# WIND TURBINE SITING IN AN URBAN ENVIRONMENT: THE HULL, MA 660 KW TURBINE

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## ABSTRACT

The installation in 2001 of a Vestas 660 kW wind turbine at Windmill Point in Hull, Massachusetts represents a high point in the long history of wind energy activity at this location. The site is in a highly populated coastal area, within 8 miles of Boston (city hall) and within 5 miles of Logan Airport. Its location makes this project unique in the United States. This paper documents the history of this project, from its early precursors in the 1800's, through the installation of a 40 kW Enertech machine in the 1980's to the installation of the new turbine. The turbine is owned and operated by the Hull Municipal Light Plant (HMLP), and the project was developed by HMLP with assistance of the University of Massachusetts' Renewable Energy Research Laboratory and the Massachusetts Division of Energy Resources. The issues that were addressed and the factors that led to successful realization of the project are discussed here. In addition, a summary of the first year's performance of the wind turbine is given. The paper also presents an overview of possible future wind generation projects that are under discussion in the town. These include (1) the installation of a second land-based wind turbine, (2) the construction of a small offshore wind farm, and (3) using wind to power a proposed desalination plant.

## *1.0 Introduction/Background*

The town of Hull, Massachusetts is located on a peninsula in Boston Harbor, as shown in Figure 1. Its population averages about 11,000, and increases to over 16,000 during the summer vacation season.. Electricity is supplied to the residents by the Hull Municipal Light Plant (HMLP), a municipally owned utility. Annual average power consumption is approximately 6 MW (corresponding to an energy use of approximately 53,000 MWh/yr). HMLP purchases most of its electricity at wholesale from the Massachusetts Municipal Wholesale Electric Company. In 2001 HMLP installed a new, 660 kW turbine at Windmill Pt., at the tip of the town. This turbine site is close to the high school, within 100 ft of the site of a 40 kW turbine (since removed), which had been installed approximately 20 years beforehand.

Insofar as the town is in a highly populated coastal area, within 8 miles of Boston (city hall) and 5 miles of the runways at Boston's Logan International Airport it might at first seem that it would be a difficult location at which to site a wind turbine. In fact, there are many factors that affect the siting of a wind turbine anywhere. Some of these tend to make siting more difficult at towns such as Hull; others make it easier. The purpose of this paper is to examine those factors and the manner in which they affected Hull's

decision to proceed with its new turbine. In addition, the paper addresses the possibilities for future wind energy development in Hull, and considers how the experience of Hull may be relevant to other communities.

**Figure 1 Hull Location (with respect to Boston Harbor)**

### 1.1 Initial Interest in Wind Energy Development

The first thing to consider is why the residents of town such as Hull (or any town, for that matter) would consider installing a wind turbine in the first place. Based on conversations that occurred during the planning process basically three reasons could be discerned:

- Environmental symbolism: Environmental symbolism was probably the most important factor among the early proponents of the project. These proponents surmised that Hull had an attractive wind resource, knew that Hull had a history of using wind energy, believed that wind energy could again play a significant role in the town, felt that Hull could make a statement that wind energy was an attractive and environmentally sensible option for the town, and anticipated that a turbine there could serve as an example for other towns contemplating similar projects.
- Electricity cost savings: Potential cost savings in electricity was a second reason that was voiced. A number of residents believed that it should be possible to generate electricity from wind at lower cost than the town's municipal light plant could purchase it. If this could be shown to be the case, then that was seen to be a purely pragmatic reason to consider the project.
- Stability of electricity rates: Price stability in electric rates is a variant of the second reason. In this case, the concern was less with immediate cost savings, and more with insuring more stable electricity costs over the lifetime of the project. The reason was based in the observation that the majority of costs associated with wind energy generation occur at the beginning of the project, and are thus predictable and stable.

### 1.2 Obstacles to Wind Energy Development

Regardless of the possible benefits of a wind energy project to a town, there are invariably a number of issues or obstacles that must be considered. The following is a list of potential issues that are typically considered in any project of this type. The issues

in so far as they were perceived at Hull are summarized in the list. The important ones are elaborated upon in greater detail later in the paper.

- Beneficiaries of project vs. those impacted by project: The proposed owner and operator of the project was always to be the Hull Municipal Light Plant. The beneficiaries were thus the residents of Hull. Similarly, those affected were also residents, with those closest to the turbine being the most affected.
- Visual impact: The new turbine was expected to be large, and thus to be quite visible. To some extent the concern for the visual impact was less than it might otherwise have been
- Noise: Noise is commonly brought up in relation to wind turbine proposal. The proximity of Hull the Logan Airport flight path, as well as the experience with a previous turbine near the site diminished concern with this issue. Nonetheless, detailed consideration was given to this issue in the development process.
- Avian impact: The possible effect of a wind turbine on birds has become a concern in nearly every siting exercise ever since the problem first arose in California. The issue did arise in Hull as well, but in fact generated little debate.
- Value of energy produced: The value of energy is an important consideration in every wind energy project because it has direct impact on the project's economics. In Hull, the value of was taken to be the average unit cost of energy paid by the municipal light plant to its supplier, Massachusetts Municipal Wholesale Electric Company.
- Guaranteed market for the energy: Having a guaranteed market for wind generated electricity is crucial to any project. In many cases, what is sought is power purchase agreement (PPA). Since Hull has a municipal light plant, it is its own market, and needed no additional PPA.
- Responsibility of operation, maintenance and dismantling: A 40 kW wind turbine was previously installed near the high school, and was operated and maintained by school as well. This method of O&M was perceived as being a factor in the low availability of that turbine. Accordingly, at the outset of the new project, HMLP proposed to assume the role of operator and maintainer.
- Skepticism in technology: Skepticism in new technology is common and not without foundation. Hull had some experience with modern wind energy technology, so it was not completely new to them. The previous turbine did not function as well as hoped. Nonetheless, it did function to some degree, and it may be that the experience with that turbine, together with an understanding of how the wind turbines had changed over the last twenty years, prevented residents from expressing much concern over the technology.
- Confidence in proponents: Townsfolk may understandably be skeptical about advice from any source, whether from local proponents, developers, salesmen, or officials from out of town. The process Hull used was conducive to building up trust, by being slow, deliberate, and securing the assistance of entities that were familiar with the technology and the issues, but did not stand to profit from the outcome.
- Permitting and zoning: Permitting and zoning are often issues in any proposed wind energy project. In Massachusetts, municipal light plants are exempt from zoning requirements, so that was not a concern in Hull. In any case, the land where the turbine was sited was owned by the town. Difficulties with other permitting issues

were minimized on account of the deliberate process of involving the town in the decision making.

### 1.3 Factors Affecting Hull's Decision to Install a Wind Turbine

The factors affecting Hull's decision to install a new wind turbine are closely related to the issues that needed to be addressed to realize such a project (as outlined above). The most important factors are summarized below.

- Municipal electric light plant. Hull is one of 40 towns in Massachusetts that have municipally owned electric utilities. All of these utilities were set up in the early days of electrification (before 1927). They serve about 13% of the customers in the state. Municipal utilities can generate their own electricity, although most of them do not do so. In general, they purchase electricity from wholesalers, such as the Massachusetts Municipal Wholesale Electric Company, and then distribute that power to customers in the town. Municipal utilities own and service the distribution system in their town. Thus, they are experienced in issues associated with electricity supply. Municipal utilities are operated under the management of a Light Board, which is elected by residents of the town. Day to day operation is carried out under the direction of the Superintendent or Operations Manager. The presence of a municipal utility in a town simplifies the process of acquiring distributed generation (such as a wind turbine), since there is clear mechanism for doing so. This was certainly true in the case of Hull, where the municipal light plant was a participant in all stages in the process.
- Local champions. Undertaking projects of the type described in this paper can be a long, slow process. Experience has shown that having a few local people ("champions") who can push the project along can greatly facilitate the process. Hull was fortunate to have two champions, one a determined resident, the other the Operations Manager of the Light Plant.
- Good wind resource. It was already apparent to the casual observer that Hull has a promising wind resource. Hull is on a peninsula far out in Boston Harbor, with as good an exposure to the winds as anywhere on the coast of Massachusetts. Historical experience from the days of sail, as well as the performance of the previous wind turbine, all were consistent with that observation. During the course of the project, the wind resource was quantified to some extent by reference to monitoring stations at nearby Logan Airport and Thompson Island.
- Public involvement. Public involvement is one of the keys to addressing concerns of the residents. The decision making process involved the public at every step. This process was facilitated by the participation of the municipal light plant in the project.
- Previous experience. As mentioned above, and as will be described in more detail below, Hull had previously had a wind turbine installed very close to where the current turbine is now located. Experience with that turbine was not altogether positive, but it did help to focus attention on important issues and minimize concern with issues that are less important.
- Public benefit. As discussed above, the energy produced by the turbine was recognized to benefit the town directly, through reduction in purchased energy. This was made particularly concrete by the Light Plant's decision to use part of the "profit" from the wind turbine to cancel the bills to the town for the street lights.

- Available site: No project can succeed without a suitable site. Hull was fortunate in that it owned a site (Windmill Point) with good exposure to the winds, where the turbine could be sited without serious conflicts with other uses.
- Technical support: Innovative projects such as the one in Hull often require significant technical support to be brought to successful fruition. Hull was fortunate in that it could take advantage of the Commonwealth's Division of Energy Resources long standing partnership with the University of Massachusetts Renewable Energy Research Laboratory to assist in this project

## *2.0 History of Wind Energy in Hull*

Hull has a long history of the use of wind for land based application, beginning at least 200 years ago. The following is a brief history of Hull's use of windmills and wind turbines.

### 2.1 Early Windmills in Hull

The tip of the Hull peninsula, where the new turbine is located, has been referred to as "Windmill Point" since at least the early 1800's. The spot acquired the name because it was the site of a windmill which was used in the production of salt from sea water. A mill similar to the one used in Hull is shown in Figure 2.

**Figure 2 Windmill of type used in Hull (photo from Orleans, MA)**

### 2.2 The First Modern Wind Turbine in Hull

In the early 1980's the town of Hull applied for and received a grant to install a wind turbine. In January 1985 a 40 kW horizontal axis wind turbine (Enertech model 44/40) mounted on an 80 ft tower was installed on the grounds of the High School at Windmill

Point. The cost of the turbine and its installation was $78,000 with funds provided by the Massachusetts Executive Office of Energy Resources (EOER). The power produced by the wind turbine was intended to offset electrical loads at the High School. When the turbine output exceeded the school's demands, the surplus was fed into the Hull Municipal Lighting Plant grid. The Hull High School was responsible for the operation and maintenance of the wind turbine.

The performance of this wind turbine was at its best during its first full year of operation (March 1, 1985- February 28, 1986), and, as shown in Table 1, it produced about 84,800 kWh, thus operating at a capacity factor of 24.2%. During this first year period it supplied about 40% of the school's power, resulting in about $8,000 in cost savings.

**Table 1 First Year Performance of 40 kW Wind Turbine in Hull**

| MONTH | TURBINE OUTPUT (kWh) | SCHOOL DEMAND (kWh) |
|---|---|---|
| Mar-85 | 11,208 | 23,640 |
| April | 6,507 | 17,880 |
| May | 6,456 | 22,200 |
| June | 7,179 | 13,560 |
| July | 2,572 | 8,040 |
| Aug | 2,339 | 7,800 |
| Sept | 2,719 | 16,560 |
| Oct | 6,860 | 18,240 |
| Nov | 9,284 | 22,560 |
| Dec | 8,845 | 21,840 |
| Jan-86 | 12,945 | 23,040 |
| Feb | 7,924 | 18,840 |

Figure 3 (Bolgen, 1996) shows the annual production of the 40 kW wind turbine for 1985 through 1995. It was originally projected that the turbine would generate about 75,000 kWh per year (a capacity factor of 21.4%). However, as shown in Figure 2, this estimate was only reached or exceeded in 1986 and 1995. Furthermore, the total generation for the 11 full years from 1985 through 1995 was about 495,000 kWh, only about 60% of the expected performance of the wind turbine.

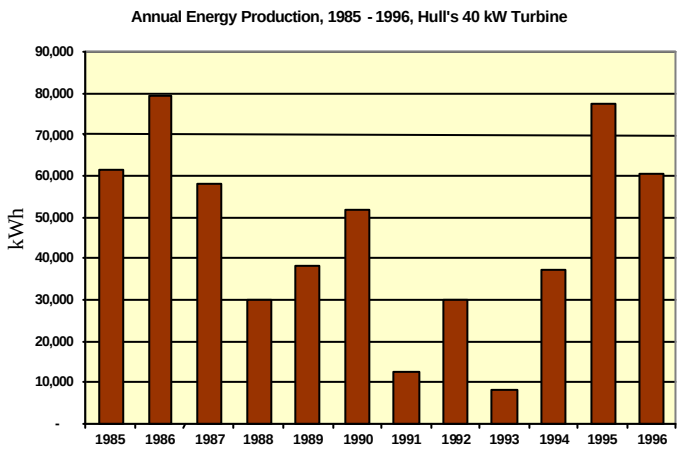


**Figure 3 Energy Production Summary of 40 kW Hull Wind Turbine**

The reasons for the relatively poor performance of this machine can be explained by a relatively large amount of repairs required to the machine. Table 2 gives a summary of some of its major repairs during this time period. The machine was damaged beyond repair in March 1997 during a windstorm (70 mph peak winds) when its tip brake mechanism failed.

**Table 2 Summary of Major Repairs to 40 kW Hull Wind Turbine**

| Time Period | Component Repair |
|---|---|
| Nov 87- May 88 | Tip Brake Replacement |
| June 89-Aug 89 | Controller Problems |
| June 91-July 92 | Circuit Breaker Problems |
| April 92- June 92 | Power Cable Failure |
| Jan-93 | Generator Winding Failure |
| Mar-97 | Tip Brake Failure- Major Machine Damage |

On a positive note, despite the number of turbine repairs needed it was estimated (Bolgen, 1996) that the 40 kW wind turbine produced an estimated $61,500 worth of electricity for the Hull School Department. The estimated maintenance and repairs were about $17,000, thus the net savings of the turbine was about $44,500. This was still more than real cost of the turbine, so the overall economics were not positive. The experience did prove of value, however, in it help paved the way for later developments.

## 2.3 The Dark Days of Wind Energy in Hull

Encouraged by the early success of the 40 kW wind turbine, HMLP supported plans for a proposal in 1987 to install more and larger wind turbines at the Windmill Point site. As a result of this work, the proposed project was awarded a $600,000 grant from the EOER, (now the Massachusetts Division of Energy Resources or DOER), to install 500 to 600 kW of wind turbine capacity at this site. Due to the requirements that 30% of the grant be repaid to the state, it was important to justify the economics of the wind turbine to the town. Calculations made at the time, however, showed that the economic value was not sufficient to justify the project. The idea of a utility scale wind energy system for Hull was abandoned for the time being.

During the early 1990's the DOER still held the opinion that the Hull wind site was still promising enough to support a larger wind turbine and proposed the siting of a new wind turbine. In 1992 they issued a formal proposal (Bolgen, 1992) in response to a New England Electric Power Company (NEP) Request for Power Supply Proposals from Renewable Resource Technologies. The proposed project planned to install 500-660 kW (using two wind turbines) at the Windmill Point site and was to be funded entirely by DOER through the use of DOER's Renewable Energy Alternatives Program. The anticipated generation was estimated to range between 700 to 1160 MWh and power

from the turbines was to be wheeled through Hull to a NEP substation on the Hull-Hingham town line. In addition to a detailed discussion of state-of-the-art wind turbines for the proposed system, the proposal discussed the environmental characteristics of the installation, potential licensing status as well as its economic considerations.

Despite the work of the DOER and its consultants and the approval of the HMLP Plant Board, the proposal was defeated in a 1993 town meeting. In true New England fashion the opponents of the proposal referred to the promoters from DOER and its consultants as the "skinny guys in suits." Thus, a combination of bad timing, the worsening performance of the 40 kW machine, and the lack of local "wind energy champions" contributed to this wind system's proposal failure.

The picture improved during the fall of 1997, however, when a group of citizens and High School teachers held meetings to plan the "repowering" of the High School site. This planning was incorporated into the senior physics class at the high school and had support from both the high school and HMLP. This new interest and support led a new group of citizens to form Citizens for Alternative Renewable Energy (CARE) who then went to the HMLP, urging them to continue a wind energy siting study. Following a positive response from the utility, this group asked the Massachusetts DOER to support a new study. This time DOER enlisted the help of the University of Massachusetts' Renewable Energy Research Laboratory (RERL) to perform a wind turbine replacement options study. The RERL had been working with DOER for a number of years as part of the Commonwealth's Strategic Envirotechnology Partnership (STEP), and providing assistance to Hull make sense under this arrangement. This work is summarized next.

## *4.0 Project Development for New Wind Turbine, "Hull 1"*

### 4.1 New Siting Study

In 1998, the UMass RERL, under sponsorship from the Massachusetts DOER, carried out a detailed technical study for the evaluation of possibilities for the replacement of the wind turbine installed at the High School. The work (Ellis, Rogers, and Manwell, 1999) reviewed the issues related to the installation of a wind turbine at the High School site and identified the potential merits and impacts of a number of different wind turbines. For this proposal, it was assumed that HMLP would assume responsibility for the operation of the machine. The work (which involved extensive interaction with numerous Hull community groups) consisted of the following six major parts:

A) Detailed Description of the Proposed Site: This part of the study was straightforward and consisted of a detailed description of the Windmill Point site and the surrounding neighborhood.

B) Description of the Available Wind Resource: Under this phase of the work, wind data measurement taken for the early 40 kW wind turbine installation were used, along with data from nearby Logan airport and Thompson Island. (It should be noted that RERL had, with DOER support, been monitoring the winds at Thompson Island, approximately 3 miles away, since 1996.) This combination of data was used to generate the Weibull statistics for a typical year's wind data for the Windmill Point site. In addition, an estimate of the wind shear coefficient for this site was made.

C) Description of Candidate Turbines: A review of potential commercial available turbines ranging in size from 80 to 600 kW was carried out under this task. The candidate turbines were chosen based on screening criteria that included: use of proven design concepts, operational reliability, maintenance training, safety, and established business presence in the U.S.

D) Review of Environmental, Regulatory, and Public Acceptance Hurdles: Under this phase of the work, a number of important issues were investigated. The more important ones included: 1) noise issues and regulations (probable noise levels at the site were estimated), 2) visual appearance (turbine color schemes and tower designs were discussed), 3) electrical network connection issues, 3) FAA issues- since the proposed site is 1500 ft below the ILS (Instrument Landing System) approach for runway 32 at Logan airport, this was a particularly important potential problem to addressed, and 4) other electromagnetic interference issues.

E) A Preliminary Economic Evaluation: This work started with an electrical power production estimate for each of the candidate wind turbines based on the previous work for the available wind resource. Next, a lifecycle cost analysis was made for each of the candidate turbines

F) Discussion and Recommendations Section: This section included a summary of the previous results and overall ranking recommendations for the candidate turbines.

It should be noted that much detail went into this detailed engineering study because of its potential to guide future projects in Massachusetts, especially the coastal communities. Thus, care was taken to make it function as a template for other towns or agencies who might plan similar projects.

## 4.2 Selection of New Wind Turbine

Following the positive results and recommendations of the previous study, and after a number of news reports on the subject (Boston Globe, the Patriot Ledger, the Tiny Town Gazette, and the Hull Times), HMLP ran an information campaign to notify the town's citizens of a public meeting on June 16, 2000 at the High School. Representatives from the Hull Light Board, Massachusetts Municipal Wholesale Electric Company (MMWEC), RERL, and CARE; the town manager; and the town historian, led the presentation. This group fielded questions from the public and responded to fellow panelists. Following the strongly positive results of this meeting, it was announced that HMLP would solicit a Request for Proposals (RFP) for a wind turbine. At the same time, announced its intention to apply for the various permits that would be required.

Over the following months, a detailed RFP was prepared (Hull Municipal Light Plant, 2001). The RFP was formally released in January 2001, and by March several bids were received. In April the Vestas' bid was accepted. They proposed their most popular machine at the time, the V47 with a rotor diameter of 47 m, a rated power of 660 kW, and a hub height of 50 m. The turnkey contract price was $698,699, including a standard set of spare parts. Note that this figure did not include work done directly by HMLP, valued

at $54,000. This work included purchase and installation of the transformer, providing a buried cable, and connection with the HMLP distribution system. The total installed cost was thus approximately $753,000. Vendor selection was followed by contract negotiations. These led to the signing of the contract on August 13..

### 4.3 Installation of New Wind Turbine

Excavation for the foundation began in November 2001, and by the end of November the foundation concrete was cured. On December 16th the tower was in place and the rotor was installed. At 2:45 PM on December 27th the turbine was put online. The new wind turbine is shown in Figure 4. Three historic "firsts" were simultaneous achieved when the turbine was connected to the grid: (1) it was the first commercial-scale wind turbine to go online anywhere on the U.S. coastline between Maine and Florida, (2) it was the first urban-sited turbine on the North American continent, and (3) it was the first such publically-owned wind turbine to be sited in the United States within easy walking distance of a stop on a mass transit system (a ferry).

**Figure 4 660 kW Vestas Wind Turbine at Hull High School**

## *5.0 Current Project Status*

### 5.1 Energy Production

As previously noted, the installation in 2002 of a Vestas 660 kW wind turbine at Windmill Point (now called Hull No. 1) represented the high point of almost 20 years of wind energy activity at this location. In its first year of operation (12/27/01 to 12/26/02) it had a capacity factor of 27.6% (Production of 1,594 MWh). During its current second year of operation (1/1/03 to 5/1/03, the capacity factor has been 35.5%, giving a cumulative capacity factor of 29.6%. A comparison between the first and second year's power production is given in Figure 5.

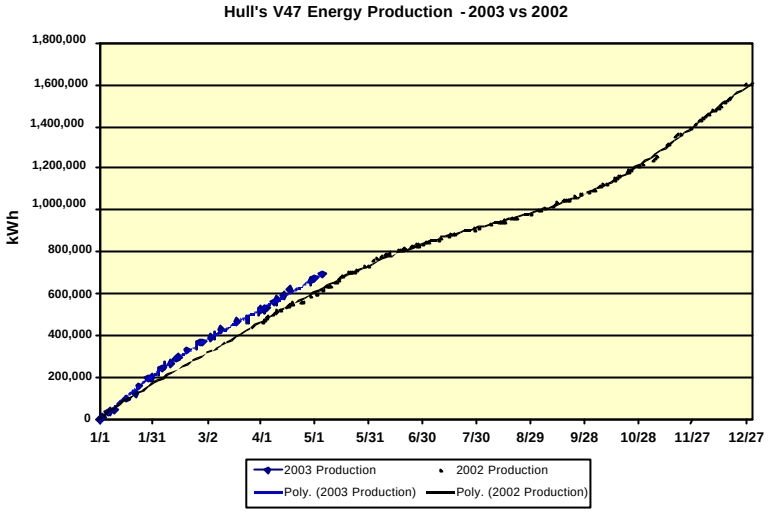


**Figure 5 Cumulative Energy Production of Hull Wind Turbine**

The CARE group has established a website for the wind turbine (CARE, 2003) and, as of day 400 since commissioning, there have been over 6,000 hits to the homepage. In addition, a number of technical meetings that have been held at the High School site. For example, a tour of the wind turbine and a project history presentation were major parts of a recent technical conference (RERL, "Wind energy in New England Islands and Coastal Communities", 2002). Many groups of visitors have made special trips to the site and media coverage of the installation, and its successes and awards, have been extensive.

## 5.2 Economics of the New Hull Wind Turbine

As previously indicated, the installed cost of the new wind turbine was $753,000. Using the measured production of the turbine it is possible to evaluate its economic value. The evaluation takes into account the value of the Renewable Energy Credits (REC), which have been developed in conjunction with the Massachusetts Renewable Portfolio Standard (RPS), and the federal Renewable Energy Production Incentive (REPI). The assumptions in the analysis are listed below. The values shown correspond to the known costs, as of the first year. The discount rate is estimated, in accordance with a typical rate of interest that HMLP might pay on a revenue bond, if one were needed. The inflation rate is also estimated. It may be noted that Hull purchased the wind turbine outright, and no loan was involved. It is also assumed in the following that the REC's and REPI will apply over the lifetime of the project. The analysis below treats the incentives (REC's and REPI) as effectively resulting in an increase in the value of the electricity produced. See http://www.state.ma.us/doer/rps/ for more details on the Massachusetts RPS.

Capital cost, $C_C$ = $753,000
Down payment as fraction of capital cost = 1
Interest rate on loan, i = (not applicable)
Annual energy production, E = 1,594,000 kWh
Value of energy purchases avoided, $V_A$ = $0.08/kWh
Value of REC's, $V_{REC}$ = $0.03/kWh

Value of REPI, $V_{REPI}$ = \$0.018/kWh
Maintenance contract, $C_M$ = \$9,880/year
Insurance cost, $C_{INS}$ = \$9,000
General inflation rate = 3%
Discount rate, d = 5%
Project life, L = 20 yrs
Loan period, N = (not applicable)

The total unit value of the energy produced, $V_T$ is given by

$$V_T = V_A + V_{REC} + V_{REPI} = \$0.128 / kWh$$

The total operation and maintenance cost is

$$C_{O\&M} = C_M + C_{INS} = \$18{,}880 / yr$$

The simple payback period for the investment is:

$$P = \frac{Capital cost}{Net\ revenues}$$
$$= \frac{C_C}{(E)(V_T) - C_{O\&M}} = \frac{\$753{,}000}{(1{,}594{,}000\ kWh/yr)(\$0.128/kWh\ yr) - \$18{,}880/yr}$$
$$= 4.1\ yr$$

The levelized cost of energy produced by the turbine may be found with the above assumptions as follows (see Manwell, McGowan and Rogers (2001) for more details):

$$COE = \frac{\left[P_d + P_a Y\left(\frac{1}{1+r}, N\right) + C_{O\&M}\, Y\left(\frac{1+i}{1+r}, L\right)\right]}{E\, Y\left(\frac{1}{1+r}, L\right)}$$

where

$P_d$ = Down payment = \$753,000
$P_a$ = Amount borrowed, = \$0
The variable $Y(k,\ell)$ is a function used to obtain the present value of a series of payments. It is determined from:

$$Y(k,\ell) = \sum_{j=1}^{\ell} k^j = \begin{cases} \dfrac{k - k^{\ell+1}}{1-k}, \text{ if } k \neq 1 \\ \ell, \text{ if } k = 1 \end{cases}$$

Accordingly, the cost of energy is:

$$COE = \frac{\$753{,}000 + (\$18{,}800)Y\left(\frac{1+0.03}{1+0.05}, 20\right)}{(1{,}594{,}00\ kWh)Y\left(\frac{1}{1+0.05}, 20\right)}$$
$$= \frac{\$753{,}000 + (\$18{,}800)(16.44)}{(1{,}594{,}00\ kWh)(12.46)} = \$0.053 / kWh$$

It can be seen from the above analysis that the wind turbine should be an economic success, provided that it continues to perform as it has done so far. Over the course of the project life, the net present value of the savings to the town will be approximately $2 million. Note also that if the effects of inflation and discount rate were ignored in the analysis, then the cost of energy would be less than $0.04/kWh and the savings to the town would be close to $3 million.

### *6.0 Prospects for Additional Wind Turbines*

In August 2002 a survey was commissioned by HMLP regarding the new 660 kW wind turbine and the possibility of additional wind turbines in Hull . Of the 499 responses, 475 approved the idea of more wind turbines. Eleven did not approve of more turbines, even though some of these were not opposed to Hull No. 1. Thirteen were noncommittal, but did have questions or comments on the project. Accordingly, HMLP is now considering the options for installing additional turbines.

Mariner's Point in Hull has been identified as one of the best sites for a second wind turbine, and RERL has recently installed a 40 m wind data acquisition system there. In addition, HMLP is working on the permitting process for this site. If siting and permitting results from this site are favorable, bid requests for a second turbine may be out by the end of 2003.

Another need for increased electrical generating capacity in Hull has emerged in recent times with a proposal for a town owned desalination plant. Currently, the town of Hull relies on a private water supplier and has experienced limitations on water supply- and relatively high water costs. As a result, the town has recently studied the feasibility of developing its own drinking water source, treatment facility, and distribution system (Woodward and Curran, 2002). This study has concentrated on the possibility of using a reverse osmosis desalination water treatment system with a capacity of 7,600 to 9,500 cubic meters/day (2 to 2.5 million gallons/day). And, as shown in Figure 6, the study identified three potential sites in Hull that could accommodate the desalination treatment and source structures.

**Figure 6 Potential Hull Sites for Desalination Plant**

If such a plant were to be built, one of the major economic considerations would be the availability and cost of the electricity required. Power consumption is estimated at 5 kWh/cubic meter for the reverse osmosis system being considered. Because of the success of Hull No. 1, HMLP is considering options for supply the desalination plant with electricity from another utility scale wind turbine installation.

One option being considered is a small offshore wind farm in Hull harbor. A proposed layout for a 9 turbine (GE 3.6 MW) system in the Hull Harbor is shown in Figure 7.

**Figure 6 Harbor with Curved Siting Arrangement**

The annual generation of a single 3.6 MW offshore turbine would roughly equal the requirements of the desalination plant, as shown in Figure 7. The output from 5 turbines would provide the majority of the town's electricity. Nine turbines would provide more electricity than the town uses, so much of it would be exported to other utilities. It should also be noted that the size of the first offshore plant at Hull might be limited to 5 machines because of potential grid connection limitations.

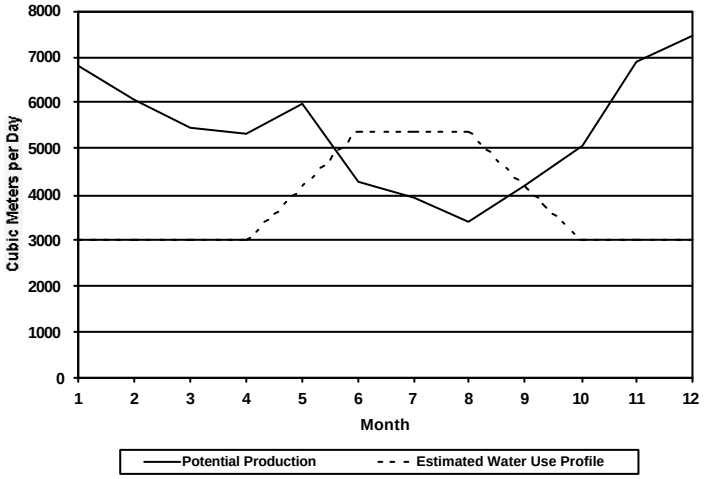


**Figure 7 Water demand and wind turbine output curve**

## *7.0 Summary and Conclusions*

The success of the project described in this paper has demonstrated that it is quite possible to site a wind turbine in an urban environment in New England. The secret to the success was first of all to recognize and address the obstacles that were likely to be encountered. The second secret was to have the right mix of favorable factors. In the case of Hull, these were:

- Municipal electric utility that was an active participant in the process
- Local champions.
- Good wind resource
- Public involvement.
- Previous experience.
- Public benefit.
- Available site
- Technical support

Because of the success of Hull No. 1, investigations are now underway which may result in the installation of at least on more turbine of equal size or larger, and a small offshore wind farm is being considered as well. Following the model used in siting Hull No. 1, the investigation of the offshore options are emphasizing the following points: The project should be (1) suitable scale, (2) attractive, (3) achievable, (4) well-planned, (5) compatible with other activities in Massachusetts Bay, and (6) able to serve as a model for other communities (in Massachusetts and world-wide).

It is the hope that other communities will be able to learn from the approach followed by Hull. No other community will be exactly the same, but it is probable that most will have similar inspiration. All of them will need to consider the likely obstacles and address each of them. Finally, some similar combination of factors will need to be found that can make the desired project a reality. The importance of the municipal electric utility in the case of Hull cannot be overstated. Many tasks that could be daunting for other communities are readily solvable when a municipal electric utility is one of the participants. How communities that are not served by a municipal electric utility can carry out such projects is a question that still remains to be resolved. Whatever the model that emerges is, it is likely that it will embody many of the attributes that have proved crucial in Hull.

## 8.0 ACKNOWLEDGMENTS

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