Energy Audit

for the

Town Hall

Town of Shutesbury
Massachusetts

Massachusetts Department of Energy Resources

April 2009

Prepared by

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1. EXECUTIVE SUMMARY

An energy audit was performed on the Town Hall located at 1 Cooleyville Road in the Town of Shutesbury as part of the Energy Audit Program sponsored by the Massachusetts Department of Energy Resources (DOER). The audit consisted of a building evaluation aimed at 1) assessing the overall energy efficiency of the building and its on-site systems, 2) identifying potential areas of improvement in the building and systems based on a maximum of a 15 year payback period, and 3) where appropriate, proposing alternatives to the conventional systems.

The energy audit of the Town Hall was part of a multi-site audit within the Town of Shutesbury. A town wide summary, under separate cover, compiles recommendations for all of the buildings and sites included in the audit project.

Several Energy Conservation Measures (ECMs) have been identified for this property. The table on the following page summarizes these ECMs in terms of description, the initial investment required to implement these ECMs, their impact on energy and cost savings and the simple payback in terms of years.

For the Town Hall, the options have a combined savings of 41% on fuel and 9% on electricity. The total cost of upgrades is just under $25,000, with an average payback of 10 years.

Several renewable energy types were considered for this site. An onsite wind generation system is recommended for further consideration.

Energy Conservation Measures Summary Table

Town Hall			Annual Energy Savings				Annual Cost Savings			Simple Payback ECM Cost/ Savings (years)
			Electrical		Fuels	Energy	Electrical	Fuels	Total	
ECM#	Description	ECM Cost	kWh	kW	Oil Gal.	Total MMBTU	$	$	$	
HSs	Heating System	$10,130	0	0.0	288	39.9	$ -	$ 691	$ 691	14.7
CSs	Control System	$1,626	0	0.0	82	11.4	$ -	$ 197	$ 197	8.2
BEs	Building Envelope	$9,668	0	0.0	410	56.8	$ -	$ 983	$ 983	9.8
EHs / APs	Electric Heaters / Appliances	$1,031	1,532	2.9	(25)	5.2	$ 207	$ (60)	$ 147	7.0
MCs	Motor Controls	$2,403	0	0.0	129	17.9	$ -	$ 309	$ 309	7.8
other	Dehumidifier Adjustment	$100	1,500	0.0	0	0.0	$ 203	$ -	$ 203	0.5
	TOTAL	$24,958	3,032	2.9	884	131.3	$ 409	$ 2,121	$ 2,530	9.9

Total Building Energy Usage	33,992	0	2,164	416.2	$ 4,589	$ 5,194	$ 9,783
Savings Reduction (%)	9%	N/A	41%	32%	9%	41%	26%

2. INTRODUCTION

Through the Energy Audit Program (EAP) offered by the Commonwealth of Massachusetts, Department of Energy Resources (DOER), technical assistance is provided for all buildings owned and operated by cities, towns, regional school districts and wastewater districts to identify capital improvements to reduce energy costs. The technical assistance provided by DOER includes an initial benchmarking of buildings and structures included in the application. Based on the results of the benchmarking, a detailed energy audit may be performed as well as a variety of feasibility studies to evaluate the potential to incorporate renewable energy sources. This comprehensive assistance provides communities with the knowledge needed to reduce energy consumption and associated financial resources.

The purpose of this audit report is to provide the program participant with a list of energy conservation projects, their costs and estimated energy savings. This information may be used to support a future application to DOER's Energy Conservation Improvement Program (ECIP), support performance contracting or justify a municipal bond funded improvement program. ECIP is a state funded grant program that provides funds for energy conserving capital improvements.

The approach taken in this audit included a thorough walk-through of the building(s) and associated systems and equipment, including both process systems and building systems. The major areas covered in the audit included the building envelope, process systems, electrical systems, HVAC systems, lighting systems and operational and maintenance procedures. A major element of the audit also included an initial interview and ongoing consultation with operational and maintenance personnel, as well as building occupants. This approach is critical to the quality of the audit process, since the input of building personnel is invaluable to the effort to obtain accurate information required for the audit.

CET's energy auditor Bill Lafley and Precision Decisions' licensed professional engineer Chris Vreeland performed the onsite audit, developed the recommendations and wrote the audit report. Personnel from the municipality provided site-specific information in advance of the audits as well as observations during the site walkthrough.

The recommendations within this report are based on one year of submitted usage data, a site review and preliminary evaluation. The energy savings and energy production figures are projected estimates based on conceptual project upgrades, information gathered at the site, and from the historical utility information provided. The actual savings may vary from these estimates due to a variety of factors. The figures used for the cost of recommended upgrades are 'opinions of probable cost' and are intended to be used for feasibility purposes only. The recommended measures should proceed to detailed design and further re-evaluation followed by competitive bidding per the Massachusetts Procurement Guidelines. The resulting responses to the bid should be used for budget approval purposes. For more information see: *Office of the Inspector General, Municipal, County, District, and Local Authority Procurement of Supplies, Services, and Real Property, Publication No. CR-1520-170-200-09/06-IGO.*

3. FACILITY DESCRIPTION

The Town Hall in Shutesbury is a 5,512 square foot, 2 story building located at 1 Cooleyville Road. The original building was constructed in 1949 and was used as a school; a handicapped access entrance and a hydraulic elevator were added in 2000. Occupancy is year-round with approximately 5 employees and a variable number of the public present from 7 AM – 5 PM, with regular meetings and events in the evenings. The building has one set of stairs, five office spaces, three meeting rooms, a small break room and a kitchen.

Building Envelope

The building is wood construction and has a pitched roof. The roof covering is asphalt shingles over wood decking and is in good condition. The main ridge line runs north to south, and there is also a small south-facing roof at the rear of the building.

The walls in the original section have no insulation. The walls are aluminum-sided except for the front entrance section of the original building. The ceiling over the original section has 4 - 8 inches of loose fiberglass insulation in fair to poor condition with a vented attic space above. The attic insulation over the new handicapped entrance portion of the building is two layers of 6 inch (R19) fiberglass batt insulation. The basement walls are uninsulated.

The interior office areas of the building are primarily finished with drywall, vinyl tile or carpet, and suspended acoustic ceiling tiles.

All the windows in the building are double hung, double pane wood windows in good condition.

There are four entrances into the building. The main front and two basement entrances in the original section of the building are wood doors. The new, rear handicapped entrance is an insulated steel door with a double pane, fixed window.

Lighting

The lighting in the building is shown in the table below:

Area	Type	Number	Wattage	Control
Offices and meeting rooms	T8-2 lamp	41	38	Manual
Hall –basement	T8-2lamp	1	38	Manual
Halls- 1st floor	3-lamp hanging	4	15	Manual
Offices and meeting rooms	T8-4Lamp	12		Manual
Stairway	T8-2lamp	1	38	Motion
Men's room	CFLs	3	15	Motion
Women's room	Halogen flood	1	75	Motion

Exterior lighting is provided by a mercury vapor streetlight on the front of the building, three coach-light fixtures with CFLs (two in front and one in the rear), and 10 floodlights on motion detectors.

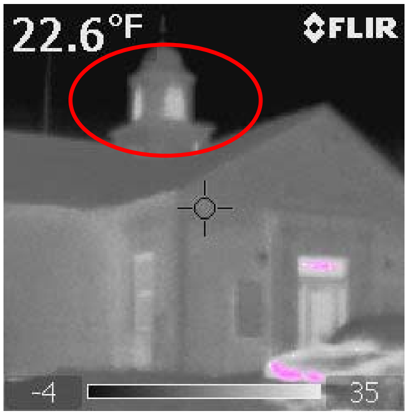
Heating and Cooling System

An oil-fired Pensotti boiler rated at 309,520 BTUH heats the water circulated through the system. The tested efficiency was 76.9 %.

Thirteen local thermostats control the temperature of each occupied space.

There is no central AC. Window AC units are used for various offices and the units are removed in the winter.

The building also has a Lifebreath® heat recovery ventilation unit located in the basement; it is ducted only into the basement meeting room and the senior center room, and is operated year-round.



There is also an old ventilation system in the building that is no longer in service. It is ducted to the 4 large offices on the main floor (registers are on the walls) and has ductwork in the attic leading to the cupola; there are two fan motors located in the attic. There are no dampers on the ductwork so at present the ventilation system is passively allowing large amounts of heat out of the building *(see infrared photo to left – cupola is bright white in color, or warm)*.

Hot Water System

Potable water is received from a well pump. There are two restrooms in the building. The fixtures are low flow water efficient fixtures. Potable hot water is generated by one Ruud 40 gallon electric water heater. It is located in a storage room in the basement. The pipes are uninsulated, but there are no pipes in unconditioned areas.

Computers, Appliances & Other Plug Loads

The site also has the following major plug loads:

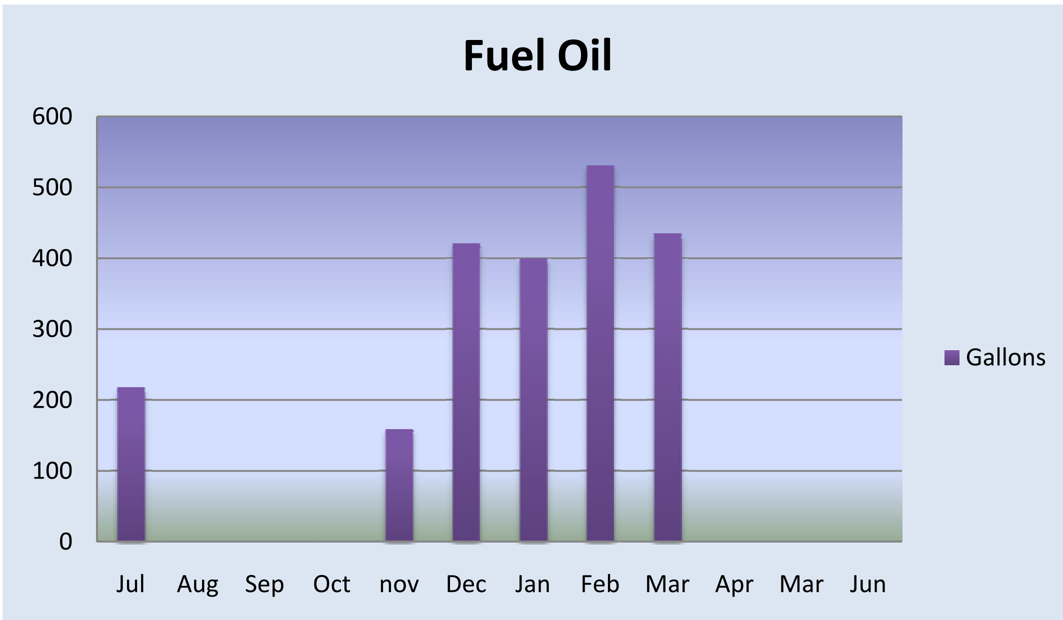
11 computer stations
4 photo copiers
1 fax machine
2 portable refrigerators
1 refrigerator
1 electric range
1 water cooler
1 dishwasher
3 microwave ovens
2 coffee makers
1 television
3 dehumidifiers
1 air purifier

Energy Profiles

The site uses oil and electricity.

Fuel Oil

The Town Hall used 2164 gallons of #2 fuel in FY07.



The most recent bill for the Town of Shutesbury has a rate of $ 2.40 per gallon with potentially variable costs in the near future.

A rate of $2.40 per gallon was used for savings estimates in this report.

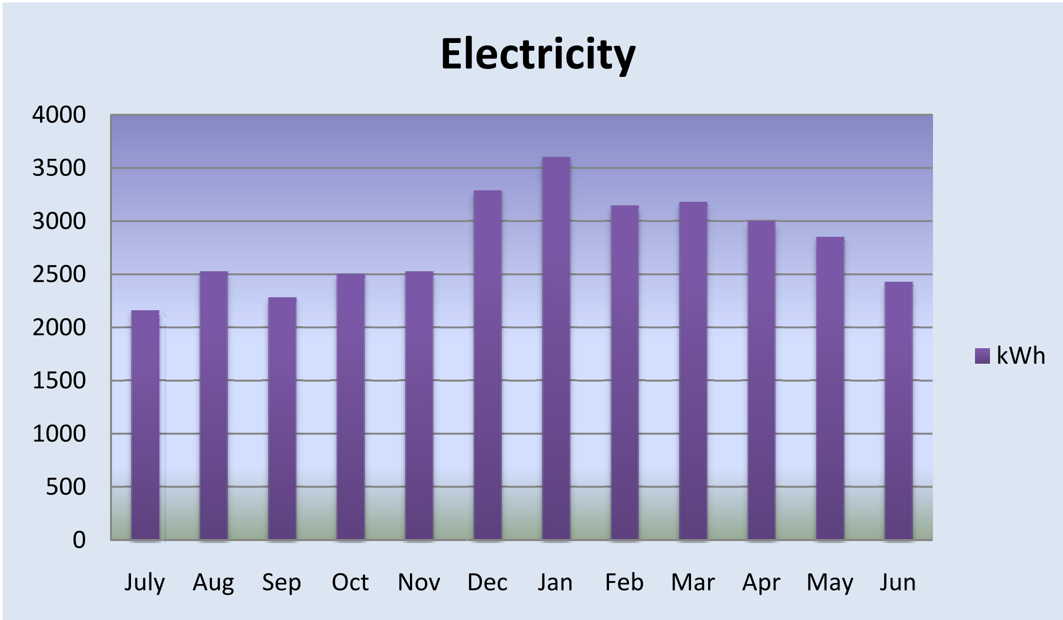
Electrical

Electricity is provided by National Grid (NGrid). Electricity is billed under the G1 rate. For the fourth quarter of 2007 these rates were as follows:

Delivery Services		
Transmission Charges		
Energy Charge		$0.014240 kWh
Demand Charge		$0.000000 kW
Distribution Charge		
Customer Charge		$8.900000 flat monthly
Energy Charge		$0.041840 kWh
Demand Charge		$0.000000 kW
Transition Charges		
Energy Charge		$0.002140 kWh
Demand Charge		$0.000000 kW
Energy Conservation Charge		$0.002500 kWh
Renewable Energy Charge		$0.000500 kWh
Supplier Services		
Generation Charge		0.0741 kWh
Total rate for Energy Usage (kWh)		$0.135320
Total rate for Energy Demand (kWh)		$0.000000
This results in the following:		
Average Monthly Usage	2791 kWh	$377.68
Average Monthly Demand	0 kW	$0.00

A rate of $0.135 per kWh is used for savings estimates in this report. There is no demand charge for this account.

The electric usage for FY08 at the Town Hall was 33,492 kWh.



The electrical usage is variable throughout the year, with a minor increase in the winter. The majority of the electrical usage (approx 2500 kWh/month) is therefore not related to heating or cooling. This baseline usage would be for lighting, appliances and other plug loads (computers, copiers, etc).

There is very limited usage of air conditioning indicated in the summer electrical usage. This is a refreshing change compared to many office buildings that run A/C throughout the summer regardless of outdoor temperature. Clearly, this reflects the local and municipal efficiency commitment of the town personnel in Shutesbury.

4. ENERGY CONSERVATION MEASURES

For the Town Hall the following energy conservation measures were evaluated:

Heating system upgrades
Control system upgrades
Building envelope improvements
Electric heater upgrades
Motor control(s) for fans and/or pumps

For each ECM detailed below, there is a corresponding appendix that further details the quantitative assumptions, projections and opinions of cost for the measure. The name of each appendix corresponds with each ECM section (i.e. ECM LU1 would be found in Appendix LU).

ECM HS1 – Heating System Burner Upgrade

The combustion efficiency of the existing boiler was measured with a combustion analyzer at 76.9%. This level is low, but not unexpected for a boiler of this age. A new burner should be installed which would increase the efficiency into the low to mid-80s percentile. Alternatively, an entirely new boiler could be installed that would bring the efficiency into the low 90s. For the burner upgrade the estimated energy savings is 129 gallons of oil resulting in an annual savings of $309. The estimated cost of the measure is $1,989 yielding a simple payback of 6.4 years. For the boiler replacement the estimated energy savings is 288 gallons of oil resulting in an annual savings of $691. The estimated cost of the measure is $10,130 yielding a simple payback of 14.7 years. Both of these options have acceptable project economics; however, there are additional maintenance costs and inevitable end-of-life costs that will likely be incurred with running the older boiler for another 5-10 years. It is left to the town to determine which option best suits their capital and expense plans.

Note: The boiler replacement is used for the figures in the executive summary. If the new boiler option is pursued, a heat load analysis should be performed prior to the purchase since the building will likely require a smaller boiler once the building envelope upgrades are completed. Selecting a boiler that is too large will result in short cycling which uses more energy and increases maintenance costs.

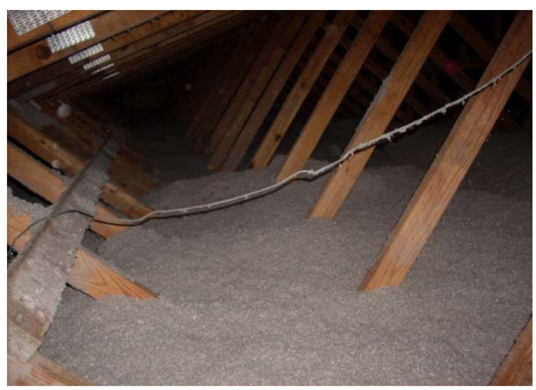
ECM CS1 – Install Programmable Thermostats

The manual thermostats throughout the building should be replaced with programmable thermostats; they should be set to 55 F during unoccupied times, with ample warm up time given to reach 68 F for each work day. The estimated energy savings is 82 gallons of oil resulting in an annual savings of $197. The estimated cost of the measure is $1,626 yielding a simple payback of 8.2 years. This upgrade is recommended at this time.

ECM BE1 – Upgrade Attic Insulation/Airsealing

The un-floored attic should be insulated with at least 8” (R30) of blown-in cellulose insulation. Before the insulation is added, the attic floor should be airsealed with the following areas addressed:

- All wire, pipe, exhaust fan, duct and chimney penetrations and wall tops should be sealed with caulk or expanding foam.
- The central hallway walls extend into the attic forming a short knee wall. These walls are open at the top and should be sealed with reflectex and filled and sealed with expanding foam.
- The outside walls in the front of the building are open at the top and should be sealed with reflectex and filled and sealed with expanding foam (*This should only be done if the exterior walls are not to be insulated – see ECM BE2*).



Once the areas listed above are airsealed, the blown-in cellulose insulation can be installed over the entire attic.

The reduction in summer cooling was not factored into the analysis due to the limited level of A/C usage. The estimated energy savings is 153 gallons of oil resulting in an annual savings of $366. The estimated cost of the measure is $4,331 yielding a simple payback of 11.8 years. This upgrade is recommended at this time.

ECM BE2 – Insulate Walls

The majority of the walls in the building are uninsulated (except for the new portion). This was deduced from a combination of an infrared scan of the building, probing in openings in the walls, and the inspection of the tops of the walls located in the front section of the building (which is of balloon construction). These walls should be insulated with dense-packed blown-in cellulose insulation.

The reduction in summer cooling was not factored into the analysis due to the level of A/C usage. The estimated energy savings is 257 gallons of oil resulting in an annual savings of $617. The estimated cost of the measure is $5,338 yielding a simple payback of 8.7 years. This upgrade is recommended at this time.

ECM EH1 – Install Electric Workstation Heaters

Electric plug-in space heaters that use up to 1500 watts each are being used at several workstations. These should be replaced with electric floor mats which use only 100-120 watts. They should be plugged into outlet occupancy sensors to turn the units off when the workstations are not being used. The combined annual savings from two heater replacements is 954 kWh (which will be partially offset with 25 gallon increase in oil) resulting in a yearly savings of $69. The estimated cost of the measure is $299 yielding a simple payback of 4.3 years. This upgrade is recommended at this time.

ECM AP1 – Appliance Upgrade

The old refrigerator in the kitchen was set on its highest setting (#9) and monitoring of it recorded a usage of 942 kWh per year. It is recommended that it be replaced with a new ENERY STAR®-rated refrigerator (15 cubic feet) that has an annual estimated usage of 364 kWh. The estimated energy savings is 578 kWh/year resulting in an annual savings of $78. The estimated cost of the measure is $732 yielding a simple payback of 9.4 years. This upgrade is recommended at this time.

ECM MC1 – Remove Fans or Upgrade with Dampers and Controls

There are two exhaust fans in the attic which provide some building ventilation. The system appears to be in a state of disrepair: one belt is off one of the fans and the controls for both are missing. As noted in the facility description, these fans are likely part of a fresh air ventilation system that functioned when the building was more densely occupied as a school; the system is now a source of heatloss in the winter. Even with the fans not working there is considerable air circulation due to natural convection (especially in the winter). The fans could simply be removed and the ducts sealed off. This would reduce the building ventilation. The building has a heat recovery ventilator (HRV) which should provide adequate fresh air to the basement when there are only a few occupants. The rest of the building technically meets the fresh air requirements of ASHRAE because the rooms each have operable windows. Since the building has limited occupancy and fairly loose construction, mechanical ventilation is less of a concern. After the walls and attic are sealed and insulated the second floor might feel stuffy at times. If this occurs, a second HRV could be added to provide ventilation to the second floor.

Another consideration would be to keep the existing fans and use them for summer ventilation. This would provide copious amounts of fresh air during moderately warm days. On very hot days the system would be turned off (to prevent bringing in humid, hot air). Late in the day when the outside temperature drops, the system would be turned on; it would run through the night to cool the building down for the next day. This practice of *night flushing* is often used in residential applications with a whole house ventilation fan. This does not work well in commercial applications where window A/C units are used as inevitably the expensive cold air from operating the units gets sucked out of the building throughout the night. However, since minimal A/C is used at the Town Hall this option may be considered and would potentially eliminate the use of A/C units entirely. If this option is pursued, the fans would need to be repaired with controls wired to a central location. A variety of automatic controls can be considered to perform night flushing (timers, differential thermostats, etc). To prevent heat loss during the winter dampers should be installed; or, insulated covers could be installed on the inlet registers.

The lost energy due to the existing setup is estimated at 129 gallons per year or $309. A budget of $2,400 is estimate to remove the existing system, seal the register holes, and install a second HRV; this cost would be less without the HRV if it is not needed. Alternatively, this amount could cover the cost of most (if not all) of the fan rehabilitation and controls. The simple payback of this measure would be approximately 8 years.

5. OPERATIONAL ANALYSIS

The quality of the maintenance and operation of the energy systems for a building has a direct effect on its overall energy efficiency. Energy efficiency needs to be a consideration when implementing facility modifications, equipment replacements, and general corrective actions. The following is a list of activities that should be performed as part of the routine maintenance program for the site. These actions, which have been divided into specific and general recommendations, will help improve energy conservation and support the measures identified in this report.

Specific Recommendations

At the time of the audit site visit (in January) the dehumidifier in the storage room in the basement ran continuously; a monitor calculated its usage at 4500 kWh/year. A relative humidity sensor should be placed in this area to monitor humidity levels, and the dehumidifier should be turned off or set on a low setting when the humidity is below 50%. Generally, humidity levels are very low during the winter months; the dehumidifier may not even be needed for three or four months during this season which would contribute to significant electricity savings.

General Recommendations

The following general recommendations and tasks should be continued or implemented (where applicable):

Building Envelope

1. Caulking and weather stripping is functional and effective.
2. Holes are patched and sealed in the building envelope.
3. Cracked windowpanes are repaired.
4. Window air conditioners are removed prior to the heating season.
5. Automatic door closing mechanisms are functional.
6. Interior vestibule doors are closed.
7. Storm windows are closed in the fall and throughout heating season.
8. Screens are removed on south facing windows during heating season.
9. Maintain gutters, manage roof runoff and perimeter surface water.

Heating and Cooling

10. The pilot lights on furnaces are turned off in the summer.
11. The burners are clean and fuel/air ratios are optimized.
12. Heat exchange surfaces of furnaces are clean and free of scale.
13. Utilize existing setback thermostats. Reduce the set point of the setback from 62 F to 55 F. Extend hours as needed to reach occupied set point at start of workday.
14. Reduce temperature settings in unoccupied areas and set points are seasonally adjusted.
15. Control valves and dampers are fully functional.

16. Pneumatic control systems are checked for air leaks, and corrected if needed.
17. Equipment is inspected for worn or damaged parts.
18. Ductwork is sealed.
19. Hot air registers, and return air ductwork are clean and unobstructed.
20. Air dampers are operating correctly.
21. Heating is uniform throughout the designated areas.
22. Evaporator and condenser coils in AC equipment are clean.
23. Air filters are clean and replaced as needed.

Domestic Hot Water

24. Domestic hot water heater temperature is set to the minimum temperature required.
25. All hot water piping is insulated and not leaking.
26. Tank-type water heaters are flushed as required.

Lighting

27. Turn off lights in rooms when there is enough natural lighting.
28. Use single (compact fluorescent) desk lamps in offices and turn off overhead lights if applicable.
29. Over-lit areas are managed by bi-level switching or photocell controls.
30. Only energy efficient replacement lamps are used and in-stock.
31. Lighting fixture reflective surfaces and translucent covers are clean.
32. Walls are clean and bright.
33. Timers and/or photocells are operating correctly on exterior lighting.

Miscellaneous

34. Use energy saver mode on monitors, and hibernate mode on computers.
35. Use energy saver mode on all copiers, fax machines, etc.
36. Turn off/shutdown all office equipment at night.
37. Refrigerator and freezer doors close and seal correctly.
38. Reduce number of refrigerators. (Combine smaller ‘private’ refrigerators into one single larger unit for the building).
39. Set refrigerator(s) on energy saver mode and/or adjust to medium temperature setting.
40. Set freezer(s) on lowest energy (highest temp) mode when not getting used.
41. Kitchen/bathroom exhaust fans are only used when needed.
42. Office/ computer equipment is either in the “sleep” or off mode when not used.
43. Conduct all recommended equipment specific preventive maintenance tasks.
44. Verify that peak demand on the building/equipment has not changed significantly since the original building commissioning or the most recent retro-commissioning.
45. Replacement equipment (pumps, compressors, etc) are not over/undersized for the particular application.
46. Replacement equipment should be energy conserving and/or high premium devices (compare life cycle costs, not first costs).

6. CLEAN ENERGY OPPORTUNITIES

The Commonwealth of Massachusetts is dedicated to promoting clean energy as an alternative to traditional sources of energy. As such, the DOER and other agencies have developed a number of programs to promote the use of clean energy sources by potentially providing technical assistance and/or financial incentives based on project feasibility. A brief discussion of the various programs is provided below, along with specific projects that may be appropriate for the respective technologies.

Solar Photovoltaics

Through the Commonwealth Solar Program [1] , rebates are offered to encourage the installation of solar photovoltaic (PV) power by homeowners, businesses and municipalities. The rebate program is designed to help defray the costs that are associated with the installation of eligible systems from 20% - 60%. Rebate applications have been available since January 23, 2008. Incentives are greater for projects on public buildings and those that incorporate products manufactured in Massachusetts. The rebates are available for systems that will be directly owned by the applicant, as well as those financed through a third-party ownership model that takes advantage of federal and state tax credits. A total of $68 million is available over the next four years. The following table provides the initial rebate levels:

Non-Residential Rebates for Incremental Capacity ($/Watt)				
Incremental Capacity	**First: 1 to 25 kW**	**Next: > 25 to 100 kW**	**Next: > 100 kW to 200 kW**	**Next: > 200 kW to 500 kW**
Base Incentive	$3.15	$3.00	$2.00	$1.40
PLUS: Additions to Base Incentives				
Massachusetts Manufactured System	$0.15	$0.15	$0.15	$0.15
Public Building	$1.00	$1.00	$1.00	$1.00

Third-Party PV Financing Resources

MTC and DOER encourage applicants to explore various options for financing their PV project. One such option is known as Third-Party Financing. With Third-Party Financing, the PV system is owned and operated by an entity that is separate from the building owner or the PV installer. The Third-Party Financing entity has sufficient financial capital to pay for the entire installation and to maintain and operate the system over its lifetime. In return, the building owner, or

1 Web site: www.commonwealthsolar.org

“host” site, signs a long term contract agreeing to purchase all the power produced by the PV system.

Third-Party Financing is a way to install a large PV array with little or no up-front capital expense from the building owner or “host” site. This type of financing may be most applicable to entities such as non-profits or public buildings. The Third-Party PV Owner can utilize the substantial tax incentives available for PV projects, along with rebates and other incentives, plus the sale of the electricity from the PV array to finance the PV project. Third party financing for municipal PV systems is just taking hold in Massachusetts. At this time, the sites of primary interest are buildings with large flat roofs that can accommodate at least 100 KW of solar.

Solar Hot Water

The State supports the use of solar hot water systems and the payback periods are generally attractive for buildings with high water usage. Systems are generally composed of solar thermal collectors, a fluid system to move the heat from the collector to its point of usage, and a reservoir or tank for heat storage and subsequent use. The systems may be used to heat water for home or business use, for swimming pools, radiant floor heating or as an energy input for space heating and cooling and industrial applications. Attractive applications for town buildings and facilities may include municipal pools, schools with full year hot water usage (summer locker room and/or kitchen usage), fire stations, and public housing facilities. On a periodic basis, the DOER accepts grant applications for solar hot water systems. A maximum of $50,000 per project is available for installation; however, applicants may propose greater grant requests, which will be considered based on the merits of the project and available funding.

Wind and Hydroelectric

Through the Large Onsite Renewables Initiative (LORI) [2], rebates are offered to encourage the installation of wind and hydroelectric for homeowners, businesses and municipalities. The rebate program is designed to help defray a portion of the costs that are associated with the installation of eligible systems.

The LORI awards grants for feasibility studies and design and construction projects for projects that are greater than 10 kW. Feasibility grants are capped at $40,000 with an applicant cost share of 15%. Design grants are capped at the lesser of $125,000 or 75% of actual cost and construction grants are capped at the lesser of $275,000 or 75% of actual costs.

Ownership of existing water diversions or dams with large flows or heads is generally needed for a viable hydroelectric projects. Land with average annual wind speeds of 14 mph or greater are needed for a viable wind project; this is more common along coastlines and at higher elevations (>1800 ft) and along ridge lines. Various types of permits are generally required for both types of projects.

2 Web site: www.masstech.org/renewableenergy/large_renewables.htm

Wood Pellet Fueled Heating

On a periodic basis, the DOER accepts grant applications for wood pellet fueled heating systems [3], which burn pellets made from renewable sources of energy such as compacted sawdust, wood chips, bark and agricultural crop waste. Funding is available to cities, towns, regional school districts, as well as water and wastewater districts. A maximum of $50,000 per project is available for installation; however, applicants may propose greater grant requests, which will be considered based on the merits of the project and available funding. A total of $525,000 is available for this program. The grantee is responsible for repaying 30% of the funds granted within one year of the completed installation.

District Energy

A district energy system consists of a central plant that produces steam, hot water or chilled water to provide space heating, domestic hot water heating, and air conditioning. Modern systems typically rely on hot water distribution rather than steam. The district energy is delivered through a network of pre-insulated buried pipes to a clustered community of commercial, industrial and residential customers. As a result, individual buildings don't need their own boilers, furnaces and cooling systems. Applications for towns can include a cluster (2 or more) of town buildings, school buildings located proximate to each other. The development of small district energy systems serving public buildings can provide an anchor for the expansion of the system into town centers to serve privately owned buildings. Using biomass as a fuel source for the district system enables the rapid displacement of fossil fuels used for building heating and appreciable reductions in town greenhouse gas emissions. Funding is available for towns that can demonstrate good district energy applications to perform feasibility studies of district energy systems that primarily serve town buildings.

3 http://www.mass.gov/Eoca/docs/doer/pub_info/doer_pellet_guidebook.pdf

Clean Energy Assessment

The Town Hall was assessed for solar, hydroelectric, biomass and wind.

Solar Hot Water and Photovoltaics

The first criterion for a good solar site is to have a relatively large roof area with excellent unshaded solar access. This site has limited available area. Most of the roof area faces east and west and is steeply pitched, thus making it is unsuitable for solar.

Technically, there is enough roof area to accommodate a small solar hot water system. The Town Hall is a poor candidate for solar hot water, however, given the marginal solar access in combination with very limited hot water usage.

A ground mount system is feasible for the land behind the Town Hall, but at this time third party interest is limited for ground mount systems due to their higher installation costs (unless they are very large – 500 kW+). It may be some time before the market develops to a point where this is possible.

Hydroelectric

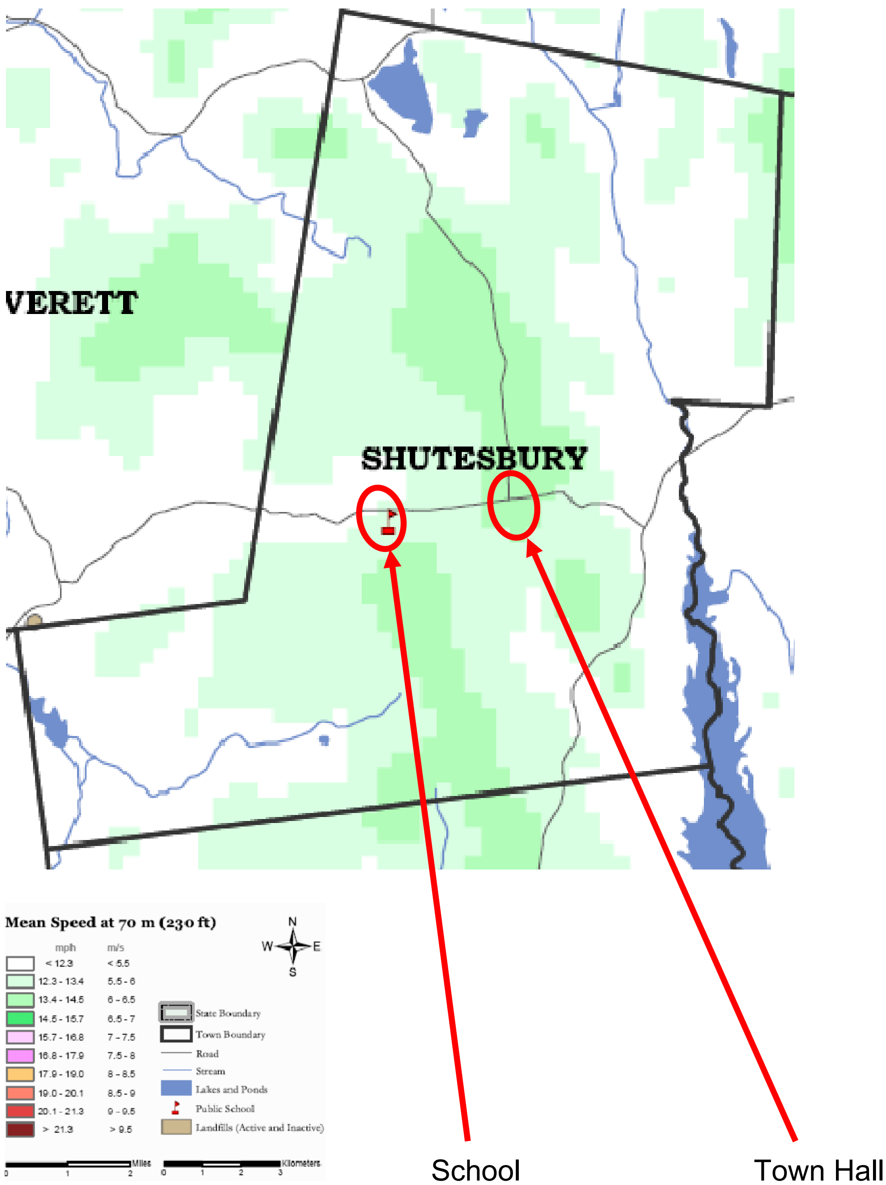
There is no river or stream located at this site; therefore it cannot be considered for hydroelectric.

Biomass

The level of fuel usage (once conservation upgrades are made) is too small for a wood chip or pellet boiler. A residential-sized pellet stove could be considered to heat the lower level; floor registers could be added to convect heat to the second floor. An oversized hopper would be needed so that the unit would only be refilled periodically. A 50,000 BTUH unit with an oversized hopper is estimated at $4,500 installed. Given current pellet prices of $250-$300 per ton, however, the unit will provide minimal energy cost savings when compared to oil. Pellet prices should moderate over the next year or two; the pellet stove option should be reevaluated at that time.

7. WIND

Much of the Town of Shutesbury, although at a high elevation with fairly windy plateaus, does not have significant sites for commercial wind development. The Town Hall, which might be considered windy by the layperson, is actually in a marginal wind location relative to the viability of a small scale wind turbine development. The sites of primary interest are greater than 14.5 mph. There are none in the town below 200 feet of elevation.



In 2007 there was initial interest and subsequent investigation into a wind turbine at the Town Hall. At that time a 10 kW wind turbine was pursued as it was felt a very small scale project would be best suited for the site and it would make a significant reduction in the net electrical usage for the building. As with many wind projects, zoning and siting discussions prolonged the development process. Finally, a small wind bylaw was developed and passed in 2008. However, the project did not proceed due to funding limitations.

Concurrent to this activity, several dozen small wind turbines (mostly 10 kW) were being installed at various locations throughout the state; most of these were partially funded through the MTC SRI Rebate program. In early 2008, MTC conducted a study of the performance of 19 of the small wind turbines to track actual performance against the modeling used to estimate performance. Some very disappointing results were revealed, with average outputs at less than half of what was projected. As a result, the SRI program was halted until early 2009. (The full study and a follow-up summary are included as an appendix to this report.)

To summarize the findings, the results were attributed to poor siting methods in some instances and to equipment issues in others. Not all of the difference was quantified, but is probably due to the small size and relatively low elevation of these installations since this discrepancy is not demonstrated in the larger (and higher) wind projects.

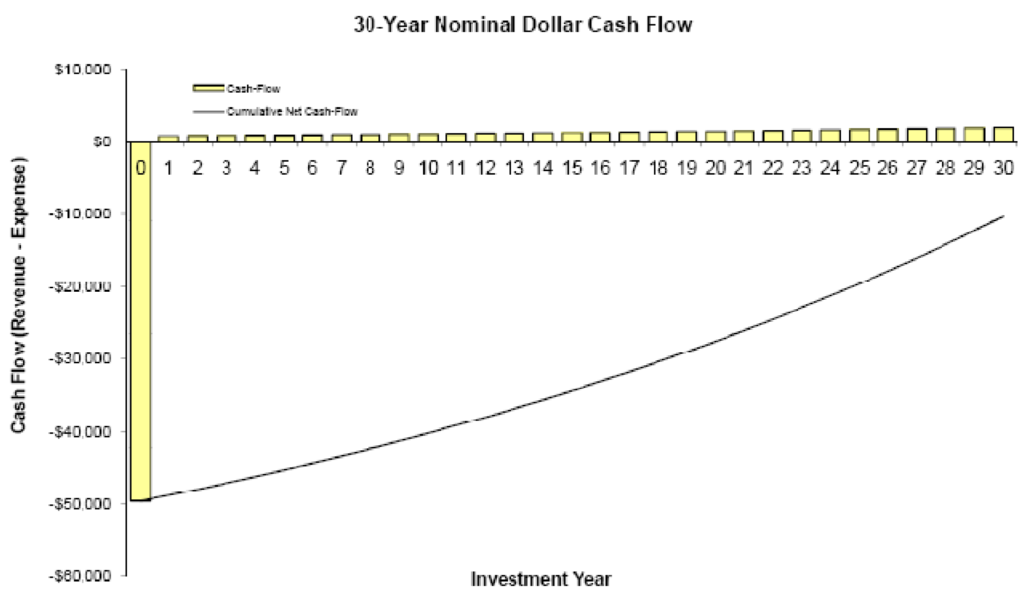
The new MTC SRI program has changed funding and siting criteria.

10 kW Wind Turbine

The Town Hall was modeled with the new data for a 10 kW wind turbine; a financial model was developed from the estimated production data and the most recent pricing for a Bergey turbine and self-supporting lattice tower.

This details of this analysis are included in Appendix W1. In summary, the 10 kW turbine at a hub height of 120 feet is estimated to produce approximately 6800 kWh per year. The total installed cost of the system is estimated at $90,750. The latest SRI program rebate is estimated at $23,143.50. A portion of the rebate is based on the rated output of the unit at 11 meter/second (as opposed to the nameplate rating). The second portion of the rebate is based on the first year of actual production; therefore the exact rebate cannot be determined as it is based on *estimated* production. For the financial model it was assumed that the town would use $18,000 of its Clean Energy Choice funds (these were at $16,000 as of January 2009). The project economics were run on the remaining $49,607 to determine if this is a viable investment for the town to fund. Based on the model the breakeven point (years to net positive cash flow) is greater than 30 years. Without the rebate and Clean Energy funds the breakeven is over 50 years. Since both of these projections exceed the life of the project, a 10 kW turbine at this site it is not recommended at this time.

Note: this analysis was also run assuming the project was funded by a municipal bond with a 20-year term and 2% interest; it had a negative net present value.



Net Metering Law Changes

There have been some major changes involving the *net metering* laws for Massachusetts, which were significantly improved in July 2008 as part of the Green Communities Act. *This act covers a wide range of changes to energy policies in the Commonwealth; only a few of the pertinent changes are discussed here.*

The maximum size of a project that qualifies for net metering was raised from 60 kW to 2 MW. There are three classes of net metering facilities designated in the new bill: under 60 kW, 60 kW - 1 MW, and 1 MW - 2 MW. Each category has several implications, most notably how they deal with excess monthly generation and how it is *credited*.

Under the previous provisions, the power generated by a turbine over 60 kW that is not used on site (i.e. the excess power) was *sold* back to a third party (often the utility, but could be another entity) at the wholesale market rate. This is, on average, only 1/2 to 2/3 of the final price paid by a customer for electrical usage when including delivery charges (transmission, transition, etc). The new change allows for a municipal entity to have up to 2 MW *per unit* and still net meter. This allows excess power to be made during windy times and *credited*; that power can then be tapped for use during non-windy periods.

In addition, the net metering law used to have a monthly limit; it now allows for carrying the *net metering credit* forward. This is especially good for wind turbine projects which tend to produce more in the winter and less in the summer.

The last major change in the bill is that several accounts (minimum of ten) within the same *neighborhood* can participate in the same project in terms of aggregating the power from the net metered facility.

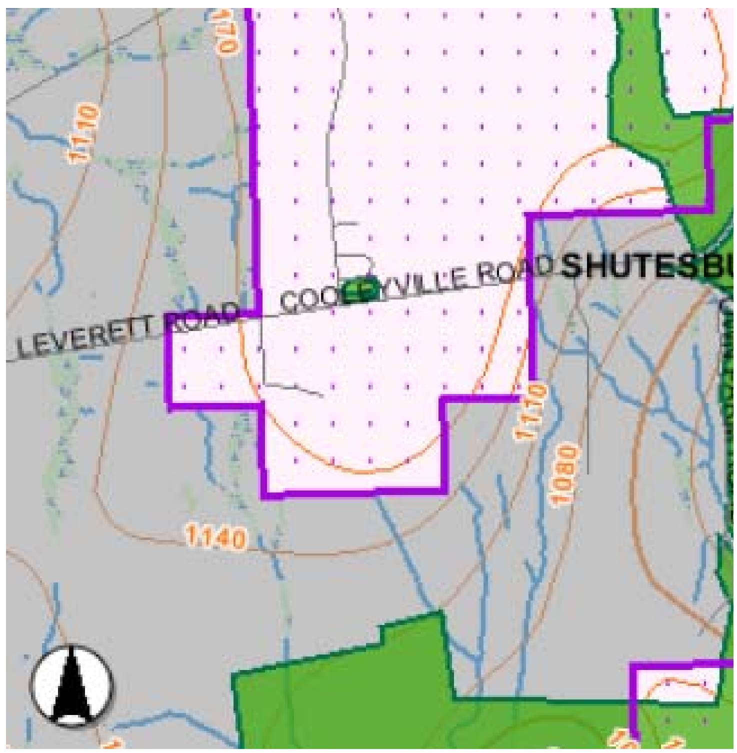
This last provision was not very detailed within the energy bill. This leaves much of the definitions (such as how far a neighborhood can extend) up to the Department of Public Utilities. A broader interpretation of *neighborhood* has been discussed, and it is possible that all of the public buildings might be considered to qualify under one project.

If this is the case, the approach would be to *neighborhood* together all eleven municipal buildings. The annual consumption of the eleven buildings totals just under 300 MWh per year. Based on this consumption, the estimated production of a 200 kW wind turbine would be nearly all used by the town. However, a unit this size would not be practical for the site behind the town hall. It is possible that some other property to the north could be procured, donated or leased to the town for a turbine this size.

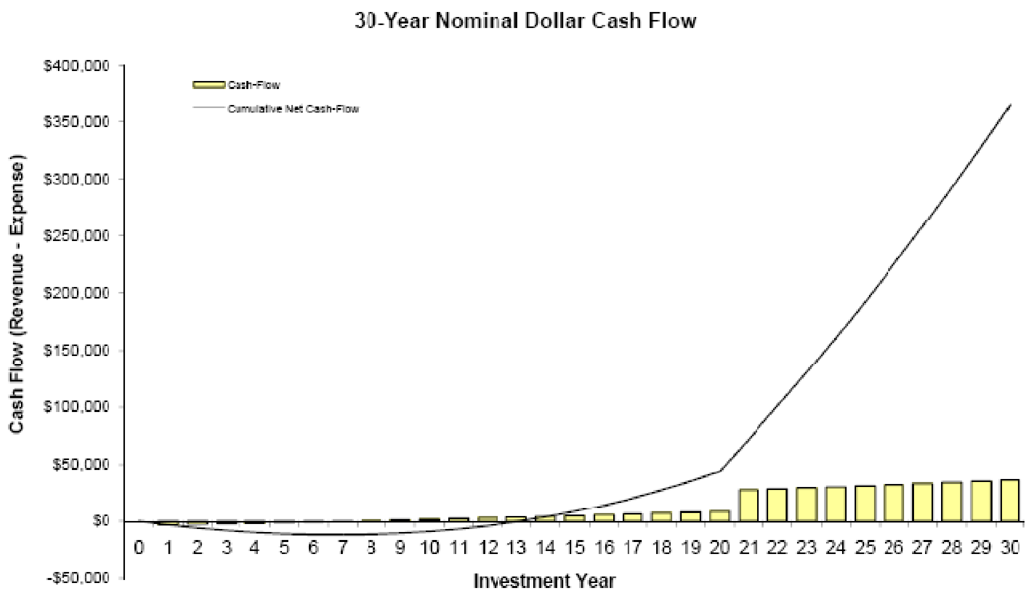
100 kW Wind Turbine

The largest size turbine that might be considered for the Town Hall site is a 100 kW. This would require a taller hub height of at least 160 feet, based on the terrain and vegetative cover on adjacent lots (which is assumed will not be cleared). With a hub height at 160 feet, a 100 kW turbine would be just under 200 feet (for installations of 200 feet or above a light is required by the FAA). At this height the fall zone would exceed the property limits; therefore easements would likely be required from the abutters and a variance to the small wind bylaw. This would also be a fairly large installation for a *neighborhood* setting by today`s standards. However, this may be less of an issue in the future when there is an increase in public support of wind power and turbines become commonplace.

A model was run for a 100 kW turbine with a 160 foot hub height. This resulted in an annual production estimate of 124,000 kWh. The economic model for a single 100 kW wind turbine was run with a total project cost (including design) of $550,000. It is assumed that $40,000 would be obtained from MTC in support of design and $225,000 would be obtained from MTC in support of construction. These figures were deduced from previous LORI funding levels; at this time, no future LORI funding program or levels have been announced. The balance, $285,000, is assumed to be funded by a municipal bond with a term of 20 years. The Green Communities Act and the Federal Stimulus Package from October 2008 both had provision for municipal bonds for energy projects.



The results of the analysis is a project that takes 13 years to reach a net positive cash flow. The first seven years actually had a slight negative cash flow; this will be significantly impacted by the interest rate of the bond and could be positive with a lower interest rate. See Appendix W2. The project returns significant revenue to the town after the 20 year bond is paid off (net annual cash flow of nearly $30,000).



The project was run at an interest rate of 2% which is higher than current municipal bond rates. However, it is assumed that interest rates will increase by the time this project is bonded. Higher rates are possible as well; a rate of 3.5% yields project economics with 15 years to net positive cash flow.

Note: These financial models include estimates for operating and maintenance costs, as well as a 3% annual increase in energy costs.

One concern with a financial model at this time is the escalation in price over the next 3-5+ years (which is the amount of time it will likely take to execute a project). Wind turbine prices have increased nearly 50% over the past four years. Although energy prices have moderated the trend may continue; there has been an extension of federal tax credits and there is continued interest in clean technology worldwide. A carbon cap and trade system would also likely spur further demand for wind turbines. While the cost of electricity has (and may continue to) increased, it is not necessarily going to match the increases in the project costs; this will potentially result in less favorable project economics. Therefore, financial modeling should be performed repeatedly throughout the project development with the most up-to-date estimated costs.

The small lot size at the Town Hall it may not prove feasible to install a 100 kW turbine. According to the wind maps, the area to the north of the Town Hall has comparable (even slightly higher) wind speeds. Each specific site would need to be investigated to determine its feasibility. None of these sites are of interest as a utility scale wind installation at this time, given the limited wind speed. However, there may be interest in moderate scale (100-250 kW) net metered installation(s) that aggregate several meters under the neighborhood provisions of the Green Communities Act.

Next Steps for Wind

There are several items to consider as to whether or not the town should further pursue a wind turbine project.

A preliminary economic analysis was provided in this report; this should be reviewed by the town finance board. It may be concluded that these economic returns are too low compared to other investments. Most of the conservation projects have better economic returns and should be completed prior to investment in a wind turbine.

If the wind project is considered to have financial interest, then alternative sites should be considered for a potentially larger wind turbine that would provide enough power for all town buildings.

There are other details for a wind project which can potentially thwart the development of the project: noise, zoning, perceived aviary issues, visual impact, etc. These issues become qualitative at times and are hard to definitively address with formal studies, or with technical or even financial solutions. They will often be determined by community sentiment towards wind turbines. It is advisable to gage the sentiment towards wind early in the process so as not to waste time and money on the development of a wind project; the town of Shutesbury should have a good sense of this from its initial project developments with the 10kW wind turbine at the Town Hall and the subsequent small wind bylaw.

Even if the majority of the town is in support of a wind turbine project, there are several steps during the project implementation that opponents can use to delay or halt the process. These items are not reviewed here as we do not wish to arm opponents with a battle plan; the message is that larger wind turbine projects have met with significant permitting obstacles that put a strain on the level of community support as the project progresses. Therefore, if the town is fairly split in support or only marginally in favor of a larger project, a prolonged project development phase could prove exacerbating. Once some initial discussions have occurred and an alternative site has been identified, a straw poll of some kind should be conducted to gage the level and fortitude of community support for a larger project.

Appendix HS

Heating System Upgrade

Town of Shutesbury

Town Hall

April-09

			Base Case				Proposed				Annual Savings			Total Est.	Simple
Area	ECM#	Description	Annual Usage	Efficiency	Net Energy	Annual Cost	Annual Usage (	Efficiency	Net Energy	Annual Cost				Cost	Payback
			Gallons		MBTU		Gallons		MBTU		MBTU	Gallons	$		
	HS1	Boiler	1754	76.9%	187	$4,210	1466	92.0%	187	$3,519	40	288	$691	$10,130	14.7
		Burner	1754	76.9%	187	$4,210	1625	83.0%	187	$3,901	18	129	$309	$1,989	6.4
Total	HSs	Heating System	1,754												
Fuel Type:	Oil														
Cost:	$2.40														

Opinion of Cost

Measure	Item	Detail	UOM	Qty	Equip (ea)	Matl (lot)	Labor (hr)	Labor rate	Subtotal	Engineering	Conting	Total	Source
										12%	10%		
HS1		Replace Boiler	ea	1	$5,200	$703	40	$60	$8,303	$996	$830	$10,130	Est
		Upgrade burner	ea	1	$800	$200	10.5	$60	$1,630	$196	$163	$1,989	Est
									$0	$0	$0	$0	Est
									$0	$0	$0	$0	Est
									$0	$0	$0	$0	Est

Appendix CS Control System Upgrade

Town of Shutesbury

Town Hall

April-09

			Base Case				Proposed				Annual Savings			Total Est.	Simple
Area	ECM#	Description	Annual Usage	Efficiency	Net Energy	Annual Cost		Efficiency	Net Energy MMBTU					Cost	Payback
			Gallons		MBTU				MBTU		MBTU	Gallons	$		
	CS1	zone 1 - P stat	1466	92.0%	187	$3,519		92.0%	176		11	82	$197	$1,626	8.2
Total	CSs	Control System	1466								11	82	$197	$1,626	8.2
Fuel Type:	Oil														
Cost:	$2.40														

Opinion of Cost

Measure	Item	Detail	UOM	Qty	Equip (ea)	Matl (lot)	Labor (hr)	Labor rate	Subtotal	Engineering	Conting	Total	Source
										12%	10%		
CS1	T Stat	zone 1 - P stat	ea	13	$75	$0	0.5	$55	$1,333	$160	$133	$1,626	Est
													Est
													Est
													Est
													Est

Appendix BE | Building Envelope Upgrade | Town of Shutesbury | Town Hall

April-09

Area	ECM#	Description	Base Case				Proposed				Annual Savings			Total Est.	Simple
Area	ECM#	Description	Annual Usage	Efficiency	Net Energy	Annual Cost	Annual Usage (	Efficiency	Net Energy	Annual Cost				Cost	Payback
			Gallons		MBTU		Gallons		MBTU		MBTU	Gallons	$		
	BE1	Attic Insulation/Airsealing	2164	76.0%	228	$5,194	2011	76.0%	212	$4,827	21	153	$366	$4,331	11.8
	BE 2	Insulate Walls	2164	76.0%	228	$5,194	1907	76.0%	201	$4,577	36	257	$617	$5,338	8.7
Total	BEs	Building Envelope	2,164							9,404	57	410	$983	$9,668	9.8
Fuel Type:	Oil														
Cost:	$2.40														

Opinion of Cost

Measure	Item	Detail	UOM	Qty	Equip (ea)	Matl (lot)	Labor (hr)	Labor rate	Subtotal	Engineering	Conting	Total	Source
										12%	10%		
BE1	Attic	Attic Insulation/Airsealing	ea	2448	$0.50	$0	1	$0.95	$3,550	$426	$355	$4,331	Est
BE 2	Attic	Insulate Walls	sq ft	1750	$1.25	$0	1	$1.25	$4,375	$525	$438	$5,338	Est
													Est
													Est
													Est

April-09

			Base Case				Proposed				Annual Savings			Total Est.	Simple
Area	ECM#	Description	Annual	Fixture	Fixture	Usage	Annual Usage	Fixture	Fixture	Annual Usage				Cost	Payback
			Hours	Quantity	Wattage	kWh	Hours	Quantity	Wattage	kWh	kWh	kWh	$		
	AP-1	Replace Refrigerator	4380	1	215	942	4380	1	83	364	0.13	578	$78	$732	9.4
	EH-1	Toe Heater	350	2	1500	1,050	400	2	120	96	2.76	954	$69	$299	4.3
												Oil Offset			
											-60	-25			
Total	EHs	Electric Heaters / Appliances	0	0		1,992		0		0	3	1532	$147	$1,031	7.0
Power	Electric														
Cost:	$0.135	kWh	$0.00	kW											

Opinion of Cost

Measure	Item	Detail	UOM	Qty	Equip (ea)	Matl (lot)	Labor (hr)	Labor rate	Subtotal	Engineering		Conting	Total	Source
										12%		10%		
AP-1	Appliance	Replace Refrigerator		1	$0	$600	0	$70	$600	$72		$60	$732	Est
EH-1	Toe Heater	Toe Heater		2	$105	$0	0.25	$70	$245	$29		$25	$299	Est

Appendix MC   Motor Controls   Town of Shutesbury   Town Hall

April-09

Area	ECM#	Description	Base Case: Elec Use	Base Case: Heat Loss	Base Case: System	Base Case: Annual Cost	Proposed: Elec Use	Proposed: Heat Loss	Proposed: System	Proposed: Annual Cost	Annual Savings			Total Est.	Simple
			kWh	MMBTU	Efficiency		kWh	MMBTU	Efficiency		Gallons	kWh	$	Cost	Payback
	MC1	Ventilation	0	16.4	92%	$309	0	0.0	92.0%	$0	129	0	$309	$2,403	7.8
Total	MCs	Motor Controls	0	16		$309	0	0		$0	129	0	$309	$2,403	7.8
Fuel Type:	Oil														
Cost:	$2.40														

Opinion of Cost

Measure	Item	Detail	UOM	Qty	Equip (ea)	Matl (lot)	Labor (hr)	Labor rate	Subtotal	Engineering	Conting	Total	Source
										12%	10%		
MC1	Ventilation	Ventilation	ea	2	$150	$350	12	$55	$1,970	$236	$197	$2,403	Est

Appendix W1

Financial Assumptions

Downpayment Percentage (%)	1
Interest Rate (%/year)	0
Marginal Effective Income Tax Rate (%/year)	0
Debt Term (years)	20

Site Characteristics

Site Properties

Average Wind Speed (m/s)	5
Anemometer Ht (m)	30
Wind Shear Exponent	0.143
Weibull k	2
Site Elevation (m)	359.7560976

Avoided Energy Costs

Average Cost of Electricity ($/kWh)	0.13
Nominal Electricity Escalation Rate (%/year)	0.03

System Characteristics

System Costs

Total Installed Cost ($/kW)	49606.5
Variable Costs ($/kWh)	0.015
Nominal Variable Cost Escalation Rate (%/year)	0.02
Fixed Costs ($/kW)	0
Nominal Fixed Cost Escalation Rate (%/year)	0.02

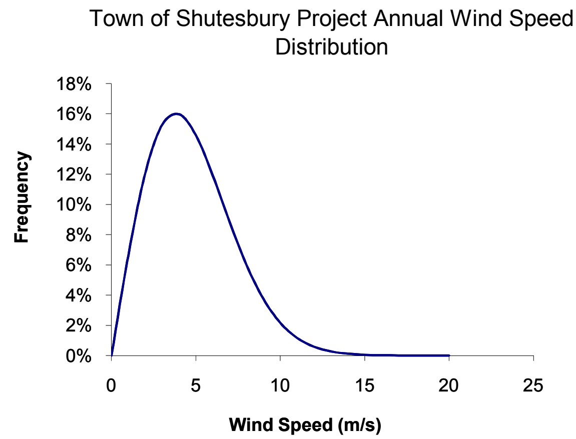
Physical Characteristics

Rated Power (kW)	10
Rotor Hub Height (m)	37
Availability (%)	0.95
Performance Margin	0
Performance Derating	0.4021

Hub Height Average Wind Speed (m/s)	5.15
Air Density Factor	0.97
Average Annual Power Output (kWh)	6827
Implied Capacity Factor	8%

Wind Project System Summary Report

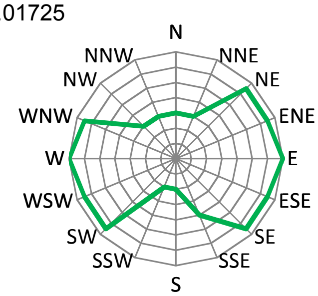
Customer Name:	Town of Shutesbury
System Designer:	C Vreeland
Report Date:	4/17/2009

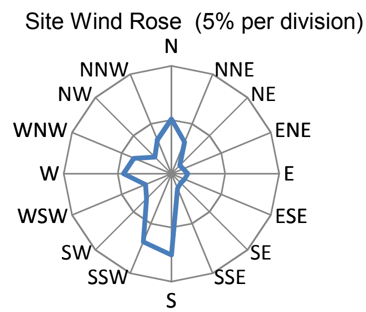


Site Information

Latitude:	
Longitude:	
Annual Avg. Wind Spd:	5 m/s
Avg. Wind Shear Exp:	0.33
Avg. Obstacle Height:	50 Feet
Avg. Hub Height Wind Spd:	4.7 m/s
Conversion Losses	13%
Misc. Losses	
Weibull K Factor:	2.01725

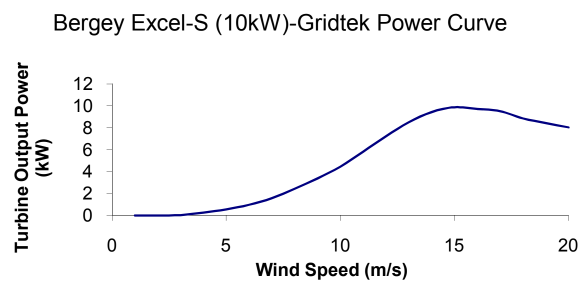
Obstacle Height by Direction
10 ft/division





System Information

Turbine Manufacturer:	Bergey
Turbine Model:	Excel-S (10kW)-Gridtek
Tower Height:	120 Feet
Rated Output Power:	10 kW
Rated Wind Speed:	13.8 m/s



Energy Production Estimates

As Proposed	
Estimated Annual Energy Output:	6,828 kWh/yr
Estimated Annual Capacity Factor:	7.8%
Increase Hub Height by 20 Feet	
Estimated Annual Energy Output:	8,331 kWh/yr
Estimated Annual Capacity Factor:	9.5%
Production Increase vs. Proposed System	122%
Under Ideal Site Conditions	
Estimated Annual Energy Output:	8,190 kWh/yr
Estimated Annual Capacity Factor:	9.3%
Production Increase vs. Proposed System	120%

Environmental Benefits of Small Wind System

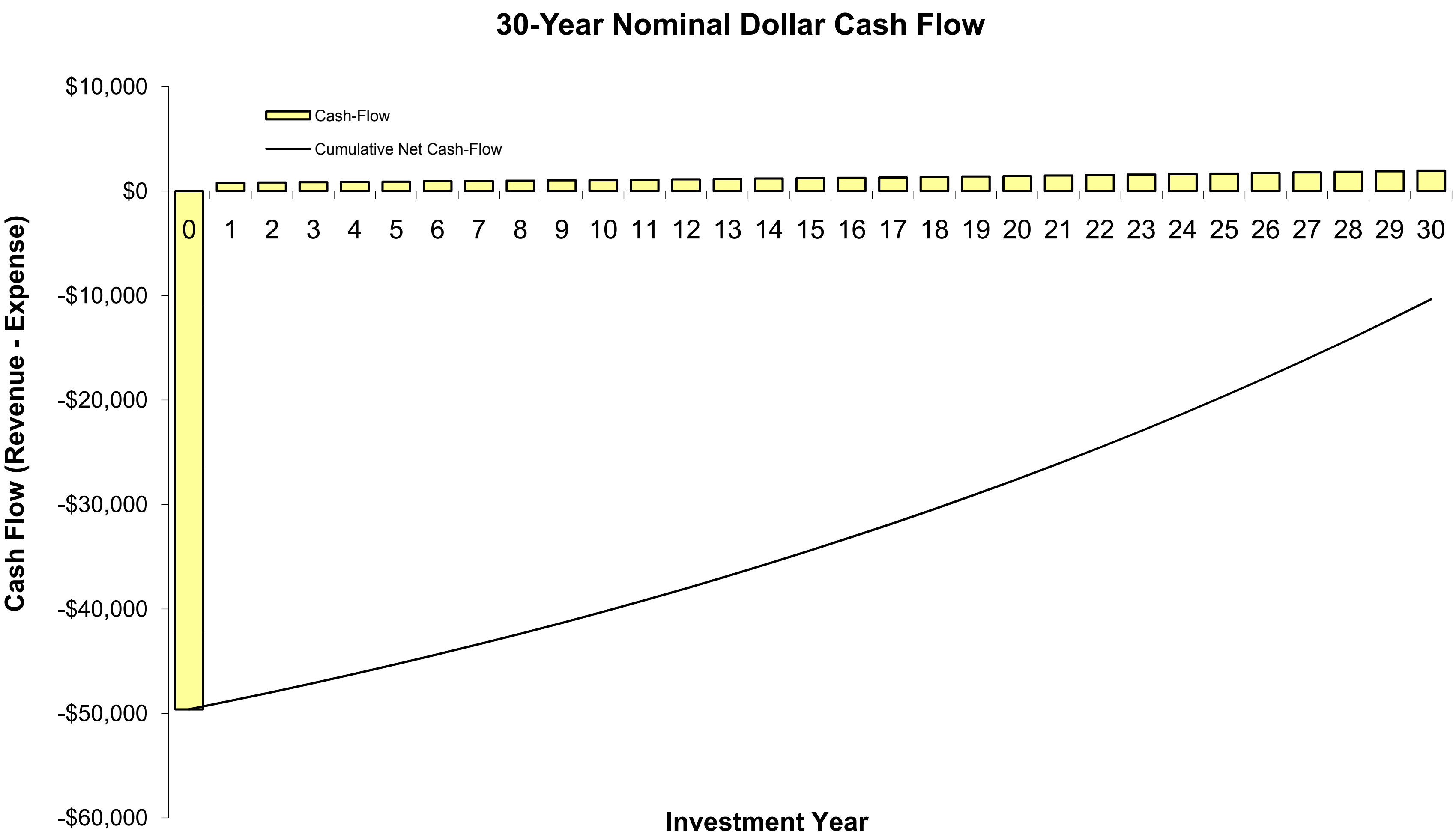
Annual Pounds of CO2 Emissions Offset	8,371
Equivalent Acres of Trees Planted	1.04
Equivalent Cars Taken Off Road	0.7

MTC Minimum Technical Requirements

Turbine Hub Height is 30+ Feet Above All Surrounding Obstacles?	Yes
System is Expected to Perform At 10%+ Capacity Factor?	No

Report Generated Using SWEETv2.2

Developed by The Cadmus Group, Inc. www.cadmusgroup.com
For questions/comments, send email to: PTS@cadmusgroup.com


30-Year Nominal Dollar Cash Flow
$10,000
$0
-$10,000
-$20,000
-$30,000
-$40,000
-$50,000
-$60,000
Cash-Flow
Cumulative Net Cash-Flow
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Cash Flow (Revenue - Expense)
Investment Year

Summary Assumptions

Power Output (kWh/year)	6,827
Average Cost of Electricity ($/kWh)	$0.13
Nominal Electricity Escalation Rate (%/year)	3.00%
Total Installed Cost	$49,607
Downpayment (%)	100.00%
Debt Term (years)	20
Interest Rate (%/year)	0.00%
Marginal Effective Tax Rate (%/year)	0.00%
Variable Cost ($/kWh)	$0.02
Nominal Variable Cost Escalation Rate (%/year)	2.00%
Rated Power (kW)	10
Fixed Cost ($/kWh)	$0.00
Nominal Fixed Cost Escalation Rate (%/year)	2.00%

30-Year Nominal Cash-Flow (All units are expressed as dollars unless otherwise noted)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenue																
Power Output (kWh/year) (A)		6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827
Avoided Cost of Electricity ($/kWh) (B)		$0.134	$0.138	$0.142	$0.146	$0.151	$0.155	$0.160	$0.165	$0.170	$0.175	$0.180	$0.185	$0.191	$0.197	$0.203
Total Revenue (A*B)		$914	$942	$970	$999	$1,029	$1,060	$1,092	$1,124	$1,158	$1,193	$1,229	$1,265	$1,303	$1,343	$1,383
Expenses																
Initial Capital Expenditure (Downpayment)	$49,607															
Amount Financed	$0															
Total Debt Payment		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Before-Tax Debt Interest Payment		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Debt Principal Payment (C)		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
After-Tax Debt Interest Payment (D)		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Variable Costs (E)		$104	$107	$109	$111	$113	$115	$118	$120	$122	$125	$127	$130	$132	$135	$138
Fixed Costs (F)		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses (C+D+E+F)		$104	$107	$109	$111	$113	$115	$118	$120	$122	$125	$127	$130	$132	$135	$138
Net Cash-Flow	-$49,607	$810	$835	$861	$888	$916	$944	$974	$1,004	$1,036	$1,068	$1,101	$1,136	$1,171	$1,207	$1,245
Cumulative Net Cash-Flow	-$49,607	-$48,797	-$47,962	-$47,100	-$46,212	-$45,296	-$44,352	-$43,378	-$42,374	-$41,338	-$40,270	-$39,169	-$38,033	-$36,862	-$35,655	-$34,410

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Revenue															
Power Output (kWh/year) (A)	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827	6,827
Avoided Cost of Electricity ($/kWh) (B)	$0.209	$0.215	$0.221	$0.228	$0.235	$0.242	$0.249	$0.257	$0.264	$0.272	$0.280	$0.289	$0.297	$0.306	$0.316
Total Revenue (A*B)	$1,424	$1,467	$1,511	$1,556	$1,603	$1,651	$1,701	$1,752	$1,804	$1,858	$1,914	$1,972	$2,031	$2,092	$2,154
Expenses															
Initial Capital Expenditure (Downpayment)															
Amount Financed															
Total Debt Payment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Before-Tax Debt Interest Payment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Debt Principal Payment (C)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
After-Tax Debt Interest Payment (D)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Variable Costs (E)	$141	$143	$146	$149	$152	$155	$158	$161	$165	$168	$171	$175	$178	$182	$186
Fixed Costs (F)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses (C+D+E+F)	$141	$143	$146	$149	$152	$155	$158	$161	$165	$168	$171	$175	$178	$182	$186
Net Cash-Flow	$1,284	$1,324	$1,365	$1,407	$1,451	$1,496	$1,542	$1,590	$1,640	$1,690	$1,743	$1,797	$1,852	$1,910	$1,969
Cumulative Net Cash-Flow	-$33,126	-$31,802	-$30,438	-$29,031	-$27,580	-$26,084	-$24,541	-$22,951	-$21,312	-$19,621	-$17,879	-$16,082	-$14,229	-$12,320	-$10,351

Appendix W2

Financial Assumptions

Downpayment Percentage (%)	0
Interest Rate (%/year)	0.025
Marginal Effective Income Tax Rate (%/year)	0
Debt Term (years)	20

Site Characteristics

Site Properties

Average Wind Speed (m/s)	5.5
Anemometer Ht (m)	50
Wind Shear Exponent	0.143
Weibull k	2
Site Elevation (m)	359.7560976

Avoided Energy Costs

Average Cost of Electricity ($/kWh)	0.13
Nominal Electricity Escalation Rate (%/year)	0.03

System Characteristics

System Costs

Total Installed Cost ($/kW)	285000
Variable Costs ($/kWh)	0.015
Nominal Variable Cost Escalation Rate (%/year)	0.02
Fixed Costs ($/kW)	0
Nominal Fixed Cost Escalation Rate (%/year)	0.02

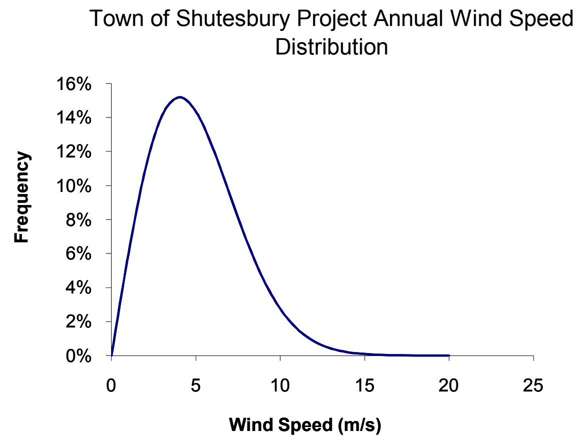
Physical Characteristics

Rated Power (kW)	100
Rotor Hub Height (m)	50
Availability (%)	0.95
Performance Margin	0
Performance Derating	0.24

Hub Height Average Wind Speed (m/s)	5.50
Air Density Factor	0.97
Average Annual Power Output (kWh)	127045
Implied Capacity Factor	15%

Wind Project System Summary Report

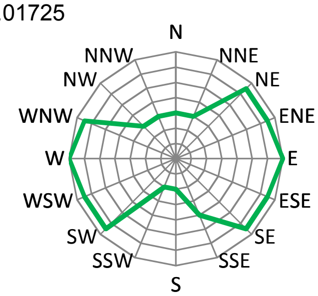
Customer Name: Town of Shutesbury
System Designer: C Vreeland
Report Date: 4/17/2009

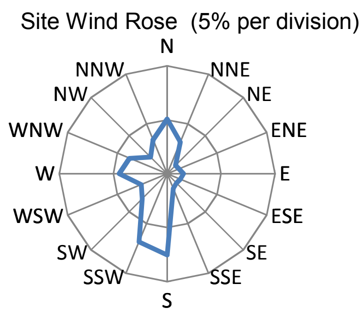


Site Information

Latitude:	
Longitude:	
Annual Avg. Wind Spd:	5.5 m/s
Avg. Wind Shear Exp:	0.33
Avg. Obstacle Height:	50 Feet
Avg. Hub Height Wind Spd:	5 m/s
Conversion Losses	13%
Misc. Losses	
Weibull K Factor:	2.01725

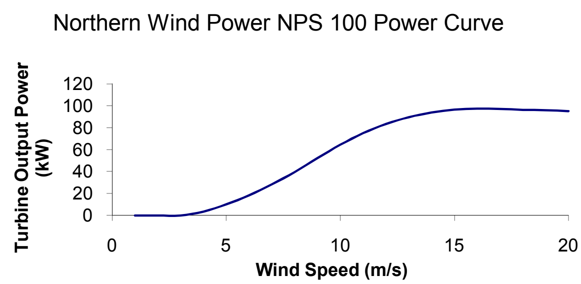
Obstacle Height by Direction
10 ft/division





System Information

Turbine Manufacturer:	Northern Wind
Turbine Model:	NPS 100
Tower Height:	160 Feet
Rated Output Power:	100 kW
Rated Wind Speed:	15 m/s



Energy Production Estimates

As Proposed	
Estimated Annual Energy Output:	124,299 kWh/yr
Estimated Annual Capacity Factor:	14.2%
Increase Hub Height by 20 Feet	
Estimated Annual Energy Output:	139,843 kWh/yr
Estimated Annual Capacity Factor:	16.0%
Production Increase vs. Proposed System	113%
Under Ideal Site Conditions	
Estimated Annual Energy Output:	151,306 kWh/yr
Estimated Annual Capacity Factor:	17.3%
Production Increase vs. Proposed System	122%

Environmental Benefits of Small Wind System

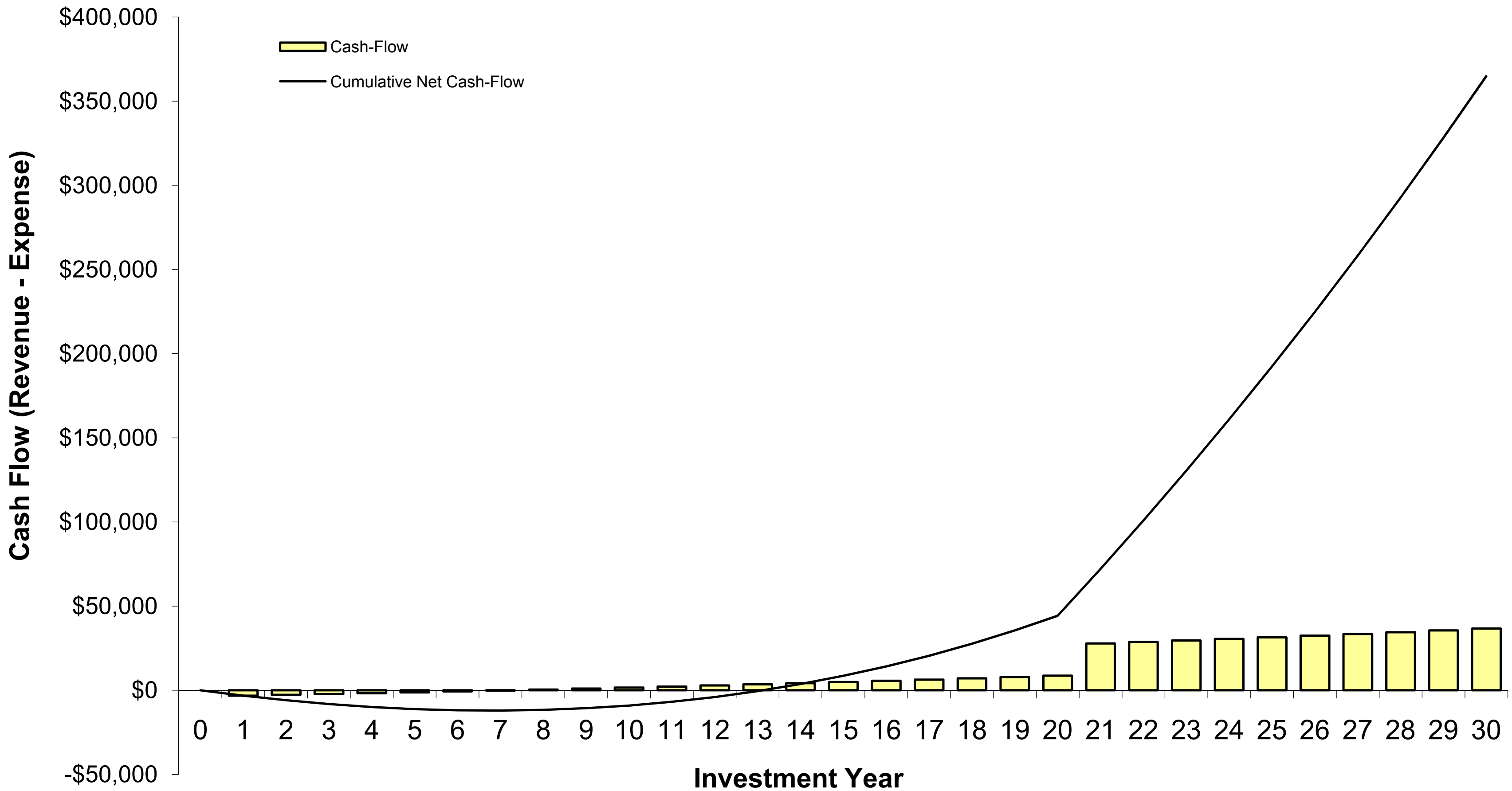
Annual Pounds of CO2 Emissions Offset	152,390
Equivalent Acres of Trees Planted	18.89
Equivalent Cars Taken Off Road	13.3

MTC Minimum Technical Requirements

Turbine Hub Height is 30+ Feet Above All Surrounding Obstacles?	Yes
System is Expected to Perform At 10%+ Capacity Factor?	Yes

Report Generated Using SWEETv2.2
Developed by The Cadmus Group, Inc. www.cadmusgroup.com
For questions/comments, send email to: PTS@cadmusgroup.com

30-Year Nominal Dollar Cash Flow



Summary Assumptions

Power Output (kWh/year)	127,045
Average Cost of Electricity ($/kWh)	$0.13
Nominal Electricity Escalation Rate (%/year)	3.00%
Total Installed Cost	$285,000
Downpayment (%)	0.00%
Debt Term (years)	20
Interest Rate (%/year)	2.50%
Marginal Effective Tax Rate (%/year)	0.00%
Variable Cost ($/kWh)	$0.02
Nominal Variable Cost Escalation Rate (%/year)	2.00%
Rated Power (kW)	100
Fixed Cost ($/kWh)	$0.00
Nominal Fixed Cost Escalation Rate (%/year)	2.00%

30-Year Nominal Cash-Flow (All units are expressed as dollars unless otherwise noted)

	0	1	2	3	4	5	6	7	8	9	10
Revenue											
Power Output (kWh/year) (A)		127,045	127,045	127,045	127,045	127,045	127,045	127,045	127,045	127,045	127,045
Avoided Cost of Electricity ($/kWh) (B)		$0.134	$0.138	$0.142	$0.146	$0.151	$0.155	$0.160	$0.165	$0.170	$0.175
Total Revenue (A*B)		$17,011	$17,522	$18,047	$18,589	$19,146	$19,721	$20,312	$20,922	$21,549	$22,196
Expenses											
Initial Capital Expenditure (Downpayment)	$0										
Amount Financed	$285,000										
Total Debt Payment		$18,282	$18,282	$18,282	$18,282	$18,282	$18,282	$18,282	$18,282	$18,282	$18,282
Before-Tax Debt Interest Payment		$7,125	$6,846	$6,560	$6,267	$5,967	$5,659	$5,343	$5,020	$4,688	$4,348
Debt Principal Payment (C)		$11,157	$11,436	$11,722	$12,015	$12,315	$12,623	$12,939	$13,262	$13,594	$13,933
After-Tax Debt Interest Payment (D)		$7,125	$6,846	$6,560	$6,267	$5,967	$5,659	$5,343	$5,020	$4,688	$4,348
Variable Costs (E)		$1,944	$1,983	$2,022	$2,063	$2,104	$2,146	$2,189	$2,233	$2,277	$2,323
Fixed Costs (F)		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses (C+D+E+F)		$20,226	$20,265	$20,304	$20,345	$20,386	$20,428	$20,471	$20,515	$20,559	$20,605
Net Cash-Flow	$0	-$3,214	-$2,743	-$2,257	-$1,756	-$1,240	-$707	-$159	$407	$990	$1,591
Cumulative Net Cash-Flow	$0	-$3,214	-$5,957	-$8,214	-$9,970	-$11,210	-$11,917	-$12,076	-$11,669	-$10,679	-$9,088

	11	12	13	14	15	16	17	18	19	20
Revenue										
Power Output (kWh/year) (A)	127,045	127,045	127,045	127,045	127,045	127,045	127,045	127,045	127,045	127,045
Avoided Cost of Electricity ($/kWh) (B)	$0.180	$0.185	$0.191	$0.197	$0.203	$0.209	$0.215	$0.221	$0.228	$0.235
Total Revenue (A*B)	$22,862	$23,548	$24,254	$24,982	$25,731	$26,503	$27,298	$28,117	$28,961	$29,829
Expenses										
Initial Capital Expenditure (Downpayment)										
Amount Financed										
Total Debt Payment	$18,282	$18,282	$18,282	$18,282	$18,282	$18,282	$18,282	$18,282	$18,282	$18,282
Before-Tax Debt Interest Payment	$4,000	$3,643	$3,277	$2,902	$2,517	$2,123	$1,719	$1,305	$881	$446
Debt Principal Payment (C)	$14,282	$14,639	$15,005	$15,380	$15,764	$16,159	$16,563	$16,977	$17,401	$17,836
After-Tax Debt Interest Payment (D)	$4,000	$3,643	$3,277	$2,902	$2,517	$2,123	$1,719	$1,305	$881	$446
Variable Costs (E)	$2,369	$2,417	$2,465	$2,514	$2,565	$2,616	$2,668	$2,722	$2,776	$2,832
Fixed Costs (F)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses (C+D+E+F)	$20,651	$20,699	$20,747	$20,796	$20,847	$20,898	$20,950	$21,004	$21,058	$21,114
Net Cash-Flow	$2,210	$2,849	$3,507	$4,185	$4,884	$5,605	$6,348	$7,113	$7,902	$8,716
Cumulative Net Cash-Flow	-$6,877	-$4,028	-$522	$3,664	$8,548	$14,153	$20,501	$27,614	$35,517	$44,233

	21	22	23	24	25	26	27	28	29	30
Revenue										
Power Output (kWh/year) (A)	127,045	127,045	127,045	127,045	127,045	127,045	127,045	127,045	127,045	127,045
Avoided Cost of Electricity ($/kWh) (B)	$0.242	$0.249	$0.257	$0.264	$0.272	$0.280	$0.289	$0.297	$0.306	$0.316
Total Revenue (A*B)	$30,724	$31,646	$32,595	$33,573	$34,580	$35,618	$36,686	$37,787	$38,921	$40,088
Expenses										
Initial Capital Expenditure (Downpayment)										
Amount Financed										
Total Debt Payment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Before-Tax Debt Interest Payment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Debt Principal Payment (C)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
After-Tax Debt Interest Payment (D)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Variable Costs (E)	$2,888	$2,946	$3,005	$3,065	$3,126	$3,189	$3,253	$3,318	$3,384	$3,452
Fixed Costs (F)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Expenses (C+D+E+F)	$2,888	$2,946	$3,005	$3,065	$3,126	$3,189	$3,253	$3,318	$3,384	$3,452
Net Cash-Flow	$27,836	$28,700	$29,590	$30,508	$31,454	$32,429	$33,434	$34,469	$35,536	$36,636
Cumulative Net Cash-Flow	$72,069	$100,769	$130,359	$160,867	$192,321	$224,750	$258,184	$292,653	$328,189	$364,826

THE CADMUS GROUP, INC.

Progress Report on Small Wind Energy Development Projects Receiving Funds from the Massachusetts Technology Collaborative (MTC)

Shawn Shaw

REVISED
4/14/2008

Executive Summary

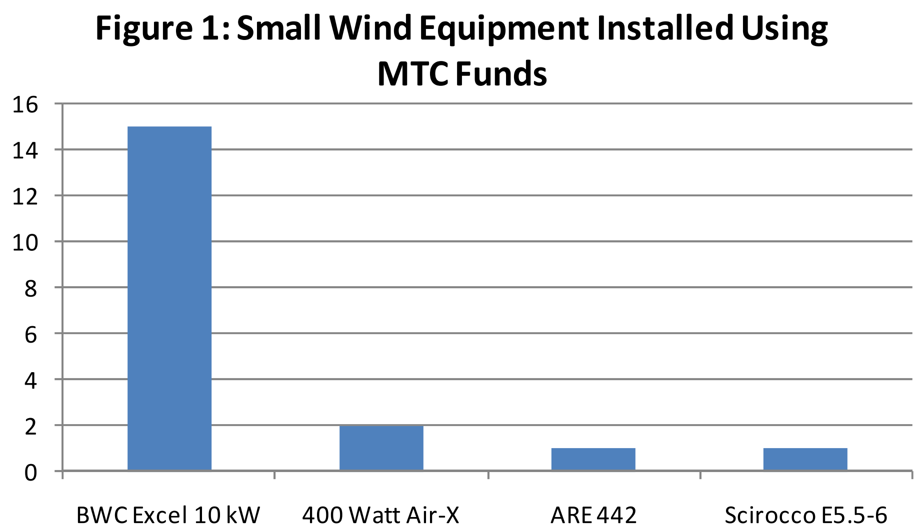
This document outlines the status of MTC funded small (10 kW or less) wind projects. Energy production data is examined by equipment make/model and installer to look for trends in performance. The primary metrics used for comparison in this document are capacity factor and relative production. Relative production is estimated by dividing the actual energy output of the system by the installer's estimate, as provided in the MTC grant application. This gives a sense of both the actual turbine output, normalized to equipment, but also the accuracy of the installers' estimates of energy output. Based on these preliminary data:

- The average capacity factor for 19[1] existing small wind turbines currently installed and reporting to the Production Tracking System (PTS) is 4%. This is less than half of the target capacity factor of 10%.
- Installers, on average, are significantly overestimating annual energy production. On average installers are overestimating energy generation by a factor of 3 to 4
- The most prolific small wind installer, with 6 installations included in this analysis, is Installer 10. These systems are performing with an average capacity factor of 3%.
- The most commonly installed small turbine, using MTC funds, is the Bergey Excel-S, with an average capacity factor of 4%.
- The cause of the overall poor performance of installed small wind energy systems is not known with complete certainty. Known contributing factors include inverter synchronization/standby time, higher than expected site turbulence, and lower than expected average wind speeds.
- Of the 19 systems analyzed, 16 have been inspected by Cadmus. Of these 16, only 6 were found to meet the estimated 10% capacity factor requirement of the SRI program, based on Cadmus' site survey and use of the SWEET modeling tool.

Equipment Performance

There are a wide variety of wind turbine models installed to date using MTC funds. The breakdown of small wind turbines installed, thus far, using MTC funds is given in Figure 1. Only the 19 systems included in the analysis are included in this chart. A full list of systems installed using MTC funds is available in Appendix A.

[1] As of this writing, there are 33 small wind systems registered in the PTS. A number of systems had to be excluded for a variety of reasons, as outlined in Appendix A.



Of equipment installed, Bergey Windpower's Excel-S is, by far, the most prevalent model installed, with 15 installations. However, the overall performance of this model was low, with an average capacity factor of just 4% (ranging from 1% to 9%). The best performing turbine model included in this analysis is the ARE 442, a 10 kW turbine, operating with an average capacity factor of 11%. This turbine is installed on Martha's Vineyard, in an extremely windy location, however, so this performance may not indicate a superior turbine - only a superior site. The Eoltec Scirocco, installed in a much more modest wind regime, comes in second, with a capacity factor of 7%. Finally, the worst performing systems currently in operation are two Southwest Air-X turbines. These small battery charging turbines are producing at only an average capacity factor of 1%. The average capacity factor of these, and other turbines, installed to date are shown in Figure 2. Data for the Southwest Skystream may be unrealistically low, at least partly due to a known equipment problem with the Skystream that has effectively stopped production at the Emerson site and may be impacting production at other sites as well. According to Southwest Windpower, a new UL listed replacement part will be available for these systems within the next few weeks and we should see improved output from the Skystreams once those repairs are made.

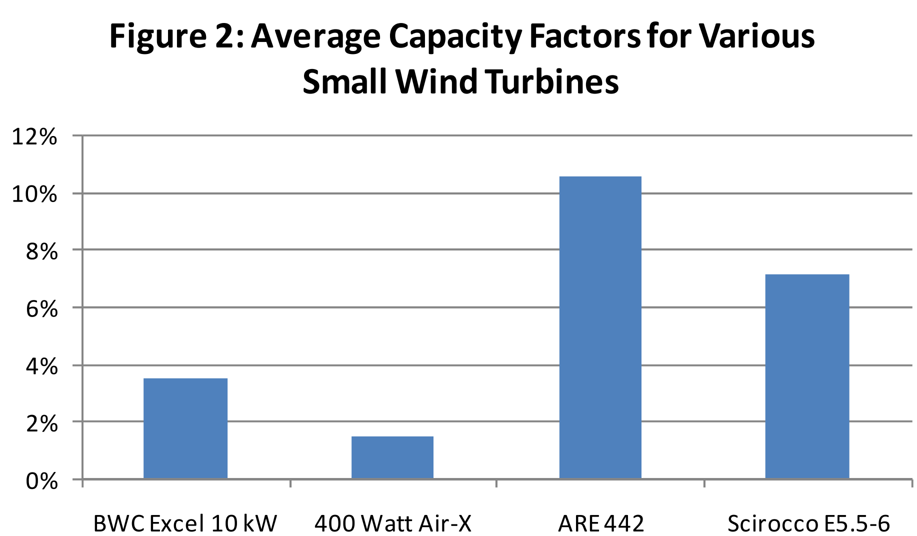
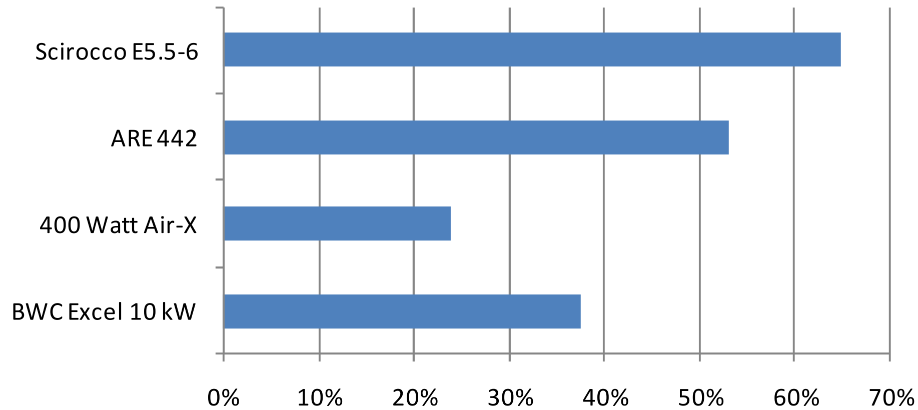


Figure 2 makes no distinction as to the cause of the low energy production and, in many cases, poor site selection, insufficient tower height, or low wind speeds are the driving factors behind lackluster system output. Using the relative production may be a better indicator, based on site surveys conducted by Cadmus.

Figure 3: Relative Production of Small Wind Systems by Turbine Model



The relative production is calculated using the annual[2] energy production of the systems, divided by Cadmus' best estimate of annual energy production. With 12 installations, the relative performance of the Bergey Excel-S remains surprisingly low. At 38% relative production, this indicates that, on average, the Excel is producing only about one third of its predicted energy output. Cadmus' estimate includes roughness and wind shadow impacts from surrounding obstacles, corrected[3] wind speed estimates from the AWS Truewind map, and published power curves. In comparison, estimates completed by installers were less accurate in predicting the output of these small wind systems, with an average relative production of only 27%. Removing one outlying system, installed by a homeowner and performing exceptionally well, reduces this number to only 23%.

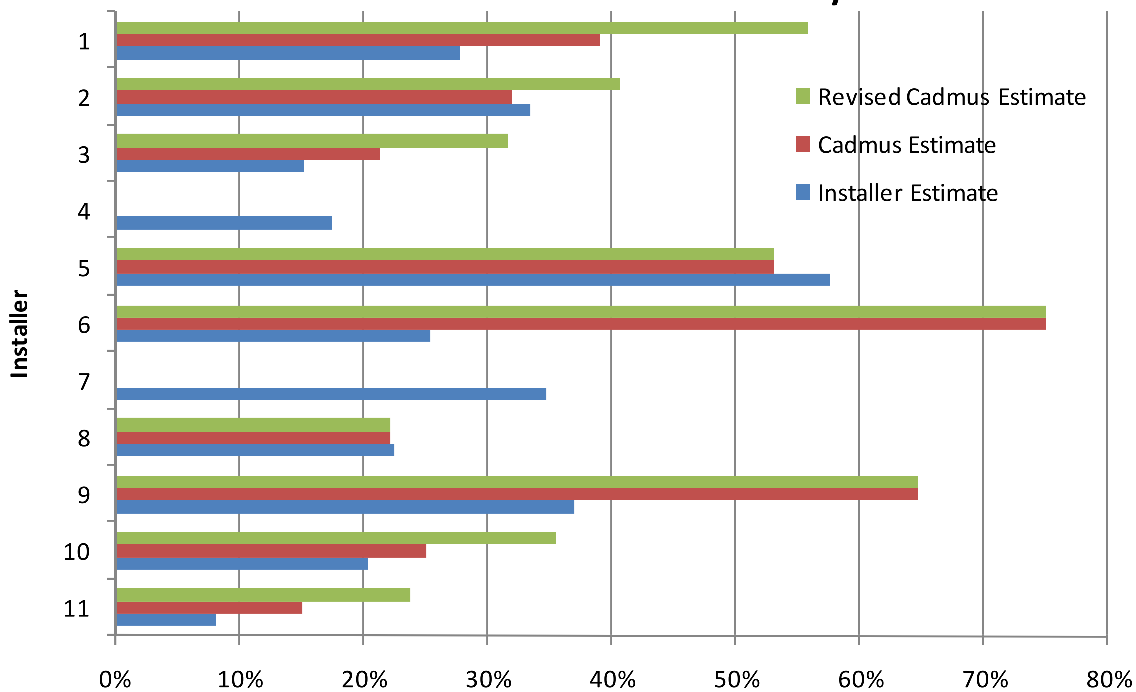
Installer Performance

There are currently 10 installers with small wind systems installed and reporting to the PTS. Most of these installers have installed only one or two systems that are currently reporting to the PTS. The most prolific installer statewide is Installer 10, with 6 installations reporting to the PTS, with an average capacity factor of 3%. Interestingly, the best producing system is installed by the system owner, with an average relative production of 81%, as shown in Figure 4. Figure 4 shows, side by side, the accuracy of production estimates completed by the installers, as well as by Cadmus. In Figures 4 and 5, the term "revised" indicates sites where Cadmus has adjusted the wind speed based on available data from RERL. Installer 5 has provided the most accurate energy production estimate, with a single turbine operating on Martha's Vineyard at approximately 58% of their estimated energy output. Other installers typically are typically achieving 20-40% relative production figures, based on the estimates that they provided in the SRI applications.

[2] Some systems do not yet have one full year of logged energy production. In these cases, we have applied seasonal weighting factors to extrapolate annual energy production values. This method is typically accurate to within 10% when compared with data from systems which have more than 1 year in service.

[3] For several regions, particularly Cape Cod and the South Coast, the Truewind map appeared to deviate from data collected in recent meteorological studies. For sites in these general areas, an adjustment factor was applied to the Truewind wind speed. This correction factor was determined based on the average difference between measured and wind map wind speeds for one or more sites in each region. See page 5 for discussion of this preliminary adjustment method.

Figure 4: Estimated Energy Production by Installer, Relative to Actual Production of Installed Systems



Causes of Poor Performance

The underlying cause(s) of this poor performance are not presently known with great certainty, however there are several clear contributing factors. Based on our experience inspecting systems, the installers almost universally overestimate annual energy production. Often this overestimation is quite significant. For the sites inspected by Cadmus, an independent energy production estimate is generated based on site conditions and system configuration. However this estimate, while generally more comprehensive than the original estimate by the installer, does not provide a sole explanation of the lower than expected energy output. Figure 5 provides an illustration of relative production for a number of sites inspected by Cadmus over the past several months. In almost all cases, Cadmus' estimate, using the SWEET model, are closer to the observed energy output than the installers' estimates but overall relative production remains at less than 50%. Figure 5 also shows revised estimates based on corrected wind speeds, as discussed below.

This result suggests that site conditions such as terrain roughness and tree cover, as modeled by SWEET, are not the primary driver of the lower than expected energy production. The SWEET model does, we believe, a good job of accounting for tree cover and site roughness but relies on key inputs such as annual average wind speed and the manufacturer's power curve to produce annual energy output estimates. Potential causes of poor production include:

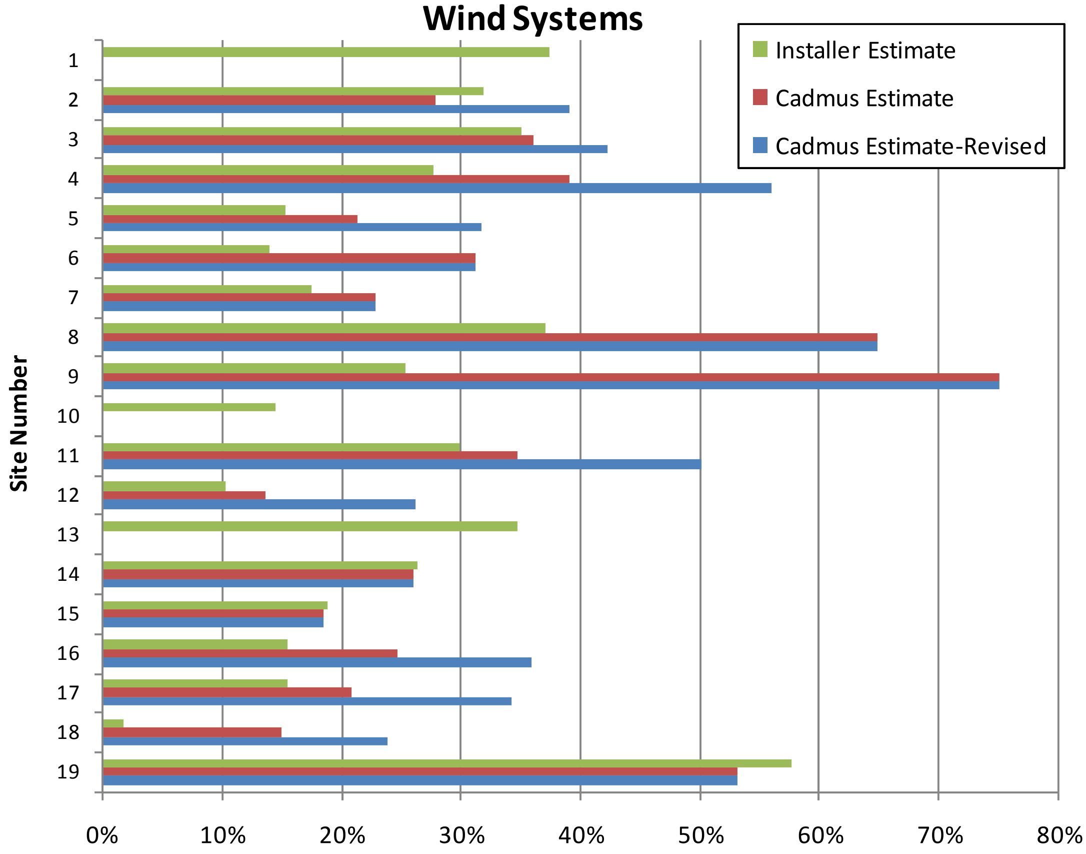
- Accuracy/variability of annual average wind speed
- Accuracy of manufacturer power curve
- Inverter efficiency, standby settings, and power draw
- Greater than expected losses due to site conditions (turbulence/wind shear)
- Other system losses (e.g. wiring/voltage drop, wind speed/direction changes)

These issues are discussed further below.

Individual System Performance
Figure 5, below, displays the relative production of the 19 small wind systems included in the analysis. Overall, it is clear that installer estimates tend to be significantly less than estimates completed by Cadmus at post-installation site inspections. There may be several contributing factors to this, including a lack of installer education, inclusion of early systems (many of these are first or second time installations for each installer), and systems installed under less strenuous MTC program requirements.

From the data in Figure 5, it can be difficult to draw general conclusions. One general observation that can be made is that estimates tend to be less accurate for systems with shorter towers and/or dense vegetation. For example sites 18, 5, 6, 7, and 12 all have less than the AWEA recommended clearance between hub height and surrounding obstacles. By comparison, systems such as sites 3, 2, 4, 8, 9, 11, and 19 all have hub heights greater than 30 ft above surrounding obstacles. Even at these sites, however, predictions are typically overestimating actual production by as much as 60%. Including an additional margin to account for turbulence intensity can improve these estimates (and will be added to future versions of SWEET), reducing the overestimation to 30-40% for most sites. Discussion with both NYSERDA and Wisconsin Focus on Energy indicate that overestimation is common for small wind systems, particularly those installed in complex terrain, such as is typical in Massachusetts, New York, and Wisconsin.

Figure 5: Energy Output Relative to Predicted for Small Wind Systems



Wind Speed
Of the above, average wind speed has significant potential error (due to siting concerns, wind map inaccuracies, etc.), as well as a large compounding effect on energy output. A small error in the wind speed estimate can result in a very significant impact on energy production. Due to the economic constraints of small wind projects,

it is almost never feasible to collect actual wind speed measurements, leaving the various wind maps as the sole means of estimating the available resource.

Fortunately, Massachusetts is blessed with a fairly rigorous set of measured wind speed data, due to the ongoing efforts of the Renewable Energy Research Lab and the MTC Community Wind Collaborative. A preliminary survey of the available wind speed data, based on RERL's measurements, can be compared with the AWS Truewind map to generate a very coarse understanding of how accurate the wind maps might be for various regions of Massachusetts. A preliminary assessment is given in Table 1, for a handful of selected sites.

Location	Anem. Height (m)	RERL Wind Speed (m/s)	AWST Wind Speed (m/s)	Wind Map Correction
Western Mass				
Savoy	50	5.84	5.7	**1.02**
Cape Cod				
Barnstable	30	4.87	5.9	0.83
Falmouth	30	4.98	5.9	0.84
Average				**0.83**
South Coast				
Dartmouth	50	4.8	5.6	0.86
Mattapoisett	50	5.74	6.4	0.90
Scituate	30	4.99	5.7	0.88
Average				**0.89**
North Shore				
Lynn	30	5.53	5.6	**0.99**

From this table, it appears that the wind map may be overestimating wind speeds by 10-20% in the region around the south coast and Cape Cod. This is an important area for small wind project development and, to date, most of the small wind systems installed have been installed in these areas. For other areas of the state, the wind map appears to be consistent with RERL measurements. Unfortunately, even incorporating these adjustment factors into the energy production estimates does not fully account for the poor performance of most systems, as shown in Figure 5.

In addition to potential inaccuracies in the wind speeds estimated by the wind map, which are essentially long-term estimates, there is the possibility that 2007-2008 wind speeds have been lower than long term averages. If this were the case, the poor performance of these small wind systems might be only a temporary phenomenon caused by an unusually calm year and might be expected to improve in future years. To address this, Cadmus has examined long-term wind speed averages for Boston and Falmouth. These two sites have robust sets of long term data, which was compared against measurements taken in 2007. The results of this comparison are given in Figures 6 and 7, respectively.

Figure 6: 2007 Wind Year Comparison with Long Term Average: Falmouth, MA

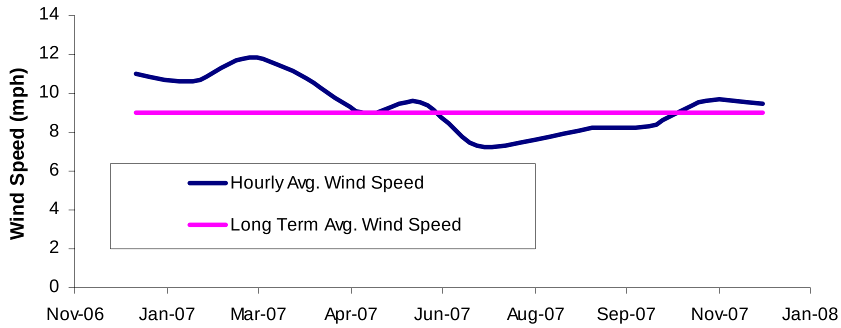
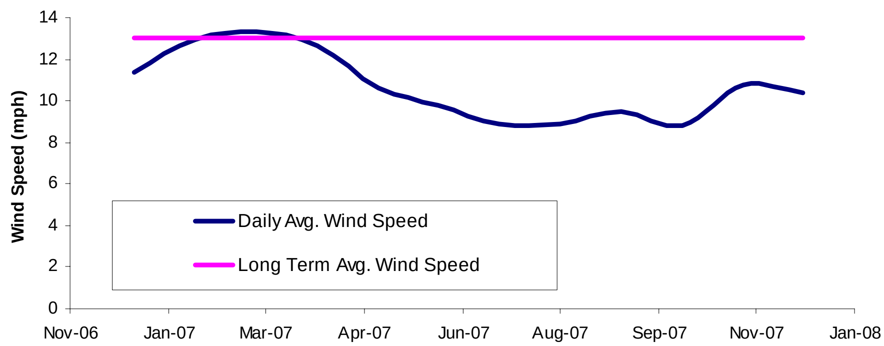


Figure 7: 2007 Wind Year Comparison with Long Term Average: Boston, MA



Unfortunately, examination of wind speed data at these two locations does not provide the needed evidence to suggest that 2007 wind speeds, as seen by the various small wind turbines installed in Massachusetts, were consistently lower than long term averages. In fact, the 2007 wind speeds seen in Falmouth, were actually slightly higher than the long term average. With many of the currently installed small wind systems installed in the Falmouth area, we cannot, from the data presently available, make any generalizations regarding macro scale wind speed impacts on small wind turbine output. Examination of additional station data might shed additional light on this situation but, at this point, the low production of many of the MA small wind systems does not appear to be due to a low wind speed year in 2007.

Accuracy of Manufacturer Reported Power Curves

The SWEET tool, along with every other known estimating method associated with small wind turbines, relies upon manufacturer reported power curves. Unfortunately, the development of these power curves is not as closely regulated as the development of power curves for larger turbines. Standardized test methods are beginning to become available from AWEA and IEC but these standards continue to focus on larger turbines. This leaves small wind turbine manufacturers with a significant amount of latitude in determining their power curves and little has been done to certify these power curves through third party testing. Invariably, these curves should be viewed as marketing pieces, more than stringent engineering test results. At present there is no readily available way to ascertain the accuracy of these curves without further field testing under conditions typical to the northeastern US. Even testing completed, to date, by NREL to verify power curves has focused entirely on very laminar wind flow regimes which may not accurately predict a turbine's power curves under more turbulent conditions.

Inverter/Equipment Losses
In addition to uncertainty around the manufacturers' power curve data, there is considerable uncertainty around the additional losses associated with wind turbine balance of system (BOS) components. Each inverter/controller includes both standby and active efficiency losses. Typically, inverters are 90-95% efficient, with standby power consumptions generally less than 10 Watts. There can also be additional losses (typically less than 5%) due to voltage drop over long wire runs. These parameters can be relatively easy to quantify, as published data is available from agencies such as the California Energy Commission (CEC) on inverter efficiency/standby losses. What can be more difficult to quantify are losses associated with inverter standby times coinciding with periods of high winds. While initially counterintuitive, in fact, some small wind turbines include controls that put the inverter into standby or monitoring mode when turbine output falls below a certain level. If the wind at a site is particularly gusty, a turbine can go through repeated on/off cycles. In these situations, an inverter may shut down as the wind speed decreases but, depending on its factory set response time, the inverter may remain in standby mode through one or more subsequent gusts. Not only is average wind speed important but it is also important to have wind speeds that remain steadily above cut-in wind speed for the turbine. Winds that vary between 0 and 8 m/s may mathematically average to 4 m/s over the year but will not produce the same energy output as a site with steady 4 m/s winds. Overall, AC energy production should be derated by approximately 10-15% to account for inverter efficiency and standby losses. The losses due to directional variability will require further study to quantify.

Additional Site Losses
In addition to the site losses discussed previously, such as obstacle height, there can be additional effects attributable to site conditions. For example, in cases where obstacles approach turbine hub height too closely, the turbulent effects can cause more than reduced or inconsistent wind speeds but can also cause the apparent direction of local wind to shift erratically. As this wind shifts, most small wind turbines yaw to bring the rotor into line with the wind. As the turbine yaws, its power output is significantly diminished. Therefore, a site where the wind direction shifts considerably, a small turbine might spend a significant portion of the time yawing, rather than producing useable electricity. Typical values for turbulence intensities range from 0.15, for a relatively smooth/open site, to 0.3 or slightly higher for rough/complex terrain or lower tower heights. This value is typically applied as a derate factor to annual energy output.

Though the site assessment attempts to be comprehensive, there can also be macro-siting considerations that affect local wind speeds. Geographic features, such as bodies of water and sloping terrain can impact local wind speeds and be difficult to quantify. Ideally, these sorts of features are included in wind speeds estimated on the various wind maps but, in reality, there will be some uncertainty, particularly in complex terrain.

Other Losses and Considerations
In order to better understand this issue, we have researched wind turbine field performance studies completed elsewhere. Results appear mixed, with no clear guidance given on causes for low performance. For example, as part of the NY/NJ Distributed Wind Power Field Verification Project, 4 Bergey Excel turbines were installed and monitored over a 2 year period. During this time, the turbines showed capacity factors ranging from 3.1% to 13.1%. The sites with lower production appeared to have more buildings/trees near the tower base but the reports did not include a discussion of turbulence effects.

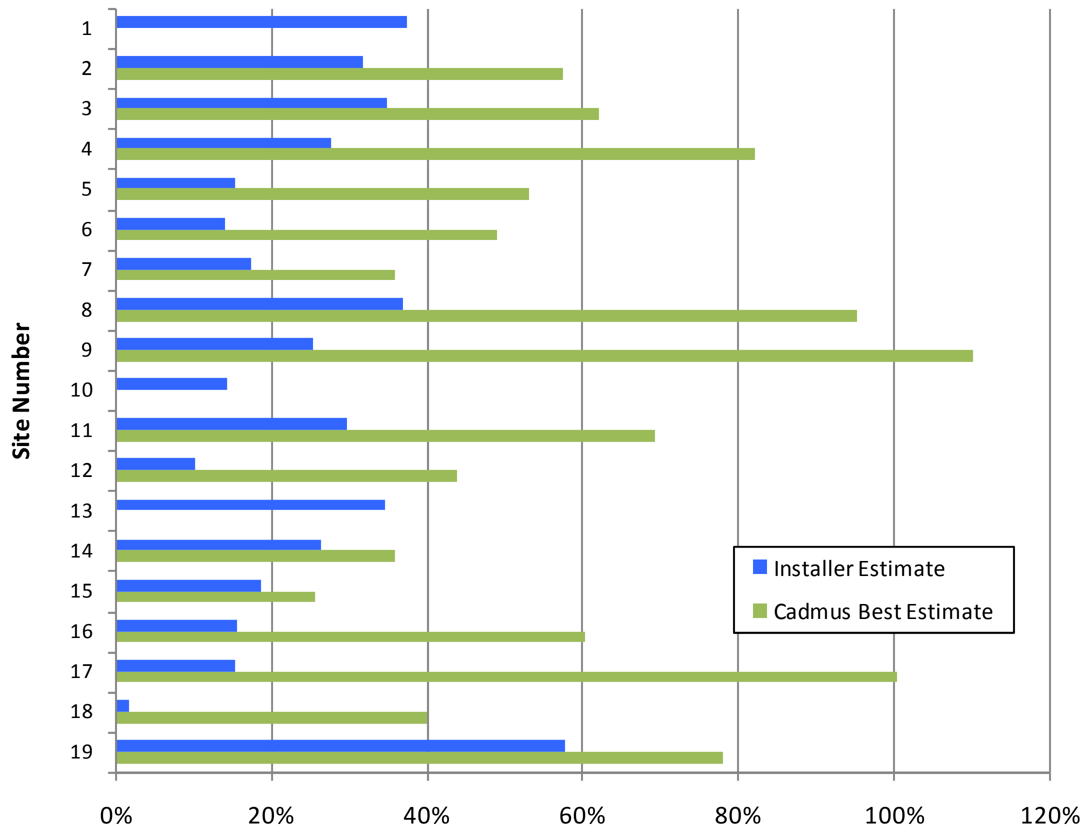
Another field study, conducted by NREL in the Pacific Northwest, on 4 installed Bergey Excel turbines shows similarly varied results. In general, all 4 turbines underperformed by 20-50% and this underperformance was not explainable due to the difference between measured and estimated wind speed.

These results all suggest contributing factors beyond simple wind speed. In particular, turbulence may be a more significant impact than was previously thought. Wind turbines operate most efficiently when dealing with laminar (smooth flowing) winds and are able to extract more energy from this type of wind than from more erratic, or turbulent, winds, even if the measured wind speeds are the same. Much of the field data collected in these, and other, studies is based on measurement with a single anemometer and, therefore, cannot be used to estimate wind shear and turbulence impacts on energy production but it is likely that these factors contributed to the observed underperformance.

Putting it Together

Combining the losses discussed above, leads to a closer estimate of actual annual energy output for small wind systems. While more specific/accurate numbers should be developed, most sites assessed using the SWEET tool should be further derated by a factor ranging from 0.6 to 0.77 to account for turbulence intensity and inverter efficiency/standby. Applying these factors to the systems, produces relative production numbers much more in line with historical production, as sown in Figure 8. Examination of this graph shows that many systems are now producing within close to 20% of these newly predicted values. Even with these factors included, this estimate continues to overpredict annual energy output for many systems, however, indicating that further study is needed to characterize the myriad factors that can impact the energy output of a small wind energy system.

Figure 8: Best Estimate for Small Wind System Relative Production



Recommendations

Small wind energy is popular at present and, despite little success to date, may yet present a renewable energy option competitive with other small scale renewable energy/distributed generation technologies. The key to unlocking this potential will be to obtain a better understanding of the available wind resource, technology capabilities, and improving estimation methods. To this end, Cadmus recommends the following as we proceed into a new small wind energy program at MTC.

Conduct Small Wind Energy Performance Verification Study

This study, already in its planning/setup phase, will provide key information on both the wind resource and the real-world performance of the Bergey Excel-S and related equipment. Though it will take more than 12 months to get definitive data from this study, preliminary findings could become available beginning in late summer/early autumn. Alternative versions of the proposed study are also an interesting option. For example collecting a smaller subset of data (e.g. wind speed and direction) at a larger number of sites could help to refine our estimating methods for future small wind projects fairly quickly. In particular, a better understanding of turbulence intensity at the lower hub heights common to small wind turbines will be critical to accurately estimating energy production.

Adopt Small Wind as a Research Program

In order to better understand the workings of small wind in non-optimal settings, MTC may elect to pursue a one year research focused program to support small wind installations. This program would seek to adopt innovative measures to assess small wind potential in MA, including:

- Improved collaboration and data sharing with sister agencies. Cadmus already has existing relationships with Mick Sagrillo (Wisconsin Focus on Energy) and NYSERDA that could potentially lead to valuable data/experience sharing. To date, MTC has collected more detailed production data than either of these agencies. However, Wisconsin includes wind speed and power data logging on all funded systems. With 44 systems currently installed, these data could be a valuable source of information that could apply to Massachusetts systems.
- Provide incentives to cover installation of DAS to monitor turbine performance and wind speed data on new and/or existing systems. This interval (e.g.1 5 minute) data could be dumped to the PTS for analysis for relatively low cost. A basic DAS to monitor wind speed and AC power output of the turbine can be purchased for approximately $1,000.

Improve Resolution of Wind Speed Data

There are significant data available that could be used to verify the wind speeds predicted by the AWS Truewind maps. Additional monitoring data from RERL, anemometry installed on existing small wind towers, and weather stations should be examined, particularly near Cape Cod and the south coast region, to improve our understanding of the actual wind speeds available in those areas. In addition, the AWS Truewind maps should be compared against other wind maps (e.g. DOE Wind Atlas), with an eye towards more conservative estimates at low anemometer heights.

Improve the SWEET Model/Estimating Methods

There are several improvements that could be added to SWEET to improve accuracy. Examples include:

- Adding inverter efficiency/standby draw data
- Add a turbulence intensity factor
- Making effective ground level calculations more conservative
- Adding a safety margin to account for various system losses (e.g.15%), particularly for systems with battery backup
- Adding an additional output page with educational message, showing output at an optimal site, output with a taller tower, etc. as an educational tool to promote better siting/system design

Adjust Program Structure to Minimize Risk of Underperformance

On currently installed systems, rebate dollars paid by MTC have not generated the expected benefits. While this may change as installers gain more experience with small wind systems and other issues are resolved, for the time being there is a risk that MTC may heavily fund systems that do not produce sufficient clean energy to justify the subsidy. To minimize this risk, we suggest the following changes when implementing the new small wind program:

- Pre-approval review of all sites/systems prior to committing funds (as done by Wisconsin, NY, and others). This review should include a site survey and energy production analysis for the site.
- Continued inspections of systems but with only selected structural inspections, as flagged during post installation inspection, to reduce program costs. Proven installers would face less frequent post installation inspections. Conducting pre approval screening would reduce the cost of post installation inspections somewhat.
- Strictly enforce capacity factor and AWEA siting guidelines from existing SRI program on future applications.
- Establish additional criteria, such as minimum wind speed (e.g. 5 m/s at 30m) to help filter out systems likely to underperform. If these systems perform well, future applications may gradually become less stringent
- Hold one, or more, quality installation training sessions/meetings for installers with a focus on energy production estimates.

Conclusions

Though the overall performance of the small wind systems installed in Massachusetts is lackluster thus far, the technology appears to be viable but highly subject to variables which are difficult to quantify (e.g. turbulence, wind speed, etc.). As the SRI program, with regard to wind energy, has matured, installers have been, and continue to be, educated in good site selection and installation practice. While work remains to be done, many installers are now more carefully assessing site conditions and providing better quality installations. However, in order to realize cost effectiveness on par with, or better than, PV systems, more action will be needed to educate installers and to weed out systems that will not meet performance expectations. For example, of the 16 systems inspected by Cadmus and included in this analysis, 10 would have been eliminated by Cadmus' site survey. Following MTC's existing siting and capacity factor requirements can go a long way towards eliminating the worst performing systems. Strengthening those requirements will only help to insure that only the better sites receive funding. The current underperformance of small wind remains unexplained and more data is needed to accurately assess the long term costs/benefits of including small wind energy in the MTC clean energy portfolio.

Small Wind Systems Registered in the PTS as of 2/14/2008

System Name	Analysis Notes
A & P Chardon	WindTechCo system, no longer operational
Against the Grain	Not included-data not clear given turbine change
Ashlane Farms	Included, no changes needed
B. Fearing	Due to equipment issues related to Skystream, not included in analysis
Beaulieu	Included, no changes needed
Briarknoll Energy Trust	Included, production data manually entered based on Q/A audit completed by Cadmus on 4/4/2008
C & P McVay	Included, no changes needed
C Croteau	Included, no changes needed
Cape Cod Reg Tech HS - WIND	Not included-data not clear given turbine change
Carlton School	Not included-turbine not interconnected to school electric grid
Centerville Elementary School	Based on long history of poor performance, removed due to lack of relevance to currently installed systems
Cider Hill Farm - wind	Included, no changes needed
Cider Hill Farm-Fern St	Not included, less than 3 months production data
Covanta	Included, no changes needed
D Mason	Included, Jan production entered manually
D Silvia	Included, no changes needed
D Vachon	Included, no changes needed
Falmouth Academy	Included, no changes needed
G Cook	Included, no changes needed
G&K Harcourt	Wind turbine changed, data not included in analysis
Kendrick Poultry Farm	Included, no changes needed
Fraser	Included, no changes needed
MVRHS	Included, production entered manually from 6/2007-2/2008
N. Bekemeier	WindTechCo system, no longer operational
P. Mitchell	System having firmware problems-SWWP working on repair, not included in aggregate analysis
R. W. Emerson	System having firmware problems-SWWP working on repair, not included in aggregate analysis
Rochester Golf Club	Significant inverter downtime due to improper surge protection, included in data set because issues were not caused by manufacturer defect and reflect real site conditions
S. & B. Garde	WindTechCo system, no longer operational
S. Mahoney-Battles	Included, no changes needed
Sylvan Nurseries-WIND	WindtechCo system, data includes PV array and is not included in analysis
Sylvan Nursery Inc Wind	Included, no changes needed (cost data not used)
W. Maloney	System not operating correctly yet, unknown equipment issues-not included in analysis
Wyndfield Studios	Originally a WindTechCo project, completed by another installer

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Small Wind Progress Briefing Summary

Revised: June 12, 2008

Background

This document outlines the status of small (10 kW or less) wind projects funded by the Massachusetts Technology Collaborative (MTC). The MTC, as administrator of the Renewable Energy Trust, has been providing funding for renewable energy systems since 2002 and funding small wind systems through the Small Renewables Initiative since 2005. The MTC is committed to supporting responsibly sited renewable energy systems that provide social and economic benefits to electricity ratepayers in the Commonwealth. Through the Small Renewables Initiative, MTC has made about one hundred awards to small wind projects, more than 30 of which are now installed and operating.

Through its Small Renewables Initiative, MTC provides rebates provided directly to small wind customers who are responsible for hiring their own turnkey installation firm. The customer's installation company assists the customer with MTC's rebate application process and then they design and install the wind project. Once the system is installed and operational, the small wind customers enter their system's energy production data into an MTC database on a monthly basis.

MTC has monitored the energy production reported for the first several systems, and after it became clear that that none of these systems was achieving the expected production levels, we commissioned the Cadmus Group, Inc. to perform a complete and systematic analysis of the production data and the earlier production estimates. The following is a summary of their findings. A complete version can be found on the Small Renewables Initiative website: http://masstech.org/renewableenergy/small_renewables.htm

Summary of Findings

The average production for the 19 existing small wind turbines highlighted in the progress briefing is less than one-third of the average production projected by installers, with a range of ratios varying from 2 percent to 59 percent of estimated production.

Simple Economic Analysis

MTC understands that every project is different, and that many wind turbine technologies, if sited properly, can provide substantial social and economic benefits. Table-1 illustrates a basic economic analysis of the results for a typical small wind project. The numbers used for both the estimated and actual data are based on information collected from the sites that have 10 kilowatt turbines installed.

This simple analysis assumes (1) $0.18/kWh is the constant value of avoided electricity (2) all electricity produced would be consumed onsite and (3) that the value of Renewable Energy Certificates (RECs) is $0.03/kWh over the life of the project.

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Assumptions:	
System Size (watts)	10,000
System Cost ($)	$ 67,500
MTC Current Base Incentive ($)	$ 22,500
Cost to Customer ($)	$ 45,000

Annual Estimates:	Estimate (Average) **	Actual (Average) **	Difference
Production (kWh)	13,427	5,740	7,687
Value of Electricity ($)	$2,417	$1,033	($1,384)
Value of RECs ($)	$403	$172	($231)
Total Value	$2,820	$1,205	($1,614)

Table 1- Basic Small Wind Economic Analysis

** The "estimated" and "actual" production values are averages based on data taken from the 16, 10 kW systems included in the analysis and detailed in Table 2.

Next Steps

The full progress briefing outlines a number of potential reasons for the system underperformance including, but not limited to (1) inaccurate wind speed estimates, (2) lack of accuracy in manufacturer-provided information, (3) equipment inefficiencies, (4) turbulence caused by neighboring obstructions and (5) wiring inefficiencies.

MTC is now considering program changes to the Small Renewables Initiative that will apply to future small wind projects. MTC expects that these program changes will be announced in late summer, 2008.

Current and future small wind customers are strongly encouraged to discuss with their installer how the findings of the progress briefing may apply to their project.

If you have questions about this information, please feel free to contact:

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ID	Capacity (kW ac)	Latitude	Longitude	City	Total Cost	MTC Grant	Date Installed	Estimated Annual Production (kWh)	Corrected, Actual Annual Production (kWh)	% of Estimated Production	Equipment Manufacturer	Tower Height (m)	Installer
1	0.4	41°41'03.27" N	70°37'04.93" W	Bourne	$6,643	$1,100	9/25/2006	640	93	15%	Southwest Windpower	11	Silva Energy
2	10	42°46'00.94" N	71°07'28.20" W	Haverhill	$75,500	$35,000	12/22/2006	11,000	3,044	28%	Bergey Windpower Co.	48	Atlantic Millwrights
3	10	41°51'29.59" N	70°31'44.75" W	Plymouth	$53,500	$27,500	12/30/2006	20,820	7,646	37%	Bergey Windpower Co.	30	Self Installed
4	10	41°45'52.55" N	70°55'54.31" W	Freetown	$56,930	$42,500	1/4/2007	10,722	3,395	32%	Bergey Windpower Co.	30	Alternate Energy Systems
5	10	42°52'28.91" N	70°55'30.50" W	Amesbury	$43,225	$37,500	1/13/2007	11,500	3,287	29%	Bergey Windpower Co.	37	Vermont Green Energy Systems
6	10	41°44'19.22" N	70°50'13.03" W	Rochester	$56,930	$47,500	3/7/2007	12,918	2,218	17%	Bergey Windpower Co.	24	Alternate Energy Systems
7	10	41°26'55.11" N	70°52'41.96" W	Oak Bluffs	$90,000	$30,000	6/1/2007	16,056	9,409	59%	Abundant Renewables	31	South Mountain Company, Inc.
8	10	42°52'28.91" N	70°55'30.50" W	Amesbury	$42,525	$27,500	6/4/2007	11,500	2,574	22%	Bergey Windpower Co.	37	Vermont Green Energy Systems
9	10	41°33'24.50" N	70°37'32.93" W	Falmouth	$75,663	$47,500	6/27/2007	21,772	3,652	17%	Bergey Windpower Co.	24	Alternate Energy Systems
10	10	41°45'16.45" N	71°00'43.93" W	Freetown	$59,677	$30,000	7/5/2007	9,508	1,672	18%	Bergey Windpower Co.	24	Beaumont Sign Company
11	0.4	42°13'53.67" N	70°45'40.11" W	Scituate	$3,373	$1,100	7/28/2007	640	13	2%	Southwest Windpower	8	Silva Energy
12	10	42°03'14.69" N	70°55'32.90" W	East Bridgewater	$59,930	$32,500	8/30/2007	9,259	1,232	13%	Bergey Windpower Co.	30	Alternate Energy Systems
13	10	41°31'24.38" N	71°01'45.33" W	Westport	$64,998	$32,500	9/13/2007	16,021	6,362	40%	Bergey Windpower Co.	11	Lighthouse Electrical Contracting, Inc.
14	6	42°38'19.04" N	72°49'37.83" W	Heath	$32,065	$12,000	9/14/2007	10,128	4,032	40%	Ecoltec	32	Berkshire Photovoltaic Services (BPVS)
15	10	42°47'19.96" N	70°35'37.95" W	Newbury	$49,335	$35,000	10/15/2007	11,000	2,709	25%	Bergey Windpower Co.	24	NorthShore Solar & Windpower
16	10	41°37'02.41" N	71°04'44.68" W	Westport	$62,800	$35,000	10/23/2007	13,747	3,999	29%	Bergey Windpower Co.	36	Northeast Windpower Corp.
17	10	42°19'30.23" N	72°06'45.25" W	New Braintree	$63,625	$22,250	10/30/2007	18,747	3,092	16%	Bergey Windpower Co.	27	Alternate Energy Systems
18	10	41°36'40.49" N	71°03'05.08" W	Westport	$57,546	$42,500	11/7/2007	9,949	3,348	34%	Bergey Windpower Co.	24	Lighthouse Electrical Contracting, Inc.
19	10	41°31'52.16" N	71°04'41.62" W	Westport	$47,152	$40,000	12/20/2007	10,314	4,614	45%	Bergey Windpower Co.	24	WindTech Co
	TOTAL				$1,001,417	$578,950	$745,721	226,241	66,391				
	AVERAGE				$52,706	$30,471	$39,248	11,907	3,494	27%			

Table 2 - Summary Data for 19 Reviewed Systems

****** Not all of the installed systems have 12 full months of production data, so in some cases, actual annual production was extrapolated using long term trends in order to create the actual annual production data set.
Note: List sorted by installed date