CHARACTERIZATION OF WIND RESOURCES IN OBERLIN, OH FOR POTENTIAL COMMERCIAL WIND POWER

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ABSTRACT

Here we report on our effort to characterize wind resources in Oberlin, OH with the goal of developing commercial wind power. The effort began in Fall 2003 resulting in the construction of a 50-m-tall wind-monitoring tower in June 2006. Here we describe the various steps in our project and the data obtained thus far. Data are combined with several commercial wind turbine performance curves to project annual energy production for our location. The results of the simulations are used to discuss the economics of wind power for Oberlin. We also examine historical weather data from other sources to look for year-to-year variation in wind speeds.

1. INTRODUCTION

In the fall of 2003 one of us taught a large, half-semester, lecture-style course (*Energy Technology I*) that introduced students to a variety of energy issues. Ten students continued on in the second half of the course, *Energy Technology II*, a workshop intended to explore one energy topic in greater depth [1].

The timing coincided with the construction of Ohio's first commercial wind turbines, two Vestas 1.8 MW wind turbines in the City of Bowling Green (BG), about 75 miles west of Oberlin. Students and professor decided to use the workshop to investigate whether something similar could be accomplished in Oberlin [2]. These seeds have grown into the *Oberlin Wind Power Initiative*. Students in the fall 2003 workshop heard directly from several key players in the BG wind project including Fletcher Miller (*Green Energy Ohio* - GEO), Kent Carson and Randy Hevner (both of AMP-Ohio), and Darrel Stockburger (Bowling Green Municipal Power Co.). Students investigated various aspects of the BG project including wind monitoring, zoning, turbine technology, economics, green tags, and government incentives for wind power. Students produced final reports on the topics investigated.

The crucial question is whether Oberlin has the wind resources to justify investment in commercial wind turbines. This question was answered for Bowling Green in 2000 when GEO completed a 12-mos experimental study to characterize wind conditions there. These data were used to build the economic case that eventually resulted in AMP-Ohio investing in commercial wind turbines at Bowling Green. (The City of Oberlin is actually a part owner of two of the BG wind turbines.)

The *Oberlin Wind Power Initiative* remained dormant until the fall 2004 when Roth and Scofield decided to initiate a wind-monitoring effort. Initial energies were directed towards partnering with GEO through their *Tall Towers Program*. Months passed before it became clear that Oberlin would not be selected as one of GEO's monitoring sites. Further discussions with GEO turned to the possibility of their loaning a temporary wind-monitoring tower to the Oberlin effort. In the spring of 2005, when that option also fizzled, the group decided to look for funds to purchase their own monitoring equipment. Roth secured several small College grants that were used to purchase a used weather station [3].

In May 2005, with strong support from *Oberlin Municipal Power and Light Systems* (OMLPS), Oberlin City Council awarded the *Oberlin Wind Power Initiative* a grant in the amount of $13,000 for monitoring winds in Oberlin. These funds were used to purchase a temporary tower, weather sensors, and equipment for logging data. Equipment was ordered in June and arrived by the end of the summer. Fall 2005 and Spring 2006 were used to obtain the necessary legal documents in order to erect the wind-monitoring tower. The time was also used to set up the instrumentation, work out bugs, and select a wind-monitoring site. The final construction permit was issued in May 2006 from the State of Ohio and the tower was erected June 6-9, 2006.

2. INSTRUMENTATION

The NRG NOW 50mHD wind-monitoring tower package was selected for the project [4]. This is a "tilt-up" tower that can, in principle, be raised without major equipment, requiring only a gin pole, winch, and a team of 6-8 people to handle the guy wires. The package comes with guy anchors, guy cables, sensors, booms, cables, a data logger, and software. The sensors include four NRG #40 anemometers, two NRG #200P wind vanes, and a #110S temperature sensor. To these we chose to add an RH-5 relative humidity sensor and a BP20 barometric pressure transducer.

The NRG logger is specifically designed for collecting wind data and storing 10-min averages to be periodically (manually) off-loaded to a memory card, allowing subsequent transfer to a computer for analysis. The logger is able to be powered for long periods of time with a battery and is especially suited for remote wind data logging, but it is not readily adopted for making real-time data available on the Internet. We were convinced that the educational value of our project would be greatly increased by making real-time data available on the *World Wide Web*. The NRG logger is not readily adapted for this application.

Accordingly, the decision was made replace the NRG logger with a more versatile *Campbell Scientific, Inc*. (CSI) model CR-1000 logger [5]. One of us had significant experience using a CSI logger for a similar application [6]. This logger has 16 single-ended (or 8 differential) analog input channels and two pulse counters. The analog inputs were more than sufficient for measuring signals from the temperature, humidity, and pressure sensors, and also the outputs of the two wind vanes. The built-in pulse counters can handle two anemometers (which produce AC signals whose frequencies are proportional to the wind speed). To handle the four anemometers we also purchased a CSI model LLAC4 4-channel low-level AC conversion module.

Internet access was accomplished using *North Coast Wireless* Internet provider with an antenna mounted part way up the wind tower [7]. The Internet transceiver was connected to the logger via a CSI model NL-100 network interface.

The CSI logger and sensors require very little power, and can run for months off of a 12V marine battery. But the Internet radio and NL-100 network interface required steady power of about 8 Watts – enough to drain a 100Ah marine battery in less than a week of continuous operation. To recharge the battery we purchased two, 65W photovoltaic panels from CSI along with a voltage regulator. An electronic circuit was designed to provide analog voltages to the logger for monitoring the PV panel voltages, currents, and the battery voltage and current. In addition, power to the radio and the NL-100 was derived from the logger's switchable 12V source – allowing the logger to turn this power on/off under program control. This enabled us to upload a program to the logger to have it periodically turn off the Internet radio to save energy, and to come back on-line at regularly scheduled intervals.

Internet-based communication to the logger was achieved using CSI's *Loggernet 3.1* software installed on a networked personal computer at Oberlin College. This proprietary software allows us to remotely program the logger and to download its data. The logger was programmed to perform measurements once per second and to store 1-minute averages. The logger's internal clock was synchronized with the computer's clock once daily, and the computer's internal clock was automatically updated daily over the Internet. The logger's internal memory is sufficient to store just over 1 month of data. A Loggernet task was set up to download new data from the logger via the Internet every 2 minutes. These data were written to a text file that could be accessed by other computers using ftp protocols. A second campus computer acted as a web server, hosting the site http://wind.oberlin.edu. National Instruments LabView software was used to write programs that display the data on the web. The equipment costs are summarized in the Table 1.

TABLE 1: EQUIPMENT LIST AND COSTS

$8,795	NRG Now 50 mHD tower package (w/sensors and logger)
$695	NRG gin pole
$335	NRG relative humidity sensor add-on
$360	NRG barametric pressure sensor add-on
$1,296	CSI CR1000 logger
$130	CSI LLAC4 module
$397	CSI NL-100
$1,280	CSI, 2 x 65W PV modules
$155	CSI battery regulator
$250	CSI Loggernet 3.1 software upgrade
$680	NCW internet service
$200	Commercial building permit fees
$500	Engineering fees
$15,073	**Total**

3. SITING, PERMITS AND TOWER RAISING

3.1 Siting

The original intent had been to locate the monitoring tower on farmland owned by Oberlin College. *New Russia Township* trustee Richard Williams approached us regarding the possibility of locating the tower on the *New Russia Township Nature Preserve* one block east of our original site. The *Nature Preserve* had two advantages over our original site – higher visibility on State Route 58, and it was adjacent to an old windmill constructed many years ago by

Mr. Cobb, whose farm had been purchased for the Nature Preserve. New Russia Township trustees authorized this use and provided additional funds of $2,500 for the remote Internet access and power required for this new site. The tower was located at (N41º 18.47', W82º 12.89') at the SE corner of the intersection of Butternut Ridge Rd. and SR-58, just north of Oberlin City limits.

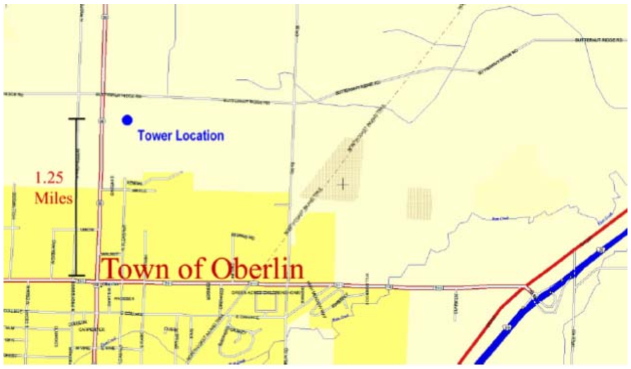

Fig. 1: Map showing tower location just north of City of Oberlin.

3.2 Permits

In our earlier study of the BG wind project we learned there were various legal and zoning hurdles for the construction of wind turbines. In all our discussions, however, it had escaped us that there were similar hurdles for erecting the temporary NRG wind-monitoring tower. As we began the permitting process we learned that there were several important hurdles: 1) we had to get FAA approval for this structure, 2) as the structure was taller than 50 ft. we required a zoning variance from the *New Russia Township* Zoning Appeals Board, and 3) we needed to apply to the *State of Ohio* for a Commercial Building permit. This latter requirement is the same as if we were constructing a large commercial building – it included requirements for mechanical engineering drawings. If we were to connect power to the tower we would also be required to supply electric engineering drawings. And, like all commercial buildings, various inspections would be required.

The FAA permit application was straightforward, as was the hearing with the Zoning Appeals Board. Together these steps delayed us by about 2 months. The commercial building permit, however, was a serious obstacle for which we were unprepared. Obtaining this delayed the project an additional six months or more. We avoided the electric drawings by using a low-voltage battery to power the tower rather than 120VAC. We thought the engineering drawings that came in the NRG Tower manual would be suitable for the application, but these specifically included a liability disclaimer and they were not sealed by an engineer licensed in the State of Ohio. We struggled to locate an engineering firm that would take on the project – the only bid we got was from a firm that was going to charge us $13,000 for the engineering work – nearly doubling the project budget!

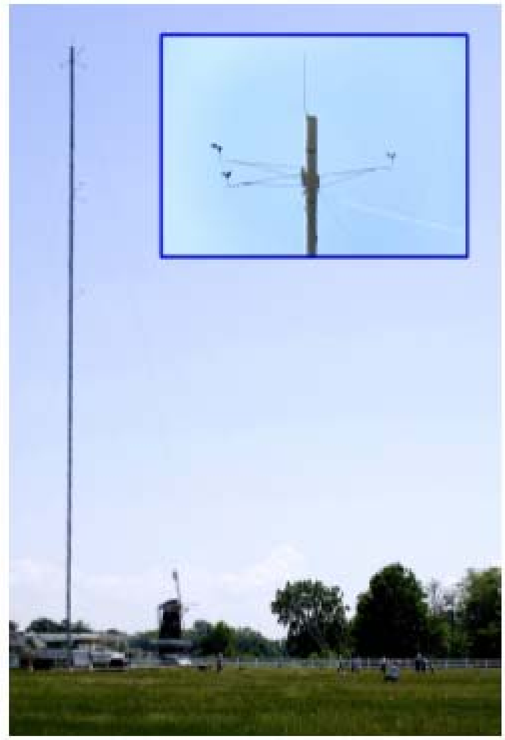

Fig. 2: Photo of the wind-monitoring tower with the Cobb windmill in the background (photo by Melinda Keller). The inset shows the sensors and booms near the top.

Finding ourselves overwhelmed we brought in Leo Evans from the Oberlin College Office of Facilities Planning to handle the rest of the permitting process for us. Eventually he made contact with a mechanical engineer who had performed similar work for GEO on another project. He generously agreed to do the work for a small fee of $500.

3.3 Tower Raising

The construction permit was issued in late May 2006. In June, a crew from OMLPS along with a few volunteers began assembling the tower on the NR township site. An OMLPS machine was used to install nine ground anchors, eight for the guy wires, and the ninth to tether the electric winch that would pull down the gin pole to raise the tower. A 6 ft. x 6 ft. section of ground was excavated to a depth of about 12 inches and back-filled with stone. The metal tower base was assembled and located over the stone, held in place both with a copper-clad grounding rod and two wood 4x4's sunk at one end in the ground. Tower raising was achieved by following the detailed steps described in the NRG tower manual under the supervision of Vic Oeftering, mostly by the OMLPS crew. The tower was outfitted with sensors and cables while it lay on the ground.

4. <u>WIND DATA</u>

Data monitoring began on June 9, 2006. It took part of the next week to work out bugs with the wireless Internet communication, but by the middle of the following week were posting data to the web at http://wind.oberlin.edu. Except for one day in October when the battery went dead, data have been recorded on 1-minute intervals. All data in logger memory are lost when a new program is uploaded to the logger. The standard procedure then is to download all the data immediately prior to uploading a new logger program. This process usually results in the loss of a few minutes of data. We have changed the program about 10 times since the beginning of monitoring.

The one significant data loss occurred in mid October when the battery voltage dropped below the logger threshold following a prolonged period of overcast weather. Approximately 1 day of data were lost. After this the logger was re-programmed, first to shut down the Internet radio from 10 PM to 6 AM daily, then later in December, to shut down the radio during 8 of every 10 minutes – updating the web page every 10 minutes, rather than every two minutes. The logger was later reprogrammed to eliminate these energy-saving measures with the onset of spring.

The monthly averages of wind speeds measured at 50 m are plotted as the dark red bars in Figure 3. Alongside (hatched green) we have plotted the corresponding averages from the Nov. 1999 – Oct. 2000 study conducted by *Green Energy Ohio* at Bowling Green. For December through April Oberlin wind speeds have averaged around 12.0 mph. It is apparent that, except for October and April, the Oberlin wind speeds are lower than those observed in 1999-0 at Bowling Green. Comparing the two we find the 10.3 mph average annual wind speed in Oberlin to be 24% lower than that found at Bowling Green. As wind power scales with the cube of the wind speed, this difference is significant.

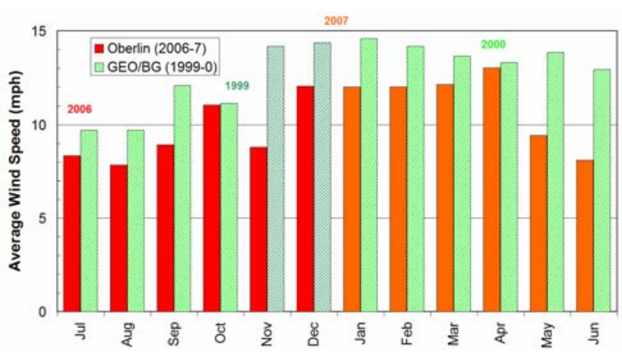

Fig. 3: Monthly wind speeds at 50 m height for Oberlin (solid red) and Bowling Green (hatched green).

Northern Ohio weather was relatively dry last summer, and this winter has been relatively mild – as compared with weather in previous years. This begs the question, "Are wind speeds in Oberlin significantly lower than those in Bowling Green or rather, is the climate this year simply less windy (both in Oberlin and Bowling Green) than it was in 1999-2000?" And more generally, "How much variability is there in the winds at a specific location from year to year?" A similar issue has been raised by GEO in connection with wind measurements observed in their *Tall Towers Program* [8].

This question would be easily answered if the 50-m wind-monitoring tower erected in 1999 at Bowling Green were still gathering data. But this is not the case – the tower was removed shortly after the GEO was completed and no such data are available.

In an effort to understand historical trends we have looked at archived weather data from the Ohio Department of Agriculture R&D Centers (OARDC) [9]. Below we graph the annual wind speeds archived at two OARDC stations located at Hoytville (light blue) and Wooster (dark red). Hoytville is located about 10 miles south of the Bowling Green wind turbines.

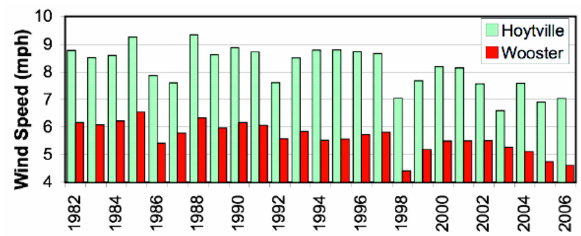

Fig. 4: Average monthly wind speeds for two OARDC stations, Hoytville and Wooster.

The numeric values of these wind speeds are not directly comparable to our own owing to the different heights and surroundings for the respective weather stations. But the year-to-year variation is relevant. Similar trends are seen for both OARDC stations; they suggest that wind speeds were greater in 1999 and 2000 than 2006. Moreover, both graphs show occasional dips in annual wind speeds (1996-7, 1992, 1998, 2003) that might be connected with global climate patterns – perhaps El Niño or La Niña. And, of some concern to anyone making a 20-year investment in wind power, both graphs show a long-term trend of decreasing wind speeds – which could be associated with global climate change. The trend is plausible since Ohio's wind speeds are greatest in winter, and for the last 30 years there is a trend for winter to be milder in Ohio.

Our specific question is whether the differences between the Oberlin and BG/GEO wind speeds (shown in Figure 3) can be explained by climate changes from 1999 to 2006. To

address this we have graphed, in Figure 5, the monthly average wind speeds for the OARDC Hoytville station for the same time periods as the BG/
GEO and Oberlin wind studies. The light green bars correspond to the months of the 1999-0 GEO/BG wind study while the dark red bars correspond to months for the Oberlin study. Except for October and March, these data suggest lower wind speeds in the last year than were present back in 1999-0. In fact, the average for the 9 months Jul – Mar is 12% lower this last year than during 1999-0. This would suggest that, in part, long term changes in weather are responsible for the differences between the Oberlin and BG/GEO data shown in Figure 3.

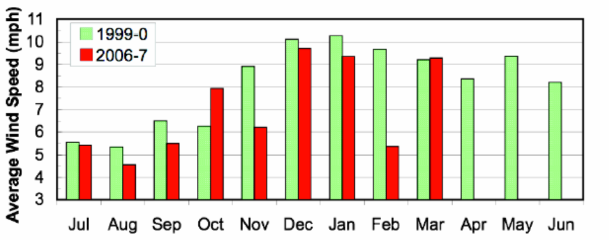

Fig. 5: Monthly average wind speeds from the Ohio Agricultural Research and Development Center (OARDC) in Hoytville, OH.

If Ohio's winds were unusually low this last year one would expect this to show up in the energy production figures for the Bowling Green's commercial wind turbines. We have obtained monthly energy production figures for the BG wind turbines from Nov. 2003 through Feb. 2007 [10]. Energy production figures do not support the idea that this last year's winds were lower than usual.

We are somewhat uncomfortable in relying on the OARDC historical data inasmuch as we do not know the history of these weather stations – who knows what changes in height, location, methodology, and surroundings may have taken place over the years at these OARDC stations? So we have turned to another source of archived weather data, the *National Climate Data Center* which maintains archived data from NOAA airport weather stations [11].

Archived weather data are available from the *Lorian County Regional Airport* a few miles NE of Oberlin and from the *Toledo Express Airport*, about 15 miles NW of Bowling Green. Average monthly wind speeds from these two airports are graphed in Figures 6 and 7 respectively, again, for the two time periods that correspond to the BG/GEO wind study (light green) and Oberlin study (dark red). In contrast to the OARDC data shown in earlier, the NOAA data do not support the contention that winds at Toledo or Oberlin were significantly lower this year than 7 years ago. Data from both airports clearly show that Nov. 2006 wind speeds were significantly lower than those in 1999. But this trend is not observed for other months.

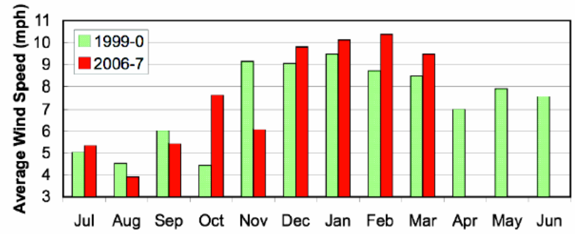

Fig. 6: Average monthly wind speeds archived for the Lorain County Regional Airport near Oberlin.

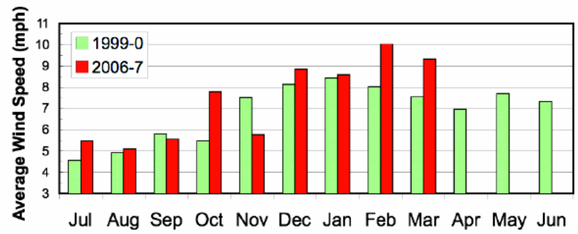

Fig. 7: Average monthly wind speeds archived for the Toledo Express Airport.

As with the OARDC weather data, we don't know how conditions at these NOAA weather stations have changed over the years. But owing to their purpose and location in the middle of large, open airports, we are inclined to have more confidence in the historical trend shown by the NOAA wind data. We therefore conclude that the differences in wind speeds between the Oberlin and BG/GEO studies are mostly associated with geographical differences, not long-term shifts in weather.

In concluding this section we emphasize that trends observed in the annual OARDC wind data (Figure 4) are interesting and could have important implications for commercial wind power. But this needs to be investigated with more care by those with expertise in climate and weather.

We now go about analyzing our data to determine economic viability for commercial wind power.

5. <u>SIMULATED ENERGY PRODUCTION</u>

There is, of course, no inherent reason why we should compare Oberlin's wind resources with those at Bowling Green. BG does serve as a useful yardstick, however, because it serves as an example of a successful wind project. If our wind resources were similar to those at Bowling Green we would be fairly confident that commercial wind power might be achieved economically.

In fact, the situation is better than this, for two reasons. First, we have measured the wind speeds at 30-, 40-, and 50-m. Commercial wind turbines are typically constructed at higher heights where wind speeds are certainly greater than what we have measured – the Vestas 1.8 MW wind turbines at Bowling Green have a hub height of 250 ft. And second, in the 5 years since the Bowling Green wind turbines were ordered, turbine manufacturers have developed turbines that work efficiently at even lower wind speeds. The economic case for Oberlin must be determined by a careful analysis that begins by calculating the amount of electric energy that "would have been generated" had a particular wind turbine been installed at our monitoring location and experienced our measured winds. We begin by using wind speeds measured at 50-m.

Table 2 shows a tiny subset of our wind data, where minute-by-minute averages have been combined to form 10-min averages. Readings from the two anemometers at the top of the tower were average to form the wind speed at 50 m, shown in the second column. Average wind directions were carefully calculated in polar coordinates (i.e., so that 355 and 5 deg. average to give 0 deg).

TABLE 2: TYPICAL OBERLIN WIND DATA

Time	WS-50m (m/s)	WD-50 (deg)	WS-40m (m/s)	WD-40 (deg)	WS-30 (m/s)	Air-T (deg-C)	Pressure (bars)	RH (%)
11/28/06	5.5	161	4.5	163	3.9	8.3	88.49	87
11/28/06	5.4	159	4.4	160	3.8	8.2	88.48	86
11/28/06	5.3	155	4.6	157	4.1	8.4	88.48	85

These data were combined with the specifications for a particular wind turbine. The turbine curve for one model of interest, the Vestas 82/1.6M is shown in Figure 7 [15]. This graph is a plot of electric power output versus wind speed. The cut-in and cut-out speeds for this turbine are 3.5 and 20.0 m/s, respectively. The nominal wind speed at which it produces a max power of 1,650 kW is 13.0 m/s. The wind data (above) are loaded into a spreadsheet. The turbine curve is then combined with the wind data to produce another column corresponding to the power produced (during a particular 10-min interval) but the turbine given the wind speed measured at a height of 50 m [12].

We have written a LabView program to readily perform this calculation given two input files, the first being the large file containing our weather data on 10-min intervals and the second being a small file containing performance parameters for a particular wind turbine. We have combined data for 12-mos (Jul'06 – Jun'07) with performance curves for seven different commercial wind turbines to calculate the amount of energy each would produce, presented with our wind speeds at 50 m. These results are summarized in Table 3 for three GE, two Vestas, a Mitsubishi, and an RE Power Systems turbine.

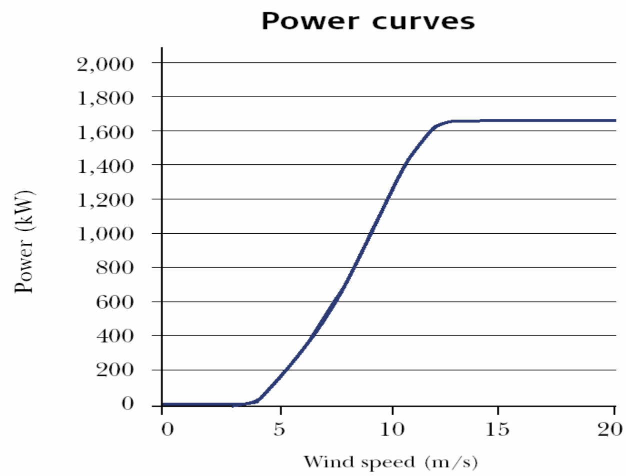

Fig. 7: Turbine performance curve taken from the brochure for the Vestas model 82/1.6M wind turbine.

TABLE 3: SIMULATED ENERGY PRODUCTION

Turbine Specifications					12-mos simulation		
	Peak P	wind speed (m/s)			Energy	FTE	Capacity
Model	(kW)	max-P	cut-in	cut-out	(kWh)	hours	Factor
GE1.5 xle	1,500	12.5	3.5	20.0	1,886,179	1257	14.4%
GE1.5 sle	1,500	12.5	3.5	25.0	1,592,077	1061	12.1%
GE2.5 xl	2,500	12.5	3.5	25.0	2,564,851	1026	11.7%
V80-1.80	1,800	15.0	4.0	25.0	1,629,080	905	10.3%
V82-1.65	1,650	13.0	3.5	20.0	1,882,991	1141	13.0%
MWT92/2.4	2,400	12.5	3.0	25.0	2,289,027	954	10.9%
REPmm92	2,000	11.2	3.0	24.0	2,542,004	1271	14.5%

Bigger turbines obviously produce more energy. What matters, however, is the cost per kWh of energy produced. Absent detailed turbine pricing information we assume an installation cost of $1,500 per kW [13]. Using this cost figure, the cost of any particular turbine is then simply proportional to its peak power. Hence a useful measure of energy produced per unit cost is just the annual energy produced (in kWh) divided by the peak power (in kW). This is what we call the full-time-equivalent (FTE) hours – it is the number of hours the turbine would have to run at full power to produce the simulated annual energy. Table 3 shows that the *RE Power Systems* model mm92 has the highest FTE, with the next highest being the GE1.5xle.

A more common figure of merit for wind turbines is to calculate the "capacity factor." This is the ratio of the FTE hours to the number of hours in a year. It tells you the fraction of the time the turbine would need to run at full power to produce the same amount of energy. Our simulations give a capacity factor of 14.5% for either the GE model 1.5xle or the RE Power Systems mm92. By comparison, simulations using the GEO/BG wind data with a Vestas V80-1.8 wind turbine yield a capacity factor of about 23%.

We note that both the GE1.5xle and REPmm92 turbines have FTE figures roughly 40% higher than that of the V80-1.80 turbine, the model installed at Bowling Green. This is an indication of how much turbine technology has improved for use with lower wind speeds in the last few years. If turbines were being purchased today for installation at Bowling Green, the V80-1.80 would, of course, no longer be the best choice.

6. ECONOMIC MODEL

Is it currently economical to produce wind energy in Oberlin? Since the RE Power Systems turbine is not actually available in the US, we use numbers from the GE 1.5xle turbine. Information from the vendor puts the current price of this model at $1,800,000 for either 59 m or 80 m hub heights [14]. The idea would be to borrow the funds for this project over 15 years at, say, a 5% annual interest. The project would undoubtedly require maintenance – at Bowling Green they purchased a service contract at an annual cost of $50,000 per turbine. We will make that same assumption here. Putting this together we find that a 15-year loan requires $173,000 annual payment to service the loan. Thus, with the maintenance contract, the annual cost is $223,000. With 1,886,000 kWh of electricity generated annually the cost per kWh comes to about $0.12. This is significantly higher than the average retail electric rate in Oberlin ($0.09/kWh) and more than twice the current wholesale generation cost for OMLPS ($0.053/kWh) [15].

Of course, the annual energy used in the above calculation is based on the 50 m wind data, whereas the hub height for the GE 1.5xle turbine can be 59, 80, or even 100 meters. There are mathematical tools for using the wind speeds measured at three heights (30-, 40-, and 50-m) to project the wind speed at higher heights – say 80 m, pretty close to the height of the Bowling Green wind turbines.

In an open, flat field the wind is expected to vary with height as

$$v(h) = v_0 \left(h/h_0 \right)^{\alpha},$$

with α = 0.10 to 0.12 [reference]. In urban environments the exponent is larger due to vertical obstructions such as trees and buildings [12].

We have used our wind speed measurements at three heights to project the wind speed at 80 m, allowing α to be a fit parameter. Not surprising, the projected speed at 80 m is, on average, about 20% higher than that measured at 50 m. We have then run our wind turbine simulations using these projected wind speeds at 80 m. The results are shown in Table 4. The last column is calculated by multiplying the second column by the ratio 12/9.

TABLE 4: ENERGY SIMULATIONS (80 METER)

Turbine Model	Annual Energy (kWh)	FTE hours	Capacity Factor
GE1.5 xle	2,656,790	1771	20.2%
GE1.5 sle	2,300,430	1534	17.5%
GE2.5 xl	3,703,330	1481	16.9%
V80-1.80	2,417,670	1343	15.3%
V82-1.65	2,722,590	1650	18.8%
MWT92/2.4	3,322,510	1384	15.8%
mm92	3,667,780	1834	20.9%

Our simulations using projected wind speed at 80 m gives capacity factors of 20-21% for the two best wind turbines – in the ballpark of what is reasonable. The annual energy production is about 45% higher than for the 50-m wind speeds, hence the annual revenue is higher. Using this annual energy production figure, the projected cost per kWh is reduced to about $0.08 – pretty close to that projected for the Bowling Green turbines (using 50 m wind data) at the beginning of that project.

On the revenue side one must also consider federal and state incentives (or tax credits) and revenue from the sale of green tags. Through the Ohio Department of Development's office of Energy Efficiency, Oberlin could receive a production incentive grant at a rate of $0.01/kWh for the first five years of generation. Oberlin would also be eligible for a payment of $0.019/kWh due to the Federal *Renewable Energy Production Incentive* under the *Energy Policy Act of 2005*. However, the latter payment is subject to the availability of annual appropriations. Furthermore, it would be possible to sell green tags. AMP-Ohio was able to sell the green tags form the Bowling Green Wind project for 2-3 cents/kWh to *Green Mountain Energy*. Thus, the combination of subsidies (not including green tags) could lower the price to $0.05/kWh which would be competitive with current OMLPS wholesale generation costs. We caution placing too much weight on this figure, however, as we expect the installed cost of a single wind turbine may be 50% higher.

7. SUMMARY AND CONCLUSIONS

We have presented 12-mos of data from our wind-monitoring effort in Oberlin, OH. Our results show that Oberlin wind resources are somewhat lower than those at Bowling Green, OH. Our 12-mos average wind speed is 10.2 mph at a height of 50 m. Using our data to project wind speeds at a height of 80 m we find that a GE1.5xle wind turbine could produce energy at an unsubsidized cost of about $0.08/kWh – 2-3 cents cheaper if you include government incentives. With government incentives the cost becomes competitive with current wholesale generation costs, making commercial wind power viable for the City of Oberlin.

The *Oberlin Wind Power Initiative* is largely associated with Oberlin College. The College has gone on record in its commitment to "climate neutrality" [13]. An investment in wind turbines either near Oberlin, or at some remote location with greater wind resources (such as Bowling Green or off-shore Lake Erie) could be an important step toward achieving this goal. Having some "on-campus" wind-generation component would provide important visibility and accessibility for student projects. Furthermore, wind energy generated within Oberlin College's electric grid has economic value equal to the retail cost of electric energy, whereas the economic value to utility-owned wind power is just the wholesale generation cost. No doubt wind power will look even more attractive in a few years as fossil fuel costs continue to rise, wind turbine technology continues to improve, and public concern over global climate change translates in economic incentives to reduce green house gases.

As our monitoring period comes to a close we are considering what to do next with the monitoring tower. One possibility is to extend our study another year at the same location. A second possibility is to move a few miles north on SR-58 where the 70-m Ohio wind map suggests winds might be slightly stronger. We would have more confidence in the 80-m extrapolated wind speed if the tower were located in the middle of an open farm field. A third possibility is to seek permission from BFI to place the tower on their Oberlin landfill – probably the highest elevation in Lorian County.

8. ACKNOWLEDGMENTS

The authors would like to express appreciation to many individuals and organizations that made this project possible. Thanks go to the *Oberlin City Council* for providing the bulk of the funding for this project, and to the *New Russia Township* trustees for providing the tower site and additional funding for wireless network access and remote power. Thanks especially to Steve Dupee, OMLPS Director, for his strong support, and to all the guys at OMLPS that participated in preparing and raising the tower. We also thank *North Coast Wireless Systems* for their generous assistance and John R. and Matt Fridenstine for generously hosting our secondary wind monitoring site. Thanks also go to Eric McMillion and Leo Evans (Oberlin College) for their assistance in obtaining the required construction documents. Thanks also to Fletcher Miller for his advice and assistance, to David Sonner for his support and advice, and to Chris Martin for his help in accessing NOAA archived weather data. And last, thanks to Bill Mohler for his critical work on the remote power systems, instrumentation, and network communications.

9. REFERENCES

1. The students were Emery Barter, Sarah Darley, Diana Frame, Stephen (Sam) Merrett, Michael Roth, Adam Sorkin, Molly Spector, Louis Stanislaw, Eden Trenor, and Kate Weinberger. Michael Roth ('06) remains active in the project.
2. The Cities of Oberlin and Bowling Green have important similarities: 1) they are both "college towns" with residents particularly supportive of renewable energy; 2) they both own municipal power companies; and 3) they have similar geography, both being located in northern Ohio, surrounded by flat farmland.
3. The logger was eventually installed at the base of a Ham radio tower on the "Fridenstine Farm" that hosts two anemometers that measure wind speeds on the SW of Oberlin.
4. We purchased the NRG-NOW, 50-m HD, Symphonie System from NRG Systems, Inc., Hinesburg, VT, www.nrgsystems..com.
5. The CR-1000 logger was purchased from Campbell Scientific, Inc. of Logan, UT, www.campbellsci.com. We also purchased their NL-100 network interface, Loggernet 3.1 software, two 65W photovoltaic panels, and a regulator.
6. See John H. Scofield, Philippe S. Cohen, Cary Tronson, and Scott Gould, "Real-time, web based energy monitoring system for a solar academic building ," *Solar 2004 Conference Proceedings*, Portland, OR, July 11-14, 2004.
7. North Coast Wireless Communications, Inc. is located in Wellington, OH, and is on the web at http://www.ncwcom.com/.
8. Steve Watts, June 15, 2006 Preliminary Report of the Ohio Tall Towers Wind Assessment Initiative, Green Enegy Ohio.
9. Archived weather data from various OARDC weather stations are found on the web at http://www.oardc.ohio-state.edu/centernet/weather.htm.
10. Private communication, Kevin Manard, Director, Bowling Green Municipal Power Co.
11. NOAA archived data are available at http://cdo.ncdc.noaa.gov/ulcd/ULCD.
12. Turbine output depends on air density which, in turn, varies with temperature and pressure. These factors will be considered after we compile 12-mos of data, but here are ignored.
13. Darrel Stockberger, private communication.
14. Vijay Patel, private communication. The minimum order, however, is 100 MW (i.e 60 turbines).
15. Private communication, Steve Dupee.