Tighe&Bond

Wind Turbine and Energy Consumption Analysis for Two Farms

Prepared For:

Town of Chilmark
Chilmark, MA

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Section 1
Overview

This report was completed at the request of the Town of Chilmark, MA (Town) in order to provide the Town with the necessary technical information regarding two proposed wind turbine projects that are currently under review by the Chilmark Zoning Board of Appeals (ZBA). The two wind turbines are currently proposed at The Grey Barn Farm and the Allen Farm in Chilmark. Both proponents have been working with wind turbine developers to install small scale turbines that would provide electricity for on-site operations as well as qualify for net metering under the Massachusetts Green Communities Act of 2008 (220 CMR 18.00).

The Grey Barn and Allen Farms have received Building Permits from the Town without obtaining a Special Permit from the ZBA. The permits were granted under the agricultural exemption outlined at MGL c. 40 A § 3, which states that a Special Permit is not required if the energy from the wind turbines will primarily serve agricultural use.

Following the granting of the building permits, multiple appeals were filed against both farms' permits on the basis that the turbines' energy production would be connected to the electricity grid and would not be primarily serving agricultural uses. The Town requires assistance to verify whether the projects do indeed qualify for the agricultural exemption. The Town has sought a legal opinion from Rackemann, Sawyer & Brewster (RSB), who determined that the projects would qualify for the agricultural exemption if 51% of the electricity generated by the proposed turbines is used for commercial agricultural purposes.

Tighe & Bond was hired by the Town as an independent third-party consultant to gather and analyze data to help the ZBA determine if the primary purpose of each wind turbine's output will be used for agriculture. To assist the Town with this task, Tighe & Bond evaluated the following information with respect to both farms:

- **The expected annual electricity generation from the proposed turbines:** This information was generated using WindPRO, a software product commonly used for wind turbine development that offers many levels of analysis. For this analysis, a simple calculation of the energy production was performed with the METEO module. The analysis only took into account the wind speed data provided and the characteristics of the turbine planned for installation.
- **Total annual electricity used for agricultural purposes at each farm:** This data was provided by the project proponents and confirmed by Tighe & Bond.

Based on these evaluations, Tighe & Bond has provided an opinion on whether the two projects meet the requirements of the agricultural exemption by calculating wind turbine energy production as a percentage of agricultural energy use on-site. The report outlines the methodology and assumptions used by Tighe & Bond to analyze the projects and verify the calculations and data provided by project proponents.

At the request of the Town, this report also provides background information on Massachusetts' net metering regulations and the way that on-site energy use is typically calculated for projects that are net metered. This information is intended to help the Town understand and respond to questions about how a project owner can take credit for electricity use at a particular site if the wind turbine is connected to the grid. The report provides a discussion of current industry standards for net metering, interconnection to the grid, and on-site use of privately generated electricity in Massachusetts.

Based on the information provided from the project proponent and on our analysis, the proposed wind turbine project at Grey Barn Farm should qualify for the agricultural exemption because the annual energy production is expected to be approximately 134,000 kWh or 153,000 kWh (depending on turbine height) and the energy that the Farm is expected to consume for agricultural purposes is approximately 290,000 kWh per year. Total annual consumption is significantly greater than the estimated annual energy production so the site will be a net importer of power. In the context of net metering, 100% of the power produced on site will effectively be used for commercial agricultural purposes at the Farm.

Based on the information provided from the project proponent and on our analysis, the proposed wind turbine project at the Allen Farm should also qualify for the agricultural exemption because the annual energy production from the proposed turbine is expected to be approximately 122,000 kWh and the energy that the Farm is expected to consume for agricultural purposes is approximately 78,000 kWh per year. In the context of net metering, about 78,000 kWh/yr of power produced on site (or an amount equal to the total demand of the Allen's electricity consumption) will effectively be used for commercial agricultural purposes at the Farm. The Allen Farm does not have the ability to use the excess power or surplus of net metering credits at this time and under the future plans as submitted to Tighe & Bond.

Section 2
Net Metering Practices and Standards

This section of the report provides some background information related to the accounting of on-site renewable energy generation and electrical consumption in the context of Massachusetts' Net Metering regulations. This information is intended to provide background for the ZBA's assessment of whether it is valid to consider that the energy from the proposed wind turbines will indeed be used for agricultural purposes at the two farms even if the turbines are connected to the electrical grid.

In July 2008, Governor Deval Patrick signed the Green Communities Act into law. The purpose of the Green Communities Act is to encourage the development of renewable and clean energy sources in the Commonwealth as well as promote energy efficiency. As a part of the Green Communities Act, the Department of Public Utilities updated the state's net metering regulations (220 CMR 18.00) in June 2009. Net metering allows customers of an electric distribution company to generate their own electricity in order to offset their electricity usage.

As set forth in the DPU regulations (220 CMR 18.02), the proposed wind turbines at Grey Barn Farm and Allen Farm will qualify as "Agricultural Net Metering Facilities." The Grey Barn Farm will be considered a Class II Agricultural Net Metering Facility (rated capacity greater then 60 kW) and the Allen Farm will be considered a Class I Agricultural Net Metering Facility (rated capacity less then 60 kW).

Net metering is based on the principal that small energy generators usually need to remain connected to the grid for back-up power, but should be compensated for the energy production they supply to the grid when more electricity is generated than the customer is consuming. To encourage small energy generation, facilities that qualify for net metering are compensated the retail rate for the excess energy they produce as opposed to the wholesale rate received by larger energy producers. This is done by measuring the difference between electricity delivered by a generation company and the electricity that is generated by a customer and fed back to the distribution company. Conceptually, the concept is equivalent to a meter that literally runs backwards for electricity leaving the customer's property. The customer's monthly electricity bill reflects the net electricity produced and consumed by the customer, representing that the electricity produced is used on-site. Refer to Figure 5-1 for an illustration of this concept.

The goal of Massachusetts' net metering regulations is to promote the generation of renewable energy. To require that a generator verify that an electron produced at a particular site is also used at that site is unreasonable, and contrary to the goals of the Green Communities Act. As allowed by state regulations, and as is common industry practice, it is standard to consider the energy portion of a customer's energy production that is less then their consumption as "on-site consumption." Despite the fact that the proposed turbines at the Grey Barn Farm and Allen Farm will be connected to the electrical grid, within the context of net metering, the farms' electrical loads will be offset by the renewable energy produced by the proposed turbines.

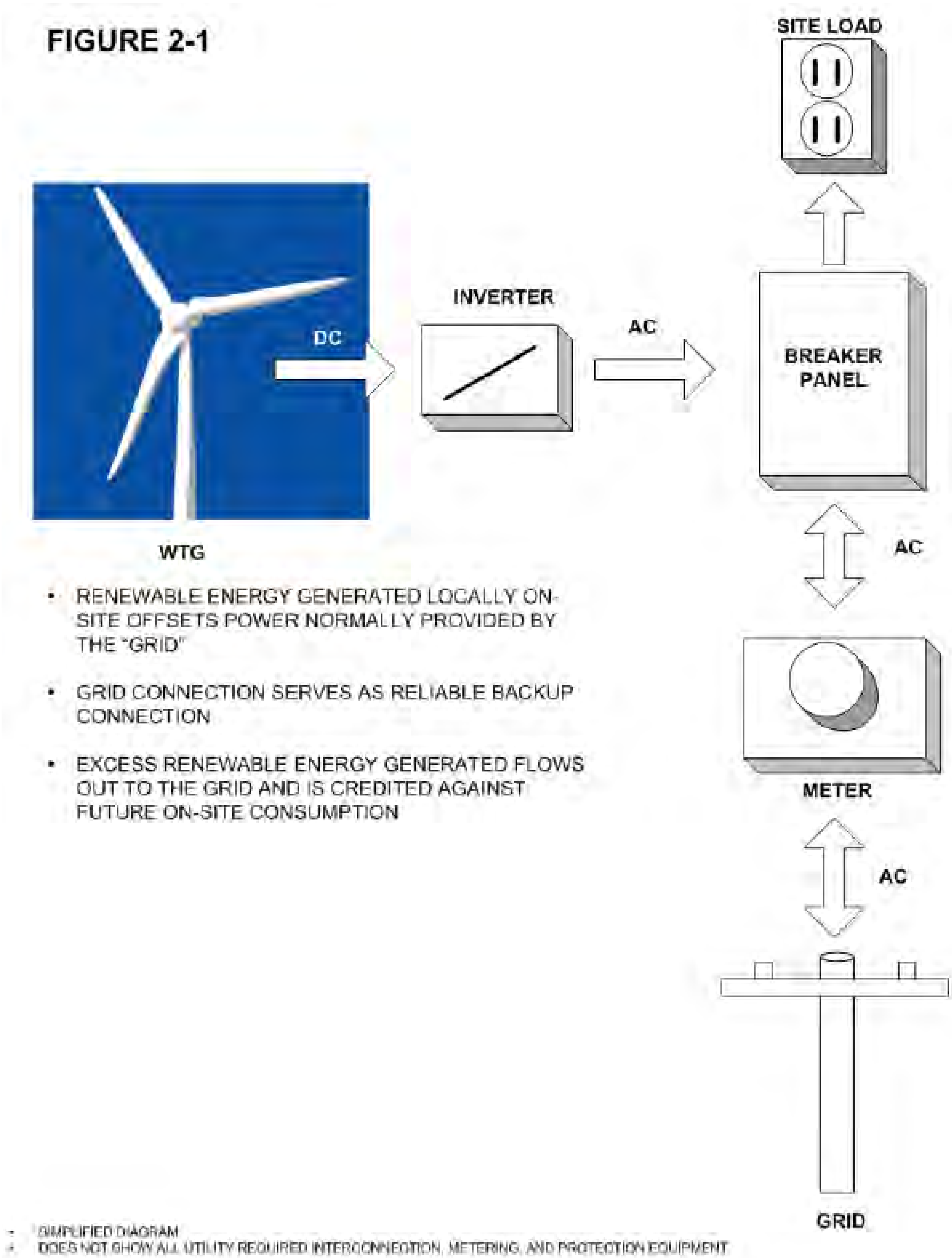


FIGURE 2-1
SITE LOAD
INVERTER
AC
DC
BREAKER PANEL
WTG
AC
METER
AC
GRID
• RENEWABLE ENERGY GENERATED LOCALLY ON-SITE OFFSETS POWER NORMALLY PROVIDED BY THE "GRID"
• GRID CONNECTION SERVES AS RELIABLE BACKUP CONNECTION
• EXCESS RENEWABLE ENERGY GENERATED FLOWS OUT TO THE GRID AND IS CREDITED AGAINST FUTURE ON-SITE CONSUMPTION
• SIMPLIFIED DIAGRAM
• DOES NOT SHOW ALL UTILITY REQUIRED INTERCONNECTION, METERING, AND PROTECTION EQUIPMENT

Section 3
Grey Barn Farm Assessment

3.1 Executive Summary

Based on the information provided from the project proponent and on our analysis, the proposed wind turbine project at Grey Barn Farm should qualify for the agricultural exemption because the annual energy production is expected to be approximately 134,000 kWh or 153,000 kWh (depending on turbine height) and the energy that the Farm is expected to consume for agricultural purposes is approximately 290,000 kWh per year. Total annual consumption is significantly greater than the estimated annual energy production so the site will be a net importer of power. In the context of net metering and within the assumptions outlined in this Section and in Appendix A, 100% of the power produced on site will effectively be used for commercial agricultural purposes at the Farm.

Tighe & Bond performed this analysis according to industry standards, under the supervision of Massachusetts Professional Engineers Registered in Electrical and Civil Engineering. Our assumptions are based on experience in the wind industry and with small agricultural operations. Operations particular to the Grey Barn Farm were assessed to determine whether they fit within standard agricultural or similar industry operations. Each piece of equipment-related information submitted by the Grey Barn Farm was checked against manufacturer's specifications or similar equipment to obtain accurate estimates of equipment energy demand. During the analysis, we confirmed the definition of agriculture by the Massachusetts General Laws and confirmed that each item included in our estimate of energy production falls within the definition.

Tighe & Bond's wind resource analysis utilized data that was provided to us by other consultants. We verified the source of the data and compared it to other wind speed databases, which did not show significant difference. Our wind analysis includes a detailed description of the level of analysis that was performed and the input assumptions as well as background information.

We are confident in our energy production and consumption estimates, considering the amount of input data and level of analysis performed, but there are many factors that could cause the energy consumption and production estimates to vary. Any farming or business operation is subject to such factors and we feel it is important to discuss them as a part of any estimate. Operational factors that could have an impact on energy demand include the times of year and frequency that freezers and refrigerators are accessed, the irrigation land area and schedule, the number of workers milking, livestock number fluctuations, and the amount of customers served at the store. Other factors include the ambient conditions, such as temperature, humidity and rainfall. Variation in the shape and materials of buildings could greatly impact Heating Ventilation and Cooling (HVAC) loads for a building of the particular size. Also, variation in demand for the dairy products could affect operations. The turbine performance could vary from the estimate due to factors including the quality of the input data, the flow model used, operational conditions and use patterns that may be affected by noise or shadow mitigation, climatic and topographic changes, or the increase of large trees or buildings proximate to the turbine.

3.2 Wind Resources

This section describes the methodology that Tighe & Bond used to calculate the expected annual energy production (AEP) at the Grey Barn Farm. The assessment was conducted according to the following order of tasks:

1. Obtain average wind speed for the project site from a virtual wind speed data source. Virtual wind speed data is compiled from multiple sources of historically measured wind speed data. Complex flow models that account for the earth's surface characteristics and topography are used to extrapolate the data to nearby locations. The models facilitate the extraction wind speed data at any location. Please note that neither Tighe & Bond nor either of the proponents have measured wind speeds on-site at this time.

2. Make simple assumptions to expand the data to a full frequency distribution of wind speeds. The virtual wind speed data obtained as described above comes as an average wind speed at one elevation above ground level. In order to get a better understanding of site-specific wind resources, assumptions are made based on other historical data in order to predict how often each wind speed will be occurring on the Site (called a frequency distribution). Furthermore, information on site-specific terrain is used to estimate how quickly the wind speed increases as height above ground level increases. This allows for an estimation of the frequency distribution at the hub height (center of the turbine rotor) of the turbine.

3. Use the wind speed data and the turbine power curve, provided by the manufacturer, to calculate the estimated annual energy production (AEP) using WindPRO software.

Some background information is included in the following sections to support the assumptions made.

3.2.1 Annual Energy Production Assumptions

The Grey Barn Farm is working with Alteris Renewables (Alteris) to develop a 100 kW wind turbine. This turbine, a Northwind 100, is a proven model with many successful installations. It has a hub height of 30 meters (98 feet) or 37 meters (121 feet) and a rotor diameter of 21 meters (69 feet). The maximum blade tip height of this turbine is approximately 132' for the 98' hub height machine and 156' for the 121' machine. Tighe & Bond obtained the turbine specifications from the manufacturer on January 3, 2011 (Appendix A).

Tighe & Bond calculated the expected annual energy production of the proposed wind turbine using the following assumptions:

1. Average wind speed at 121 feet above ground level is 5.46 m/s (meters per second) and the wind speed at 98 feet above ground level is 5.18 m/s, as recorded by AWS TruePower's WindNavigator. WindNavigator is a reputable virtual wind speed data source, commonly used in the preliminary stages of developing a wind turbine. A screen-print of the screen showing the average wind speed (created by Alteris Renewables on January 4, 2011) is provided in Appendix A.

2. Shear coefficient, or power law exponent, for the Site is 0.3. Wind shear is the change in wind speed with height. On rough land ("roughness" determined by factors such as nearby forest and buildings), such as on Martha's Vineyard and most of Massachusetts, the shear is best represented by a mathematical relationship called the power law. The power law exponent determines how quickly the wind speed increases with height above ground level. Typically, forested and suburban areas with trees and buildings have a shear exponent between 0.25 - 0.45. Since a lower shear exponent means lower wind speeds at hub height, it is conservative to keep the shear coefficient low at this stage of project development; therefore, 0.3 will produce a conservative estimate of wind speeds. This value and the power law determine the vertical profile of the wind speed.

3. A Weibull frequency distribution of wind speeds was assumed with a shape coefficient equal to 2.33 (k factor). The frequency of occurrence of wind speeds is typically called the frequency distribution, or probability distribution. A probability distribution is a graphical representation of the probability that a particular value in a data set lies between two bounds. Two probability distributions are generally used for wind data sets: the Rayleigh Distribution and the Weibull Distribution. These distributions are each described mathematically by a probability density function. The Weibull probability density function was used to create a frequency distribution for this study because it is the preferred model for complex terrain (hills and trees), such as seen throughout Massachusetts and New England.

   The Weibull factors k and c describe the shape and scale of the probability distribution graph, respectively. The optimal wind speed probability distribution for energy generation and turbine selection has a sharp peak shape and a large area under the curve. A higher k-value (shape coefficient) corresponds to a sharper peak and constant wind speeds. A higher c-factor (scale coefficient) corresponds to a greater area under the curve and greater mean wind speed.

   The Weibull shape coefficient for the Grey Barn Farm was developed from CWEST, a preliminary project assessment tool created by the Cadmus Group for the Massachusetts Clean Energy Center. This tool is commonly used for preliminary wind resource assessments. Using the average wind speed from AWS and the site-specific shape factor, the scale factor was calculated to be 5.18 and 6.16 for the 98' and 121' tower height data, respectively.

4. The following losses typical of a preliminary wind energy project were assumed (total 13%):

   a. Availability (3.0%) - Downtime due to turbine service
   b. Balance of plant (1.0%) - Substation Maintenance
   c. Grid availability (1.0%) - Grid unavailable due to external circumstances
   d. High wind hysteresis (5%) - Required restart after high-wind cut-out, as defined by each turbine's power curve.
   e. Electrical losses (2.0%) - Transformer and line losses
   f. Performance degradation due to icing (0.5%) - Ice accumulation on blades

g. Grid curtailment and ramp-rate (0.5%) - Power outage during low wind (requires restart, which demands power)

Under the above assumptions, the AEP for the Northwind 100 with a hub height of 98’ is 134 MWh (134,000 kWh) per year. The AEP for the Northwind100 with a 121’ hub height is 153 MWh (153,000 kWh) per year. See the WindPRO reports in Appendix A for an overview of the assumptions and calculations.

Factors that may cause the wind turbine performance to vary from the estimate include the quality of the input data, the modeling practice followed, operational conditions and use patterns that may be affected by noise or shadow mitigation, climatic and topographic changes, or the increase of large trees or buildings proximate to the turbine.

3.3 Energy Consumption

An analysis of the annual energy consumption at the Great Barn Farm was completed. The proponents submitted a set of information regarding electrical demand for proposed farming operations and equipment and Tighe & Bond reviewed the information for accuracy. According to the definition of agriculture in MGL c. 128 § 1A, all of the sources of electricity considered in this analysis qualify as farming activities, including activities that occur “on a farm as an incident to or in conjunction with such farming operations, including preparations for market, delivery to storage or to market or to carriers for transportation to market.” No residential or other non-agricultural uses were included in the analysis.

The Grey Barn Farm is currently under development and has no historic electricity consumption data. The farm will be a sustainable dairy farm with approximately 25 milking head. The farm will pasture the cows in the summer months and use their own grain crop feed in the winter. Farming operations also include milking the cows, pasteurization and cheese production and storage. The farm will include milking and washing equipment, several buildings, climate control systems, and refrigeration and freezing systems.

The Grey Barn Farm submitted a spreadsheet to Tighe & Bond with expected energy consumption calculations. Grey Barn Farm also submitted evidence that the equipment included in their calculations has been purchased as well as design plans for the farm, but not all of this information has been included in this report in the interest of the Grey Barn Farm’s confidentiality. The site Master Plan is included in Appendix A.

Tighe & Bond used several methods of energy consumption estimation to verify the probable energy consumption for each line item. For HVAC (heating ventilation and cooling) and lighting estimates, we used standard resources for estimating electrical infrastructure loads, such as the National Electric Code (2011) and RS Means (2011) and made estimations based on building square footage. For major equipment, such as pumps and condensers, we used the horsepower (hp) rating of the machine and assumed a use pattern (number of hours per day and days per year the machine is operating) based on our knowledge of typical agricultural operations as well as the cycle-times of the equipments. For heating and cooling equipment, Tighe & Bond performed a basic heat-transfer analysis, based on physical principles, to yield the amount of energy that would be required to perform the operation the equipment was intended for. In some cases, we used the design of the electrical service that was performed by another consultant and submitted by the Grey Barn Farm in order to back-calculate the load expected on the electrical service.

Assumptions and comments relative to the energy consumption estimate are provided in the Grey Barn Farm Schedule of Electrical Usage Comparison included in Appendix A. We only included line items that are requisite for dairy farm operation (milking equipment, various pumps, building climate control, etc.) and items that appear to be related to agricultural operations that were found on purchase orders submitted by Grey Barn Farm. We found that all of the equipment that the Grey Barn Farm used in their estimate has been committed to and will be used for agricultural operations. The evaluation spreadsheet with the Grey Barn Farm and Tighe & Bond calculations is provided in Appendix A. Estimation of these loads was provided by a qualified electrical engineer, professionally registered in Massachusetts and certified as a CPE, DGCP and CPQ. It is believed that our estimate is conservative by standard electrical engineering practices and that the Grey Barn Farm also provided a conservative estimate.

Overall, it is expected that energy usage for agricultural purposes on the Grey Barn Farm will be approximately 280,000 kWh per year. This takes into account major equipment and buildings, the amount of time they are likely to be in use on an average day, and the amount of days the equipment will likely be in use. It is believed that this is a conservative estimate. In several instances Tighe & Bond calculated a higher general energy consumption estimate for a piece of equipment, but remained conservative in favor of the Grey Barn Farms assumptions. Tighe & Bond also identified another possible major source of electricity consumption (i.e. the Greenhouse) that was not considered in the data provided by the Grey Barn Farm, but did not endeavor to estimate the projected consumption as the analysis already demonstrates that electrical demand at the Farm significantly exceeds the potential energy production from the proposed turbine.

Tighe & Bond is confident in the accuracy of the energy consumption estimate based on the assumptions listed in the Grey Barn Farm Schedule of Electrical Usage Comparison in Appendix A. While the equipment purchased is designed to operate under conditions yielding this level of consumption, it should be noted there are numerous factors that could cause variations in the energy consumption. Major factors that could affect the Grey Barn Farm consumption once the farm is in operation are described below.

Many of the assumptions about the Grey Barn Farm’s operations were made based on our knowledge of electrical usage associated with agricultural operations. Note that this assessment could vary based on the actual operations on the farm, which since it is a new farm, are also not known at this time. For example, operational factors that could have an impact on energy demand include the times of year and frequency that freezers and refrigerators are accessed, the irrigation land area and schedule, the number of workers milking, livestock number fluctuations, and the amount of customers served at the store.

Other factors that will cause variation in energy consumption from year to year are the ambient conditions, such as temperature, humidity and rainfall. Variation in the shape and materials of buildings could impact Heating Ventilation and Cooling (HVAC) loads for a building of the particular size. Also, variation in demand for the dairy products could affect operations.

3.4 Grey Barn Farm Conclusion

Table 3-1, below, shows the comparison of the energy expected to be generated by the proposed turbine at the Grey Barn Farm with the Northwind 100 at two different turbine hub heights. It is anticipated that the Grey Barn Farm will use all of the energy the turbine produces "on-site", as the Farm's electrical demand for agricultural purposes exceeds the estimated AEP by at least (for the larger turbine) 137,000 kWh annually. This equates to an electricity consumption for commercial agricultural purposes that is at least 190% larger than the turbine output.

TABLE 3-1
Grey Barn Farm Analysis, Conclusion

	Northwind100 (98'/30 m)	**Northwind100 (121'/37 m)**
Rated Capacity (kW)	100	100
Wind Speed at Hub Height (m/s)	5.18	5.46
Estimated Wind Turbine Capacity Factor	17.6%	20.1%
Estimated Annual Energy Production (AEP, kWh)	134,000	153,000
51% of Wind Turbine AEP (kWh)	68,340	70,030
Tighe & Bond Electricity Consumption Estimate (kWh)	280,000	280,000
On-Site Demand for Agricultural Purposes Greater than 51% of Turbine AEP?	YES	YES

This report summarizes the analysis undertaken by Tighe & Bond to compare the estimated annual energy production (AEP) from the proposed wind turbine at the Grey Barn Farm in Chilmark, MA with the annual energy demand related to agricultural purposes. The purpose of the analysis was to determine whether electricity generated by the turbines would offset greater than 51% of the farms' electrical load used for agricultural purposes. As determined in a legal opinion from Rackemann, Sawyer & Brewster (RSB), this is the standard that must be met in order to qualify for an agricultural zoning exemption under MGL c. 40A § 3.

A comparison of the electrical demand for agricultural purposes at the Grey Barn Farm and the estimated AEP of the proposed Northwind 100 turbine demonstrates that the amount of electricity anticipated to be generated by the turbine is significantly less then the farm's demand. Therefore, it is reasonable to conclude that greater than 51% of the energy generated by the turbine will be devoted to agricultural purposes. Based on this conclusion and the standards set forth in the RSB opinion, the Grey Barn Farm project qualifies for the agricultural zoning exemption.

Section 4
Allen Farm

4.1 Executive Summary

Based on the information provided from the project proponent and on our analysis, the proposed wind turbine project at the Allen Farm should qualify for the agricultural exemption because the annual energy production from the proposed turbine is expected to be approximately 122,000 kWh and the energy that the Farm is expected to consume for agricultural purposes is approximately 78,000 kWh per year. Therefore, 51% of the energy generated by the turbine is less then the on-site demand. In the context of net metering and within the assumptions outlined in this Section and in Appendix B, about 78,000 kWh/yr of power produced on site (or an amount equal to the total demand of the Allen's electricity consumption, up to 122,000 kWh per year) will effectively be used for commercial agricultural purposes at the Farm.

Tighe & Bond performed this analysis according to industry standards, under the supervision of Massachusetts Professional Engineers Registered in Electrical and Civil Engineering. Our assumptions are based on experience in the wind industry and with small agricultural operations. Operations particular to the Allen Farm were assessed to determine whether they fit within standard agricultural or similar industry operations. Each piece of equipment-related information submitted by the Allen Farm was checked against manufacturer's specifications or similar equipment to obtain accurate estimates of equipment energy demand. During the analysis, we confirmed the definition of agriculture by the Massachusetts General Laws and confirmed that each item included in our estimate of energy production falls within the definition.

Tighe & Bond's wind resource analysis utilized data that was provided to us by other consultants. We verified the source of the data and compared it to other wind speed databases, which did not show significant difference. Our wind analysis includes a detailed description of the level of analysis that was performed and the input assumptions as well as background information.

We are confident in our energy production and consumption estimates, considering the amount of input data and level of analysis performed, but there are many factors that could cause the energy consumption and production estimates to vary. Any farming or business operation is subject to such factors and we feel it is important to discuss them as a part of any estimate. Operational factors that could have an impact on energy demand include the times of year and frequency that freezers and refrigerators are accessed, the irrigation land area and schedule, livestock number fluctuations, and the amount of customers served at the store. Other factors include the ambient conditions, such as temperature, humidity and rainfall. Variation in the shape and materials of buildings could greatly impact Heating Ventilation and Cooling (HVAC) loads for a building of the particular size. Also, variation in demand for the agricultural products could affect operations. The turbine performance could vary from the estimate due to factors including the quality of the input data, the flow model used, operational conditions and use patterns that may be affected by noise or shadow mitigation, climatic and topographic changes, or the increase of large trees or buildings proximate to the turbine.

4.2 Wind Resources

This section describes the methodology that Tighe & Bond used to calculate the expected annual energy production (AEP) at the Allen Farm. The assessment was conducted according to the following order of tasks:

1. Obtain average wind speed for the project site from a virtual wind speed data source. Virtual wind speed data is compiled from multiple sources of historically measured wind speed data. Complex flow models that account for the earth's surface characteristics and topography are used to extrapolate the data to nearby locations. The models facilitate the extraction wind speed data at any location. Please note that neither Tighe & Bond nor either of the proponents have measured wind speeds on-site at this time.

2. Make simple assumptions to expand the data to a full frequency distribution of wind speeds. The virtual wind speed data obtained as described above comes as an average wind speed at particular elevations above ground level. In order to get a better understanding of site-specific wind resources, assumptions are made based on other historical data in order to predict how often each wind speed will be occurring on the Site (called a frequency distribution). Furthermore, information on site-specific terrain is used to estimate how quickly the wind speed increases as height above ground level increases. This allows for an estimation of the frequency distribution at the hub height (center of the turbine rotor) of the turbine.

3. Use the wind speed data and the turbine power curve, provided by the manufacturer, to calculate the estimated annual energy production (AEP) using WindPRO software.

Some background information is included in the following sections to support the assumptions made.

4.2.1 Annual Energy Production Assumptions

The Allen Farm is working with Great Rock Wind to develop a 50 kW wind turbine. This turbine, an Endurance E-3120, is a proven model with many successful installations. It has hub heights of 100, 120, or 140 feet and a rotor diameter of 63 feet. Great Rock Wind has specified a hub height of 120 feet for the calculations. For this machine, the maximum blade tip height is about 151 feet. Tighe & Bond obtained the turbine specifications from the manufacturer on January 6, 2011 (Appendix B).

Tighe & Bond calculated the expected annual energy production (AEP) of the proposed wind turbine using the following assumptions:

1. Average wind speed at 98, 164 and 230 feet above ground level is 5.2 m/s, 6.0 m/s, and 6.5 m/s respectively as developed within the CWEST program, a preliminary project assessment tool created by the Cadmus Group for the Massachusetts Clean Energy Center. These wind speeds were developed by CWEST assuming a constant displacement-height around the turbine and "rough" surface conditions. To account for surrounding 20' trees, a displacement height of 13' was assumed. Displacement height is used to approximate the highest elevation where wind speed is equal to zero, like it would be on unobstructed ground, in areas where there is a vegetation or building obstruction dense enough to cause wind speed to be equal to zero within the obstruction. For

porous cover, like vegetation, the displacement height is estimated to be 2/3 the average tree height. The wind speed increases from zero at the displacement height (or ground if smooth surface) as a function of the elevation above ground level and the shear coefficient (described below). Therefore, adding a displacement height effectively raises the ground level (or shortens the turbine) so that wind speeds going through the turbine at the height of the rotor are reduced. The surface roughness classification “rough” was also used in CWEST to develop the wind speeds on site. This is typical of Massachusetts and is characterized by land with moderate tree or forest cover and topography. The CWEST evaluation is commonly used in the preliminary stages of developing a small scale wind turbine. CWEST includes a tool for small wind power facilities to continue their evaluation and allows the user to edit the critical factors required for determining the power output of small wind turbines such as the Endurance E-3120. CWEST recommends initial discounting of the wind speed data by 10% (“Derate Factor”) due to the uncertainty associated with the model. Therefore, the wind speeds listed above are the “derated” wind speeds.

2. Shear coefficient, or power law exponent, for the Site is 0.3. Wind shear is the change in wind speed with height. On rough land (“roughness” determined by factors such as nearby forest and buildings), such as on Martha’s Vineyard and most of Massachusetts, the shear is best represented by a mathematical relationship called the power law. The power law exponent determines how quickly the wind speed increases with height above ground level. Typically, forested and suburban areas with trees and buildings have a shear exponent between 0.25 - 0.45. Since a lower shear exponent means lower wind speeds at hub height, it is conservative to keep the shear coefficient low at this stage of project development; therefore, 0.3 will produce a conservative estimate of wind speeds. This value and the power law determine the vertical profile of the wind speed.

3. A Weibull frequency distribution of wind speeds was assumed with a shape coefficient equal to 2.37 (k factor). The frequency of occurrence of wind speeds is typically called the frequency distribution, or probability distribution. A probability distribution is a graphical representation of the probability that a particular value in a data set lies between two bounds. Two probability distributions are generally used for wind data sets: the Rayleigh Distribution and the Weibull Distribution. These distributions are each described mathematically by a probability density function. The Weibull probability density function was used to create a frequency distribution for this study because it is the preferred model for complex terrain (hills and trees), such as seen throughout Massachusetts and New England.

   The Weibull factors k and c describe the shape and scale of the probability distribution graph, respectively. The optimal wind speed probability distribution for energy generation and turbine selection has a sharp peak shape and a large area under the curve. A higher k-value (shape coefficient) corresponds to a sharper peak and constant wind speeds. A higher c-factor (scale coefficient) corresponds to a greater area under the curve and greater mean wind speed.

   The Weibull shape coefficient for the Allen Farm was developed from the CWEST analysis and report. Using the average wind speed and the site-specific shape factor from CWEST, the scale factor was calculated to be 6.5.

4. The following losses typical of a preliminary wind energy project were assumed (total 13%):
    a. Availability (3.0%) - Downtime due to turbine service
    b. Balance of plant (1.0%) - Substation Maintenance
    c. Grid availability (1.0%) - Grid unavailable due to external circumstances
    d. High wind hysteresis (5%) - Required restart after high-wind cut-out, as defined by each turbine's power curve.
    e. Electrical losses (2.0%) - Transformer and line losses
    f. Performance degradation due to icing (0.5%) - Ice accumulation on blades
    g. Grid curtailment and ramp-rate (0.5%) - Power outage during low wind (requires restart, which demands power)

Under the above assumptions, the AEP for the Endurance E-3120 with a hub height of 120' is 122 MWh (122,000 kWh) per year. See the WindPRO report in Appendix B for an overview of the assumptions and calculations. This value is considerably higher than the estimate submitted by Great Rock Wind, which is a reflection in the difference in modeling practices related to the obstacle tool in CWEST. Great Rock Wind chose to include the hill to the north of the turbine as an obstacle in the evaluation.

As supported by the description of the obstacle tool in CWEST, below, we do not believe that the CWEST obstacle tool was developed for the modeling of topography or particular topographic features, but that it is intended for modeling a "displacement height" effect on the wind flow. The CWEST description is as follows:

"Dense vegetation, such as forests, near the wind turbine can effectively decrease the hub height of the wind turbine by increasing the height needed above ground level to reach a particular wind speed. This is called displacement height and is assumed to be equal to 2/3 the height of the surrounding vegetation. Large buildings or other structures can have a similar impact."

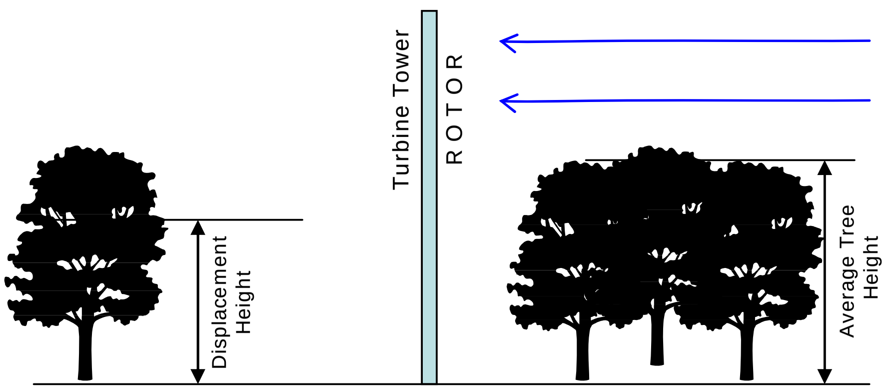
Since the hill is 800 - 900 feet away, we do not believe that the flow regime around it will be similar to that of conditions that would call for a displacement height adjustment. See Figure 4-1 for description of the difference in standard modeling practices for displacement height and single-obstacle conditions. While the flow pattern around the turbine will be affected by the hill, there are other topographical affects also involved. In this particular case, the turbine is also to the north of a similar sized topographic feature and no consideration has been taken for this feature. For both hills there will be some speed-up or slow-down of the wind caused by the slopes, but determining the impact depends on the placement of the turbine in relation to the size of the hills and the location of particularly steep slopes. It is difficult to tell, at this stage, whether the turbine would be in the "wind shadow" of either hills (wind shadow described in Figure 4-1). More detailed site assessment and modeling would be required to assess the size and shape of the topographic feature (and therefore the approximate size of the wind shadow) and the placement of the turbine. Our model, at this stage of analysis, is not adequate to properly describe the terrain and it is Tighe & Bond's modeling practice to avoid wrapping uncertainty into analyses through wind speed reductions. Our goal is to obtain a median AEP and specify the large amount of uncertainty accompanying it in recognition that the complex flow reactions to the hill cannot be considered without other considerations on a similar level of complexity. Therefore, we did not include the same hill related effect on wind speed that Great Rock Wind did and our AEP estimate is higher.

The turbine performance could vary from the estimate due to factors including the quality of the input data, the flow model used, operational conditions and use patterns that may be affected by noise or shadow mitigation, climatic and topographic changes, or the increase of large trees or buildings proximate to the turbine.

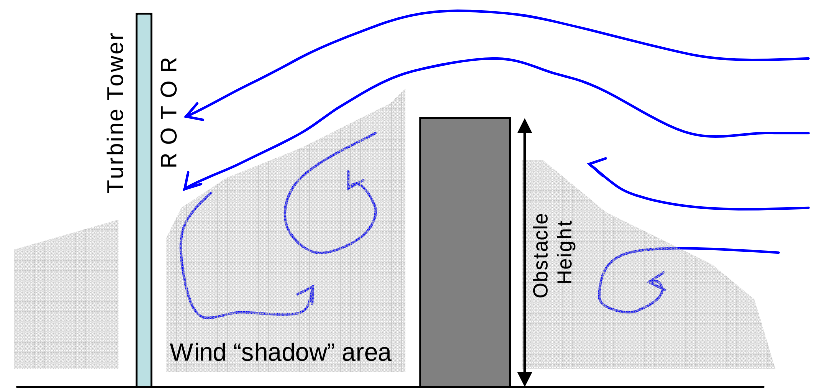
FIGURE 4-1

Displacement Height vs. Obstacle Models

Dense vegetation or buildings surrounding a turbine are modeled with a "displacement height." The "displacement height" is subtracted from the turbine height in flow calculations, effectively saying there is no wind flow in the vegetation or building cover. For tree cover the displacement height is considered 2/3 the average tree height.



Obstacles such as single large structures or sharp topographical features are modeled as a true flow obstacle in most analyses. The computations define a "shadow" of reduced flow around the obstacle due to turbulence. If the turbine is in the "shadow," production will be affected.



Note: Diagrams are conceptual only. Not to Scale. No wind flow modeling was used in determining the flow patterns.

4.3 Energy Consumption

An analysis of the energy consumption at the Allen Farm was completed. The proponents submitted a set of data on their farming operations and equipment and Tighe & Bond reviewed the information for accuracy. According to the definition of agriculture in MGL c. 128 § 1A, all of the sources of electricity considered in this analysis qualify as farming activities, including activities that occur "on a farm as an incident to or in conjunction with such farming operations, including preparations for market, delivery to storage or to market or to carriers for transportation to market." The energy consumption associated with the proponent's residential use was subtracted from the analysis.

The Allen Farm has a variety of operations and products related to small-scale meat production. The Farm has several buildings including the Farmhouse, Store, Horse Barn, two barns on the North side of the property and one south side barn. Due to the necessity to store meat, the Allen Farm has a number of pieces of refrigeration and freezing equipment in various buildings. Also, since the Allen Farm in interested in providing their livestock with high quality feed, their crop operations include irrigation and compost tea brewing, which are relatively energy intensive.

Tighe & Bond used several methods of energy consumption estimation to estimate the probable energy consumption for major equipment of building on the Farm. For HVAC (heating ventilation and cooling) and lighting estimates, we used standard resources for estimating electrical infrastructure loads, such as the National Electric Code (2011) and RS Means (2011) and made estimations based on building square footage. For major equipment, such as pumps and condensers, we used the horsepower (hp) or kiloWatt (kW) rating of the machine and assumed a use pattern (number of hours per day and days per year the machine is operating) based on our knowledge of typical agricultural operations as well as the cycle-times of the equipments.

See the Allen Farm Schedule of Electrical Usage Comparison, located in Appendix B, for an overview of the major sources of energy consumption on the Farm. Calculations and supporting data provided by the Allen Farm are located in Appendix B. We have created a spreadsheet showing their data next to our data and assumptions for ease of review. We did not include assumptions and comments from the Allen Farm in this table to avoid presumptions and transcription errors.

It should be noted that calculation of the Allen Farm residential energy use by standard practices yielded a number far higher than reflected in meter readings even though the meter readings also included a large amount of agriculture-related use.

The Allen Farm has some expansion that is underway at their farm (Called "Planned and Committed" on the Allen Farm Schedule of Electrical Usage Comparison, located in Appendix B; invoices were submitted for each item in this category). They have recently purchased and installed a large new compost tea brewer. This machine is used to make a special mix of compost, microorganisms, and nutrients that will be added as a soil amendment during the growing seasons. The brewer has an aeration pump and a circulation pump. These machines can also be operated with or without heating. At this time, the Allen Farm has elected not to include a heater to the large brewer. The large brewer is expected to begin operation in spring 2011. The Allen Farm did recently add a heater to a smaller compost tea brewer, also expected to begin operation in spring 2011. Other expansion that is planned and committed includes the installation of a greenhouse to extend the growing season for some high value produce, such as tomatoes. The greenhouse will have radiant heating with a tankless water heater for cold days and a circulation pump. It is expected the greenhouse will be completed by the next cold season. While evidence does not exist the greenhouse heating system has been purchased, it is reasonable to presume there would be little reason for anybody to buy the majority of the materials for a greenhouse and not continue to add heating, as planned. Therefore, the heating equipment and related energy consumption was included in the estimate.

The Allen Farm has also specified equipment that they have not purchased and installed yet, but that will become a part of their operations, particularly if a wind turbine to provide clean and local energy is permitted. These items have been identified as “Planned and Uncommitted” on the energy consumption analysis in Appendix B.

Overall, it is expected that energy usage for agricultural purposes on the Allen Farm upon the start-up of their planned and committed equipment will be approximately 78,000 kWh/year. This takes into account major equipment and buildings that are currently in operation by inclusion of the existing meter reading data and the planned equipment that has been purchased or installed at this time, but is not yet operational. For each piece of equipment, Tighe & Bond estimated average daily energy demand (kWh/day) as well as the number of days per year the equipment would be used. From this we calculated the expected output in kWh/year. Estimation of these loads was provided by a qualified electrical engineer, professionally registered in Massachusetts and certified as a CPE, DGCP and CPQ. It is believed that our estimate is conservative by standard electrical engineering practices and that the Allen Farm also provided a conservative estimate.

The package of information the Allen Farm submitted to Tighe & Bond is included in Appendix B. The Allen Farm submitted electricity consumption data for three past years: 2008, 2009, 2010. This information was used to calculate the amount of energy currently being consumed on-site.

Due to the unavailability of the Allen Farm for further comment following submission of data, any ambiguity in the information submitted was resolved by assumptions based on our knowledge of typical agricultural practices. Tighe & Bond is confident in the accuracy of the energy consumption estimate based on the assumptions listed in the Allen Farm Schedule of Electrical Usage Comparison in Appendix A. While the equipment is designed to operate under conditions yielding this level of consumption, it should be noted there are numerous factors that could cause variations in the energy consumption. Major factors that could affect the Allen Farm energy consumption are described below.

For example, operational factors that could have an impact on energy demand include the times of year and frequency that freezers and refrigerators are accessed, the irrigation land area and schedule, the number of workers milking, livestock number fluctuations, and the amount of customers served at the store.

Other factors that will cause variation in energy consumption from year to year are the ambient conditions, such as temperature, humidity and rainfall. Variation in the shape and materials of buildings could impact Heating Ventilation and Cooling (HVAC) loads for a building of the particular size. Also, variation in demand for the dairy products could affect operations.

4.4 Allen Farm Conclusion

Table 4-1, below, shows the comparison of the energy expected to be generated by the proposed turbine at the Allen Farm with the Endurance E-3120. It is anticipated that the Allen Farm will use all of the energy the turbine produces “on-site”, as the Farm’s electrical demand for agricultural purposes exceeds 51% of the estimated AEP by 15,780 kWh annually.

TABLE 4-1
Allen Farm Analysis, Conclusion

	Endurance E-3120 (120’)
Rated Capacity (kW)	55
Wind Speed at Hub Height (ft/s)	17.9
Estimated Wind Turbine Capacity Factor	31.9%
Estimated Annual Energy Production (AEP, kWh)	122,000
51% of Wind Turbine AEP (kWh)	62,220
Tighe & Bond Electricity Consumption Estimate (kWh)	78,000
On-Site Demand for Agricultural Purposes Greater than 51% of Turbine AEP?	YES

A comparison of the electrical demand by agricultural operations at the Allen Farm and the estimated AEP of the proposed Endurance E-3120 turbine demonstrates that 51% of the electricity anticipated to be generated by the turbine is less then the farm’s demand. Therefore, it is reasonable to conclude that greater than 51% of the energy generated by the turbine will be devoted to agricultural purposes. Based on this conclusion and the standards set forth in the RSB opinion, the Allen Farm project qualifies for the agricultural zoning exemption.