2006-485: RENEWABLE ENERGY RESOURCE ASSESSMENT: NEW JERSEY WINDS

Billy Hill, Rowan University
Billy Hill is a junior electrical and computer engineering student at Rowan University

Peter Jansson, Rowan University
PETER MARK JANSSON is an Associate Professor of Electrical and Computer Engineering at Rowan University teaching AC and DC electric circuits, power systems, sustainable design and renewable energy technologies. He leads numerous Sophomore, Junior and Senior Engineering Clinic Teams in solving real world engineering problems each semester. He received his PhD from the University of Cambridge, MSE from Rowan University and BSCE from MIT

Ryan McDevitt, Rowan University
Ryan McDevitt is a senior Electrical and Computer engineering student at Rowan University

Renewable Energy Resource Assessment: NJ Winds

I. Abstract

Engineering students working in the engineering clinic[1,2] of Rowan University have created the New Jersey Anemometer Loan Program for low-cost assessment of wind resources for residential, farm and commercial applications throughout the state. Under a grant from the U.S. Department of Energy and the New Jersey Clean Energy Program[3] students have specified, purchased, tested, calibrated and installed 20-meter and 30-meter towers outfitted with anemometers in southern New Jersey. The students are gathering critical resource data for assessing the economics and effectiveness of wind turbines for potential customers throughout the coastal environs of New Jersey. The students have also created the New Jersey Anemometer Loan Program official website[4] which provides consumer outreach, online wind resource links, and essential "how-tos" regarding wind resource assessment.

II. Introduction

Engineering clinic educational objectives at Rowan University include the following:
At the conclusion of the course, students will

- (i) Demonstrate expanded knowledge of the general practices and the profession of engineering through immersion in an engineering project environment of moderate to high complexity.
- (ii) Demonstrate an ability to work effectively in a multidisciplinary team.
- (iii) Demonstrate acquisition of new technology skills through use or development of appropriate computer hardware, software, and/or instrumentation.
- (iv) Demonstrate business and entrepreneurial skills which may include developing a business plan, market plan, venture plan, or other approved instrument.
- (v) Demonstrate effective use of project and personnel management techniques.
- (vi) Identify and meet customer needs.
- (vii) Integrate engineering professionalism, ethics, and the environmental in their work and as it relates to the context of engineering in society.
- (viii) Demonstrate improved communication skills including written, oral, and multimedia. This may include both patent and literature searches as well as writing a patent disclosure for novel work.

The NJ Anemometer Loan Project enabled the participating students to demonstrate their effectiveness in all but objective (iv) which was not a key requirement of the course. However, in partial fulfillment of this objective the students calculated the cost effectiveness of potential wind systems for the three sites that they selected for wind assessment. The NJ Anemometer Loan Program was initiated to allow consumers to have a low-cost assessment of wind resources for residential, rural, and commercial applications throughout New Jersey. Three sites were set up by late 2005 and over 30 additional customers are now on the project's waiting list. At least three new sites will be installed under an additional NJCEP grant in 2006. Each tower was also outfitted with anemometers and wind vanes which feed their results to a data logger located on the tower itself. Another anemometer has been tested, calibrated, and installed on an already existing tower located at the Bayshore Discovery Project located in Port Norris. Through this program, customers will pay nothing and receive monthly reports on wind output as well as a final report of the student's recommendation as to whether or not the site is feasible for wind power. Three Rowan University students have been involved with the installation of these towers. The lead faculty advisor is a Professional Engineer and has served as the project manager for this Rowan University project.

The long term goals for this project are to promote renewable energy, and determine the availability and cost of wind power at specific locations. Through the collection of resource data from these anemometer towers, reasonable assessments can be made as to whether the use of wind turbines at these locations would be both effective in producing sufficient energy and cheap in its construction and wind power production. To promote renewable energy, a website has been designed in order to describe what the goals are of the program, how the program is being worked on, and presents what has already been accomplished. A link to this website can be found at the Rowan University Clean Energy website[5]. The students who participate in this project work on it a variety of experiences in different areas. Through this project, students gain experiences in: data collection, data analysis, project management, how to assess a site based on certain specific environmental and geographic constraints, better communication skills, time management skills, instrumentation usage, organizational skills, and a better understanding of how to make assessments based on a collection of set amount of data. Not only this, but the students will get to experience physical labor as well while setting up different size wind data collection towers. These skills are invaluable when it comes to entering into a career, whether the career be engineering or some other profession.

III. Project Description

Determining feasibility of wind power requires the erection of tall masts outfitted with anemometers, wind vanes and data loggers in order to collect data on wind speed and direction. The data collected aloft is sent down to a data logger at ground level and stored there until collection of the data was required. But before this could be done, specific procedures had to be taken to raise these 20 and 30 meter towers. Before beginning erection of towers, a suitable location for the tower had to be established. Each site was looked at and observed carefully to determine a favorable location for each tower. Factors that were taken into consideration when deciding a suitable location for these towers were land elevation, slope, and location relative to adjacent trees or other tall structures. A site with a high elevation and little to no slope would be an ideal location. A high elevation is desirable in that it is more proximal to the higher wind regimes aloft and because the higher elevated site allows for better drainage of water down into the lower elevations of the land, allowing the base plate to sit in harder and sturdier ground and cause less movement. Having a smaller slope in the land allows for an easier time to set up the base plat and anchors which support the tower. The location chosen was based upon the taller objects within the area, mainly any trees that could disrupt the wind from providing its full potential of energy.

Once a location is determined suitable for a wind tower, the tower was set up in a step by step manner. These towers which were both designed and built by NRG Systems were used at both Neptune Farm and Eachus Farm in an effort to capture the data at the best possible height. A general description of how one of these towers is setup can be seen below, for the step by step instructions of the tower setup can be found on the NRG Systems website under the documentation section.

Installing the Anchors and Baseplate

The anchors for the tower assist in raising the tower but importantly will hold the tower in place for the duration of the data logging process. The group first picked an appropriate spot for the base of the tower and from there measured off the distance that the anchors were to be placed from the tower (42' for 20m tower and 60' for 30m). The group first used a post hole digger to go down the initial 10 inches and then turned the anchors by hand after that using a crowbar through the eye of the anchor. Because these anchors will be the main support for this tower over the next year it is extremely important that these anchors are firmly entrenched into the ground when turning the anchor and have no possibility of being pulled out during periods of more severe weather in the area. This work was continued until only about six inches of the anchor remained above ground, finally placing the anchor approximately 4.5 feet into the ground. Four of these anchors were installed forming the shape of a diamond around the base of the tower. A diagram of one of these anchors is shown below as Figure 1.

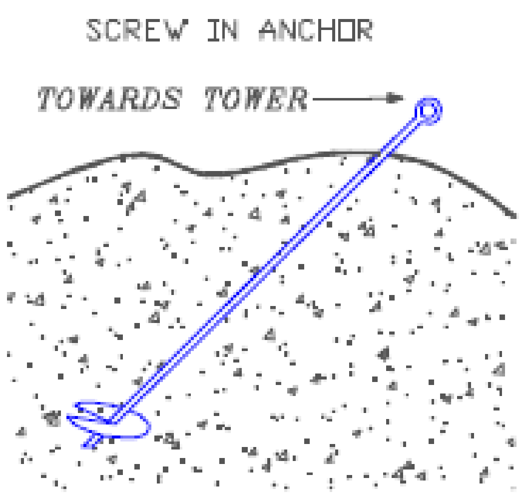

Figure 1: Diagram of anchor completely screwed into the ground

The next step was to assemble the base plate of the tower this was done by simply bolting the two sides to the bottom portion of the base plate. Once assembled, the long foot of the base plate was driven into the ground and the grounding rod was also driven through the base plate into the ground, this is to prevent the tower from sliding during the raising period. Once this was completed the base of the tower was bolted through the base plate and the rest of the tower was ready to be assembled. This base plate assembly is shown here as Figure 2.

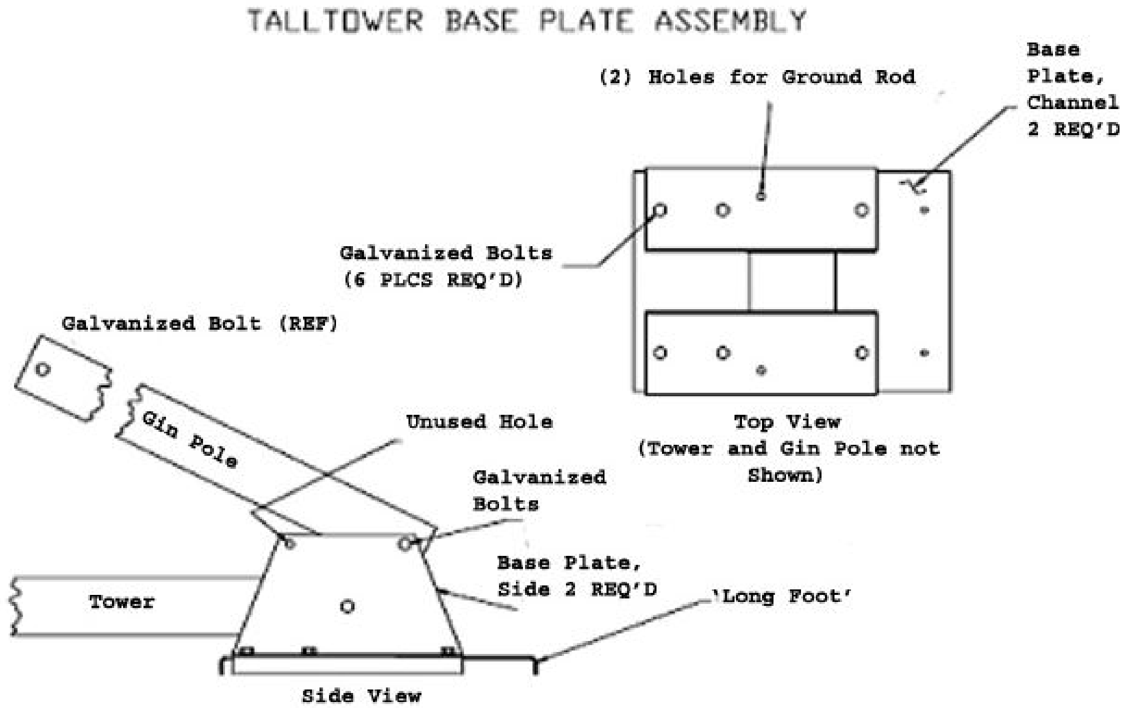

Figure 2: Base Plate Assembly for NRG tower

<u>Attaching Tower, Guy Wires, Gin Pole, and Anemometer</u>

Once the base tube is attached to the base plate the remainder of the tower is then put into place in accordance to the diagram from the manual. The individual poles simply slide onto the one before it and the guy wires slide onto the appropriate poles. This is shown in the diagram on the right. With the tower and guy wires resting upon the ground the wires were clipped off at the appropriate length as that the hypotenuse of the triangle formed between each level where the guy wires attach to the tower. With the wires at there appropriate lengths the anemometer and wind vane was the next portion to be attached. These two instruments were attached to the top of the tower along with the lightning rod using hose clamps to hold them in place and then the wires were run to the bottom of the tower and attached at each of the guy wires with pull ties and the data logger box was simply left near the base of the tower until the tower was raised. At this point the side guy wires were attached to there appropriate anchors and then the gin pole was ready to be attached. The gin pole is assembled by sliding the poles into one another as was done with the tower and then attached to the base plate. The guy wires on the side of the tower where the winch will be set up are then attached to the top of the gin pole. The erected 20 meter is shown below as Figure 3.

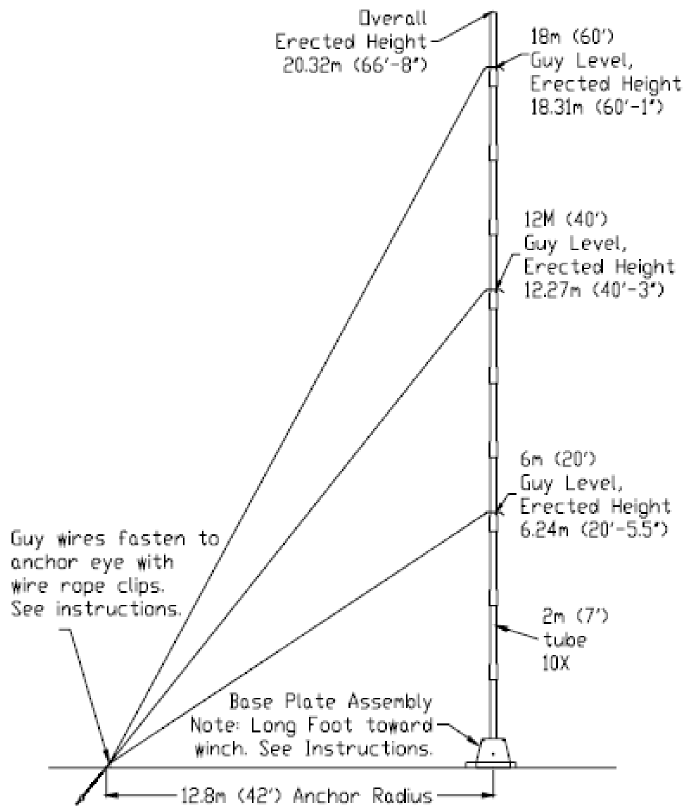

Figure 3: Diagram of erected 20 meter tower

<u>Winch Setup and Raising the Tower</u>

With the tower fully constructed the final step was to set up the winch and raise the tower. The cable on the winch is first let out and attached to the top of the gin pole as the gin pole is laying on top of the tower as shown in the diagram on the left. The gin pole is then lifted by hand so that it is perpendicular to the tower laying flat on the ground. With the gin pole in the air the tower is now ready to be raised, and so the cable on the gin pole is reeled in bringing the gin pole towards the ground at consequently raising the tower along with it. After the tower has began to lifting off the ground the wind vane is set so that it is calibrated to true north. The tower is then continued to be raised with adjustments to the guy wires being made along the way as necessary. Once the tower has been raised to approximately an 85 degree angle the guy wires are removed from the winch and attached to the anchor on the winch side of the tower. From there the tower guy wires are adjusted by hand in order to obtain as close to a 90 degree angle as possible and the data logger is then mounted onto the tower and at this point the construction of the tower is complete and the tower has begun to collect data. The entire setup of the tower with the winch attached is shown here as Figure 4.

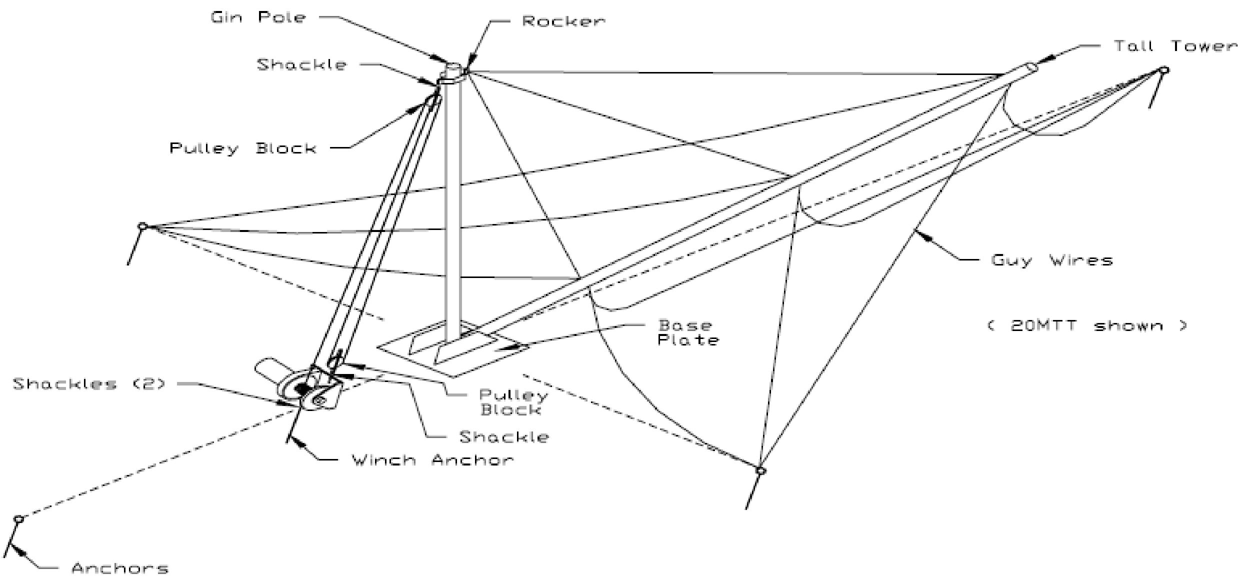

Figure 4: Layout of the tower with attached winch

Bayshore Discovery Project Site Set Up

The anemometer system for the Bayshore Discovery Project site in Port Norris, NJ was completed in a different manner then the other two sites. The tower at this site was already constructed for use of its owner and an anemometer was just to be attached to the preexisting tower. Complications arose when trying to come up with an idea on how to put the anemometer onto the tower without drilling holes into the tower. The strategy that was taken was to build a bracket that would be fit the anemometer onto the one end of the bracket with a small long black bar running through it. On the other end of the bracket, it would be connected to an aluminum bar with diameter of 1.5 inches by screws. This bar would be clamped down onto the tower using a couple of pipe clamps. In between the pipe clamps and bars would be a piece of rubber to create more friction between the bars and clamps, therefore reducing the chance of the anemometer from moving. The anemometer was placed 50 feet high (about 16 meters), and it was placed up there with the use of a fire truck provide by the Port Norris Fire Department. Figure 5 below shows the bracket that was designed and used for holding up the anemometer.

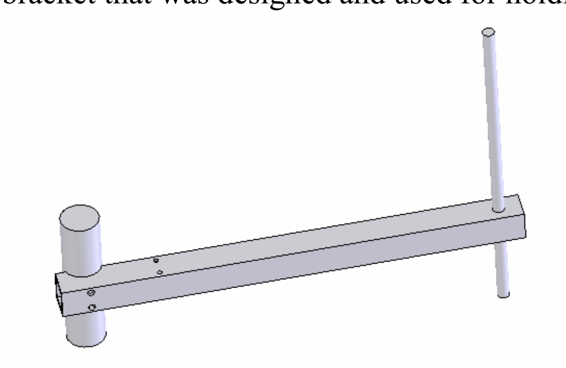

Figure 5: Picture of Bayshore Anemometer bracket

Collection of Data at Each Site

Once the towers were constructed, each was outfitted with a data logger that connected to the anemometer and wind vane attached to the top portion of each tower. The Wind Explorer data loggers were used for the 20 and 30 meter constructed towers and were provided by NRG Systems. The data logger that was used for the already built tower at the Bayshore Discovery project was provided by Onset Computer Corporation; it is called the Hobo Micro Station. Both of these data loggers are shown in Figure 6 below.

Figure 6: Date loggers used at each site

Each data logger collects the data of the wind speed as the average value taken at five minute intervals, meaning that after five minutes a wind speed is recorded within the data logger which is the average calculated value of the wind speed over that period of time. To keep the data updated as often as possible as well as to prevent loss of data, collection of the data occurred every 2 weeks. The difference between the Wind Explorer Data Logger and the Hobo Micro Station for this project is minimal as both loggers provide the same necessary data for the project; however the Hobo Micro Station does provide the user with more data collection options such as gust speed or various units for the wind speed. When the data is stored onto the computer, it is stored into a Microsoft Excel spreadsheet template created by the student design team, and there it is organized into a graph representing both the speed and direction of the wind over the span of data collection. Once these graphs are obtained, they are updated onto the New Jersey Anemometer Loan Program website. With this data in hand, reasonable assessments can be made as to how much power each site will output based on scaled factors. The height of each anemometer is scaled up to different heights of wind turbines each with a different valued output. This process will be explained in more detail in the preliminary assessments of each site.

IV. Preliminary Assessments

Based on the data that has been collected since the setup of each tower and anemometer, preliminary assessments have been made at each site according to how much kWh each site uses on average per year. Since data collection has only been compiled between the months of November thru February and not an entire year, estimation as to how much power each of the sites will produce based on the scaled factors was made. These scaled factors where calculated using the equation shown below as Equation 1.

$$\frac{V}{V_0} = \left(\frac{H}{H_0}\right)^{\alpha}$$

Equation 1: Scaling Equation for Wind Speed at Different Hub Heights

Where V_0 is the average velocity found over each hour in the data readings, H_0 is the height of the tower that the data is being collected on, H is the hub height at which you would like to know the power output at, and α is the coefficient of the terrain. The values of the coefficients of various terrain can found by determined bu consulting a suitable reference book[6]. Once you can obtain the velocity (V) of any height that you wish, you can use the values given by typical manufacturer's specifications (often found on their websites)[7, 8, 9] to find the power output at any height that you wish. A powerful and convenient spreadsheet was developed by the team to create the power output of four different wind generating systems for two mounting heights.

Neptune Farm

Neptune Farm in Salem, New Jersey is the location of the 20 meter tower that was constructed. This tower has been collecting data since November 4th 2005 and continues to do so, but the most recent data that has been analyzed is the data that has been collected from the start date up until February 28th 2006. Figure 7 below represents the data collected for the wind speed over this time period. This graph helps to give an idea as to during what part of the year the wind speed is at its fastest.

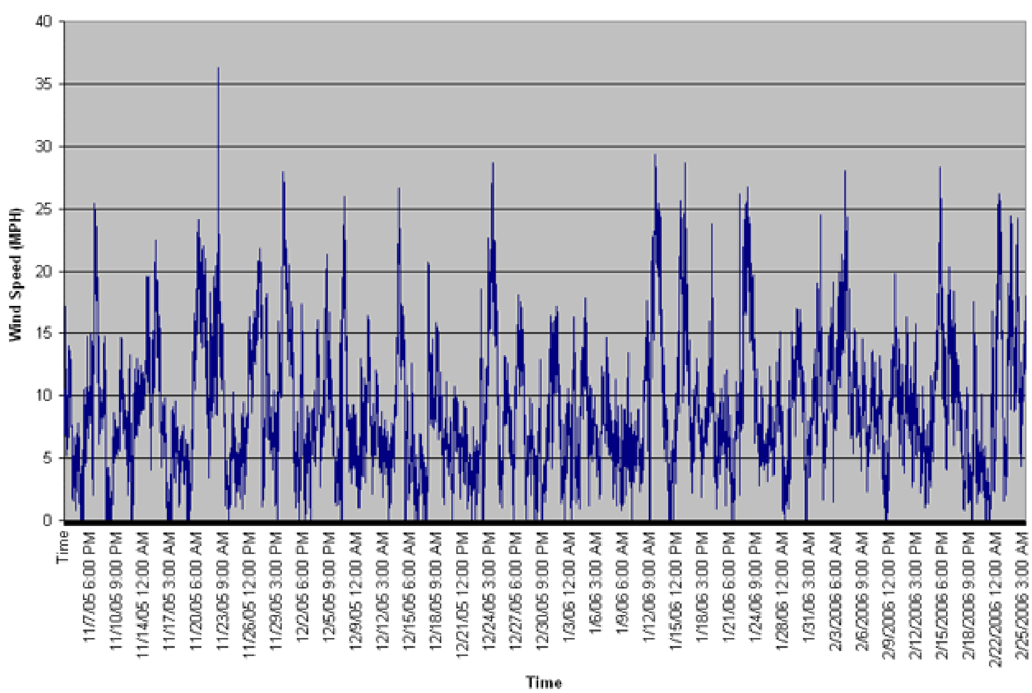

Figure 7: Wind speeds - Neptune Farm (11/4/05-2/28/05)

Table 1 below summarizes expected outputs for 50 meter and 100 meter hub heights for four different wind turbine systems as through February 28th 2006.

	50 meter Tower	100 meter Tower
10kW System	5988 kWh	7255 kWh
50kW System	46875 kWh	55943 kWh
100kW System	55225 kWh	67938 kWh
1.5MW System	1047563 kWh	1285938 kWh

Table 1: Expected Turbine Outputs - Neptune Farm (11/4/05 -2/28/06)

Neptune Farm uses on average per year 35,600 kWh. Based upon this information, the customer is provided with an assessment that fits an appropriate tower and turbine to their property. From the table above, a 50kW system at 50 meters for the entire year would produce about 46,875 kWh. This being said, it seems reasonable that this would be the cheapest tower/turbine to purchase, which would also produce enough output of energy to cover the 35,600 kWh used per year with some to spare. The initial costs of this entire system, including the turbine, tower, and installation has been estimated at a total cost of $89,338. Providing that the site qualifies, rebates in New Jersey can pay for up to 60% of the costs of the entire system bringing the costs down to $35,735. The payback for this system can be found by dividing the initial cost by the annual savings, or $\$35,735 / \$.12 * 35,600kWh = 8.36$ years. An actual final assessment can not be made until all the data for an entire year at the site has been collected and analyzed.

Eachus Farm

Eachus Farm in Upper Deerfield, New Jersey is the location of the 30 meter tower that was constructed. This tower has been collecting data since November 6^{th} 2005 and continues to do so, but the most recent data that has been analyzed is the data that has been collected from the start date up until February 28th 2006. Figure 8 shown below represents the hourly variations in wind speed at the top of the 30-meter tower located at Eachus Farm.

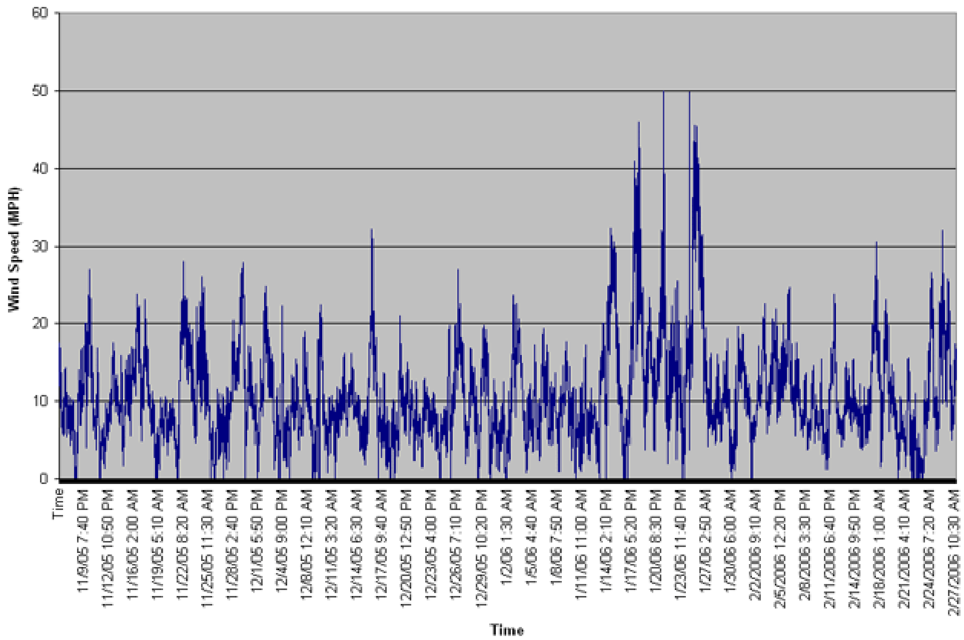

Figure 8: Wind speeds - Eachus Farm (11/6/05-2/28/06)

The table below represents expected outputs for 50 meter and 100 meter mounting heights for the four different types of wind turbine systems as of February 28th 2006.

	50 meter Tower	**100 meter Tower**
10kW System	7440 kWh	8845 kWh
50kW System	57498 kWh	65975 kWh
100kW System	76675 kWh	90850 kWh
1.5MW System	1398375 kWh	1673750 kWh

Table 2: Expected Turbine Outputs - Eachus Farm (11/4/05 -2/28/06)

From this client an average of energy used per year the farm was also obtained. Eachus Farm uses an average of 58,000 kWh per year. The assessment was completed in the same manner as was done with Neptune Farm. From the above table, a 50 kW system at 50 meters for the entire year would produce about 57,498 kWh. The initial costs of this entire system, including the turbine, tower, and installation has been estimated at a total cost of $89,338. Providing that the site qualifies, rebates in New Jersey can pay for up to 60% of the costs of the entire system bringing the costs down to $35,735. The payback for this system can be found by dividing the initial cost by the annual savings, or $\$35,735 \big/ \$.12 * 58,000kWh = 5.13$ years. The actual final wind assessment can not be completed until the data for an entire year has been collected and analyzed.

<u>Bayshore Discovery Project</u>

The Bayshore Discovery Project located in Port Norris, New Jersey, is a non-profit entity committed to the preservation of the heritage of life and commercial activities along the Delawre Bay[10]. The anemometer was mounted at a height of 50 feet (16 meters) on the tower. The data included in the analysis is from November 3rd 2005 through February 26th 2006. Figure 9 shown below represents the average hourly wind velocities for this site along the Delaware Bay.

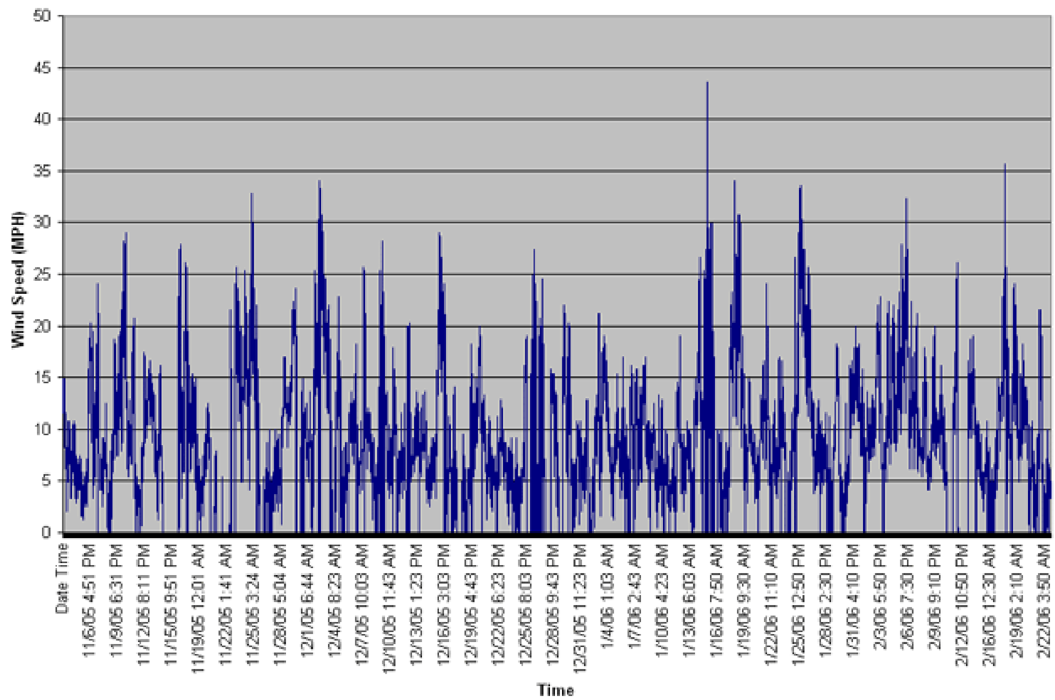

Figure 9: Wind speed over the course of 11/6/05-2/26/06

Table 3 below represents expected outputs for 50 meter and 100 meter hub heights for four different types of wind turbine systems as of February 26th 2006.

	50 meter Tower	100 meter Tower
10kW System	9718 kWh	16448 kWh
50kW System	73650 kWh	119775 kWh
100kW System	97020 kWh	203805 kWh
1.5MW System	1819125 kWh	3113125 kWh

Table 3: Expected Turbine Outputs - Bayshore Site (11/6/05 -2/26/06)

From the client, an average annual energy use was obtained. The Bayshore Discovery Project uses an average of 67,000 kWh per year. From the table above, a 50kW system mounted at 50 meters for the entire year is estimated to produce about 73,650 kWh. The initial costs of this entire system, including the turbine, tower, and installation has been estimated at a total cost of $89,338. Providing that the site qualifies, rebates in New Jersey can pay for up to 60% of the costs of the entire system bringing the costs down to $35,735. The payback for this system can be found by dividing the initial cost by the annual savings, or $\$35{,}735 / \$.12 * 67{,}000kWh = 4.44$ years. An actual final assessment can not be made until all the data for the entire year has been collected and analyzed.

V. Conclusion

At this stage of the project, data is still being collected and analyzed from each of the three sites established thus far. This process will continue for these three anemometer locations until November of 2006, when one year has passed. By that point, a more accurate assessment can be made on each site to determine their wind feasibility. Throughout the next year (2006) at least three additional towers are also being bought and set up across various locations throughout the southern Jersey area due to an additional grant from the NJ Clean Energy Program. Based on the data collected thus far, the Bayshore site appears to be the most feasible location for wind energy. Eachus Farm appears to have wind potential sufficient to meet the farms energy needs. The suitability for Neptune Farm is still unclear; although it appears now that the payback period may be at the limit of economic viability at this time. The students involved in this project successfully completed their educational objectives for this clinic project experience and also gained some valuable experiences that they can take with them into future careers. Before each tower was raised, the students learned the importance of project management, communication with clients and construction officials. The students have also developed better time management skills through the development of a project schedule and Gantt chart, which laid out all the objectives to be accomplished throughout the semester. The data that has been collected at each site has not only helped in furthering the projects goals, but has also given the students the experience in collecting, storing, organizing, and analyzing data in order to perform a sound assessment. Thanks to the accomplishments of the students, not only has the project been set out in the right direction, but they have also gained valuable engineering related experiences which can be used later on in their career.

VI. References

[1] J. L. Schmalzel, A. J. Marchese, J. Mariappan and S. A. Mandayam, "The Engineering Clinic: A four-year design sequence," presented at the 2nd An. Conf. of Nat. Collegiate Inventors and Innovators Alliance, Washington, D.C., 1998.
[2] J. L Schmalzel, A. J. Marchese and R. P. Hesketh, "What's brewing in the Clinic?," *HP Engineering Educator,* 2:1, Winter 1998, pp. 6-7.
[3] New Jersey Clean Energy Program http://www.njcep.com, *New Jersey Clean Energy Program*
[4] NJ Anemometer Loan Program - Official Website: [Available ONLINE] http://users.rowan.edu/~mcdevi24/clinic_website/website_pages/homepage.htm
[5] Rowan University Clean Energy Website: [Available ONLINE] http://www.rowan.edu/cleanergy
[6] G. A. Masters, "Renewable and Efficient Electric Power Systems," John Wiley & Sons, Inc. 2004.
[7] Bergey 10 kW Wind Turbine Spec Sheet http://www.bergey.com/Products/Excel.Spec.Frt.pdf
[8] Northern Power 100kW Turbine Spec Sheet: http://www.northernpower.com/data/Unsorted/pdb_nw100_19_1.2let-17142.pdf
[9] GE's 1.5 MW Turbine Spec Sheet: http://www.gepower.com/prod_serv/products/wind_turbines/en/15mw/tech_data.htm
[10] Bayshore Discovery Project Website: http://www.ajmeerwald.org/