 Wind Resource Assessment

At the study's onset, it was assumed that the Cummings School site possessed marginal wind resources - an average of 6.0 meters/second (m/s) at a 70 meter hub height. These data were derived from the publically-available meso-scale New England Wind Map compiled by AWS Truewind, a leader in the field. Values were accessed through MassGIS' reproduction of the Truewind maps on the MassGIS Wind Energy Site Screening Tool.

1.3.1 Data Acquisition

The project team's original intent was to gather meteorological data through the installation of a meteorological tower (met tower) at the Cummings School. Permitting of a 50m met tower in Grafton and Westborough, however, was deemed prohibitive due to a potentially problematic permitting path.

Instead of installing a meteorological tower, Tufts elected to conduct a three-month Sodar study on-site. A Triton sonic wind profiler was installed by Second Wind Inc. (SWI) on August 5, 2009 and recorded wind speed and direction values at heights of up to 200m through November 19, 2009.

1.3.2 Wind Direction Assessment

With prevailing southwesterly winds in the New England region, it was expected, going into this study, that the Cummings School wind resources would be coming from somewhere in the western hemicircle. This being said, however, measurements were only made by the Triton during summer and autumn months. Figure 1-15 depicts the percentage of time wind was blowing from each 30° interval of the compass for the months sampled at the site.

Figure 1-15 Wind Direction

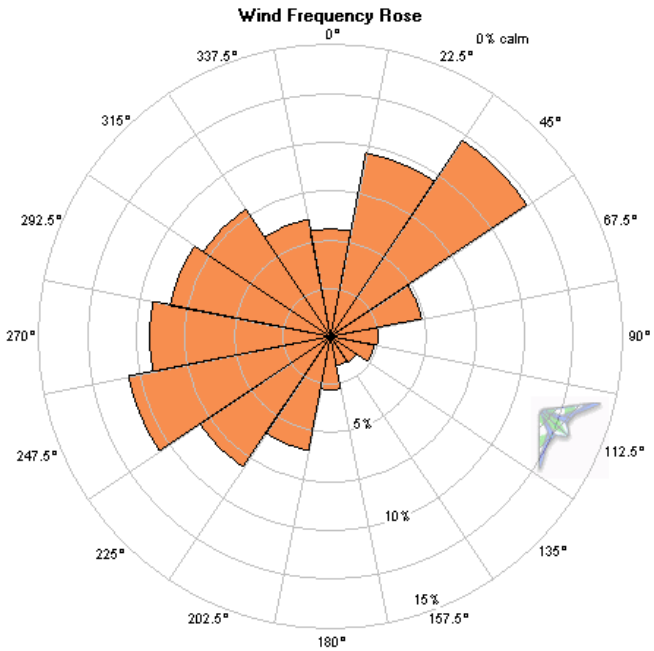
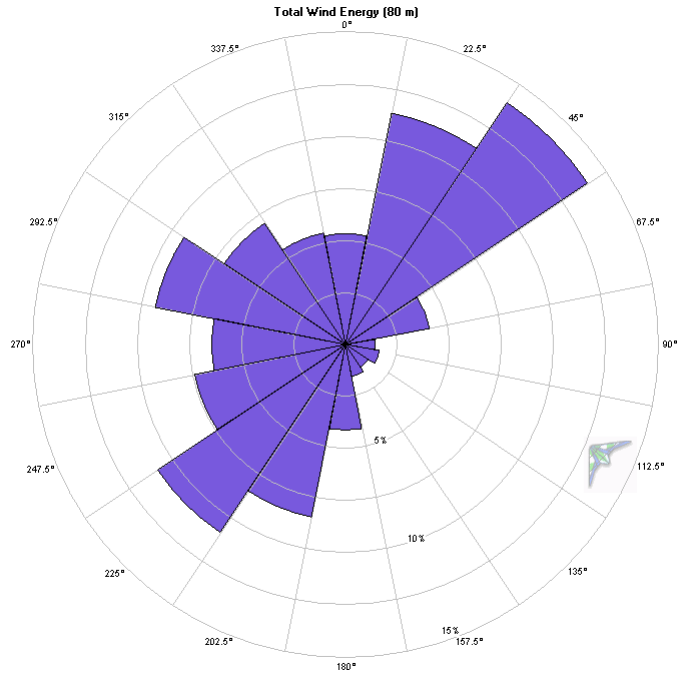


Figure 1-16 Power Density



While Figure 1-15 displays only the time share of wind for each direction interval, Figure 1-16 combines wind direction and wind speed to show what is known as directional "power density". In our database, each ten-minute interval within the sampled period has an associated wind speed and direction. Each of these intervals can be sorted by direction much like in Figure 1-15. As power density is a direct function of wind speed[3], each ten-minute period has an associated average density. These can therefore be summed within a particular interval to display that interval's power density. Specifically, for a degree interval $[A, B]$, its percentage of the overall power density is

$$\frac{\sum_{A}^{B} P_h}{\sum_{0}^{360} P_h}$$

Where P_h is the power density averaged over an hour time interval.

[3] Power density is defined as Power/Swept Area and is equal to $1/2\,\rho V^3$ where ρ is air density and V is velocity.

1.3.3 Wind Speed Assessment

As with most locations in the northeastern United States, Central Massachusetts' wind speeds vary seasonally, reaching their peak during the winter months. Table 1-1 displays wind speed averages for the months sampled.

Table 1-1
Monthly Wind Speed Averages for Duration of Sodar Study[4]

Month	40m Elevation	50m Elevation	60m Elevation	80m Elevation	100m Elevation[5]
August[6]	3.41	3.72	4.00	4.55	5.05
September	3.82	4.17	4.51	5.10	5.66
October	4.29	4.64	4.96	5.53	6.01
November[7]	4.40	4.74	5.02	5.55	5.98
Grand Total	3.95	4.29	4.60	5.16	5.66

1.3.3.1 *Correlation*

Based on the recorded data, in order to predict the long-term wind resources available at the School, wind speeds recorded over the observed period were adjusted using the Worcester Regional Airport as a data source. The Tufts' data were first tested for statistical correlation with Worcester[8] wind speeds over the course of the recorded period. A graphical representation of the level of correlation between the two datasets is displayed in Figure 1-17 below.

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[4] These measurements result in a wind shear exponent of 0.423

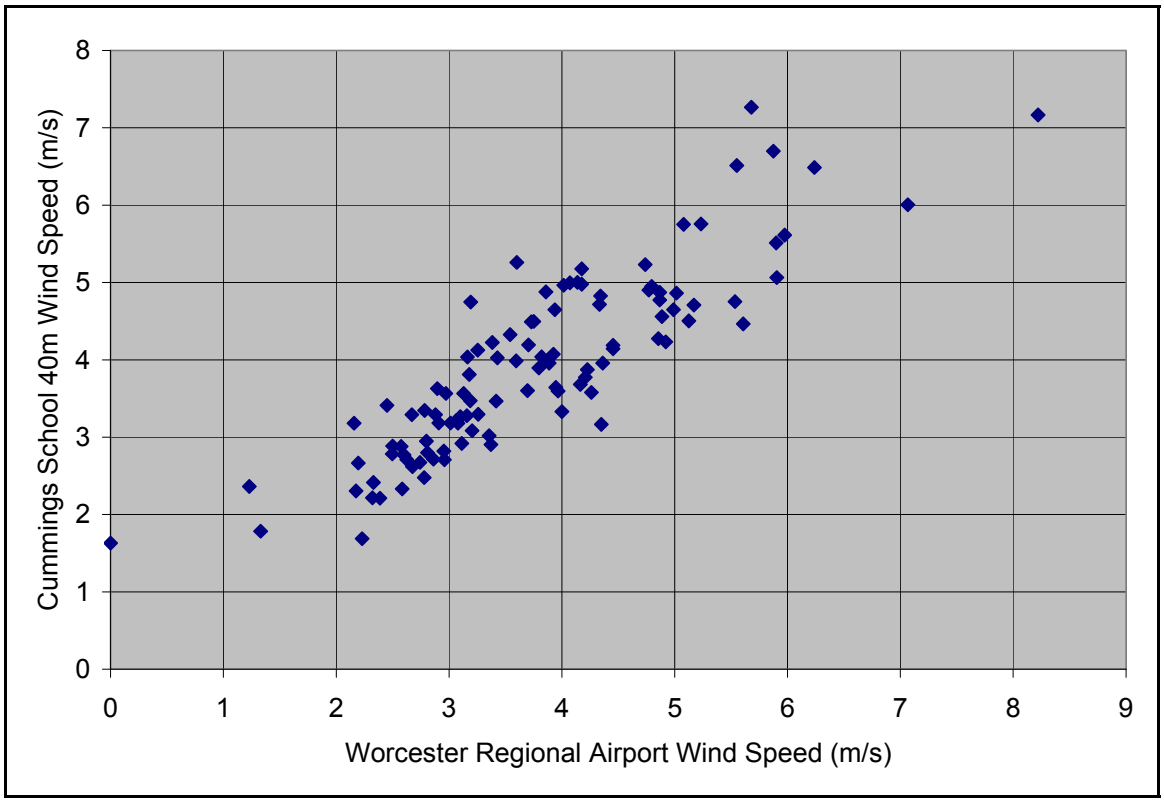
[5] Measurements were taken as high as 200 meters, but as no commercially available US wind turbine is currently available above 100 meters, thus this additional has not been included in the table.

[6] August 5th through 31st

[7] November 1st through 19th

[8] At 10.3 miles away, the Worcester Regional Airport is the only long-term data source in the vicinity of the Cummings School.

Figure 1-17
Daily Wind Speed Correlation



Worcester Regional Airport wind speed data are logged on an aviation tower[9] in the middle of their airfield and represent ground-level wind measurements. Due to this, there are inherent dissimilarities when compared to Sodar data which log at a minimum height of 40m. Understandably, the lowest Sodar elevation (40m elevation) correlates best with Worcester Airport data. Over the three months of logged data, the two recorded a 57.0% hourly[10] correlation and 87.6% daily correlation. These correlation levels are not particularly high for a wind project. Due to the unavailability of other long-

[9] Although the exact height of airport instrumentation is unknown, it is estimated at seven to ten meters in height. The height is not a crucial factor, as long as it consistent over the long-term weather data set.

[10] 10-minute data are not available from most long-term data sources, Worcester Regional Airport included

term data sources in the area,[11] Worcester data were deemed to be the best available option for completion of the Measure-Correlate-Predict assessment.

1.3.3.2 *Resource Estimation*

To be useful, Cummings School Sodar data must be adjusted for long-term weather patterns. The three month period sample represents only a short interval from which a comparison to historic trends could be made with further investment.

The following steps were taken to estimate wind resources for a typical year:

- Find the long-term weather station that is best correlated with the facility's data. Worcester Regional Airport was used for this purpose (see above).
- Align hourly Sodar data at the appropriate hub height (80m) with Worcester Regional Airport data. Calculate three month ratio of the two sites' average wind speeds (136.3%).
- Use this ratio and Worcester wind speeds from a single proxy year (2006) to develop an estimated average
- Scale the above results for 2006 to match the long-term average annual wind speed (a 1.3% decrease) at the airport.
    - This results in estimated annual average winds speeds of 6.25 m/s at 80 meters

In Table 1-2 we calculate the long-term annual average wind speed at 50 and 80 meters through the steps outlined above.

Table 1-2
Computation of Average Annual Wind Speed at Cummings School (m/s)

Parameter	Value	Computation
Tufts Wind Speed @ 80m (m/s)	5.16	(1) 9/5/09 to 11/19/09 @ 80m
Ratio of Tufts to Worcester	136.3%	(2)

[11] The only other long-term weather station within 15 miles of the project is the Oxford Municipal Airport. Data from Oxford were examined and deemed to be unusable based on missing values and coarseness of recordings.

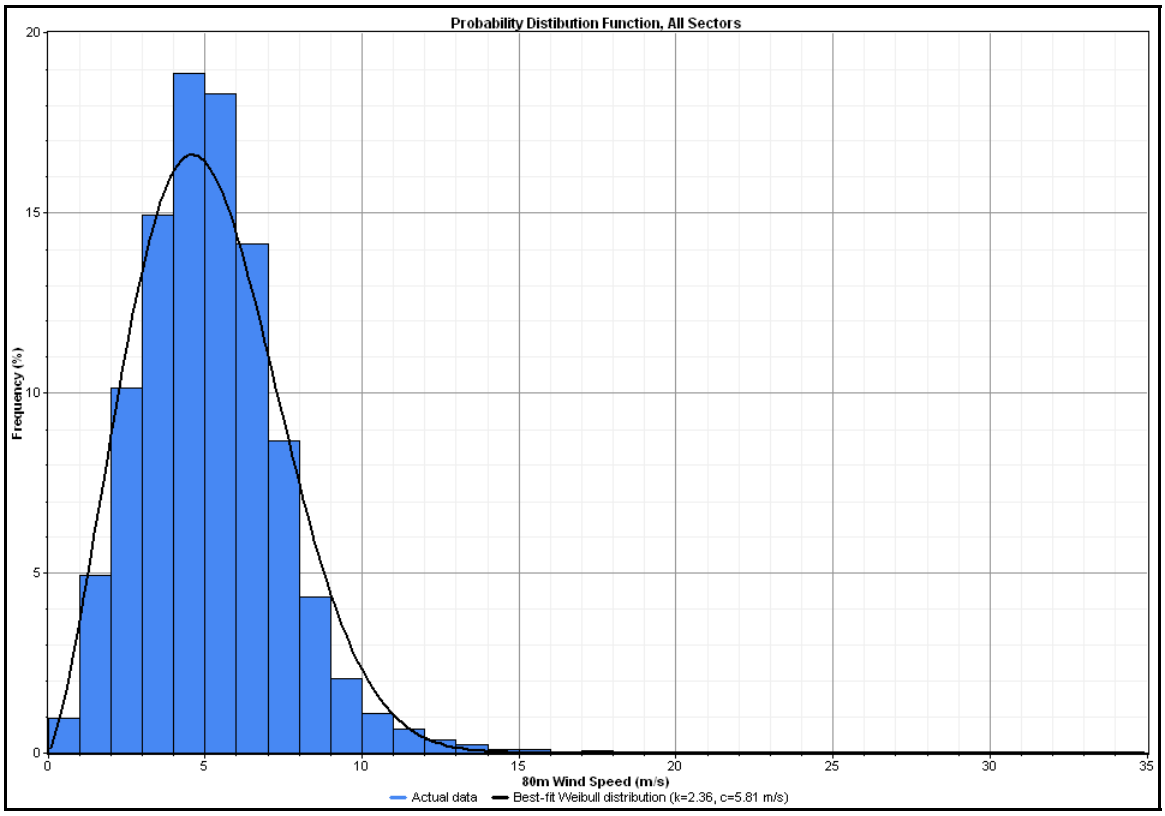
Parameter	Value	Computation
Worcester Wind Speed Proxy Year (m/s)	4.65	(3) 1/1/06 through 12/31/06
Est. of Tufts Avg Wind Speed - Proxy Year @ 80m (m/s)	6.33	(4 = 2*3)
Worcester Long-Term Average Annual Wind Speed[12] (m/s)	4.58	(5)
Ratio of Worcester Long-Term to Proxy Year	98.7%	(6=5/3)
Est. of Tufts Avg Wind Speed - Long Term @ 80m (m/s)	6.25	(7=4*6)

The estimated long-term wind average of 6.25 m/s will be assumed (along with other empirically-determined wind speed variables) for the energy production and financial analysis sections of this report. Sensitivity analysis on average wind speed is included in Section 2.6.

Associated with this average wind speed is a distribution of the wind resources over the spectrum of wind speeds observed by the Sodar unit. This distribution is displayed in Figure 1-18. This distribution is used for all energy generation (and subsequently financial performance) calculations later in the report.

[12] 25 years of wind speed data have been logged at Worcester Regional Airport. This time period is used for computation of the average wind speed of 4.58 m/s.

Figure 1-18
Distribution of Tufts Wind Speeds.



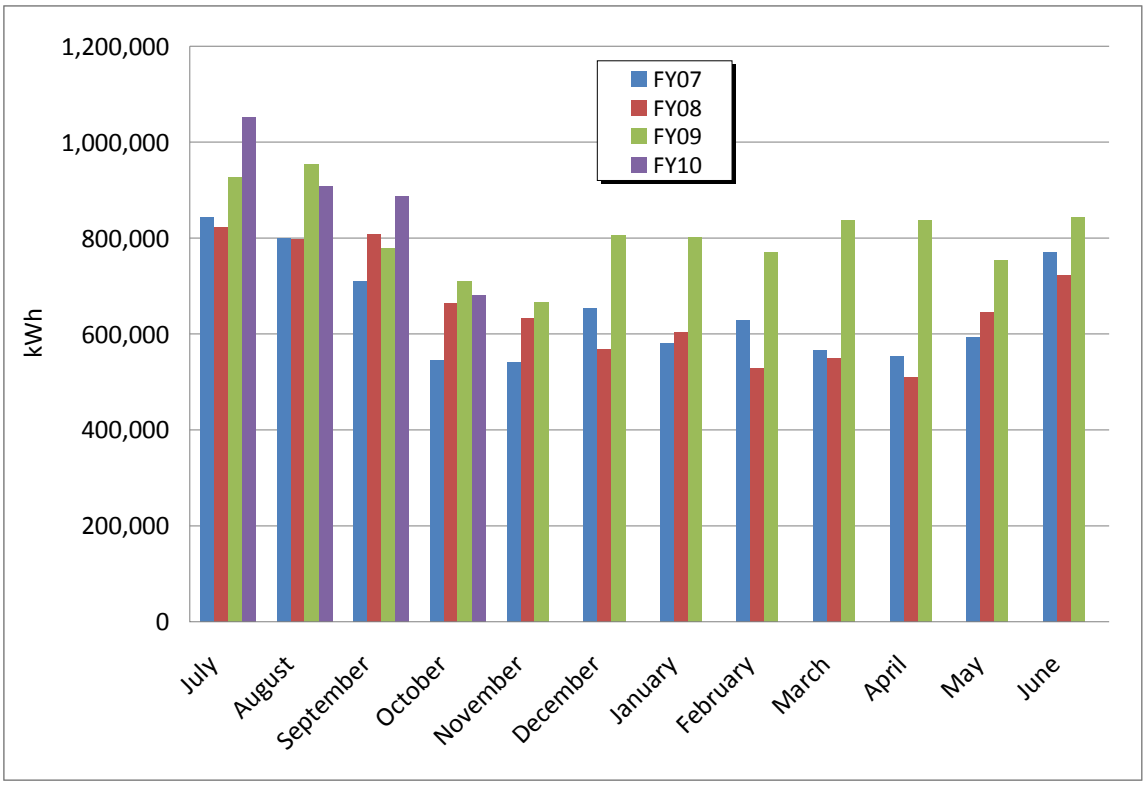
1.4 Engineering and Interconnection

1.4.1 Energy Infrastructure & Consumption

The Cummings School's campus currently receives its electricity competitively from TransCanada through National Grid's 13.8kV distribution system via a primary meter. Based on data compiled over the last four years, the Cummings School has averaged 8,440,000 kWh of energy consumption per year. Over the past 12 months, however, 9,840,000 kWh were used. A new building has recently come on-line, having some effect on the increase in kWh.

Figure 1-19 shows consumption levels for the Cummings School by fiscal year, demonstrating the increase in usage that began taking place in the latter half of the 2008 calendar year. With an average 15-minute demand of just above 1,100 kW over the last 12 months, the Cummings School will be able to consume the vast majority of a turbine's production.

Figure 1-19
Cummings School Monthly Electric Consumption (kWh)



Turbine generation in excess of Cummings School's load has the potential to be credited to other accounts within the same service territory (National Grid) and ISO[13] New England load zone[14] through the recently-enacted Green Communities Act (see Section 2.2.2 for full details).

1.4.2 From Wind to Electricity

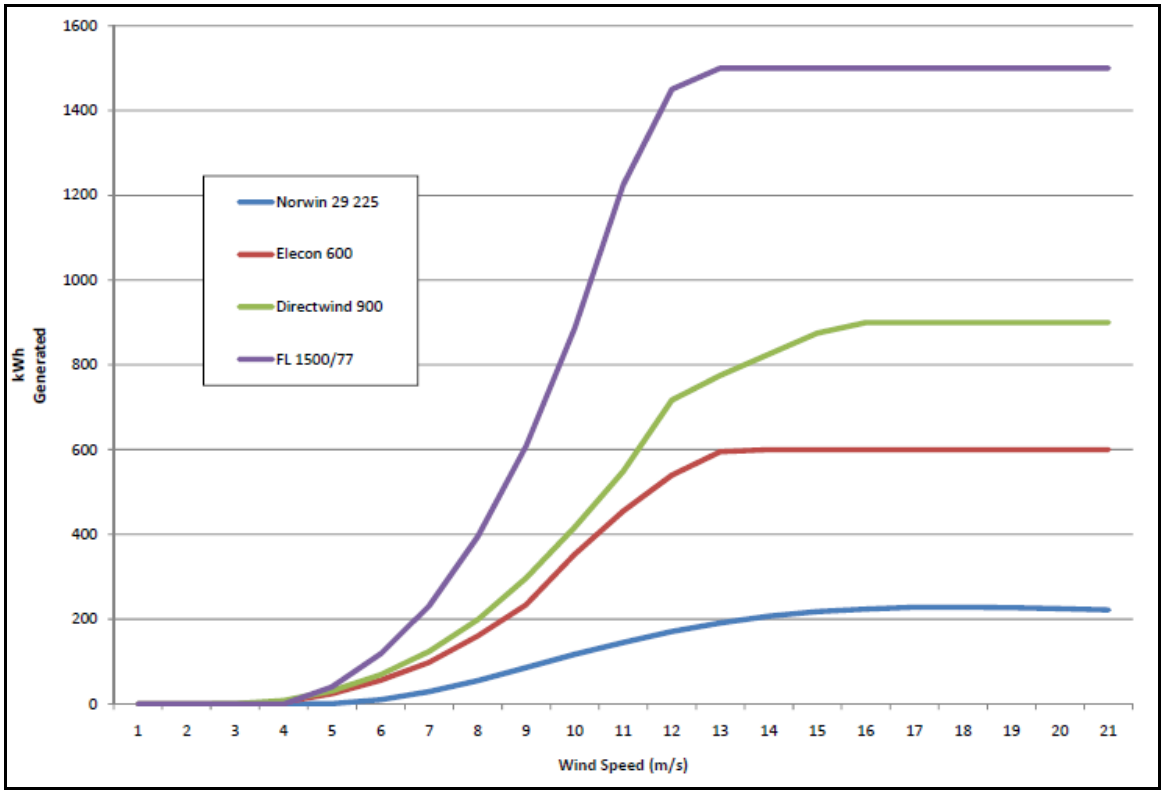
The amount of electricity produced by a specific wind turbine is primarily a function of the wind speed at the hub of the turbine. A key variable of this function is the height of the turbine tower, as wind speeds are almost invariably greater at higher elevations.

Figure 1-20 below shows some examples of turbine power curves for energy generation based on certain wind speeds.

[13] The Independent Service Operator - coordinates controls and monitors the operation of the electrical power system.

[14] The Cummings School in North Grafton is located within the West Central Massachusetts ISO NE load zone. Interestingly part of Grafton is located in the Northeast Mass Load Zone.

Figure 1-20
Example Power Curves



The net capacity factor listed in Table 1-3 is the estimated electricity produced as a percentage of the turbine at full capacity over a static period of time – a standard measurement of how effective a turbine installation is. Capacity factors between 20% and 30% are considered good for Massachusetts.

Table 1-3
Comparison of Estimated Annual Energy Production for Various Turbines

Name	Nominal kW	Net Capacity Factor	kWh of Electricity Generated by Turbine	% Total Campus kWh Consumption Generated by Turbine
Elecon 600	600	14.3%	752,373	8.9%
Norwin_46-ASR-750	750	15.1%	991,740	11.8%
Directwind 900	900	18.7%	1,472,754	17.4%
FL 1500/77	1500	23.5%	3,088,572	36.6%

1.4.3 Staging / Erection/Construction

The Cummings School is well connected to roadways in the region. Transportation of the wind turbine blades, tower sections, and nacelle to the site should not be an issue.

Construction activities can be scheduled so that the foundation and wiring runs will be built prior to the turbine's arrival. The construction of the foundation and wiring runs is estimated to take approximately two months. Turbine and tower installation, including crane set-up and break down, is expected to take approximately three weeks depending on weather (windy conditions can extend construction schedules). Construction will be arranged as to not interfere with school operations

The project team estimates permitting and construction can be completed within 18-21 months after project acquires applicable permits and approvals.

1.4.4 Electrical Engineering and Interconnection Requirements

1.4.4.1 *Existing Electrical Infrastructure*

The campus is currently supplied power from an overhead 13.8kV National Grid distribution circuit, located on Route 30 (Westborough Road) in North Grafton, MA. Presently there is a three-phase tap from Westborough Road to Willard Road. Approximately 850-feet south down Willard Road, there is a primary tap off of the overhead National Grid system to the Tufts underground primary system. An overhead primary metering pole exists at this location, prior to the underground riser. The underground primary cable goes through the first electric manhole (designated EMH#1) and then into a padmounted sectionalizing cabinet. From this point the primary cable continues both west to supply the core campus buildings, and east to supply the Bernice Barbour Wildlife Medicine Building and other facilities east of Willard Street.

1.4.4.2 *Electrical Interconnection Plan*

A number of alternatives have been considered for the interconnection of wind turbines ranging from 600kW to 1,500kW (1.5MW). Regardless of proposed turbine size, there is one probable interconnection option that would allow the new turbine to connect to the existing primary distribution system at its closest point, which would be the most economical.

The proposed interconnection is illustrated in attached Plan E-1, the one-line diagram in Appendix B. A 1,500kW wind turbine is shown, but the connection would be similar for any turbine between 600kW-1,500kW.

The wind turbine generator would operate in parallel with the National Grid Electric 13,800V distribution system. This option would require a connection to the closest existing primary point on the Tufts Grafton electrical 13.8kV distribution system, which is the padmount transformer behind the Bernice Barbour Wildlife Medicine Building. This location is northwest of the proposed turbine location, and the capacity of the existing infrastructure can support the proposed turbine output power, based on no larger than a 1500kW single turbine being considered. The proposed wind turbine location is approximately 425 feet to the southeast of the existing padmount transformer and Wildlife Building. It is the most economical to connect with primary class (13.8kV) given this distance, instead of trying to made a low-voltage (480V) connection to the electrical infrastructure present in the existing facility.

Electrical power that is produced by the wind turbine generator that is in excess of the Tufts Grafton's electrical load would flow back into the National Grid Electric distribution system.

The wind turbine generators each operate at a 600 volt class generating voltage so the interconnection facilities for all options must include a generator step-up transformer to convert the generator voltage to 13.8kV. The generator step-up transformer will have a 2000kVA power rating consistent with the generator power rating of the maximum size 1500kW and 0.9 power factor. If a smaller 600kW or 660kW turbine is chosen, then a 750kVA step-up transformer could be installed.

A 13.8kV underground cable circuit will connect the primary of the generator step up transformer to facilitate the distribution of the wind turbine generator output to the point of interconnection (existing padmount transformer).

For a generator rated up to 1500 kW, the current carrying requirement of the 13.8kV power cable circuit will be less than 100 amperes and can be accommodated by three, single conductor, 15kV class, #1 AWG, aluminum cables. New 15kV class cables should be installed in an underground conduit for physical protection rather than being directly buried.

The Project Team anticipates that National Grid Electric will require the installation of utility grade relaying be installed at the turbine location. The turbines main low-voltage circuit breaker will be capable of normal switching and fault current interruption. The new protective relaying is typically required by National Grid Electric for interconnection or parallel generation to their distribution system. The protective relays sense abnormal circuit conditions that require the wind turbine generators to be disconnected from the rest of the primary 13.8kV circuit. The protective relays that National Grid Electric will likely require include over/under voltage relays, over/under frequency relays, and overcurrent relays.

The interconnection plan also includes a three pole, non-fused padmount disconnect switch for the manual disconnection and visible isolation of the wind turbine generator from the existing distribution system. This switch is typically required by the local utility to isolate the turbine, while not affecting the reliable operation of the existing system. National Grid Electric operations personnel will need access to manually open and padlock this disconnect switch in the open position to guarantee that the wind turbine generator will not back-energize their 13.8kV distribution circuit while they are working on it or when they otherwise deem it necessary.

1.4.4.3 *Electrical Interconnection Details*

1.4.4.3.1 Utility Interconnection Requirements

National Grid has specific standards and requirements for the interconnection of distributed generation such as the proposed wind turbine generator project. The interconnection requirements address electrical system protection, revenue metering, operation, and the configuration of the primary interconnection equipment. National Grid will review the proposed design of the electrical interconnection facilities and will perform analyses to determine the impact of the proposed generation on their electrical distribution system.

Based on the results of National Grid's analysis, certain modifications may be needed within the National Grid distribution system and/or to the interconnection facilities, which will be paid for by Tufts, should they be required.

1.4.4.3.2 Generator Step-up and Step-down Transformers

The generator step-up transformer is described by specifying the transformer voltage rating (primary and secondary), power rating (kilovolt-amperes or kVA), winding configuration (primary and secondary), and construction type. Any transformer specified shall be three phase, padmount type, oil-filled, self-cooled transformers.

The primary voltage rating of the transformers shall be consistent with the nominal voltage of the National Grid distribution supply circuit to Tufts Grafton, which is 13.8kV phase-to-phase for this part of the campus. To allow flexibility for local voltage deviations that may exist on the National Grid distribution system or within the 13.8kV interconnection circuitry, the transformer primary winding shall be equipped with five (5) fixed taps to change the primary voltage rating +/- 5% from nominal voltage in 2-½ % increments. For the generator step-up transformer, the secondary voltage rating shall be consistent with the wind turbine generator voltage, which is typically in the range of 575 volts to 690 volts.

The three phase power rating of the generator step-up transformer (expressed in kVA) shall be consistent with the wind turbine generator power rating (expressed in kW) and increased for the allowable generator power factor. A 1500 kW wind turbine generator operating at a 90% lagging power factor requires a padmount transformer with a minimum continuous rating of 2000 kVA.

1.4.4.3.3 Interconnection Circuit 15kV Class Cables

The wind turbine generator interconnection option requires the use of 15kV class interconnection circuit cables. A three phase interconnection circuit of approximately 550 feet is required from the generator step-up transformer to the point of interconnection to the Tufts Grafton 13.8kV system.

The power cables shall be specified for 15kV class insulation and consist of three, single conductor cables with either aluminum or copper conductors. For a wind turbine generator with power ratings of up to 1500 kW, the size of the power cables shall be a minimum of #1 AWG Aluminum. This is typically the smallest size primary cable installed by utilities.

The power cables from the wind turbine generator step-up transformer to each 13.8kV interconnection point shall be installed in underground conduit. The conduit shall be

Schedule 40 PVC that is encased in concrete At least two (2) additional conduits for communications and control of the wind turbine generator should also be included in the conduit system, with separate communications handholes.

1.4.4.3.4 Utility Disconnect Switch

The utility, non-fused disconnect switch specified for generator interconnection shall be a manually operated, three pole padmount switch, necessary to break the current on the secondary side of the wind turbine transformer. The switch shall be rated for 600 amperes of continuous current. The disconnect switch provides a visible open point between the wind turbine generator and the National Grid system. The operating handle of the disconnect switch shall be capable of being padlocked by a National Grid lock in the open position. The position of the disconnect switch blades shall be capable of being visually observed to allow positive determination of the electrical connection between the wind turbine generator and the rest of the 13.8kV system. The utility disconnect switch must be accessible to National Grid personnel at all times.

1.4.4.3.5 Protective Relay Scheme

The required protective relays for the selected generator interconnection option will be specified by National Grid based on the results of their system impact study. Based on the Project Team's review of the National Grid Interconnection Requirements, it is anticipated that the protective relay scheme for the interconnection of the wind turbine generator will include over/under frequency relays, over/under voltage relays, and overcurrent relays. All relays shall monitor all three phases and the overcurrent protection should include ground overcurrent relaying. Upon sensing conditions that exceed allowable operating limits, the protective relay scheme shall send a trip signal to the appropriate tripping devices to open and disconnect the wind turbine generator from the rest of the distribution system.

For the interconnection, the protective relaying and controls will curtail the operation of the wind turbine generator if the electrical connection from the wind turbine generator to the Tufts Grafton's distribution system is disrupted. It will be necessary to include protective relays to sense the amount of power that flows to the system and disconnect the wind turbine generator if power flows exceed equipment ratings.

1.4.4.4 *Revenue Metering Modifications*

For the interconnection it is anticipated that Tufts Grafton will need a meter to measure the amount of power delivered from the wind turbine generator through the new 13.8kV interconnection circuitry. This metering is anticipated to be located at the wind turbine main breaker or the secondary of the dedicated transformer to be installed at the turbine. It is also anticipated that National Grid will require the existing revenue metering at the Tufts Grafton main primary switchgear to be modified to allow the measurement of power flowing to the National Grid Electric 13.8kV system during light load conditions.

1.4.4.5 *Electrical Interconnection Cost Estimates*

An electrical interconnection cost estimate is provided in this section for the recommended interconnection of the proposed 1500kW (maximum size) wind turbine generator.

The planning accuracy cost estimate has been developed for use in the feasibility analysis. The planning accuracy cost estimate is based on conceptual interconnection plans for the wind turbine generators and are generally expected to be within an accuracy of +/-25%. The cost estimate is based on recent project experience and vendor quotes and could change based on the final design and construction conditions, including some minor unanticipated site conditions. The electrical construction would most likely take 2 months and would begin concurrently with the foundation construction

Table 1-4 details the major cost items for the recommended option. After the major electrical equipment listed, the balance of the interconnection system plant and miscellaneous 13.8kV components includes surge arresters, cable terminations, control wiring, and start-up testing. The balance of the interconnection system plant and miscellaneous 13.8kV components are estimated at 25% of the total installed cost for the major 13.8kV interconnection system components.

Table 1-4
Itemized Costs for Electrical Interconnection

Item Description	Total Cost
Excavation, Backfill and Compaction for Primary Cable Ductbank (2-5")	$ 33,000
Additional excavation & backfill for 2-2" communications conduits	$ 19,250
Installation of Primary and Communications Conduits	$ 13,200
Concrete Encasement of conduits	$ 15,400

Item Description	Total Cost
Concrete Pad for New Padmount Transformer & Switch	$ 14,000
Grounding of Transformer	$ 2,000
Installation of Secondary Conduits to Turbine 6-5"	$ 4,000
Installation of Secondary Cable to Turbine, 5 sets 4W-600MCM	$ 8,500
New Padmount Transformer, 2000kVA 600v-13.8kV, installed	$ 60,000
New Padmount Utility Disconnect Switch, installed	$ 15,000
Installation of New Precast Electric Manhole 6'x8'x8'	$ 16,000
Installation of New Communication Handholes (36"x24"x22")	$ 2,400
Site Restoration - Loaming and Seeding (Manhole / Trench area only)	$ 3,500
Excavation, Backfill and Compaction for Primary Cable Ductbank (2-5")	$ 33,000
SUBTOTAL - CONSTRUCTION	$ 206,250
Contractor Markup, Insurance, Permits, etc.	$ 30,938
Additional Electrical Equipment and Testing	$ 51,563
Contingency	$ 20,625
TOTAL ESTIMATE	$ 309,375

1.5 Permitting

The Cummings School is primarily located in the Town of Grafton. Open fields appropriate for a wind turbine installation are also located on the eastern edge of campus in the Town of Westborough. We describe the permitting process for a wind turbine for each of the municipalities below.

1.5.1 Town of Grafton

Two important facts drive the potential permitting path for a wind turbine at the Cummings School in Grafton.

1. The Town of Grafton explicitly includes a permitting path via special permit for a Wind Energy Conversion System (Section 5.5).
2. The entire Tufts campus in Grafton is included in the Campus Development Overlay (CDO) District (Section 9).

Section 5.5 of the Town of Grafton Zoning By-Law adopted in September 2008 reads as follows:

5.5 Wind Energy Conversion System

A wind energy conversion system may be built, provided that the height of any tower plus the radius of any rotor mounted on such tower does not exceed 70 feet above the ground level base of such tower, and that the distance from the ground level base of the tower to any property or street line be not less than the sum of the total of the height of the tower plus the radius of the rotor. The issuance of a special permit for a wind energy conversion system shall be subject to a finding by the Grafton Planning Board that the operation of such a system is not likely to cause electromagnetic disturbances for adjacent properties. The Grafton Planning Board shall require the testimony of a qualified expert witness to give such assurance and shall further require the applicant for such a special permit pay for the services of the qualified expert witness.

All wind turbines being considered in this feasibility study far exceed 70 feet to the tip of the blade. Thus, under normal circumstances a Variance would be required to install a wind turbine on a non-overlay district parcel.

Section 9.4.E of the CDO, which partially denotes Permitted Uses, can be interpreted to allow a wind turbine as an accessory use:

9.4.E. Facilities *accessory to any of the foregoing, including water, sewage disposal, drainage, electric, telephone and other utility services; roads, walks, paths, parking areas and structures, and lighting, directional signage and vehicular services therefore; grounds maintenance, snow plowing and open space protection; and all structures, equipment and facilities necessary to any thereof.*

The first sentence of Section 9.6.2.2 could be interpreted to allow a wind turbine to exceed the normal height restrictions, as a modern wind turbine obviously needs to be built to significant heights to accomplish its intended purpose.

9.6.2.2 Height*: No building shall exceed sixty (60) feet in height, except that spires, water tanks, communication towers, chimneys, exhaust stacks, flagpoles, mechanical penthouses and other structures normally built above the roof and not devoted to human occupancy may be erected to such heights as are necessary to accomplish the purpose they are normally intended to serve. The height of a building shall be the vertical distance measured from the mean finished grade of the ground adjoining the front of the*

building, as determined by the Inspector of Buildings, to the top of the structure of the highest occupied floor in the case of a flat roof, to the deck line of a mansard roof, and to the top of the plate of a gable, hip or gambrel roof. The Planning Board may, by a vote of at least four (4) members, each of whom is eligible to vote on the project, authorize deviation from strict compliance with the provision of this section in order to allow a maximum building height of up to 75 feet, allowing review and where such deviation is in keeping with the objectives of the zoning bylaw.

No other requirement (e.g., setbacks, ground coverage, buffers / landscaping) appears to be a significant hurdle for a wind turbine installation.

Nonetheless, to acquire approval may require substantial time and investment by Tufts as it may require a modification to approved Campus Master Plan, and as recommended by the Grafton Town Planner, a revision to the Zoning by-law to explicitly permit the recommended turbine height in the CDO District (see Section 9.6.1.1).

1.5.2 Town of Westborough

The Town of Westborough does not explicitly address wind turbines or wind energy conversion systems. The land parcel owned by Tufts in Westborough is zoned as agricultural / open space. The Town of Westborough Zoning Bylaws does allow electric generation devices, but does not allow structures in non-residential area in excess of 75 feet, as stated in Section 4451.

4451. Structures - Non-Residential Areas. *In non-residential areas, no structures (including but not limited to power generation or communication devices) shall be permitted with a height in excess of seventy-five (75) feet, nor shall any such structure be permitted as part of another structure or building with an aggregate height in excess of seventy-five (75) feet. Structure height is as measured from the ground adjacent to the structure to the highest point of the structure, including any moving parts or whip antennae.*

In order to permit a wind under an ordinary permitting path, Tufts could pursue a Special Permit for exceptions (**Section 1330a**) or if that were rejected, have to pursue a Variance. Tufts could argue that the current bylaws restrictions on structure height impose substantial hardship for a wind turbine installation, as defined in Section 1320.

1320. Variances. *To authorize upon appeal, or upon petition with respect to particular land or structures a variance from the terms of the applicable zoning ordinance or Bylaw where such permit granting authority specifically finds that owing to circumstances relating to said conditions, shape or topography of such land or structures and especially affecting such land or structures, but not affecting generally the zoning district in which it located, a literal enforcement of the provisions of the ordinance of Bylaw would involve substantial hardship, financial or otherwise, to the petitioner or appellant and that desirable relief may be granted without substantial detriment to the public good and without nullifying or substantially derogating from the intent or purpose of such ordinance or Bylaw. Except where local ordinances or Bylaws shall expressly permit variances for use, no variance may authorize a use or activity not otherwise permitted in the district in which the land or structure is located; provided however, that such variances properly granted prior to January first, nineteen hundred and seventy-six but limited in time, may be extended on the same terms and conditions that were in effect for such variance upon said effective date. The Board of Appeals is hereby authorized to grant use variances conditioned upon the satisfaction of the criteria for the granting of variances in this section.*

It could be argued that height regulations are not reasonable for modern wind turbines.

1.5.3 Local Permitting Recommendation

The Town of Grafton provides a well defined permitting path for Tufts for a larger scale wind turbine, which could include modifications and approval to the current Master Plan. The permitting path for a wind turbine for Tufts is less defined in Westborough but a Variance likely would be needed, due to the proposed height of the turbine.

The Project Team recommends consulting with the Grafton Town Planner and local legal counsel to work with the Tufts regarding the optimum approval process for Tufts and Grafton.

1.5.4 State and Federal Permitting

The Project Team prepared summary permitting tables to identify actual and potential state and federal requirements, the authority and citation, and permit approval timeframe, if relevant, as is outlined below:

Table 1-5
Applicable State Regulations[15]

Regulation/Permit	Authority	Citation	Approval Time	Comments
MEPA Determination: Notice of Intent and Environmental Notification Form (ENF)	Executive Office of Environmental Affairs	MEPA Regulations, 301 CMR 11.00	~90 days	Jurisdictional authority occurs when State financial assistance; NOT APPLICABLE - No MEPA program eligibility thresholds will be met. MEPA office provides documentation of non-applicability via email for this type of project.
MEPA: Environmental Impact Review		MEPA Regulations, 301 CMR 11.00		NOT APPLICABLE
NPDES Storm Water General Permit Notice of Intent	Mass Department of Environmental Management & US EPA	Joint State/Federal Program under the CWA		NOT APPLICABLE Required if more than one acre of land is disturbed.
Notice of Intent	Mass. Natural Heritage and Endangered Species Program	321 CMR 10:00		Likely not applicable
Wetlands Program Policy: Activities In The Buffer Zone Under The Wetlands Protection Act Regulations	Massachusetts Department of Environmental Protection	310 CMR 10.00. March 1999		NOT APPLICABLE See also: Bordering Vegetated Wetland Delineation Criteria and Methodology Limited Projects: Access Roadways or Driveways (DWW Policy 88-2)
Massachusetts Water Quality Act Section 401 Water Quality Certification	Massachusetts DEP	310 CMR 10.00		NOT APPLICABLE Must be obtained if any activity alters more than 5000 SF of wetlands.

[15] Notes: Portions adapted from Renewable Energy Research Laboratory, University of Massachusetts at Amherst - Community Wind Power Fact Sheet #7

Regulation/Permit	Authority	Citation	Approval Time	Comments
Conservation and Management Permit	Mass. Natural Heritage and Endangered Species Program	321 CMR 10:00 Massachusetts Endangered Species Act – required if a "take" is required		NOT APPLICABLE, as almost certainly no endangered species on the site.
Massachusetts Forest Cutting Practices Regulations	Mass Department of Environmental Management	(304 CMR 11.00) require reviews of forest cutting plans and potential impacts on rare species.		Exempt – see 11.02 3 (e). Not applicable as no forest cutting required and institutional parcel.
General Access Permits	Massachusetts Department of Highways			Needed if road modifications to State roads must occur. Likely not applicable; to be confirmed by civil design.
Wide Load Permits	Massachusetts Department of Highways			Route approval required; Road limits will require funding of separate road survey by a Civil Engineering firm.
Project Notification Form	Massachusetts Historical Commission (MHC)	MGL Ch. 9 Sections 27-32	30 days	Any new construction projects etc. that require funding, licenses, or permits from any state or federal agencies must be reviewed by MHC for impacts to historic and architectural properties. Purpose is to protect important historical and architectural assets of Commonwealth.

Regulation/Permit	Authority	Citation	Approval Time	Comments
Noise control policy	Massachusetts Department of Environmental Protection	MGL 310 CMR 7.09 -7.10	Not applicable, not a permit or approval.	At nearest property line or residence: No increase by more than 10 dB (A) above ambient. No "pure tone" condition.
Site approval	Energy Facility Siting Board (EFSB)	M.G.L. c. 164, §69H		NOT APPLICABLE Primarily concerned with plants over 100 MW; new transmission lines over 1 mile long or over 69 kv
Request for Airspace Review	Mass Aeronautics Commission		NOT APPLICABLE – no formal permit required	MAC should be notified if projects are over 200ft tall. Localities have been known to request MAC approval even though this is not a state requirement.
NEPOOL Interconnection System Impact Study & Facility Study	RTO-NE (a/k/a ISO-NE)		None – informational only	For projects less than 5 MW the submittal of form 18.4 does not trigger a system impact study. It provides information to RTO-NE for system planning purposes.

Table 1-6
Federal Applicable Regulations[16]

Regulation/Permit	Authority	Citation	Approval Time	Comments
Notice of Proposed Construction or Alteration	Fed Aviation Admin.	14 CFR Part 77	At least 30 days	Required for crane erection and tower structure. All structures above 199 ft will need lighting

[16] Notes: Portions adapted from Renewable Energy Research Laboratory, University of Massachusetts at Amherst - Community Wind Power Fact Sheet #7

Regulation/Permit	Authority	Citation	Approval Time	Comments
Service Interim Guidance on Avoiding and Minimizing Wildlife Impacts from Wind Turbines	Fish & Wildlife Service	May 13, 2003 http://www.fws.gov/r9dhcbfa/wind.pdf	Guidance Only	
Habitat Conservation & Incidental Take Permit	Fish & Wildlife Service	Endangered Species Act		NOT LIKELY APPLICABLE – No Federal endangered species identified
Migratory Bird Treaty Act	Fish & Wildlife Service	Migratory Bird Treaty Act	Prohibits the taking, killing possession etc. of migratory birds	Enforcement potential, if there is a “taking”.
Golden Eagle Protection Act	Fish & Wildlife Service	Golden Eagle Protection Act		Enforcement potential, if there is a “taking”.
FERC Certification as Qualifying Facility (QF)	Federal Energy Regulatory Commission	18 CFR Sec. 8.11	10 business days	http://www.ferc.gov/industries/electric/gen-info/qual-fac.asp

2 Economic Feasibility Analysis

This section provides analysis on the economic viability of installing a wind turbine at the Cummings School. First, it will describe the costs, financing options, and benefits of installing a wind turbine onsite. It then will combine these factors and analyze scenarios to provide the realistic net benefits for a wind turbine installation, concluding with recommendations of next steps.

2.1 Costs for Major Scenarios

2.1.1 Capital Costs

The capital costs for wind turbines are substantial. In the 225 kW to 1.5 MW capacity costs range from $3,000/kW to $4,400/kW installed.

Major categories of costs include[17]:

- Turbine
  - Turbine and Tower
  - Freight
  - FAA Lighting
- Balance of Plant
  - Site Development
  - Pad Mount Transformer
  - Concrete and Rebar
  - Foundation Labor
  - Tower Imbeds / Bolts
  - Cranes, Crane & Erection Labor
  - Construction Supervision

[17] Adapted from "*A Comparative Analysis of Community Wind Power Development Options in Oregon*", July 2004. "Community Wind" development refers to installations that are of utility scale, but smaller than most wind farms (i.e., 500 kW to 20,000 kW projects).

    - Monitoring and Control System
- Interconnection
    - High Voltage Line Extension
    - Interconnection and Metering
    - Electrical Labor
- Soft Costs
    - Legal
    - Permitting
    - Development & Engineering
    - Insurance
    - Meteorological Tower and Feasibility Study
    - Contingencies

We estimate capital costs will be somewhat higher than is generally described in industry publications and papers because:

- Most estimates assume larger wind farm installations where fixed costs can be spread over many more turbines.
- The complexity of the electrical system and more stringent Massachusetts requirements result in higher interconnection costs than is commonly estimated.
- The high demand for wind turbines in the U.S. and internationally has increased turbine and ancillary equipment prices.
- The high cost of steel has increased the cost of the tower and structural costs (e.g., rebar in foundation).
- Construction costs are typically higher in the northeastern U.S. as compared to the rest of the country.

Table 2-1 displays estimated total installed costs for a subset of representative turbines for a single turbine project. These costs come from recent manufacturer bids and publicly available proposals for similar projects. In many cases, the economies of scale are readily apparent.

Table 2-1
Indicative Summary Design, Procurement, and Construction Costs[18]

Turbine Name	Norwin 225	Elecon 600	Directwind 900	FL 1500/77
kW	225 kW	600 kW	900 kW	1,500 kW
Design / Pre Construction	$151,280	$175,000	$200,000	$200,000
Turbine to Site	$527,900	$1,177,800	$1,730,000	$3,166,000
Civil Construction and Site Work	$50,000	$287,300	$300,000	$389,336
Electrical Install / Interconnection	$100,000	$200,000	$250,000	$309,375
Install / Erection	$50,000	$83,500	$150,000	$298,000
Customer Cost/Misc	$10,000	$12,000	$15,000	$30,000
Total	$1,089,180	$2,079,573	$2,745,000	$4,483,336
$/kW Installed	$4,840.80	$3,465.96	$3,050.00	$3,465.96

2.1.2 Operating Costs

While there are no fuel costs for a wind turbine, there are ongoing operating costs. These include[19]:

- Operations and Maintenance
- Warranty
- Equipment Repair and Replacement Fund (a/k/a sinking fund)
- Equipment Insurance
- Management / Administrative
- Miscellaneous

Table 2-2 displays the estimated annual costs for each of the selected turbines.

[18] While prices can objectively be compared via the metrics displayed in this table, it is important to note that since the market for turbines of this size is in continual flux turbine manufacturers have varying levels of credibility that are linked to many factors including established sales relationships, number of machines installed locally, and general company reputation.

[19] Adapted from "*A Comparative Analysis of Community Wind Power Development Options in Oregon*", July 2004. "Community Wind" development refers to installations that are of utility scale, but smaller than most wind farms (i.e., 500 kW to 20,000 kW projects).

Table 2-2
Estimated Operating Costs per Turbine for Selected Turbines[20]

Component	Norwin 225	Elecon 600	Directwind 900	FL 1500/77
O&M Turbine	$5,000	$10,000	$12,500	$23,500
Warranty / Sinking Repair Fund Turbine	$5,000	$10,000	$12,500	$35,000
All Other	$2,000	$2,000	$2,000	$2,000
Total Annual Costs	$12,000	$22,000	$27,000	$60,000

2.2 Benefits of Electricity Production

There are four types of energy revenue and/or avoided costs resulting from distributed generation behind-the-meter wind turbines. First is to avoid paying utility bill energy charges. Second, if there is any excess power it can be sold into the wholesale market or to be credited for net metering. Third, is to capture revenue from selling renewable energy certificates (RECs) that are available for wind turbines (or any renewable generation) installed after March 1, 1998. Fourth is to garner forward capacity market payments, whose market is in flux, and so we assume no benefits.

The balance of this section describes these first three revenue streams in turn, and then describes potential environmental benefits from wind turbine electricity production.

2.2.1 Benefits of Avoiding Utility Bill Charges

An electric bill from National Grid consists of four types of charges:

1. Customer Charges
2. Demand (kW) Charges
3. Energy (kWh) Charges

[20] Note for small installations (e.g. < 5 turbines) generally the manufacturer will train on-site personal to do low level maintenance, and pay them to perform these tasks (e.g., visual inspect after shut-down and restart). Those costs are included. This most likely would work for Tufts employees, so we believe it to be a reasonable working assumption. For a third-party owner we assume an additional $10,000 in insurance / year.

4. Other (e.g., metering, interconnection study)

Customer, demand, and "other" charges all are considered purely utility "wire charges" and generally are not offset by the installation of a wind turbine. The energy charges are a mixture of "wire" and "generation" charges, and are offset by the installation of a wind turbine.

The above charges (e.g., demand-kW, energy-kWh) are assessed for various "services" and include:

- Generation. Generation services currently can be purchased in two different ways. They are:
    1. Basic Service; and,
    2. Competitive supply service (e.g., Dominion, Constellation NewEnergy, ConEd Solutions[21], etc.); and,
- Distribution;
- Transmission;
- Competitive transition (i.e., stranded costs);
- Energy efficiency; and,
- Renewable energy fund.

Unless a customer opts to totally disconnect from the grid and rely on a combination of wind turbines and other sources of electricity (e.g., photovoltaics, banks of batteries, micro-turbines), they cannot avoid monthly customer charges nor demand (kW) charges.

What can be avoided (in part) by the installation of a wind turbine are energy charges[22]. The amount of energy charges a customer pays on the utility bill varies by their location, rate class and consumption patterns.

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[21] Currently Tufts has a generation supply contract with TransCanada. The price paid is fixed rate of 9.474 cents/kWh primarily plus ISO-NE adders for congestion, reliability must run charges, and capacity charges based on kW draw, not kWh consumption.

[22] Including a "wires" portion, e.g. the kWh portion of the transmission and distribution charges, but not the kW portion of the transmission and distribution charges.

2.2.1.1 *No Implementation of "Standby" Generation Charges*

Many utilities impose "standby" generation charges on customers that install on-site generation. Currently National Grid imposes no standby charges. It is very unlikely National Grid will ever try to impose standby charges on renewable generation wind projects, and even less likely that the request would be accepted by the Department by the Public Utilities.

2.2.2 Value of Net Metered Electricity

The 2008 legislation *The Green Communities Act* (S. 2768) outlines three general classes for net metering. A Class I facility is defined as a plant or equipment (not a transmission facility) that is used to produce or generate electricity with a capacity of fewer than 60 KW. A Class II facility is defined as a solar, wind, or agricultural net metering facility whose generating capacity is greater than 60 KW but less than or equal to 1 MW. A Class III facility is a wind, solar, or agricultural net metering facility with a generating capacity of greater than 1MW but less than 2MW. A neighborhood net metering facility is a Class I, II, or III net metering facility that is owned by 10 or more residential customers who live in the same neighborhood and are served by the same distribution company; and is located within the same neighborhood as those who own or are served by the facility.

For all three classes, the credits received depend upon categories listed in Table 2-3. If there is sufficient on-site annual consumption, then all of the turbine's excess generation can be assigned to the host utility account. If there is not enough on-site annual consumption, net metering credits may be assigned to other accounts (including those not owned by the turbine producer) within the same ISO-NE load zone and utility service territory. So if a project owner does not have enough generation to utilize all the net metering credits, then they may have to set up one or more separate bi-lateral transactions to assign the credits to other account holders (in the same service territory and load zone). The value of these bi-lateral deals is whatever is negotiated.

For Class III projects, the utility has the option of to just pay the net metering project owner. Total projects eligible for net metering are capped at 1% of a utility's peak load, approximately 47 MWs for National Grid.

Table 2-3
Net Metering Class Qualifications

Class	KW Installed	Generation	Distribution	Transmission	Transition
Class I	0-60	√	√	√	√
Class II	60+ - 1000	√	√	√	√
Class III	1000+ - 2000	√		√	√
Government	0 – 2000	√	√	√	√
Neighborhood	0 – 2000	√		√	√

The value of the net metered energy used on-site will be the sum of the components. The value of the generation component of net metered energy is based on the National Grid Basic Service costs and varies monthly[23]. The value of the other components is based on the tariff for the rate class for the on-site account: Time-of-Use G-3. It is important to note that the generation component is the lowest it has been since January 2005, and has come down because of the slack economic demand. Since January 2005 Basic Service prices have averaged 10.08 ¢/kWh.

Table 2-4
Current Value of Net Metered Energy (Assuming Rate G-3)

Rate Component	Current Value
Generation	7.73 ¢/kWh
Distribution	0.58 ¢/kWh
Transmission	1.18 ¢/kWh
Transition	0.06 ¢/kWh
Total	9.27 ¢/kWh

Net metering rules and tariffs were finalized in November 2009, and went “live” on December 1, 2009.

[23] It is not based on the competitive generation price that Tufts receives fromTransCanada.

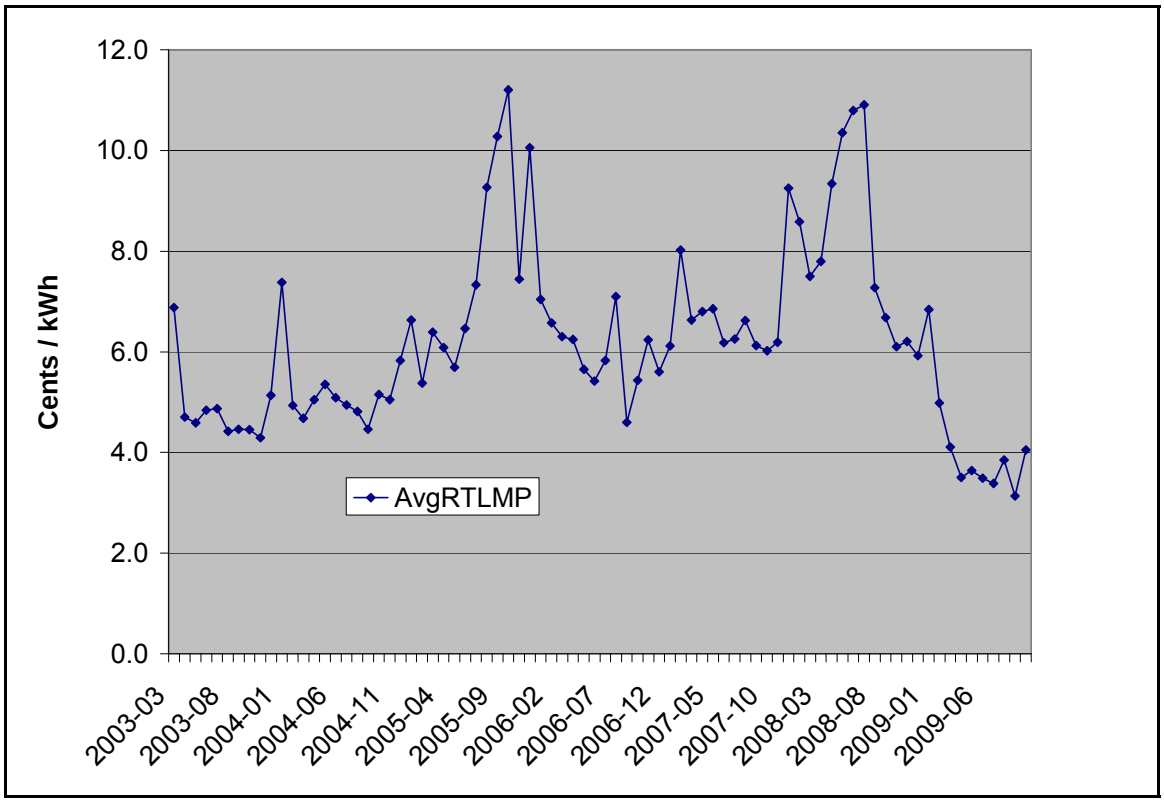
2.2.3 Protection from Volatile Electric Rates

For as long as the wind turbine is utilized, its fuel costs will be zero. This is in contrast to highly volatile natural gas, fuel oil and electricity prices. A distributed generation wind turbine can provide much of the energy currently consumed on-site (the most likely sizing will be between 50% and 250% of current on-site consumption) though, as discussed above, some will be consumed on-site and some will be exported back to the grid. Regardless, any significant turbine project will dampen the risk associated with volatile energy prices, and make budgeting and forecasting of energy operating costs more certain.

School electric costs are to a large degree based on retail generation costs which are, in turn, linked to wholesale generation costs.

As seen in Figure 2-1, the average hourly wholesale locational real time price for the Northeast Massachusetts region (NEMA) of ISO-NE (the electric grid operator) has fluctuated widely. The price spike in 2005 caused by the effects of Hurricane Katrina and 2008 when commodity natural gas prices were surging (the biggest factor affecting New England wholesale electric prices) can be easily seen, as can be the large decrease in the most current prices caused by the economic slow-down. The average wholesale price for the most recent twelve months was 7.37 ¢/kWh. In the near future, it is likely that short-term electric prices will be depressed. With an economic recovery prices will almost certainly rise, but to what degree is uncertain.

Figure 2-1
ISO-NE WCMA Region Average Real Time
Wholesale Electric Location Marginal Prices



Each 1¢/kWh increase in electric prices is expected to translate into over $80,000 in increased costs to the Cummings School per year. An installation of a 1.5 MW turbine is expected to save the Cummings School approximately $460,000 net O&M and warranty costs in its first year of installation, and would protect the school from electric rate increases due to market volatility.

2.2.4 Renewable Energy Certificate Revenue

An additional revenue stream for wind turbines in Massachusetts comes from a legislative mandate to promote renewable energy sources. The potential revenue comes from the sale of Renewable Energy Certificates (RECs), or so called “green certificates”. RECs are a tool created as a result of the Renewable Portfolio Standard (RPS) legislation adopted in some New England states, notably Massachusetts,

Connecticut, Rhode Island, and most recently New Hampshire and Maine. Vermont has a RPS, but in practice it does not promote new renewable projects to a great degree[24].

Accounting for RECs is the method to certify compliance with an RPS. The primary purpose of the RPS legislation is to create demand and financial support for new renewable electric generation sources which have significantly fewer environmental impacts than traditional fossil fuel based generation and which help diversify the domestic electricity generation mix thereby leading to greater long-term price stability.

The Massachusetts RPS mandates that 1% of all in-state investor owned utility service territory (i.e., National Grid, NStar Electric, Unitil, and Western Mass Electric) electric consumption come from new (post-1997) renewable resources by 2003. These levels increased by 0.5% each year through 2009, and will increase by 1% for each year from 2010 through 2020 for a total of 15%. Connecticut, Rhode Island and New Hampshire have similar requirements in place for in-state electricity consumption.

The alternative compliance payment (ACP, i.e., penalty) for an electricity supplier not reaching these mandates in 2009 is $60.92/MWh for Massachusetts, Maine, New Hampshire, and Rhode Island eligible projects and $55/MWh for Connecticut eligible projects. The ACP in Massachusetts, Maine, New Hampshire and Rhode Island is adjusted for inflation[25].

Energy used onsite from the wind turbine can be used to satisfy the Massachusetts and Connecticut[26] RPSs. Energy that is not used onsite, and is from a project that is deemed to be a wholesale generator, would be eligible to create RECs to satisfy any state RPS in New England.

2.2.4.1 *REC Prices*

REC prices are driven by a combination of actual and anticipated supply and demand, the ACP levels and, importantly, state rules regarding eligibility which affect both supply

[24] New Hampshire, Maine and Rhode Island have the same Alternative Compliance Payment (ACP) for Class I renewables (which includes wind) as Massachusetts.

[25] The Connecticut ACP is not adjusted for inflation.

[26] Massachusetts and Connecticut are the only New England states that allow out-of-state, behind-the-meter generation to be eligible for their RPS.

and demand. Given the uncertainty of and long lead times to implement New England renewable energy projects, and the legislative and regulatory risks associated with these government-mandated markets, there is great uncertainty of REC prices in the long-term. For 2009 compliance year, there are sufficient RECs and prices are moderate. In the out years, however, demand is stronger; supply is short; and consequently prices, particularly for Massachusetts RECs, are higher, as can be seen in Table 2-5.

Table 2-5
Recent Prices for Selected New England RECs[27]

	Vintage	Bid	Ask
MA	2009	26.0	29.5
MA	2010	29.0	33.5
MA	2011	32.0	36.0
MA	2012	34.0	37.5
RI	2009	26.0	31.5
RI	2010	33.0	35.0
RI	2011	35.0	38.5

2.3 Analyze Financing / Ownership Options

As detailed above, the cost of a wind turbine installation will range from $1,000,000 to $5,000,000. Given the high up front capital cost, various ownership options could be considered. As described above, the financial benefits of a wind turbine would be a combination of avoided utility costs and REC sales revenue. The degrees of benefits are analyzed in Section 2.5 below.

2.4 Grants

2.4.1 MRET Grants

The Massachusetts Renewable Energy Trust, which, in part, funded this feasibility study through their Commonwealth Wind (CommWind) program, has millions of yet-to-be-allocated dollars earmarked to support on-site private business and institutional

[27] ICAP United REC Recap 2009-11-25. A REC = 1 MWh of renewable generation. For example $30/REC is equivalent to 3.00 ¢/kWh.

renewable energy development. It should be noted that the MRET funds themselves originated from electric rate-based fees; so, in effect, all electric customers in Grafton have contributed significantly to this funding source. Block 2 Design & Construction funds were capped at $380,000 for non-public entities. Table 2-6 displays the amount of funding available for various turbine sizes assuming Block 3 and Block 2 incentives are equivalent. Block 3 of grant applications is due in spring 2010 with another round expected to follow roughly six months later.

Table 2-6
CommWind D&C Funding Increments

Turbine Capacity (kW)	Non-Public Entity	Public Entity
225	$285,000	$427,500
250	$294,500	$441,750
600+	$380,000	$570,000

2.5 Analyze Project Financials

This subsection analyzes the financial payback for various turbine sizes, ownership, costs, revenue, etc. It first describes the methodology employed, and then defines the primary base cases used in the analysis.

2.5.1 Methodology

2.5.1.1 *Disposition of Energy Production*

The goal of this analysis is to compute the financial payback of ownership and turbine configuration options in a realistic fashion and to confirm the suitability of utilizing historic wind resource and electric use data for projections. We have estimated the amount of annual kWh production to be used on-site, to be net metered to the site, to be net metered to other accounts off-site, and if net metering is not available, excess to be sold at wholesale rates.

2.5.1.2 *Projecting Financial Impacts to Future Years*

A wind turbine has an expected 20-year equipment life. For future years we assumed replication of wind resources and Cummings School electricity consumption. We have increased prices by assumed inflation rates (e.g., wholesale prices), decreased certain

prices per tariff filings (e.g., National Grid's transition costs are expected to decrease over the next few years) and assumed other prices would stay steady (e.g., we assumed that the renewable energy charge, the portion of the bill that funds MTC's Renewable Energy Trust, would stay constant at 0.05 ¢/kWh for the life of the wind turbine), as appropriate. Additionally we make explicit assumptions about the cost of the wind turbine installation, O&M costs, percent of time the wind turbine is available (i.e., not undergoing repair or maintenance), line losses, REC revenue, tax rates, availability of the tax credits, interest rates, loan terms, potential grants, and inflation rates.

All this information has been used to provide nominal costs and benefits of a wind turbine for each of the 20 years of expected life of operation. From these results, cash flow, internal rate of return (IRR), and net present value (NPV) can be computed.

2.5.2 Define Major Scenarios and Variants

The base case scenarios for a turbine installed at Cummings School are summarized in Table 2-7.

Table 2-7
Attributes for Financial Base Case Scenarios

Attribute	Value	Comment
Wind Resources	Annual average 6.25 m/s @ 80 meters	See Section 1.3
Electricity Consumption Patterns	8,440,000 kWh / yr	Average of three years
Project Start Date	Jan 2010	
Months to Complete	24	
General Inflation	3.50%	
Energy Inflation	4.50%	

Attribute	Value	Comment
Retail Price of Electricity	11.59 ¢/kWh	Includes 9.5¢/kWh for generation[28] and 2.1¢ /kWh utility charges. Does not include kW or monthly customer charges. Inflation adjusted.
Value of Net Metered offset Electricity	9.27 ¢/kWh	Basic WCMA Service Rate and utility charges.
REC Price	3.00 ¢/kWh	No inflation adjustment
REC Management Fee	15%	
Risk Free Interest Rate	5.00%	Used to calculate NPV
Interest Rate for Bond / Loan	5.00%	7 year loan
Down Payment	50%	
Marginal Tax Rate	0%	Tufts University is a non-profit institution.
Annual Ongoing Costs	See Table 2-2	
Gross to Net Energy Losses	10%	Includes line losses, turbine down time, etc.

2.5.3 Financial Results

As shown in the following tables and figures, the Cummings School has the opportunity for significant economic benefit from installing a wind turbine. The largest turbine analyzed, the Fuhrländer FL 1500, with its 10.5 year payback period, offers positive economic results for a turbine installation at the school. It will be the base case scenario for the remainder of the financial analysis.

Table 2-8 shows results for various turbine installations with a D&C (design and construction) grant from the Renewable Energy Trust. This scenario is assumed as the

[28] 9.5 ¢/kWh is the retail generation price Tufts is paying per their contract with TransCanada. The 7.7 ¢/kWh is the default rate of purchasing electricity competitively. Generally competitive rates have been lower default rates. Default rates change monthly. Tufts locked in a known competitive price while default prices decreased dramatically during the contract.

base case for the remainder of the report. Table 2-9 shows corresponding results without grant assistance.

Table 2-8
Financial Results for Various Turbine Installations Assuming RET Grant[29]

Turbine Configuration	NPV-10 Years	NPV-20 Years	IRR-10 Years	IRR-20 Years	Years to Cash Flow Positive
Norwin 29 225[30]	($521,994)	($386,021)	N/A	N/A	N/A
Elecon 600	($746,670)	($61,838)	-11%	4%	15.8
Directwind 900	($573,563)	$889,495	-2%	10%	11.9
FL 1500/77	($511,241)	$2,523,291	1%	12%	10.5

Table 2-9
Financial Results for Various Turbine Installations Assuming no RET Grant

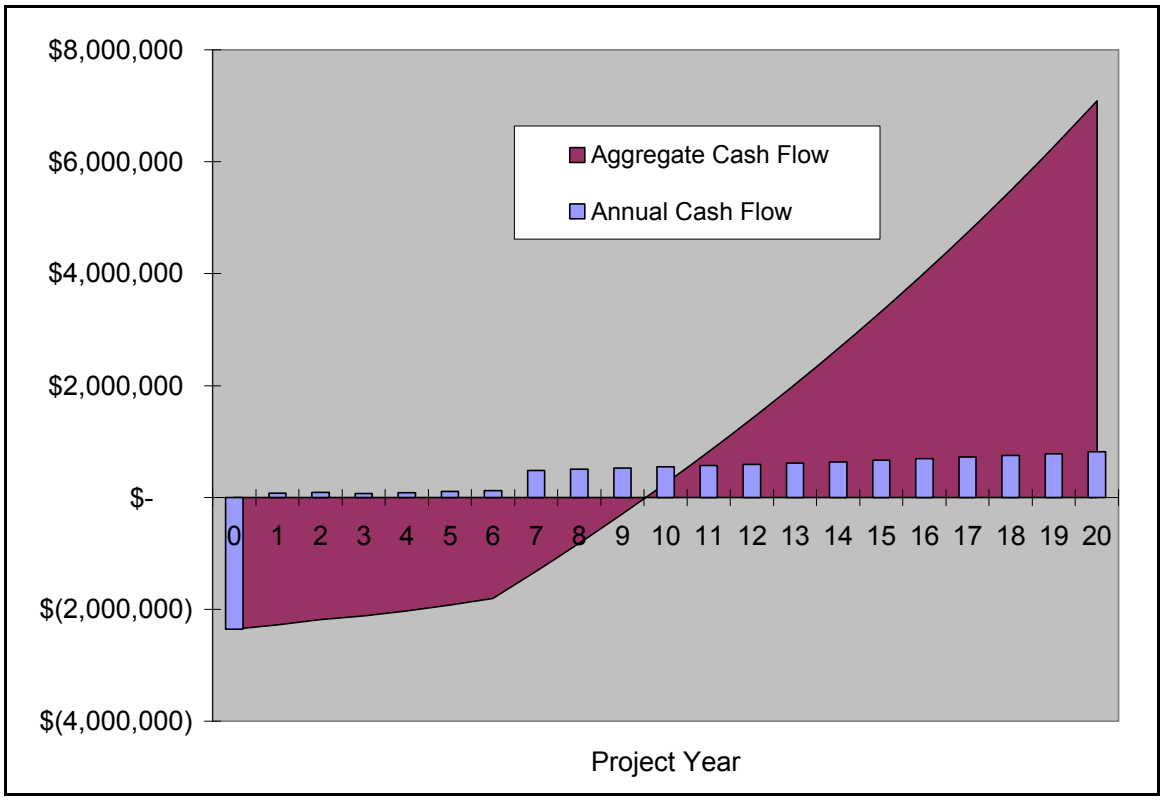
Turbine Configuration	NPV-10 Years	NPV-20 Years	IRR-10 Years	IRR-20 Years	Years to Cash Flow Positive
Norwin 29 225	($800,209)	($664,236)	N/A	N/A	N/A
Elecon 600	($1,117,622)	($432,790)	-15%	2%	18.4
Directwind 900	($944,516)	$518,543	-6%	7%	13.4
FL 1500/77	($882,193)	$2,152,339	-1%	11%	11.3

Figure 2-2 displays the cash flow for a FL 1500 with a $380,000 Commonwealth Wind grant. Other turbine installations would show similar patterns with less revenue and slower payback.

[29] This scenario is assumed for the sensitivity analysis. $400,000 was the maximum combined design and construction grant available through the MTC's Commonwealth Wind program.

[30] All turbines assume a 20 year installation lifetime. The N/A values for the Norwin 29 225 signify that turbine costs will not have been recovered at the 20 year point of the project.

Figure 2-2
Cash Flow for a FL 1500 with a $380,000 Grant



2.5.4 Third Party Ownership

As an alternative to Tufts ownership, a for-profit third party may want to own the turbine as an investment in renewable energy.

In order to take advantage of the federal tax credit opportunities, the investor must be either

- an active investor and have a sufficient tax appetite; or
- a passive investor and have a sufficient passive tax appetite.

Most any profitable for-profit corporation should be able to take advantage of the accelerated depreciation associated with wind turbine installations, so this incentive should be easily used by a third party investor.

It is further assumed a third party would:

- Sell the output of the wind turbine to Tufts at a fixed rate of 10.0 ¢/kWh[31],
- Have a combined marginal tax rate of 36.25%
- Be able to borrow money at 7.0%, and over a term of seven years, and have to provide 50% equity.

Table 2-10 shows results for a for-profit third party. The years to cash flow positive varies widely because the difference between breaking even and not breaking even for an investor is tight until the loan is paid off.

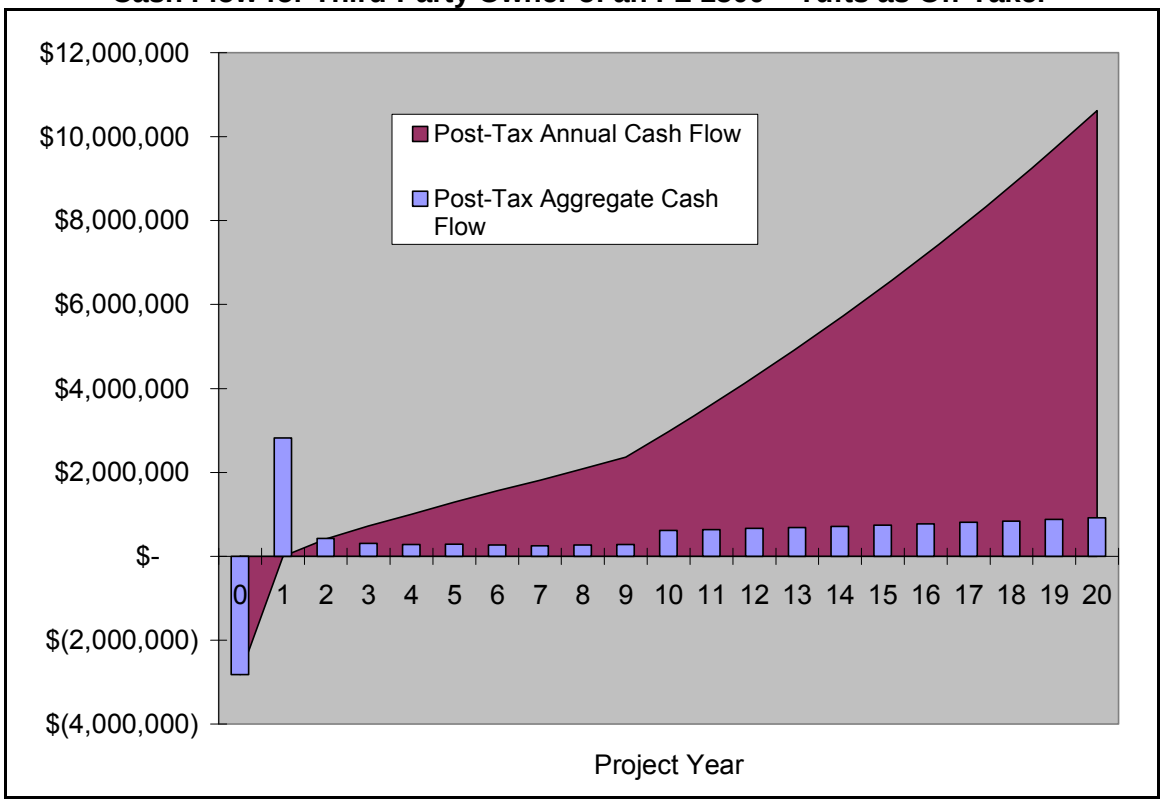
Note that for a 1.5 MW turbine Tufts garners immediate benefits of $52,000 in the first year, growing to $77,000 for the tenth year, and $119,000 in the twentieth year because of lower cost of purchasing generation from the wind turbine on the fixed cost basis. After twenty years this is over $1,617,000 on a nominal basis or, as shown in Table 2-10, $939,000 on net present value basis. Figure 2-3 shows the third party results.

Table 2-10
Post-Tax Financial Results for Third Party Scenario - Assumes $380,000 Grant

Turbine Configuration	Third Party IRR-10 Years	Third Party NPV-10 Years	Third Party IRR-20 Years	Third Party NPV-20 Years	Third Party Years to Cash Flow Positive	Tufts NPV-10 Years	Tufts NPV-20 Years
Norwin 225	($121,437)	($77,685)	N/A	N/A	N/A	$31,238	$61,020
Elecon 600	$195,038	$870,782	19%	24%	1.9	$117,077	$228,696
EWT 900	$834,681	$2,417,501	30%	33%	1.9	$229,175	$447,667
FL 1500/77	$1,984,157	$5,380,583	33%	35%	2.0	$480,612	$938,822

[31] Many developers to acquire financing and lower revenue risk find value in entering into long-term fixed price contracts, even when those prices are below the current market prices.

Figure 2-3
Cash Flow for Third-Party Owner of an FL 1500 – Tufts as Off-Taker



2.6 Sensitivity Analysis

This subsection provides an analysis of the major factors that may affect the payback on an installation of an FL 1500.

2.6.1 Wind Speed

In Table 2-11, mean wind speeds are varied at 5% intervals from the mean applicable wind speeds of 6.25 meters/second at a hub height of 80 meters. The variation of wind resources results in corresponding variations in capacity factor, and therefore financial payback. As the table shows, financial returns are very sensitive to wind resources.

Table 2-11
Sensitivity of Financial Returns to Wind Speed for a FL 1500

Wind Speed Adjustment	Turbine Capacity Factor	NPV-10 Years	NPV-20 Years	IRR-10 Years	IRR-20 Years	Years Until Cash Flow Positive
80%	13.1%	($2,218,582)	($725,044)	n/a	3%	17.7
85%	15.6%	($1,808,058)	$56,007	-10%	5%	15.1
90%	18.2%	($1,381,635)	$867,305	-6%	8%	13.2
95%	20.9%	($945,901)	$1,696,319	-2%	10%	11.7
100%	23.5%	($511,241)	$2,523,291	1%	12%	10.5
105%	26.2%	($74,130)	$3,354,925	4%	14%	9.6
110%	28.8%	$356,456	$4,174,145	7%	16%	8.8
115%	31.3%	$771,461	$4,963,722	10%	18%	8.2
120%	33.7%	$1,172,627	$5,726,968	13%	20%	7.7

2.6.2 Project Cost

Project costs vary based on site and market constraints. As can be seen in Table 2-12 financial returns are sensitive to changes in cost.

Table 2-12
Sensitivity of Returns to Capital Cost Variation for a FL 1500

Adjustment	Net Project Costs	NPV-10 Years	NPV-20 Years	IRR-10 Years	IRR-20 Years	Years Until Cash Flow Positive
80%	$3,210,169	$272,193	$3,306,726	7%	16%	8.9
85%	$3,410,804	$76,335	$3,110,867	6%	15%	9.3
90%	$3,611,440	($119,524)	$2,915,008	4%	14%	9.7
95%	$3,812,075	($315,382)	$2,719,150	3%	13%	10.1
100%	$4,012,711	($511,241)	$2,523,291	1%	12%	10.5
105%	$4,213,347	($707,099)	$2,327,433	0%	11%	10.9
110%	$4,413,982	($902,958)	$2,131,574	-1%	10%	11.3
115%	$4,614,618	($1,098,816)	$1,935,716	-2%	10%	11.7
120%	$4,815,253	($1,294,675)	$1,739,857	-3%	9%	12.1

2.7 Conclusions

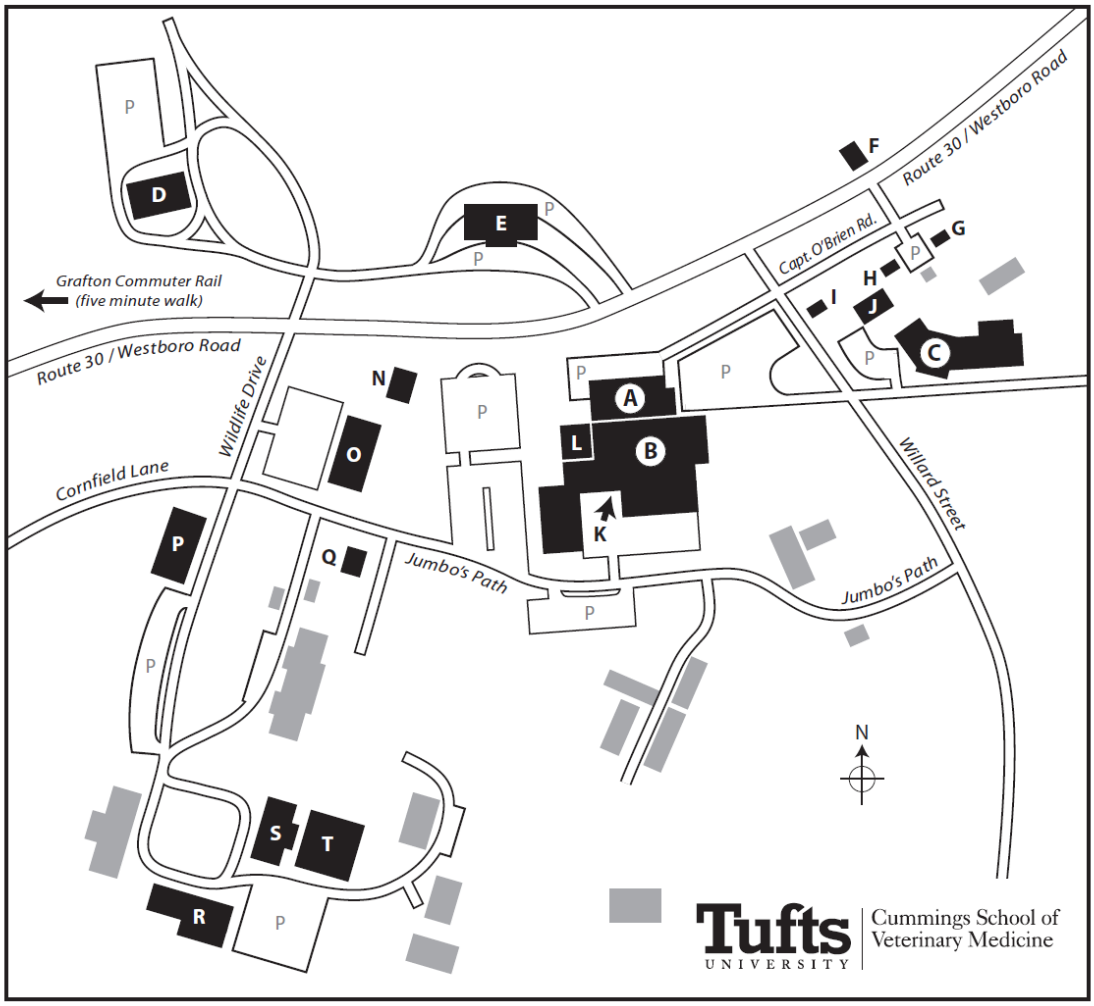
A wind turbine installation has the potential for financial and environmental benefit at the Cummings School. A 1.5 MW turbine is recommended for the project as it moves forward. Securing permits and local approval will be the project's most significant hurdle. Nonetheless, given the project's economic outlook, a turbine installation could be feasible.

2.7.1 Next Steps

- Come to an institutional decision on whether or not to pursue the project further.
- Contact Mass NHESP and US Fish and Wildlife Department concerning specific wildlife resources in the vicinity
- Engage Town and local stakeholders on the potential project and establish a preliminary schedule to promote re-zoning to permit desired turbine height and type.
- Proceed to permitting, design, engineering and construction
    - Finalize turbine location via civil engineering review
    - Apply for Commonwealth Wind funding
    - Begin permitting process at all possible levels
- Consider further meteorological study. As mentioned a full year's worth of Sodar or meteorological tower wind resource data will be required for MTC grants and other financing. Only 3 months of data was gathered during this study.

A. Campus Map

200 Westboro Road, North Grafton, MA 01536 *4/27/09*



(A) The Henry and Lois Foster Hospital for Small Animals

(B) Hospital for Large Animals

(C) Bernice Barbour Wildlife Medicine Building

D Frankin M. Loew Veterinary Education Center
E Jean Mayer Administration Building
F Locust Barn
G Center for Animals and Public Policy
H Development and Alumni Relations
I Alpha Psi Student Center
J 54 Willard Road Faculty Offices
K Agnes Varis Lecture Hall
L Lily Lerner Spay/Neuter Clinic
M Cafeteria
N Central Services/Campus Police
O Agnes Varis Campus Center & Elmes Café
P David McGrath Veterinary Teaching Laboratory
Q 1 Ridge Road Faculty Offices
R Veterinary Diagnostic *(Bldg 20)*
S Biotech Transfer Center & Laboratory Support *(Bldg 21)*
T Amelia Peabody Pavillion

B. Electrical One Line Diagram

C. Electrical Site Plan