May 2009

Winds of Worcester

Jonathan Kendall Low
Worcester Polytechnic Institute

Michael Carl Ghizzoni
Worcester Polytechnic Institute

Nicole Marie Low
Worcester Polytechnic Institute

SMJ

Project Number: SMJ-B108

WINDS OF WORCESTER

An Interactive Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science
by

Nicole Cahill
Michael Ghizzoni
Jonathan Low

Date: May 5, 2009

Approved:
Professor Susan M. Jarvis, Advisor

ABSTRACT

This report outlines an extensive study done at Worcester Polytechnic Institute about the feasibility of a wind farm in Worcester County, MA. Technical aspects, potential locations, social implications, environmental impacts, political support and economic impacts are each comprehensively examined to determine whether a wind farm would be a possibility for this area. The report is concluded in a discussion on the tipping point of wind power both in Worcester and in the U.S.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report has found that a wind farm could be very beneficial to the larger Worcester County community. Specifically this project suggests to the city of Worcester that it should install an eight to ten turbine wind farm on the area encompassing Green Hill Park and the Green Hill Golf Course. This wind farm would generate approximately 60 to 75 thousand megawatt hours of electricity per year and should meet the electrical demands of approximately 25,000 people in Worcester. These conclusions were reached by investigating the various attributes involved in designing a new wind farm location.

Seven of the main hills in the city of Worcester, MA were investigated as possible wind farm locations and compared based on elevation, available land area, and average wind speeds. Closer looks into each of these areas showed that Green Hill and Airport hill both have the needed attributes for installing a wind farm. Several available wind turbine models currently in production by companies such as GE, Norwin, Clipper, and Vestas were also compared to find the best suited wind turbine model for this commercial scale wind farm in Worcester. GE's 2.5 megawatt model was found to be the best fit currently in production that matched the sites needs based on power generation and availability.

The social implications of the wind farm were taken into account to determine the acceptance this site should expect. Research done in this project has shown that most people in Worcester support wind farms when the site is chosen well. This research involved surveys at the Holy Name School in Worcester and on an internet site that receives surveys from people living in Worcester.

This report has found that the environmental impact of a wind turbine farm is minimal. Based on research done in this report, bats are the only animals significantly affected by wind turbine installations due to their frail lungs that can be injured by pressure drops around the blades of the turbines. Any other environmental damage caused by building the site was found to be much less than that of a typical power plant and therefore may be ignored.

Economically, a wind turbine farm such as the one suggested by this report is a large investment with a long return on investment period. However, with the recent stimulus package made by President Obama and other sources of financing made available for green energy, the initial cost of the site could be reduced alongside the time needed for return on investment. Local politicians including Representative Jim McGovern, Mayor Konstantina Lukes, and Senator John Kerry, were also found to support of green energy and should be supportive toward the new wind farm.

Previous studies done at Worcester Polytechnic Institute including a prior turbine site feasibility study and a recent study done on Nantucket were used to conclude that the "Tipping Point" in Worcester and in America is about to be reached. This concept says people such as T. Boone Pickens, conditions in the area, and the notability of an idea all contribute to the point where the idea begins to spread rapidly. This report concluded that new technology and a more informed population are leading the way to a future with a high percentage of America's energy being produced by green energy sources. It is recommended that a follow up be performed investigating the progress of new wind generation technologies discussed in this report.

INTRODUCTION

The popularity of renewable energy is apparently on the rise in the United States and throughout the world. Global warming and the price of electricity has called for alternative ways of producing energy that are less harmful to the environment as well as less costly for the consumer. Wind farms have been implemented throughout the world, and are being considered in many other places such as Cape Cod, Massachusetts. Whether or not a wind farm is feasible in Worcester County involves examining potential locations and current technology, exploring the social implications and the environmental impacts, and studying political and economic influences to determine achievability, all of which is accomplished in this report.

The first section of this report discusses potential locations. Possible locations for a wind farm include Worcester's Seven Hills: Airport Hill, Bancroft Hill, Belmont Hill, Pakachoag Hill, Vernon Hill, Grafton Hill, and Green Hill. This report focuses mainly on Green Hill as a potential site for a farm.

There are several models currently in production by companies such as GE, Norwin, America's Wind Energy Inc., Clipper, Northern Power, and Vestas. The second section of this report explores these models for suitability at the potential Green Hill farm. There is also new technology in progress, such as upgrades in horizontal axis wind turbines and a completely new style by the company Mass Megawatts. Research, such as new models and improvements to existing models as well as improvements in efficiency, is also in progress. The turbine model best suited for Green Hill is the GE 2.5 megawatt wind turbine.

The social implications of a wind farm should be taken into account when performing a study on wind turbines, and the third section of this report addresses this. A medical condition

called “Wind Turbine Syndrome” has been researched by Dr. Nina Pierpoint, but has not been recognized by medical agencies. Another social issue can be the “Not in My Backyard” phenomena, and there have been studies done regarding feelings about turbines when in motion as well as of tourists in Scotland. The Holy Name School in Worcester recently erected a wind turbine, and a survey of the school shows a positive trend in attitudes toward the turbine. A survey placed on the Worcester Craigslist also shows positive feedback for a potential wind farm in Worcester.

Environmental effects of any building structure need to be explored, and is accomplished in section four of this report. With a structure such as wind turbines, flying animals are of the utmost concern. There are no major bird migration paths that cross near Central Massachusetts, however surveying the Holy Name School and the greater community on the Worcester Craigslist shows that birds are a concern. Another concern is bats, some species are reported as having issues with the pressure drop close to turbines. There are no emissions due to wind turbines, however lubrication oil can leak. The clearing of woodland areas is generally unnecessary for turbines. A consideration is the manufacturing process, however until factories are powered by renewable energy this concern must be neglected.

Section five of this report addresses the economic impacts of a wind farm. Economically, harnessing wind power for productive means is beneficial, and has been used for many years in many different ways. The government has been encouraging alternative sources of energy; however public demand of these sources usually depends on the current price of petrol. The current stimulus package by President Obama dedicates a large sum of money towards the development of alternative energy sources. Other solutions to make a turbine site more economically feasible include dual use with another type of facility.

Section six discusses political support. Politicians are also an important factor in a wind farm as their support is instrumental in gaining public support. Local politicians include Representative Jim McGovern, Mayor Konstantina Lukes, and Senator John Kerry. Local and state voting records show an increasing trend in support of green energy. The government has great plans for alternative energy sources. Globally, wind turbines have been beneficial and alternative energy seems to be becoming a global trend.

Section seven explores previous studies done at Worcester Polytechnic Institute, including a prior feasibility study, the study that resulted in the Holy Name School receiving their turbine, and a very recent study done on Nantucket. Section eight explores the idea of "The Tipping Point", which shows that a small number of people are capable of a large impact. People such as T. Boone Pickens are essential in alternative energy work. The "Power of Context" explains that the conditions in the area, such as the economy, oil supply and prices, and current technology determine whether or not public support is earned. Commercials, news stories, and knowledge of turbines determine whether people will remember them or whether they will become a distant memory. The final section discusses the future of wind energy in Worcester, MA as well as in the country at large.

A wind farm in central Massachusetts, particularly Green Hill, would be marginally feasible. Wind speeds very nearly reach that which is required to produce electricity, and the community at large is supportive of alternative energy. The environment will not suffer nearly as much as it currently does with coal and oil energy production, and politically and economically there is much support. A wind farm could be incredibly beneficial, or it could be a misuse of funds in Worcester County.

POSSIBLE WIND FARM LOCATIONS

Location is arguably the most important aspect in any wind farm project. Up until recent years wind turbines only inhabited two distinct locations. These were open plains and deserts like those of California and near wealthy people who have an interest in green energy. One of the most profitable wind farms in existence is the five thousand turbines in place in Tehachapi-Mojave, California. This site uses relatively small 108 kilowatt turbines across the entire Tehachapi Valley. Together the five thousand turbines generate approximately 1.3 terawatt hours of electricity per year which is enough to meet the electrical needs of about 500,000 southern Californians. [Wind Plants of California] While deserts and mountains are the best places for wind farms on land, wind farms put out in the ocean are extremely productive. Anyone that has been to the beach can verify that winds are often strong near the ocean. The large open area above the water allows for unobstructed wind paths and the cool air coming off the water causes wind from temperature differentials. One such wind farm that is in the process of being designed is Cape Wind on the Nantucket Sound. This project has seen a lot of support and a lot of opposition but it finally got approved by The Massachusetts Office of Coastal Zone Management in January of 2009 saying that the wind farm meets their environmental requirements. The site is still anticipated to be fully operational in 2010. The wind farm should supply about 1.4 terawatt hours per year to the Cape Cod area. [Cape Wind] The choice of these two locations was vital in to the success of these projects. In order to have this project be a success as well, it will have to investigate multiple candidate sites before making a decision.

In order to find locations in Worcester County that are suitable for wind turbine farms wind maps and maps of land ownership of Worcester County were employed. The problem with

many of the best locations around Worcester is that most windy sites such as Cascades Park and Green Hill Park tend to be on hills. Most of these hills have been made into state parks and reserves and because of this it may be harder to get approval from the community for construction at these sites. Several possibilities were investigated for wind farm sites including farm lands in the county as well as other sites that may have the space to install several turbines. Many of these sites that are farm lands were at too low of an elevation to have usable wind speeds. One such site was Nourse Farm in Westborough, MA that sits at 122 meters above sea level. This site would have a good amount of open area but wind speeds there average around only 1 meter per second or 2.1 mph. Other sites had travel routes that would impede the process of delivering the parts of the turbine to the site. A wind turbine is put together using several large pieces and requires wide roads for pieces to be brought to the site. An example of a site that has insufficient travel routes that may not allow easy transport of parts is Bancroft Hill which is investigated later in this section.

In the end the scope of the project was reduced to concentrate on the seven hills that are said to make up the city of Worcester. Any one of these hills should have the best wind speeds in Worcester since they are above the average elevation in the city. Below in Figure 1 there are two maps provided by the Massachusetts Technology Collaborative [Community Wind]. The first map shows the wind speeds in Worcester while the second shows who owns the land. Both maps have been modified to show the locations of the seven hills with yellow dots. The red dot indicates Green Hill which will be the primary target of this report.

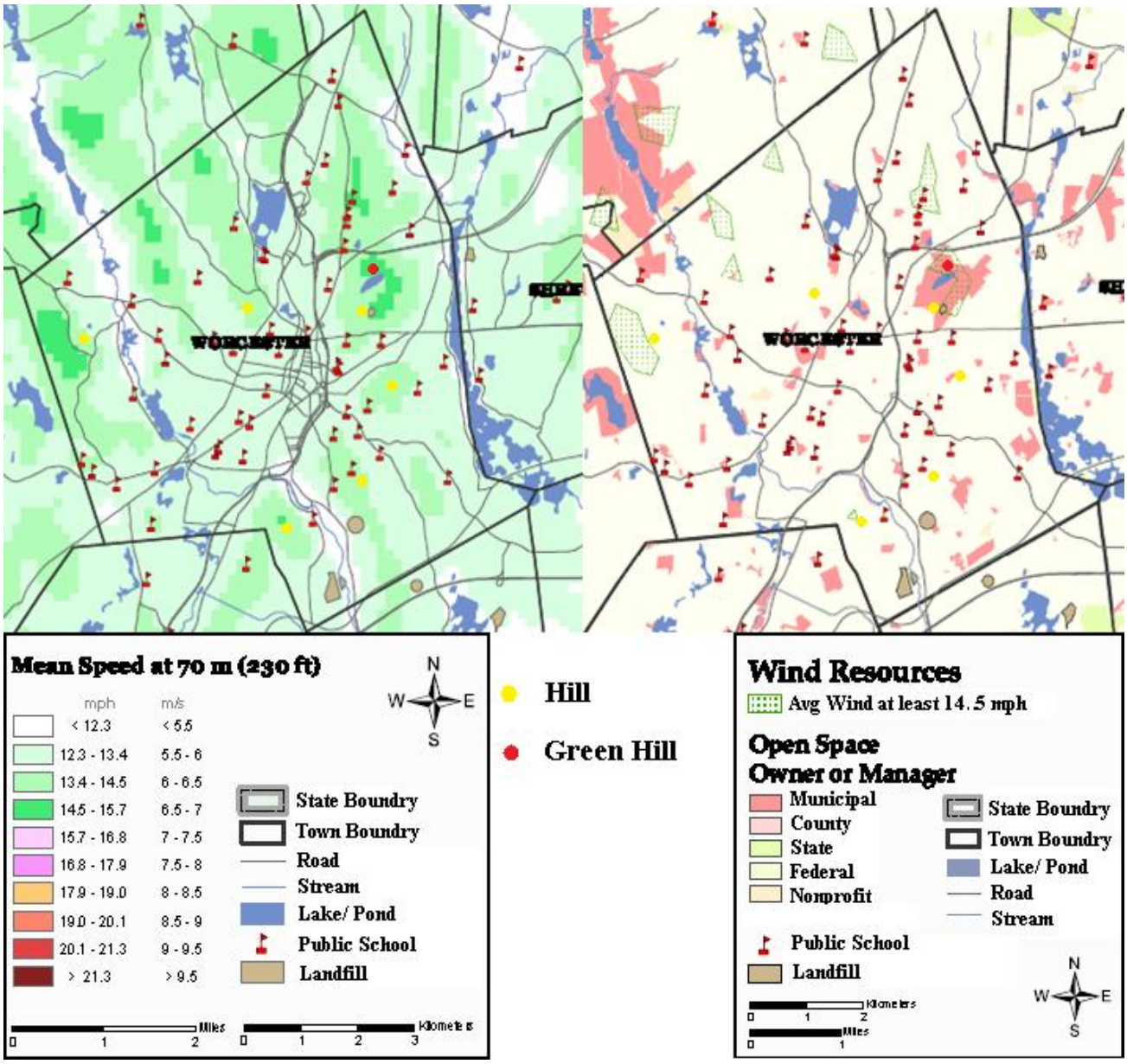


FIGURE 1: WIND SPEEDS AND LAND OWNERSHIP IN WORCESTER [COMMUNITY WIND]

Initially, Airport Hill was considered a likely site since the area was well known to have relatively high wind speeds as well as a large land area. However, this project investigated each of the hills to determine which would be the primary candidate.

Green hill was found to have two possible wind generation locations on it, a golf club and a park that are both owned by the city of Worcester. The park is located in the middle of Worcester and surrounds Green Hill Pond. Green Hill has an elevation of about 230 meters which puts it high above Worcester's average elevation of 147 meters. [BGN: Domestic Names] This height means that wind turbines on Green Hill will have access to much more wind with virtually no obstructions. The pond also adds to this sites feasibility since wind speeds increase in the open space above bodies of water. Water also causes temperature differentials due to the fact that the water cannot change temperature as fast as the air around it. This generates wind in the area due to the law of diffusion which states that the warm air around the area will move to balance with the cooler air above the water. From Figure 1 it can be seen that Green Hill is owned by the city and has average winds at about 14.5 mph or 6.5 meters per second. The golf course is also a very feasible site since it covers a large area and has very few obstructions. The course itself is about 1 kilometer long. Since it is a golf course it is closed during the winter and could benefit financially from adding a source of income such as a wind farm that would prosper in the winter months. This is the concept of co-location or dual use of a turbine site that was discussed earlier in this section. Overall, Green Hill is considered a viable candidate site for a wind farm and will be taken into consideration.

Grafton Hill is in the south-west of Worcester and contains developed land comprised mostly of restaurants. Feasibility of a possible wind farm in this location is very low despite average wind speeds around 6 meters per second. This is due to large scale commercial development of the area. One possible location near Grafton Hill is on the corner of Dartmouth Street and Whitehall Avenue. This forested location has an area of deforestation in the middle. The land appears to be privately owned as of 2003 as shown by the land ownership map. This

can be further investigated later if another more promising wind site is not found, but for this project Grafton Hill was removed for the list of feasible sites.

The third hill investigated was Pakachoag Hill. This hill is home to a golf course just like Green Hill however this golf course is much smaller and the average wind speed is slower, around 6 meters per second. This is due to its low elevation of about 135 meters. [BGN: Domestic Names] The course is comprised of only 9 holes as opposed to Green hill which has 18 holes. This lack of space and lower wind speeds make Pakachoag hill a less desirable location than Green Hill and as such, this site was not investigated further.

The next hill to be investigated was Belmont Hill. This location contains Bell Hill Park. A park is a good location for wind turbines since they usually contain few obstructions to the wind and plenty of space for a wind farm. Taking a look at a map of the park it was found that Belmont Hill is adjacent to Green Hill Park. Belmont Hill is also at a lower elevation of 153 meters when compared to Green Hill. [BGN: Domestic Names] Also, looking at a map of Bell Hill Park shows that it is much smaller than Green Hill Park and that the best land for a wind farm is along Green Hill Parkway. For all of these reasons investigation will continue using Green Hill instead of Belmont Hill unless information is found that would prove Bell Hill Park is the more feasible location.

The fifth hill investigated was Bancroft Hill. This hill sits near the Worcester Polytechnic Institute campus and it best known for Bancroft Tower, an old fort built on the top of the hill as a lookout location. The hill is at an elevation of about 153 meters which puts it slightly above Worcester's average elevation of about 147 meters. [BGN: Domestic Names] Upon visiting the location it was found that the area is free from obstructions however the top of the hill does not

offer much area to develop into a wind farm. One tower at most could be put in the location and construction could prove difficult since the hill is surrounded by a busy part of Worcester. Also the road up the hill is not improved and may not be wide enough to deliver the larger pieces of the turbine. For these reasons Bancroft Hill was not further studied.

The final site this project considered was Airport Hill. This Hill is where the Worcester Airport is situated and has been discussed as one of the most likely sites for a wind farm in Worcester, MA. The airport is roughly 4 square kilometers in area and sits at an elevation of about 300 meters. [BGN: Domestic Names] This would definitely be the most feasible wind turbine site considering its geographic attributes but it could also be the most difficult site due to regulations that take effect around airports. Any tall structures near airports need to be registered with companies similar to Towair that check the zoning laws and height restrictions for the site. Another complication with this site this report found was that the time needed to build the turbines on site would minimize the profits made by the airport. The wind farm could potentially replace the currently unsuccessful airport and clear these problems, but one major setback is the fact that Direct Air, a Virgin flight service, has announced it will fly planes from Florida to the Worcester Airport. [City of Worcester, Massachusetts] If the airport were to get more commercial flights to fly in and out and by doing so become more successful, this site may no longer be a feasible option. In this respect in addition to investigating this site the old Leicester Airport would have to be investigated as well. This airport was shutdown when the Worcester Airport opened. The Leicester Airport is located slightly North-west of the Worcester Airport and the area in which it's located has been grown in by the surrounding vegetation. Because of this the area may have to be cleared and would add to the cost of implementing a wind farm. Although this project found that the Worcester Airport would be the most feasible location for a

wind farm in Worcester in respect to its size and wind speeds, it would be very difficult to convince the city of Worcester to allow multiple wind turbines to be installed while they're trying to increase the airports number of incoming flights.

From all of these sites Green Hill was chosen as the primary candidate for many reasons including convenience, quality, and feasibility. Green Hill is approximately 200 meters wide by 100 meters long and sits at an elevation of approximately 230 meters above sea level. [BGN: Domestic Names] Wind samples taken at a weather station about a mile away at approximately the same elevation set the average wind speed on Green Hill to be 2 meters per second which is contrary to the wind speed map in Figure 1. This discrepancy could be the result of the fact that the map uses ranges to describe the average wind speeds or it could be the result of averaging in wind gusts that are not constant. In any case standard wind turbines require a wind speed of about 3.5 meters per second to constantly generate electricity. Although this sites average wind speeds seems to fall below the required speed, average wind gusts in the area are around 9 meters per second and these would allow sufficient generation of electricity. [Weather Underground] A second reference for this site's wind speeds can be seen in the Holy Name High School wind turbine on Vernon hill. This turbine is at an elevation roughly 70 meters lower than the proposed turbine height at Green Hill and Holy Name is only 2 miles away from Green Hill. [BGN: Domestic Names] The IQP team from Worcester Polytechnic Institute that did the feasibility study for the Holy Name turbine recorded average wind speeds of 3 meters per second at an elevation of 230 meters. This is faster than the data from the weather station referenced earlier and demonstrates that winds at the proposed turbine site on Green Hill should be sufficient. The group from the Holy Name IQP also used a simple wind model to determine the wind speed that would exist at the height of their turbine hub and found that the average wind speed at 260

meters should be approximately 5.65 meters per second. [Jensen, Foley and Forbes] Since the wind turbine suggested for Green Hill is at a higher elevation than this, the wind speed at the suggested wind turbine height should be well above the require cut in speed of 3.5 meters per second. Green Hill also provides a large area of unobstructed land as seen in the photo below taken in February of this year (2009). From these facts this report found that Green Hill is the most viable option for wind farm placement in the city of Worcester.

FIGURE 2: GREEN HILL OVERLOOKING WORCESTER

Green Hill is not without problems. The first problem with this location is its size. Wind turbines require spacing of roughly one to two rotor diameters. The standard GE turbine has a 77 meter rotor which means the park alone could only fit two wind turbines. Expanding to the golf course would improve this number to around ten turbines and greatly increase the farm's electrical generation. This circumstance gives way to two possible wind turbine solutions, as shown below in Google Earth: A site with up to two turbines or a full farm with up to ten possible turbines. The image is marked with possible wind turbine locations using red dots.

Overall the final site should produce approximately 7,500 megawatt hours of electricity per year per turbine. This value is calculated from a formula provided by the Massachusetts Technology Collaborative. [Renewable Energy] This formula calculates the power supplied from a wind turbine based on its maximum output at 100% efficiency and its capacity factor that rates how efficient the turbine is actually generating power. For this report an average capacity factor of 35% was assumed for a 2.5 megawatt turbine and the result was approximately 7,500 megawatt hour per year for one turbine. In conclusion, the suggested eight to ten turbines should generate between 60,000 and 75,000 megawatt hours of electricity per year.

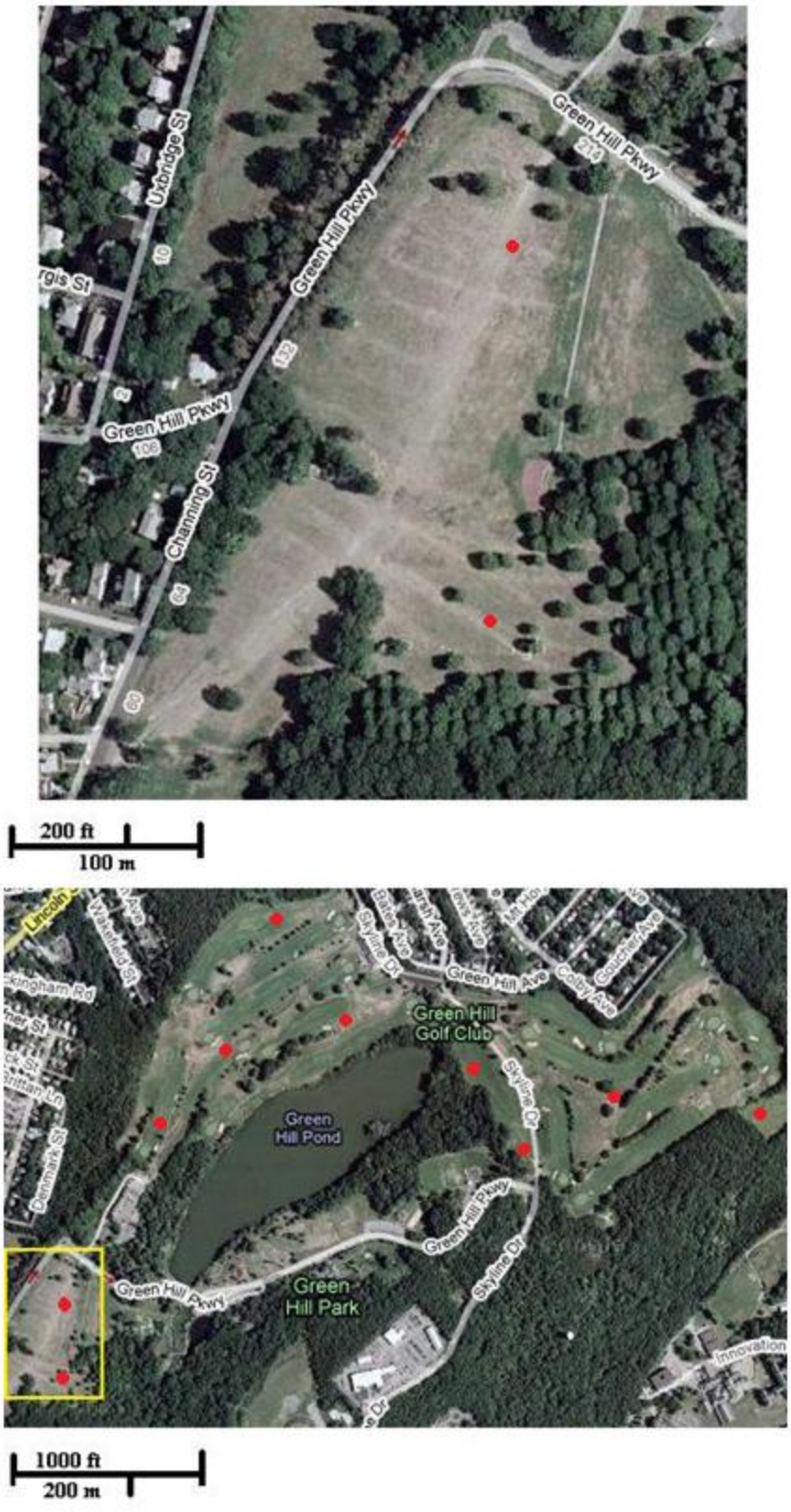


FIGURE 3: GREEN HILL SATELLITE IMAGES [GOOGLE MAPS]

TECHNICAL ASPECTS OF WIND TURBINES

Wind turbines have come a long way since they were first used in the 7th century by Persians for the sole purpose of grinding grain. The basic idea behind a wind turbine is to have the wind turn a fan-like set of blades that are connected at a central point. This point's kinetic energy is then transferred to the ground using gears or in later cases using an electric generator and wires to bring the generated electrical energy to the bottom of the tower for use in some other system. In the 12th century wind turbines were used by Europeans to pump water, saw lumber, and they were also used for their original purpose of grinding grain. Wind turbines were also used in the United States for pumping water from underground during the country's beginnings and many of those systems are still in use today. Finally, in the late 20th century, turbines were converted to generate electricity using the vast power the wind can supply. [Wind Energy]

The first modern turbines that were used for generating electricity were made in the 1930s and were so inefficient that they could only be used to charge batteries for lighting and appliances for homes that were off the grid. The reasons for this inefficiency were the fact that they were made of heavy materials like wood and there was a lot of friction in the system that caused much of the energy to be lost to heat. Turbines remained this inefficient until the oil crisis of the 1970s forced countries to look to alternative energy resources. While most failed at harnessing wind power, Denmark was successful in developing a system efficient enough to help power their country. [Wind Energy]

The modern turbine has been even further improved from Denmark's original design. The main parts of a turbine are the tower, the rotor, and the nacelle. The towers of older wind

turbines were made of wood, stone, or brick and allowed for very short elevations. Improvements in construction materials have lead to turbines made of concrete, metal, and reinforced plastics which can reach heights up to 100 meters. The rotor blades that were originally made of wood and cloth, aluminum, or steel were replaced with fiberglass blades that are lightweight and can be adjusted to best capture the winds energy. The nacelle is the unit on the top of the turbine also called the hub that connects the tower to the blades and converts the kinetic energy from the spin of the rotor to another form of energy. In the first turbines the kinetic energy was transferred directly to function as a grinder by using the spinning motion. Modern turbines change this kinetic energy to electricity using a generator. Generators have also shown improvements since they first debuted. One version includes using a generator in conjunction with a transmission much like a car. In this version the turbine can change to a higher gear if the speed of the blades spinning could cause damage to the system. A second version uses two generators for two wind speed ranges for the same reason. The most recent version uses a single generator with dual electric windings that provides the same functionality of two separate generators. [Wind Energy]

Overall these components have all improved such that wind turbines can convert wind energy to electricity close to the maximum efficiency of 59% as determined by a German physicist named Albert Betz in 1919. This maximum rating is limited by the fact that wind energy is the reason the wind is moving, so if all of the energy in the wind could be harnessed, the wind would have to stop completely and this is impossible. The following graph (Figure 4) was derived to show how efficiently any given wind turbine can harness energy from the wind. The graph depicts the power out versus the change in wind speed from one side of the turbine to

the other.(Proof of Betz' Law) As can be seen in the graph, power out over power in is at a maximum at 0.59 or 59 percent.

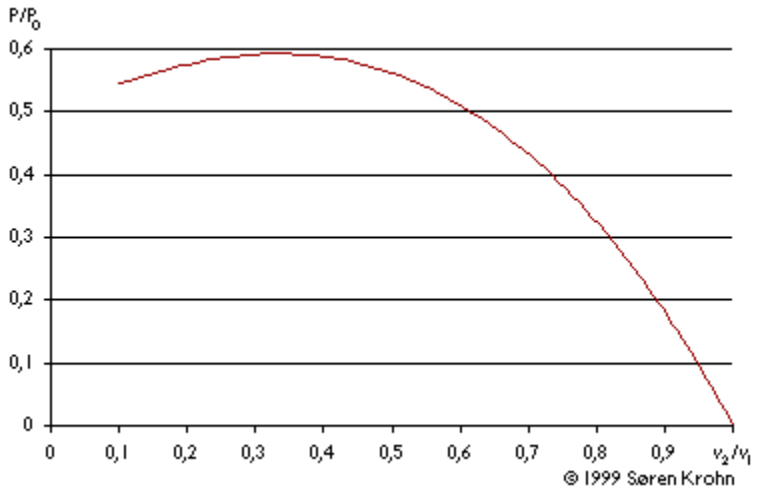
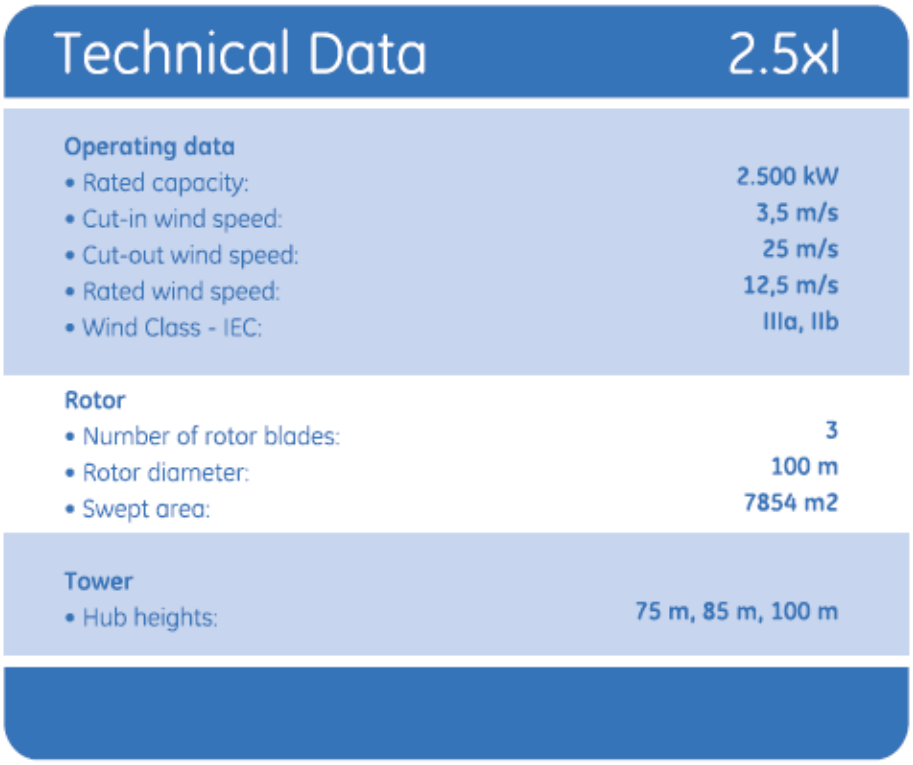


FIGURE 4: BETZ LAW POWER GRAPH [PROOF OF BETZ' LAW]

In order to determine which wind turbine is best suited for use on Green Hill, various manufacturers were examined. The primary wind turbine manufacturer in the United States is General Electric. Since most turbines were found to have similar cut-in speeds of 3.5 meters per second and because this report is investigating a large scale wind farm, only large scale turbines, above 500 kilowatts, will be investigated. GE offers two large scale wind turbines, a 1.5 megawatt version and a 2.5 megawatt version. Since Green Hill is a small location and maximum power output is desired, this project will investigate GE's 2.5xl turbine.

The 2.5xl from GE is advertised as being suitable from over 85% of wind farm sites in development today. As such this turbine should be compatible with Green Hill. As seen in the data sheet below in Figure 5, the turbine begins generating power at a minimum wind speed of 3.5 meters per second or 8 mph and cuts out at about 25 meters per second or 65 mph, typical of major tropical storm force winds. This model boasts hub heights at 75, 85, and 100 meters. At

330 meters, 100m above Green Hill's elevation, Green Hill has an average wind speed of approximately 6 meters per second with wind gusts up to 18 meters per second. These values fall right within the operating field of the turbine and give good chance of the wind at hub level being around the rated wind speed of the turbine which is 12.5 meters per second. This is the speed at which the turbine is generating its rated power of 2.5 megawatts in one hour. As seen in the graph following the data sheet, the rated wind speed is the speed at which the turbine is generating 2.5 megawatts and is at maximum efficiency. [GE Energy]



Technical Data	2.5xl
Operating data	
• Rated capacity:	2.500 kW
• Cut-in wind speed:	3,5 m/s
• Cut-out wind speed:	25 m/s
• Rated wind speed:	12,5 m/s
• Wind Class - IEC:	IIIa, IIb
Rotor	
• Number of rotor blades:	3
• Rotor diameter:	100 m
• Swept area:	7854 m2
Tower	
• Hub heights:	75 m, 85 m, 100 m

FIGURE 5: GE 2.5XL TURBINE DATASHEET [GE ENERGY]

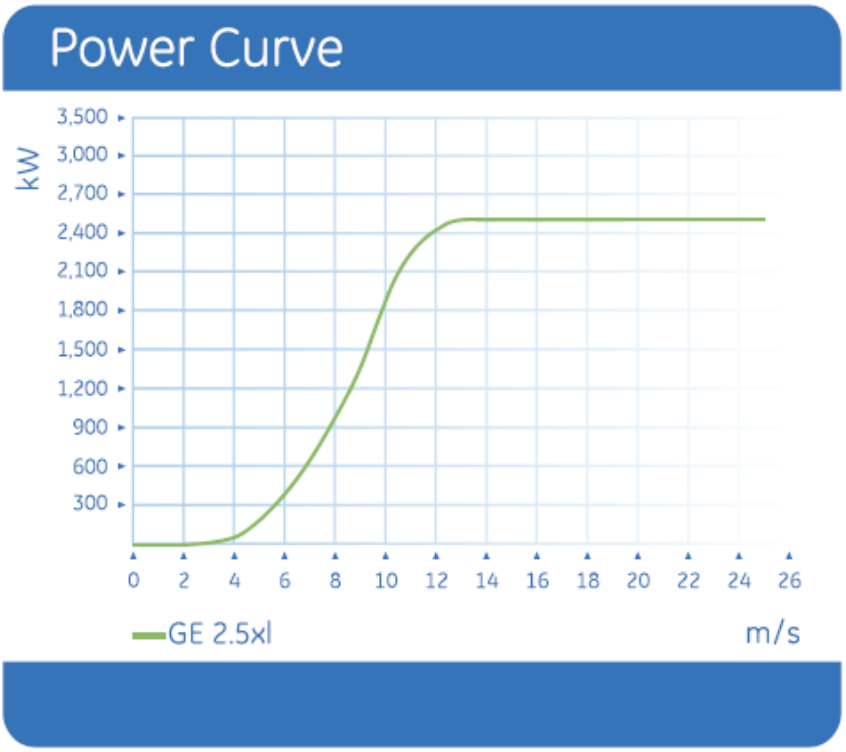


FIGURE 6: GE 2.5XL TURBINE POWER CURVE [GE ENERGY]

GE's design of the 2.5xl turbine comes with many benefits not seen in other company's models. The turbine boasts performance, maintainability and reliability based on the design of the generator system. The generator itself uses permanent magnets instead of conventional copper coils and brushes to reduce friction. This feature results in lower maintenance costs and less electrical losses. The hub also includes automated lubrication systems that ensure the turbine only needs to be maintained once a year as well as a mainframe that isolates the gearbox from unpredictable grid loads. [GE Energy] For these reasons this turbine is a prime candidate for placement on Green Hill.

The second company this project examined was Norwin Wind Turbine Technologies. This company was founded in Denmark in 1992 and boasts reliability as their main feature. When first looking into this company it was found that the largest turbine it currently supplies is a 750 kilowatt model which is much smaller than the models GE supplies. Another restriction is the tower height. Where GE manufactures its towers up to 100 meters, the Norwin model can only reach 65 meters meaning GE can reach an elevation with greater wind speeds than Norwin can reach. [Norwin | Wind Turbine Energy] In conclusion Norwin seems to be using older technology that GE has improved upon and therefore it requires no further investigation.

Another company that produces turbines like those of GE is Clipper Windpower. Clipper's design comes standard with an 80 meter tower but the company states other options are available. The turbines power curve is similar to the GE model's with a cut in wind speed of 4 meters per second, a cut out speed of 25 meters per second, and a rated speed of about 14 meters per second. [Clipper Windpower] The power curve is shown below in Figure 7.

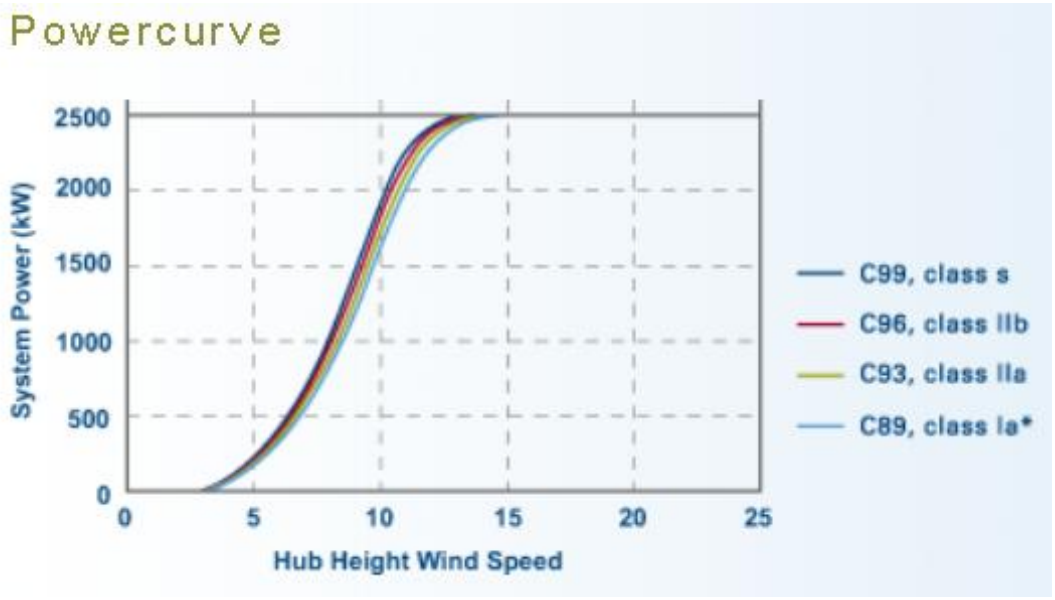


FIGURE 7: CLIPPER LIBERTY TURBINE POWER CURVE [CLIPPER WINDPOWER]

Other than the power curve GE's model seems to outperform Clipper in most aspects. Where GE's model only requires maintenance once a year, the Clipper turbine requires two visits a year for maintenance yielding a higher yearly cost. Along with this fact, GE also provides much more detailed data about their turbines on their website than Clipper does, which leads to an easier wind farm design and implementation. [Clipper Windpower]

Vestas is the main producer of wind turbines in Europe and also produces some models in America. Vestas' model that compares to GE's 2.5 megawatt turbine is the V80-2.0MW which is a 2 megawatt turbine. This model has similar cut in, cut out, and rated wind speeds of 4 meters per second, 25 meters per second, and 12 meters per second respectively. The Vestas turbine power curve can be seen below. [Vestas]

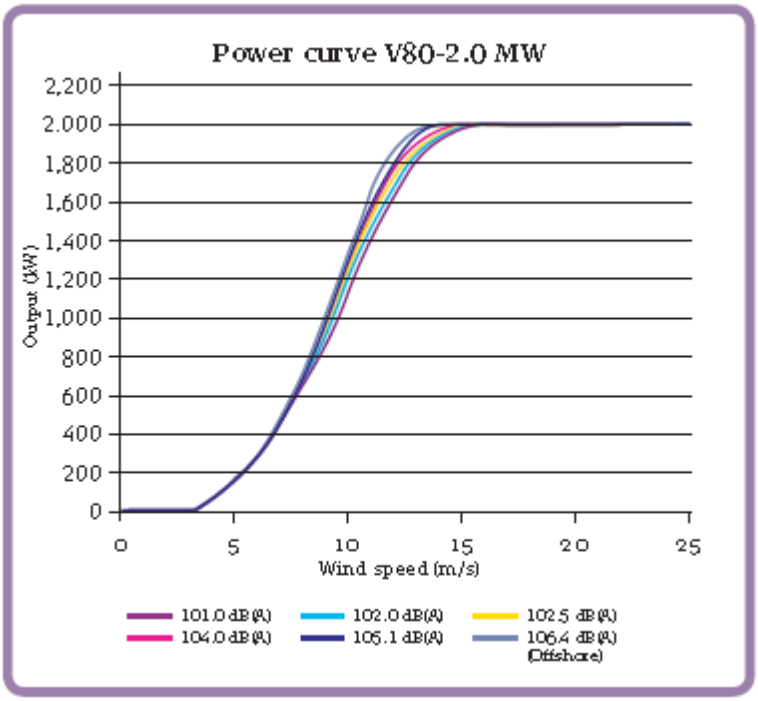


FIGURE 8: VESTAS V90-2.0MW TURBINE POWER CURVE [VESTAS]

Between the two turbines this project has selected the GE 2.5 megawatt model due to one major problem with Vestas. The Vestas Company does not provide their OptiSpeed® wind turbines to the US and Canada. OptiSpeed® for Vestas allows their turbines to run a rotor at speeds between 9 and 19 revolutions per minute in order to optimize their power output based on current wind conditions. [Vestas] In comparison GE is an American company that has expanded over the world so all of its technology is available for use in the US. GE boasts four unique systems that make it a major competitor in the wind turbine market.

The first of these features is called the WindRIDE-THRU® Turbine Operation System which provides uninterrupted operation through any grid disturbances that might occur. This system makes the GE turbine meet new transmission reliability standards that are akin to those that are imposed on thermal generators. The second system is called WindCONTROL® Power Regulation. This system allows the turbine to regulate its own power output just as conventional power plants do today. This reduces costs in running the turbine and stabilizes the frequency of the system. Third on their list is the WindFREE Reactive Power® system. This unique feature eliminates problems caused by intermittent wind by supplying reactive power when the wind isn't blowing. Using this feature the turbine can provide smooth voltage regulation and minimize the need of reinforcement energy plants. Finally the WindSCADA® system provides the tools needed to run the wind power plant efficiently. This system allows intuitive operation of the plant and easy maintenance control which reduces the number of workers needed to maintain the site. The tools included with the system are a data server, a connection directly to technicians via computer and a service support center for added assistance. [GE Energy]

Another reason to choose GE over Vestas is the fact that GE has been interfacing with America's power grid for many years and has been providing wind power solutions since 2002. [GE Energy] Overall GE simply provides more information on their product, more help in implementing a wind farm, better services in America, and a high percentage of compatibility with most wind sites in production and in existence. For these reasons this project suggests the GE 2.5xl model wind turbine be used for a wind farm placed on Green Hill.

SOCIAL RESPONSE TO WIND POWER

The acceptance of society is very important when considering any kind of large structure. If people living in surrounding neighborhoods do not like the structure, their opinions can spread and cause problems with the happiness of the community. Other factors to consider include health affects in relation to the structure, as well as the affects it will have on the natural beauty of the area.

Various studies have been conducted throughout the world related to the public perception of wind turbines. A newspaper article about Wind Turbines from New Zealand speaks about the "not in my backyard" phenomena, where people do not mind wind turbines, as long as they are not anywhere near them. [Waikato Times] Another issue is when there is no wind, people will perceive turbines as eyesores, but if they are moving, people will see them as useful and beneficial. [Social Edge] In addition, a study in 2002 found that tourists in Scotland came to the country for its beauty, and did not find the wind turbines had a negative effect on their perception of the country's natural beauty. [MORI Scotland]

The Holy Name School in Worcester, MA recently erected a wind turbine, and a survey was conducted about personal attitudes toward the turbine, with a response of nearly 600 people. The respondents were mainly students between the ages of 12 and 18, with a small amount of teachers completing the surveys as well. The complete survey can be found in Appendix A. This survey showed an overwhelming majority of support for the turbine recently erected at the school with 87% of people responding in the affirmative to whether they supported the decision for the turbine to be placed, as shown in Figure 9.

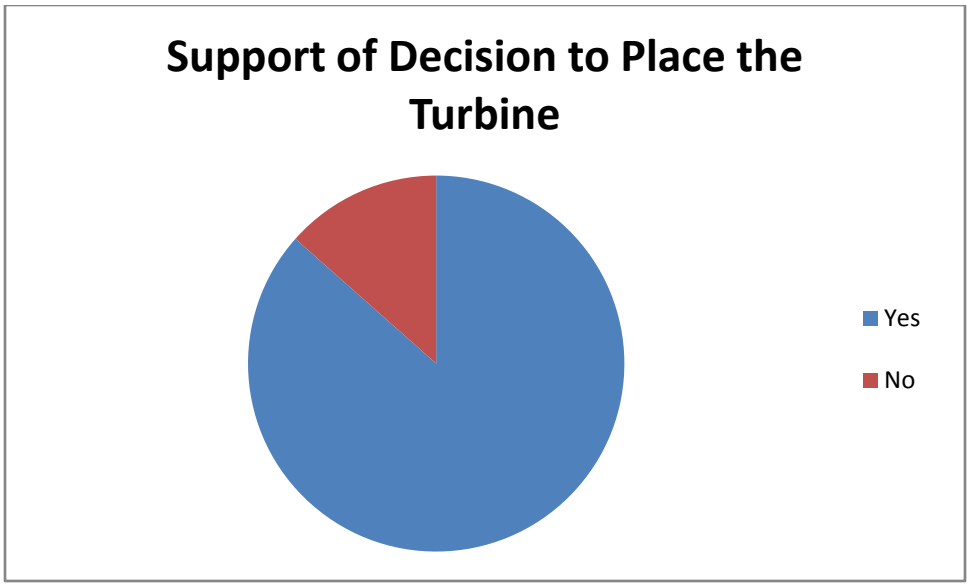


FIGURE 9: SUPPORT OF DECISION TO PLACE THE TURBINE

When asked to rate their general opinion about wind turbines on a scale of 1 to 5, with 5 being the most favorable toward them and 1 being the least favorable toward them, the vast majority of respondents rated their general feelings about wind turbines as a 3 or higher as shown below in Figure 10.

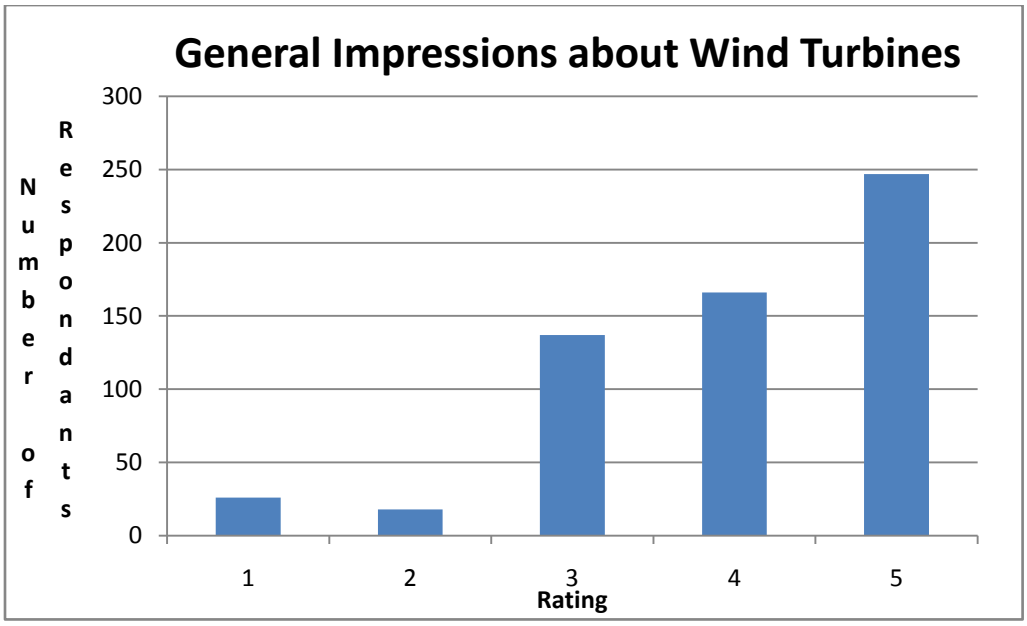


FIGURE 10: GENERAL IMPRESSIONS ABOUT WIND TURBINES

In Figure 11 and Figure 12, it is clearly seen that people are generally not favorable toward the turbine when it is not moving and are more favorable toward the turbine when it is moving, further supporting the theory previously mentioned.

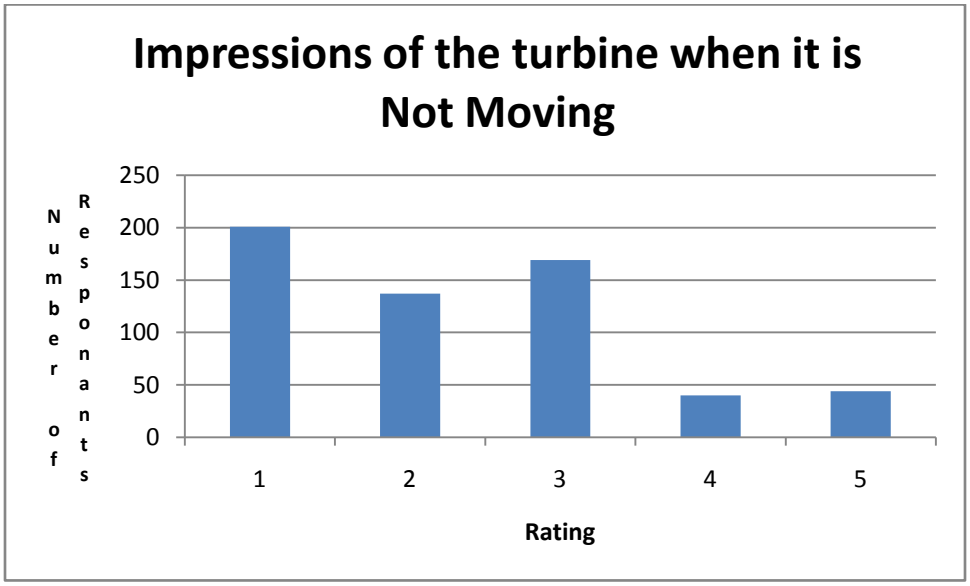


FIGURE 11: IMPRESSIONS ABOUT THE TURBINE WHEN IT IS NOT MOVING

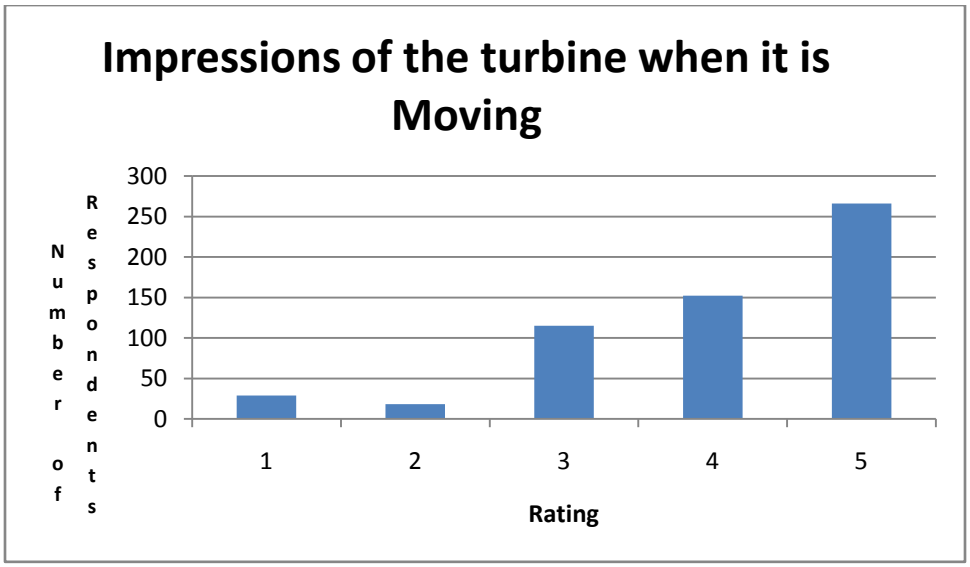


FIGURE 12: IMPRESSIONS ABOUT THE TURBINE WHEN IT IS MOVING

Wind turbines are often perceived by the public as being unsightly, and there is a fear of detracting from the natural beauty of the area. From the experience the surveyed have with the turbine at the school, the majority does not believe it detracts from the natural beauty of the campus, as shown in Figure 13.

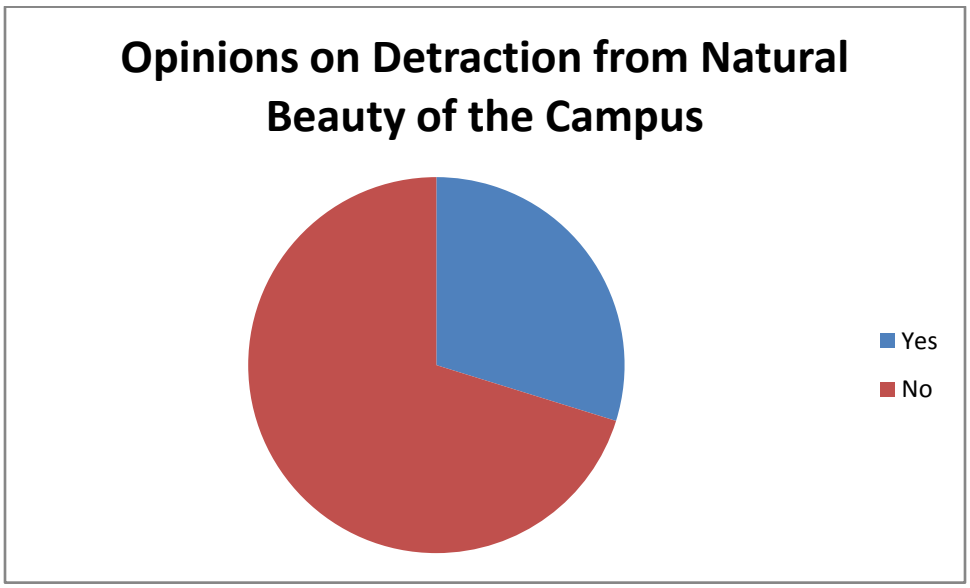


FIGURE 13: OPINIONS ON DETRACTION FROM NATURAL BEAUTY OF THE CAMPUS

There are many reasons wind turbines can be beneficial to the environment. The survey contained an open-ended question about what the surveyed believed was the greatest benefit of wind turbines, and the majority of answers included environmental factors, the electricity it produces, and monetary factors. The complete breakdown can be seen in Figure 14.

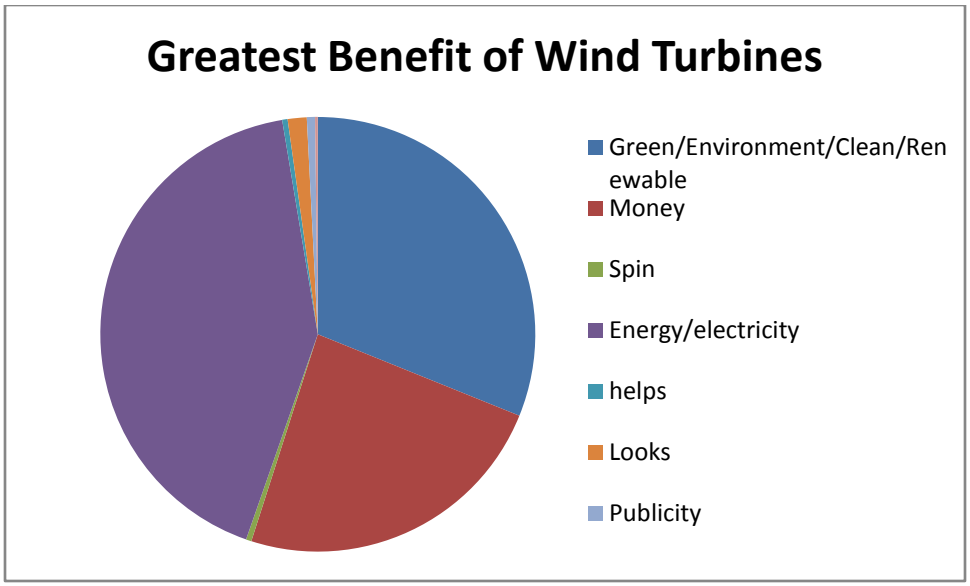


FIGURE 14: GREATEST BENEFIT OF WIND TURBINES

There is a health problem called "Wind Turbine Syndrome", primarily researched by Doctor Nina Pierpoint that has the following characteristics: sleep problems, headaches, dizziness, nausea, exhaustion, anxiety, irritability, depression, learning problems, and tinnitus. This “syndrome” has not been recognized by medical agencies, although Dr. Pierpoint has an internet web site established to raise awareness about this potential problem where others can leave testimonies about their experiences with health problems that they relate to wind turbines. [Wind Turbine Syndrome- Nina Pierpoint’s Research] In surveying the Holy Name School, some effects from the strobe movement and shadows, dizziness, and allergies due to the spread of pollen, and headaches were reported, but approximately 95% of survey respondents reported no health affects attributed to the turbine. This can be seen in Figure 15.

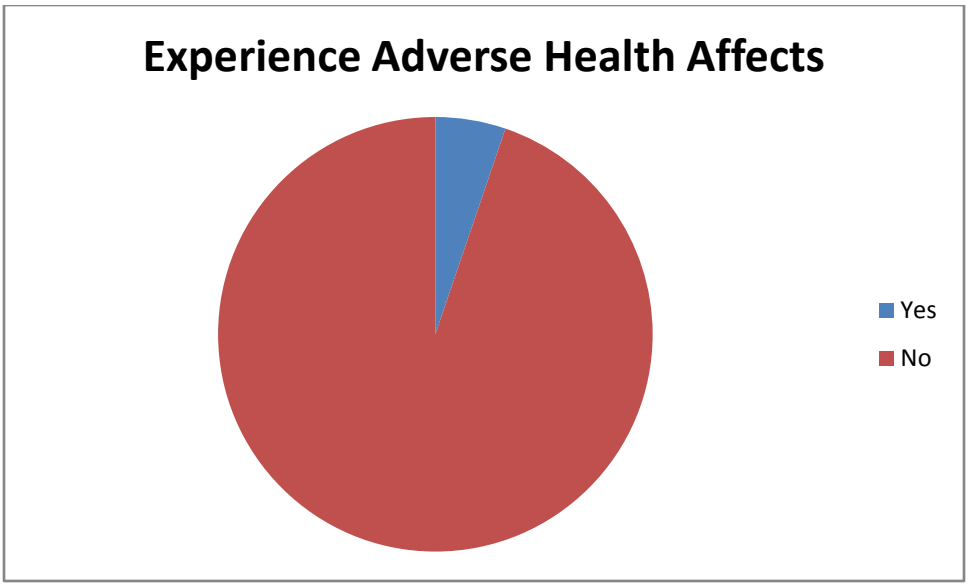


FIGURE 15: PERCENTAGE OF RESPONDENTS THAT REPORTS EXPERIENCING ADVERSE HEALTH EFFECTS RELATED TO THE WIND TURBINE

A survey was also conducted electronically through the local Worcester Craigslist, a local community web site, with a moderate response of approximately 16 people. The full survey can be found in Appendix A. When asked for general feelings about wind turbines on a scale of 1 through 5, with 5 again being the most favorable, 75% responded with a 5 and the other 25% responded 4.

Most people responded favorably when asked how they felt about wind turbines when they were not moving versus when they were moving, as show in Figure 16 and Figure 17. However, given the small sample size of this survey, it is difficult to draw conclusions from this data.

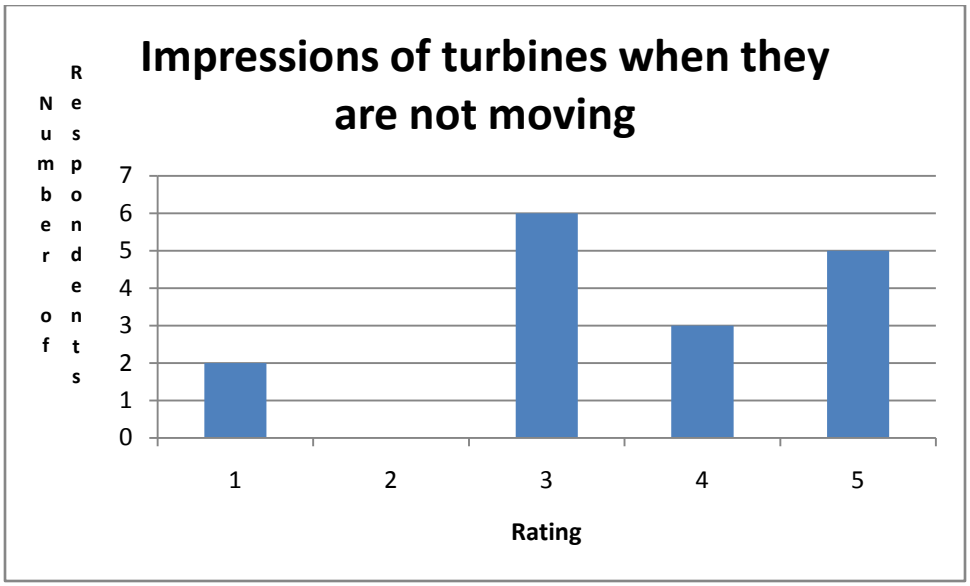


FIGURE 16: IMPRESSIONS ABOUT TURBINES WHEN THEY ARE NOT MOVING

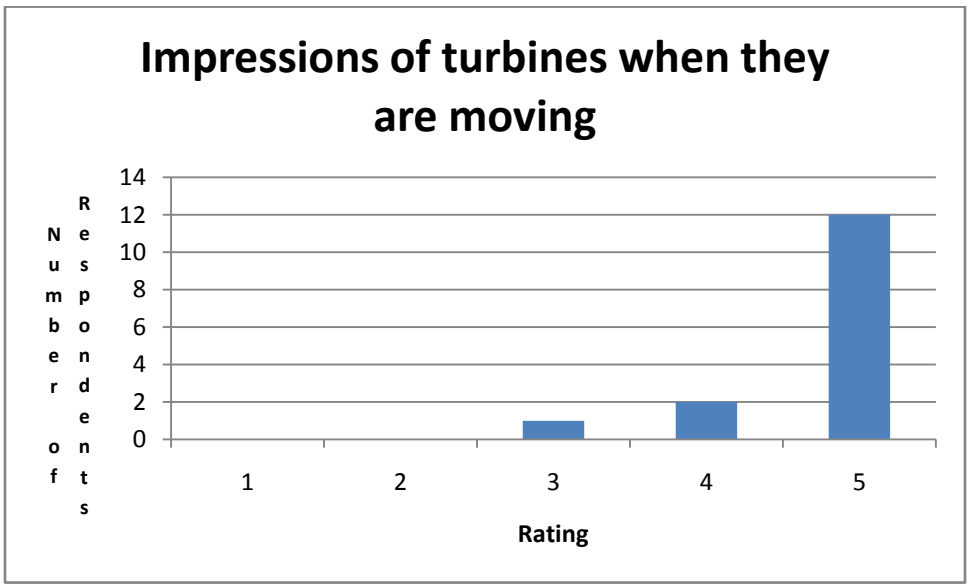


FIGURE 17: IMPRESSIONS ABOUT TURBINES WHEN THEY ARE MOVING

Green Hill could be a potential wind farm, and most people approved of this area as being such a site, shown in Figure 18.

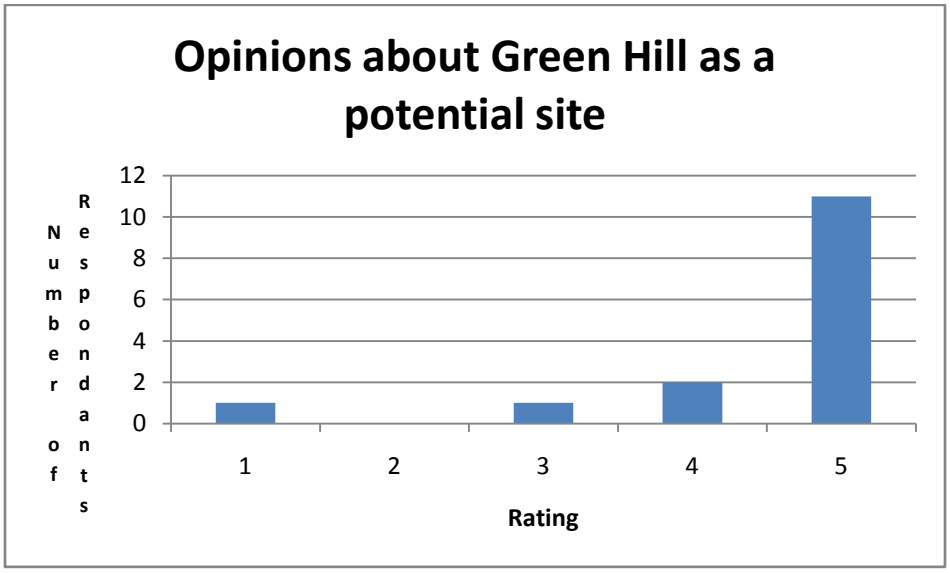


FIGURE 18: OPINIONS ABOUT GREEN HILL AS A POTENTIAL SITE

However, there is only a slight majority of people who believe that a site will not retract from the natural beauty of the area, shown in Figure 19.

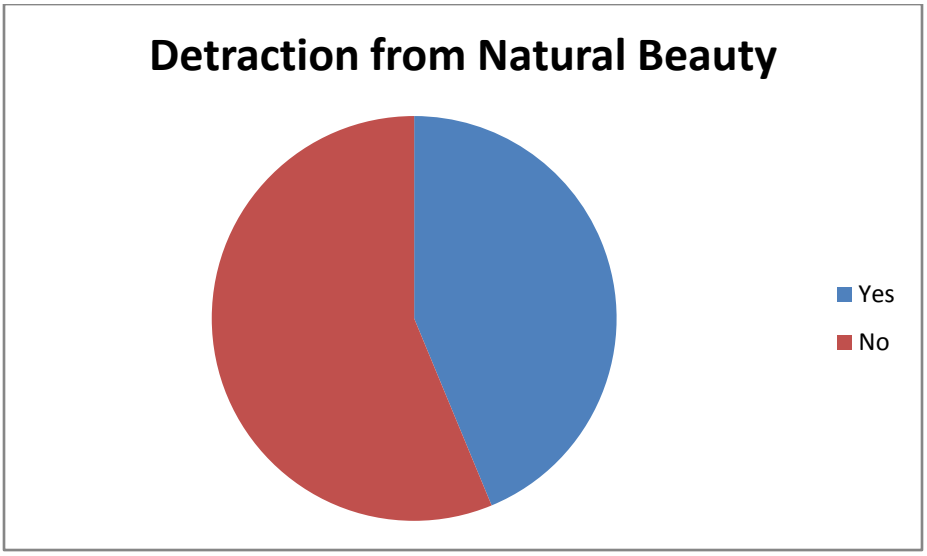


FIGURE 19: OPINIONS ON DETRACTION FROM NATURAL BEAUTY OF THE GREEN HILL AREA

Nearly 100 percent of respondents named environmental factors as the greatest benefit of wind turbines, and 100 percent of respondents in this survey believe that the benefits of turbines outweigh any negative aspects that may accompany them. When asked if there were any other comments, one person responded “I hate the appearance of wind turbines and do think that they could ruin the park, but we need to be aggressively pursuing and installing alternative energy sources even if it's at the expensive of aesthetics.” Another offered “I had one close to where I use to live and I enjoyed watching it, not an eye sore at all.” A third seems concerned for the future of the planet, declaring “If enough people support alternative energy sources we may have a planet to leave to our grandchildren.” These responses alone show a great deal of support for alternative energy, even if it involves sacrificing aesthetics, the community recognizes that these sources will soon become a necessity.

The two surveys conducted by this project show a great deal of support for alternative energy in general in the greater Worcester community. The Holy Name School’s wind turbine received overwhelmingly positive reviews in all areas, and very few reported health affects due to the turbine. Whether or not these results are an effect of influence of the media, which has portrayed alternative energies as a strong positive, is yet to be seen. This community is aware of the need for alternative energy sources, such as wind turbines, and seems ready to admit these changes into the community. A wind farm would be a socially positive contribution to the Worcester County area.

ENVIRONMENTAL EFFECTS OF WIND TURBINES

The manner in which wind turbines effect the environment is vital in the acceptance of a wind farm site. Wildlife is a major factor in building any major structure, in terms of how the structure will affect its natural habitat and whether or not the structure would endanger any species in particular. Another aspect taken into consideration is how the structure will affect the environment itself, in terms of emissions and general safety.

Wind turbines generally will affect flying animals, due to the height. Species of concern are mainly birds and bats. Studies have shown that migratory birds are generally intelligent enough to fly around wind turbines and not into them, although there have been some bird fatalities. [New Scientist] Offshore birds have had difficulty leaving their normal breeding grounds where wind turbines have been placed, resulting in the birds trying to return there and getting hit by the turbines. [Current Biology]

Focusing specifically on Worcester, MA however, research has shown that major migratory bird flyways do not pass through Central Massachusetts at all, and only crossing through the southeastern most part of the state. A map of migration pathways in Figure 20 shows evidence of these patterns. [The Nutty Birdwatcher] Minor migratory bird pathways are possible, however as mentioned above most birds are intelligent enough to fly between turbines and away from turbines, therefore birds are not the largest concern in terms of a wind farm.

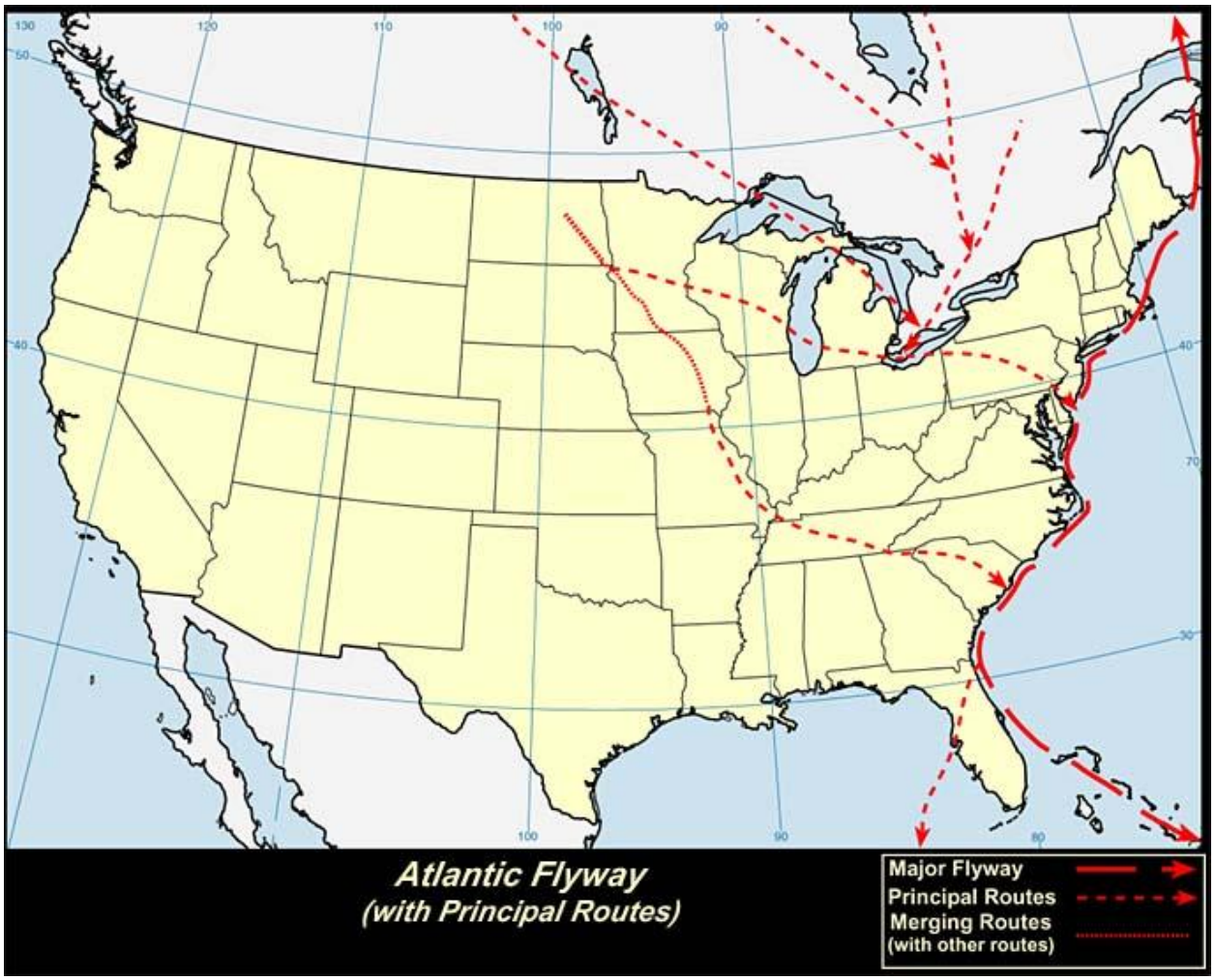


FIGURE 20: MIGRATORY BIRD PATHWAYS

A possible major concern may be bats. There is evidence that hundreds of bats have been killed by wind turbines, however this is not a result of collision. Due to pressure differences around a wind turbine, the sudden drop in pressure causes the fragile membranes of their lungs to expand and blood vessels burst, filling their lungs with blood and killing them, similar to what would happen to scuba divers if they come up to the surface too quickly. [New Scientist] There is a preliminary database still in development by the U. S. Geological Survey that tracks bat sightings called the Bat Population Database (BPD). [USGS] The most recent sightings in

Worcester in the BPD are from 1998, and they include species such as the Myotis Lucifugus (Little Brown Bat) and Eptesicus fuscus (Big Brown Bat), as well as the Pipistrellus subflavus (Eastern Pipistrelle). Specific areas of Worcester where these populations are not listed, however bats are usually hibernating in the winter when the wind speed is the greatest.

In surveying the Holy Name School about the turbine and whether or not they have seen wildlife being affected by the turbine, the most common response was that flying birds were affected. Other responses included the observation that turkeys used to be common in the area and they have not been seen recently. All together, 92.32% of those surveyed said that they did not notice any wildlife affected by the placement of the turbine. A similar response was received on the survey posted on the Worcester Craigslist, with most people responding in the negative and birds being the commonly named species affected.

Environmental effects due to emissions are negligible in wind turbines. They do not produce any pollution or consume fossil fuels; however lubricating oil or hydraulic fluid can leak and possibly contaminate water. This is an unlikely circumstance, and focusing strictly on Green Hill there are no major bodies of water in the area, so this possibility is mute. Space may be an issue, however, as wind farms generally require 0.1 square kilometers per megawatt of capacity, but clearing of woods is generally unnecessary. [American Wind Energy Association]

The manufacturing process of a turbine is something to be taken into consideration. Most of the parts are manufactured in a factory, which must use a source such as coal or oil to produce its energy. This manufacturing process does produce some pollution; however, until alternative energy sources can be manufactured by factories that generate their energy with these sources,

the environmental detriments from factory manufacturing must be overlooked. [How Products are Made]

In the site where the turbine is to be placed, the land must be graded and leveled and a concrete foundation must be laid, as well as underground cables installed. In 2002, however, the amount of electricity produced by wind turbines was 3.7 billion kilowatt-hours. This amount of electricity would require four million barrels of oil or one million tons of coal, so the environmental benefits are much greater than any detriments a turbine may cause. [How Products are Made]

Wind turbines in the Worcester County area would not have a significant detrimental effect on the environment, especially when compared to the positive effects they would provide in reducing fossil fuels. While popular belief states that they would harm birds, there are no major migration routes in the area. Bats are a major concern, and the population of bats in the area is largely unknown, however in this area the wind turbines would be the most active during the winter when bats are hibernating. Overall, wind turbines would be environmentally beneficial to the Worcester County area.

ECONOMIC ISSUES IN DEVELOPING A WIND FARM

During the past few centuries the need for renewable energy sources was throttled by the abundance of disposable resources. The recent past has revealed to us the need to expand our current energy infrastructure through cleaner and more reliable means. The global demand for renewable energy has forced the development and expansion of not only wind but all green resources at an extraordinary rate. From that demand the marginal costs, benefits, and capital involved in this section of the economy, as well as examining the influences on the market and associated groups will all be examined.[

Wind power has existed for several thousand years, any sail driven boat was wind powered. It has not always taken the form of a tall white turbine on some overlooking hilltop, nor has its primary use been the generation on electricity. The whole purpose is to convert an untapped resource for functional work and economic well being.

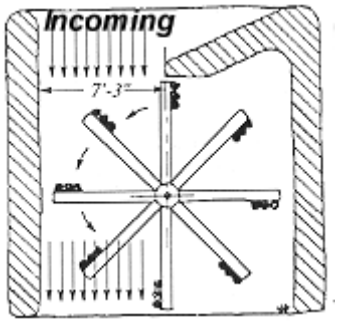


FIGURE 21: PERSIAN PANEMONE DESIGN

[4 energia, Illustrated History of Wind Power]

Starting in the early middle ages with the Persians, they sought to harness the wind in order to perform tedious work automatically. The Persians instituted a type of horizontal rotor

that would perform water pumping and other tasks without the use of manual labor. Above in Figure 21: Persian Panemone Design you can see the elementary type of design, the Panemone. However it still exists in other various improved forms today much like in Figure 22: 19th Century Panemone, a 19th century rendition of the same design.

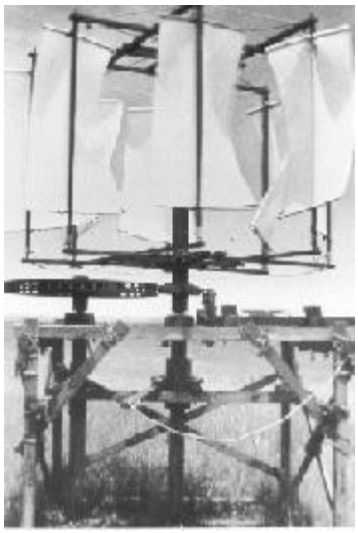


FIGURE 22: 19TH CENTURY PANEMONE

[Pakar Tuulepark, Ancient Panemone Design]

One thing to note is that even at an early age mass use of wind was not uncommon as the case of Crete, an island in the Greek isles which in around 500BC erected several dozen water pumping towers to support the island. Below in **Error! Reference source not found.** is a picture f what is left of the towers that stood in those early years.

FIGURE 23: MODERN DAY REMNANTS OF CRETE WINDMILLS

[E. Peponis. Untitled. PROJECTS:Litsa-Wind Mill-crete homes, Crete, Greece.]

In the more recent future, Charles F. Brush in his personal endeavors into wind power built "The Giant Brush Windmill" in the 1880's on the estate of his mansion in Cleveland, Ohio. This was an economic milestone because it was the first in creation to automatically operate for electricity generation. It very much earns the name "Giant" with a blade surface area of just under 2000 meters squared and 144 individual blades. Later discovered by Dane Poul la Cour, systems which used fewer blades at faster speeds were more efficient. Therefore the Brush Windmill only was capable of an output of 12KW. [VINDMÃˇLLEINDUSTRIEN]

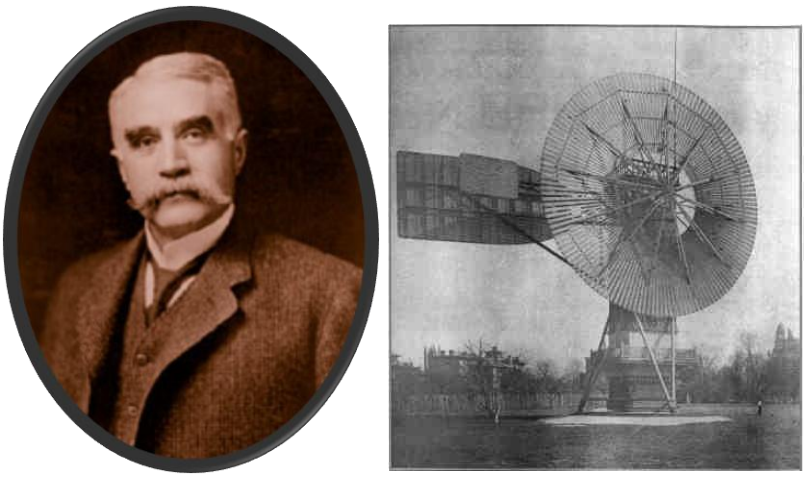


FIGURE 24: CHARLES F. BRUSH PORTRAIT & WINDMILL

[Charles F. Brush Portrait. Charles F. Brush Special Collection, Case Western Reserve University, Cleveland, Ohio.]

As with any technology, improvements in wind power came with time. As the power generated by these machines improved, the economic benefit also improved. New vertical, multi-blade systems were created and some countries jumped to the opportunity. In the 1970's through 1980's even the United States joined in. With states like California's wind rush, a period where thousands of turbines were installed in rapid succession in the 80's in response to energy crises. Even though funding was lost in that situation, the need for reliable alternative power has been demonstrated by several countries in Europe and Asia setting up large alternative measures. The reason for this sudden jump in the number of wind turbines was that the economic impact of the oil shortage in the 1970's and early 1980's severally hampered many of the markets.

[VINDMÃˇLLEINDUSTRIEN]

FIGURE 25: CALIFORNIA HILLSIDE CIRCA 1981

[Hills, Richard Leslie. Power from Wind A History of Windmill Technology. New York: Cambridge UP, 1996.]

Since the 1980's the installation rate of commercial and personal turbines has been mediocre until the past 5 years. Recently the worldwide economy has seen unprecedented highs in the energy demand. In particular the United States economy has seen these highs where petroleum based consumables skyrocketed in price. The federal government's approach to handling the resulting energy crisis could be viewed as too little, too late and the flux in the market could have been avoided given the appropriate precautions against unpredictable circumstances. The global response seems to have set off a chain reaction moving toward eco-friendly renewable energy in order to stabilize the economy and prevent this from happening again.

In the midst of this a very important development has come out of the automotive industry. Industry has brought a rash of hybrid and pure electric cars as all petroleum based energy sources have taken turns for the worse. As to be expected, the initial cost for hybrid cars is several thousand above traditional prices which can be helped by low gasoline costs and government incentives. For instance the IRS offers up to a 2,000 dollar deduction for the purchase of a hybrid car [Hargreaves, Steve]. The question is how it relates to wind power and

its feasibility in Worcester. The rise of the hybrid cars shows a national trend toward efficient money saving technologies. With wind power cost per KWh estimated between 4 to 6 cents it is a substantial upgrade from the coal based energy. Cost per kilowatt Hour can reach 9+ cents in the most populated states according to the Energy Information Administration, March 2007 as seen in Figure 26: Graph of Cost per Kilowatt Hour and Percentage Generation.

Luckily in the last 20 years the cost had dropped 80% from the 30 cents per KWh it cost to produce from wind sources. Also specifically related to Massachusetts, the percent generated by coal is much lower than some other states however the price per KWh is higher [Energy Information Administration]. In order to prevent rising prices the state must increase its self sufficiency which it has been doing through various measures.

Unfortunately in a quote from the American Wind Energy Association: "On New England ridgelines, for example, wind farms are likely to be smaller, to experience lower wind speeds, and to cost more to install than in the flat terrain of northern Plains states. While wind power may cost less than 5 cents/kWh in the northern Plains, it may cost 6-7 cents/kWh in New England". Obviously it depends on the demand of power per state as well as the capabilities of that state in terms of how it produces its energy.[Wind Energy Costs]

TABLE 1: PRICES FOR VARIOUS POWER GENERATION SOLUTIONS

Method	Cents/kWh
Traditional Power Generation	
Gas: Currently supplies around 15% of the global electricity demand	3.9 - 4.4 Cents/kW-h
Coal: Currently supplies around 38% of the global electricity demand.	4.8 - 5.5 Cents/kW-h
Nuclear: Currently supplies around 24% of the global electricity demand.	11.1 - 14.5 Cents/kW-h
Conventional, Renewable Power Generation	
Wind: Currently supplies approximately 1.4% of the global electricity demand. Wind is considered to be about 30% reliable.	4.0 - 6.0 Cents/kW-h
Geothermal: Currently supplies approximately 0.23% of the global electricity demand. Geothermal is considered 90-95% reliable.	4.5 - 30 Cents/kW-h
Hydro: Currently supplies around 19.9% of the global electricity demand. Hydro is considered to be 60% reliable.	5.1 - 11.3 Cents/kW-h
Solar: Currently supplies approximately 0.8% of the global electricity demand.	15 - 30 Cents/kW-h
Non-Conventional, Available, Renewable Power Generation Technologies	
Tide	2 - 5 Cents/kW-h
Non-Conventional, Emerging, Renewable Power Generation Technologies	
Atmospheric Cold Megawatts	.03 - 1.0 Cents/kW-h
Thermal Electric	3 - 15 Cents/kW-h
OTEC (Ocean Energy Thermal Conversion)	6 - 25 Cents/kW-h

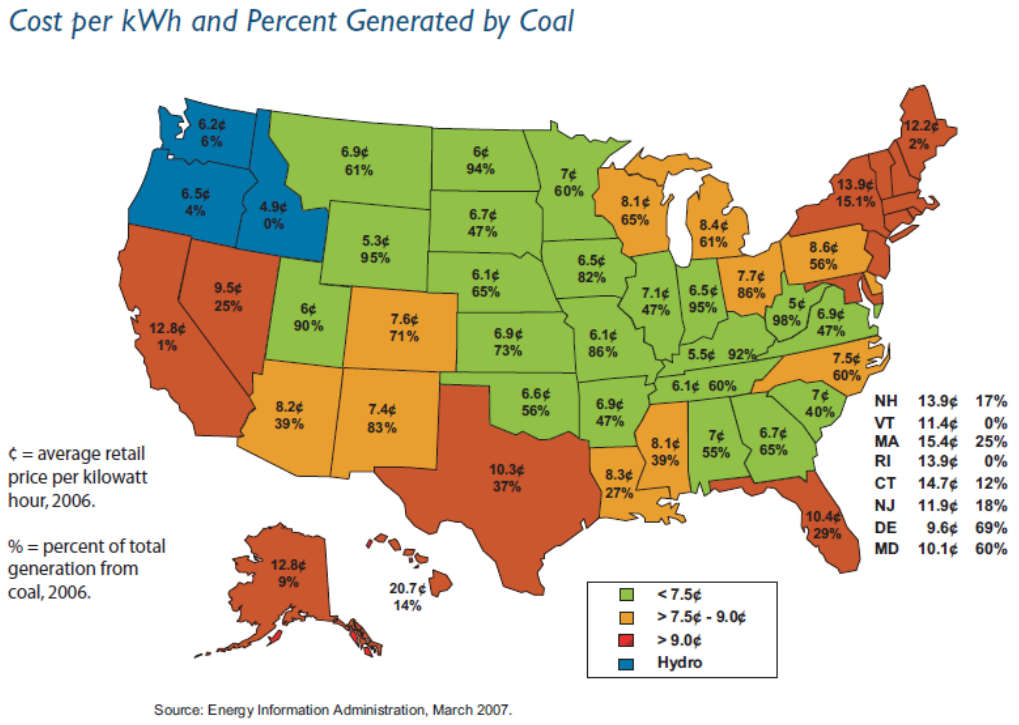


FIGURE 26: GRAPH OF COST PER KILOWATT HOUR AND PERCENTAGE GENERATION

[Energy Information Administration, March 2007]

On a global scale the earth has more than enough available wind to power the entire planet. This statistic according to Journal of Geophysical Research - Atmospheres in 2005 published by Cristina L. Archer and Mark Z. Jacobson of Stanford University. This suggests that initial investment has much higher payoff in the future for emerging leaders in renewable energy. While the country is still a long way from "a turbine for every home" we have made slow progress along with most of the first world countries toward a more sustained lifestyle. Below in Figure 27: Annual Wind Power Generation and Top Electricity Consumption one can see the upward trend most developed countries are taking.[Archer, Cristina L., and Mark Z. Jacobson]

Annual Wind Power Generation (TWh) for Top 10 countries and their total electricity consumption(TWh)[74][75][76][77]													
Rank	Nation	2005			2006			2007			2008		
		Wind Power	%	Total Power	Wind Power	%	Total Power	Wind Power	%	Total Power	Wind Power	%	Total Power
1	Germany	27.2	5.1%	533.7	30.7	5.4%	569.9	38.5	6.6%	584.9			
2	United States	17.8	0.4%	4048.9	26.6	0.7%	4058.1	34.5	0.8%	4149.9	52.0	1.3%	4108.6
3	Spain	20.7	7.9%	260.7	22.9	8.5%	268.8	27.2	9.8%	276.8	31.4	11.1%	282.1
4	India			679.2			726.7	14.7	1.9%	774.7			
5	China			2474.7	2.7	0.1%	2834.4	5.6[78]	0.2%	3255.9	12.8[79]	0.4%	3426.8
6	Italy	2.3	0.7%	330.4	3.0	0.9%	337.5	4.0[80]	1.2%	339.9			
7	Denmark	6.6	18.5%	35.7	6.1	16.8%	36.4	7.2	19.7%	36.4	6.9	19.1%	36.2
8	France	1.0	0.2%	482.4	2.2	0.5%	478.4	4.0	0.8%	480.3	5.6	1.1%	494.5
9	United Kingdom	1.0	0.2%	407.4			383.9			379.8			
10	Portugal	1.7	3.6%	47.9	2.9	5.9%	49.2	4.0	8.0%	50.1	5.7	11.3%	50.6
	World total (TWh)			**15,746.54**[81]			**16,790**[82]						

FIGURE 27: ANNUAL WIND POWER GENERATION AND TOP ELECTRICITY CONSUMPTION

The Strategic Petroleum Reserve is used to help regulate and ensure the supply of crude oil but not refined petroleum products. The reserve has been used in several economically beneficial ways. Since its establishment in 1975 it has served as a deficit reducer in the mid 90's and to substitute for the missing oil production in the Gulf of Mexico during hurricane Katrina. However in the last 6 years much congressional debate has been about expansion and stabilization in case of another shortage. Since then the market has gone though another period of inflation.

$1.70 per gallon of gasoline was the nationwide average in March 2004. Mid 2008 prices nationwide had risen to 4.12 a gallon. Over a 5 year period that's a 250% Inflation. To make matters worse in the same time period the price for crude oil had risen 487% nationally. While this crisis was building the government sought to ease the tension because of the strained economy due to many factors.[Gas Buddy 2009]

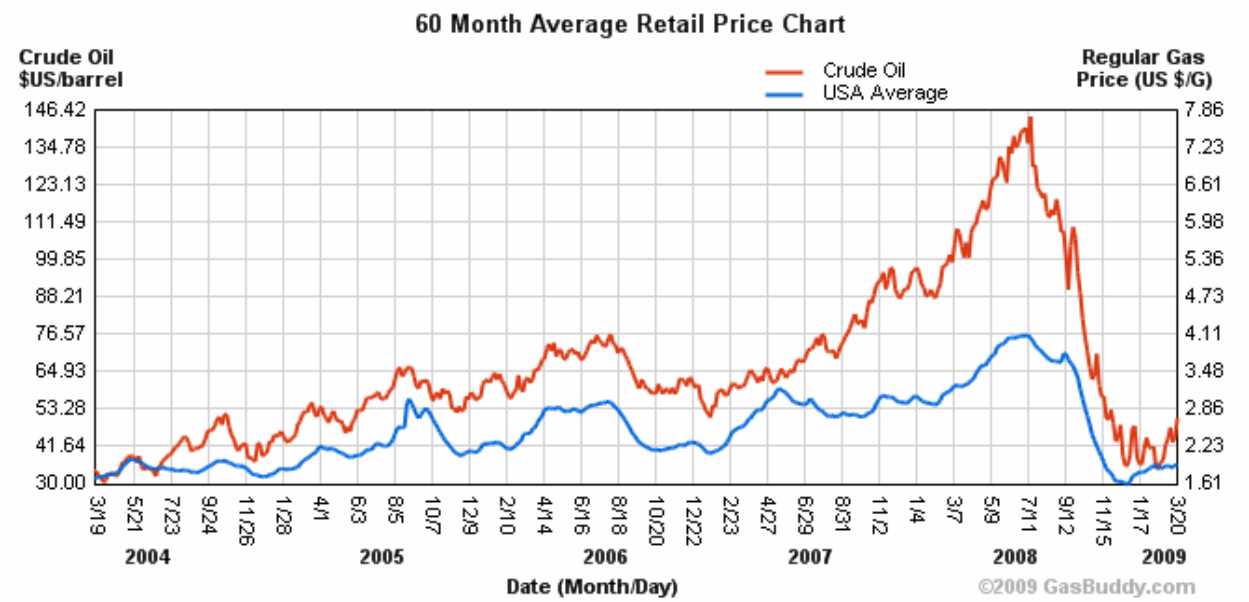


FIGURE 28: CRUDE OIL AND GASOLINE PRICES FOR US OVER 60 MONTHS

However the problem was rooted much deeper than anticipated. In the credit market the bottom had fallen out and lead to stock market freefall. Though this is not directly related to wind power as of 5 years ago it is important that to identify the fallout since the initial strain was apparent in the energy market. In 2008 and 2009 the government released 2 successive stimulus packages. Meant to unfreeze the credit market and ease consumer tension the government allocated money to be put into projects for the long lasting improving of the national economic base. Some of these funds were specifically dedicated to works to improve the country's energy independence and provide safety to avoid situations like this. [Rollcall]

Particularly in the Stimulus 2009 package pushed forward by President Barack Obama several billion dollars alone is being dedicated to green energy implementation. In the 100+ billion dollars dedicated to green energy as a sector 28 billion of that is going to fund renewable energy subsidies. More specifically 13 Billion in funds is directly going to tax breaks for large scale wind power with other funds going to manufacturing costs, small scale credits, Renewable

energy loans, and general purpose large scale projects. In a conversation with Mass Megawatts president Jon Ricker, the government is subsiding 30% of manufacturing costs this year. One such application could be a commercial wind farm in Massachusetts. In addition to the stimulus package several other incentives have worked their way into recent law making it easier to break into green energy.

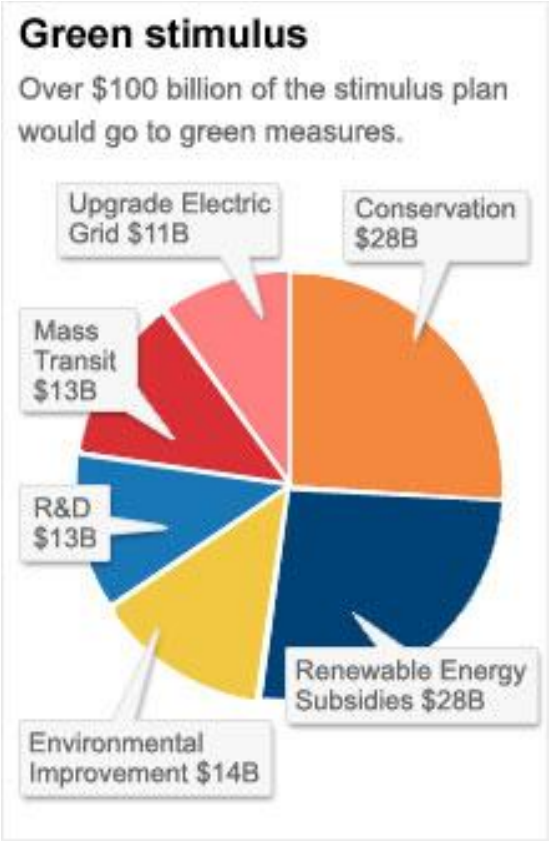


FIGURE 29: STIMULUS 2009 GREEN ENERGY BREAKDOWN

[Hargreaves, Steve]

As can be seen a substantial portion of the stimulus is going toward wind power. This means that the American public be slowly more self sufficient, however for those in the industry there are many potential profits than that of 15+ years ago.

In this new support of wind power several things a potential investor should understand. First is the initial investment is considerable and while the time to break even isn't as bad as coal, or as heavily regulated as nuclear power generation.

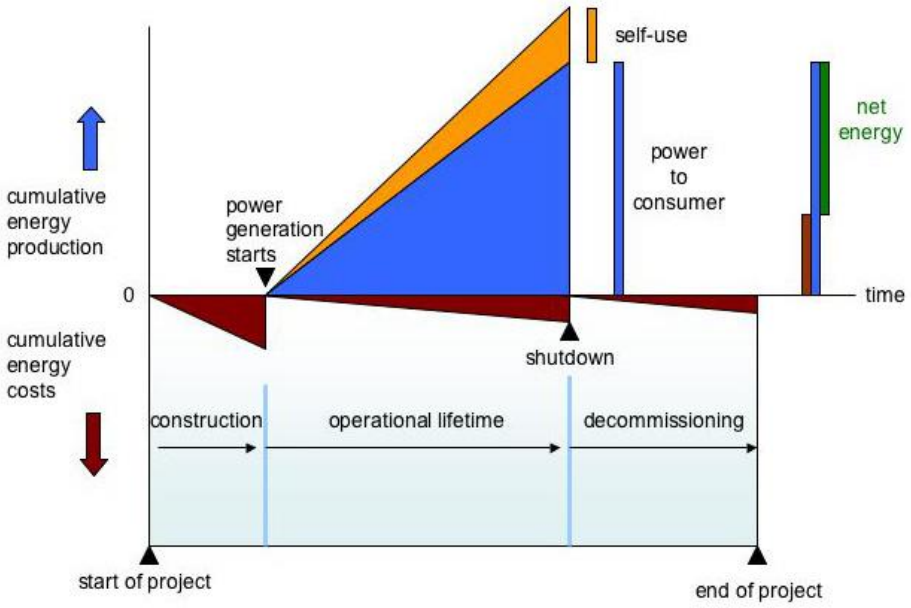


FIGURE 30: GENERALIZED OPERATIONS TIMELINE FOR WIND TURBINES IN A SELF-USE SITUATION

[Green-e]

In general the return on investment for a turbine installation is greater than 5 years. This is highly dependent on the type and conditions of the wind farm. For a smaller site much like the theoretical one in Worcester, Return on Investment is typically around 15 years. To put it in perspective, turbine prices vary widely within the same generation capability bracket. This is due to the wide selection of specialization for weather, elevation, wind conditions, and other limiting factors. In general the accepted standard for cost of is 1000 Dollars per KW installation cost with the costs scaling because installation costs are roughly the same for different output turbines. In addition to tower placement additional costs will be incurred as road construction, monitoring capabilities, power conditioning, maintenance, and grid connection.

To date the approval process for installing either a commercial or personal turbine can be quite lengthy. Cape Wind, a proposal for a 130 turbine offshore farm in the Nantucket Sound is still in the approval process after starting over 5 years ago. Considering Cape Wind faces much of its controversy because of its location in near Nantucket, a wealthy summer community, a typical installation most likely will not take as long as residents and opposition groups are stating displeasing aesthetics as a reason to prevent construction. Other restrictions are undefined area for the most part while compliance with federal Aviation Administration and other organizations. The economic justification behind wind power exists however much of the legal restrictions have yet to be set in stone. For example zoning laws exist to govern business, infrastructure, and community placement however almost no limits have been established in terms of wind turbines [Hickey, Jim]. Zoning for Turbines relies mostly on community support/opposition; in places like Martha's Vineyard and other known scenic areas towns have already set their own limits on height and placement. One solution some towns have taken is installing collective community turbines to prevent horizon clutter from many smaller turbines.

FIGURE 31: TURBINES ON THE HORIZON

There are various problems that can occur involving the economics of turbines. However there are solutions to circumvent lack of funds. And with the new administration and growing industry we can expect rapid installation and generation. A few things can be certain this will not fade away quickly, can you be sure that an expansion of the wind power will lead it to be an integral part of the grid and the economy.

POLITICAL SUPPORT FOR WIND POWER

Part of the infrastructure of any country includes energy; this resource has politically charged characteristics associated with it. These issues range from global and federal approach to handling the problems to the policy forming individuals on the local scale. Another aspect we examine is a local company and their feelings in today's political environment toward wind power.

Starting at a global level, we take a look at about the how the world leaders and governments view wind sources of energy. The world has recently seen a change in the way it thinks, that has lead to this "Green Energy" Revolution. The approach the globe has taken can be viewed in 3 distinct ways: aggressive, experimental, and planned/prepared.

FIGURE 32: MIDDELGRUNDEN OFFSHORE WIND PARK (MIDDELGRUNDEN, DENMARK)

Two countries to take as prime examples are obviously Denmark not only boasting the highest percentage wind power generated, but also a leader in technology in the field holding approximately 50% production of turbines worldwide [World Wind Energy Report 2008]. However in addition a noteworthy view can be placed upon a close neighbor to the United

States, Canada. Their recent dedication to the expansion of wind power away from the European mentality makes them a leader on this continent. Denmark, a country of just over 5.5 million people (est. January 2009) has the highest percentage of power consumed generated by wind power as compared to country use at 19.1%. [Canadian Wind Energy Association]

Second to that is Spain with 11.1% as of 2008. These countries are examples as compared to the United States wind power generation percentage of 1.3%. There are several biasing factors such as the countries size and history with natural resources that lead to these numbers however as of todays environmental, economic, social, and political views on energy the United States needs to increase its output. Primarily countries are dependent on the resources they gather from within their own borders. This theory is proven through history through wars & territorial conflicts over rich lands. Originally the United States was colonized for riches and resources in the name of England and other European countries.

FIGURE 33: GAS STATION, JUNE 15, 1979

Denmark along with the rest of the world had a major change in attitude regarding energy the energy crisis of the 1970's. The political unrest of the Iranian Revolution and the Middle East that lead to petro-chemical inflation combined with the world's leaders fear of another Chernobyl incident in the late 80' in the height of the cold war had much to do with Denmark's stand on energy. Nuclear technology has since improved however Denmark took a vow to never build a nuclear power infrastructure. Even though this may fit Denmark's agenda many nations have since embraced nuclear energy with the right precautions in place. Other than the geographical advantages the country has in terms in readily available placement sites off the coast for turbine farms; they carry a tie to their European neighbor's which makes collaborative efforts easier. For instance while large offshore farms often need suitable connections to the power grid; weaker parts of the Danish grid can be supplemented by selling excess to the European neighbors. These country to country links are one approach to which politics plays an important aspect into the development of wind power as a whole. [Giebel, Gregor, and Gregor Czisch]

A little closer to Worcester, MA is the nation of Canada. Even though this nation is 11th on the installed capacity their political agenda is much like that of the United States. In the last decade this capacity has grown 10.6 fold from 137 Megawatts to over 1400 Megawatts [Electric Power Purchases]. In order to do this provinces are being forced to adopt renewable energy resources though a feed in tariff. This not only expands the renewable infrastructure but also spurs industry growth since as part of the tariff the resources are bought above market prices. If individual states forced their respective utility suppliers by theses feed in tariffs to meet a certain percentage of their energy from wind than a growth in the wind power suppliers and a more sustainable lifestyle would be achieved. Pressure needs to be applied from the legislatures for

rapid progress to be made. Other achievements that have Canada as a prime example are their lofty goals. Gilbert Parent, former Speaker of the House of Commons and four year Ambassador for the Environment is now retired from politics in Canada however is pursuing a 30 Giga-watt wind farm capable of powering 40% of the 32 Million residents. According to the Institute for Energy Research, "Nearly 100 percent of Canada's energy exports go to the United States", one could see a potential benefit of Canada's growth in renewable energy is that we would be supporting the expansion of green energy without taking the initial investment. [Masum, Hassan].

FIGURE 34: GILBERT PARENT, CANADIAN HOUSE OF COMMONS

Canada is not the only one considering massive scale projects. The governments of China, Mexico, and India, which are all heavy manufacturing locations, boast plans of tens of thousands of Megawatts in the next 5 years. In addition with the anticipated growth in china growing faster than estimates they expect a capacity of 20GW in 2010. Basically all of the countries capable of expansion into this resource are doing so at full rate.

As with the California boom political support can quickly dry up if additional costs or lacking performance make the continuing of a project riskier. Currently in these times of economic instability a more lasting adoption renewable resources than that of the past by governing bodies, plans need to be looked at for the time ahead. "Rome wasn't built in a day" as the expression goes. Even though the ball in motion on many programs and installations a continued support must be sustained. Legislation & Capital are the keys to support that transcend time. If the individual states in USA are held accountable thorough from this point forward to maintain their own wellbeing with consequences the world wouldn't have to worry. Another point is to allow for continuing financial motivations in the way incentives, credits, loans and other various delivery methods. The economic stimulus's allow for a large amount to be injected in a short time however once that money is bled away their needs to be an ongoing source whether is be public or private. The ability to harness more of the winds potential is as much a trend as bellbottoms or Pokémon until it reaches that tipping point. [Johnstone, Heather]

In the last 3 years, billions of dollars has been in brought into this already small but developed industry. However the government officials still need to exert political control to prevent misuse. Some precautions must be put in place to ensure the money is not wasted on frivolous projects. The take on all the renewable power has been stimulated artificially at the moment. With Massachusetts receiving 1-2 Billion dollars for the upgrading of its infrastructure we leave it in the hands of our politicians. Some of this money will be spend upgrading the weakening power grid however some will be free choice.

FIGURE 35: GOVERNOR DEVAL L. PATRICK PORTRAIT

[WWW.Mass.Gov]

Governor Deval Patrick is hoping these funds can jumpstart a green increase in the way Massachusetts generated energy. Currently the state produces about 7 Megawatts from wind at 9 major locations however in a high but obtainable goal Governor Patrick has expressed the desire to see the state producing 2000 Megawatts by 2020. The math works out to 285 time increase, while this seems impossible however, "Cape Wind" a proposal to install 130 turbines in the Nantucket sound would provide 420 of those 2000. While Cape Wind has had more than its share of problems before construction can begin it lays the foundation for any similar installation [Cape Wind]. Other people requesting backing include 10 million for The Cape Light Compact to install 3 MW of solar panels providing 20% power to the cape. However they hope to expand to 14MW of capacity in their full scale proposal. This potential growth will need to be closely monitored to prevent abuse.

One thing with any rapidly growing industry is regulation. While this report examines the regulations surrounding the placement as well as the environmental and social aspects the

industry as a whole will need oversight. The rapid growth of these alternative energy solutions leaves one to think is it riding on a bubble. In this section you can see economics and politics are closely related. However it is a one hand controls the other situation. Political decisions are ultimately responsible for the way money is spent, which projects get approved, and controls the lands. With legislature, open support of specific projects, and acceptance by the citizens of an area of interest the right combination can seem impossible to navigate at times but many will face it in order to get the idea off the ground.

In zooming down from the global stage down to Massachusetts this report will examine the specifics of the voting record in order to better exemplify the path the state is on. Also we will take a look at the specifics stances of 3 influential politicians for the creation of this theoretical wind farm in Worcester County. First off we have Senator John Kerry, as former lt. governor of the Massachusetts.

Senator Kerry has been viewed as a moderate liberal with conflicting voting patterns on some issues. However on votes concerning the welfare of the economy in the last 10 years he has yet to break his stance. Not only did he vote on both economic stimulus's but sponsored the most recent one. Of the 18 sponsors for that bill 2 were from Massachusetts, Senator Kerry and Senator Edward Kennedy. Mr. Kerry's record indicates his open support of cape wind exposing a backdoor clause of Don Young's [R-Alaska] bill that would ban turbines within 1.5 of shipping and ferry lanes. This would derail the majority of offshore placement sites for turbine farms. Like many democratic counterparts Senator Kerry has taken a pro-environment pattern. [The Cape Wind Conundrum]

Next we will examine Representative Jim McGovern from the House of Representatives. Rep. McGovern has an office just outside of downtown in Worcester, MA so his opinion affects where he works just as much as it does everyone in Worcester. In 2008 Rep. McGovern voted Renewable Energy and Energy Conservation Tax Act of 2008 into law which extended multiple renewable energy incentives. Two of which are the tax Credit for the production of electricity by renewable sources until 2011, and the denying of tax deductions from domestic production of oil, gas or other petroleum based products. He takes a strong stand against organized oil opting to expansion of bio-fuels and removing oil subsidies. This matters because oil and coal are the main energy producers at this time. With Mr. McGovern's vote against every bush energy policy as well as regulation of offshore drilling and the Alaskan Natural Wildlife Reserve, he shows obvious support for a cleaner alternative rating 100% on the Campaign for America's Future (CAF). CAF is a group that wants to bring American energy independence to fruition. [On the Issues]

Mayor Constantina Lukes has been mayor since 2007. In that time she has done several things to improve Worcester's green energy reputation. The Clean and Green Awards are given to these individuals and businesses that are making the transition to greener energy and practices. These are determined on the guidelines of the Climate Action Plan as part 3 of the Cities for Climate Protection. This program was put in place before Mrs. Lukes yet she continues to enforce it to create a cleaner city. In a conversation with the mayor's office, there are several groups the mayor participates in dedicated to environmental and energy issues. The energy alliance and Brownfield group as used in conjunction with the mayor's newly created energy advisor Jon O'Dell. [Interview with the Mayor's Office]

RESEARCH DONE BY OTHER WORCESTER POLYTECHNIC INSTITUTE GROUPS

This study is not the first of its kind at Worcester Polytechnic Institute. Even Though none of the previous Interactive Qualifying Projects choose the theme of "Worcester County as the site for a wind farm", each other previous IQP has contributed a significant amount to the research. There will be two specific projects that provided the most benefit in terms of providing the base for some of our research as well as some topics to be expanded upon within the context of a wind farm in Worcester County. "Holy Name High School Wind Feasibility Study" by Brian M Foley, Tyler D Forbes, Hans E Jensen, Adam S Young as well as "Wind Generation on Nantucket" by Diana M Berlo, Jennifer L Hunt, Amanda L Martori, and Justin Skelly provided the most benefit. However other IQP's such as "The Plug-in Hybrid Electric Vehicle: Proliferation and Impact on Society and the Environment" by Hunain M Amin Kapadia, Ishrak Khair, Tanvir Singh Madan, Andrew Robert Teixeira allowed for some insight into issues discussed in this project such as the effect of petro-chemical inflation on green energy acceptance.

Holy Name High School Wind Feasibility Study has drawn particular press because of the eventual installation of a turbine based on the research of this report. This study examines some of the same topics however their research was directly related to the site which they were working. For instance this study breaks down and examines the internals of a wind turbine and its operation. While this is useful information it is really irrelevant to a farm since their low maintenance is usually suited for someone with specialized training. However they do slight

research into a variety of topics including operating characteristics, electrical grid connection, maintenance, as well as social and environmental impacts.

FIGURE 36: TURBINE AT HOLY NAME HIGH SCHOOL

Given the similar nature of the project as a feasibility study they used many of the same expected discussion points in the fields of economics including tax credits, expected return on investment versus a typical site and a general economic model. This particular IQP had the resources to collect real data on their particular site however since "Winds Over Worcester" is based on a theoretical wind farm, the location is not set in stone and therefore could not collect sufficient real data. As seen this IQP provides many introductory topics for later.

The Interactive Qualifying Project "Wind Generation in Nantucket" was prepared for the Nantucket Energy Study Committee for feasibility of installing land based turbines. This is

different than the approach Cape Wind is since their planned installation is off the coast in the shallow waters of the Nantucket sound. It is a feasibility study however it provides more of a structured timeline and specific regulations relating directly to the construction in Nantucket. The Nantucket report is quite comprehensive considering it official submission to the NESC.

In a common theme among the IQPs the reports look at the financial, political, social red tape that must be crossed in order for any wind power generation site to be considered truly feasible. A conclusion that can be made about any turbine site installation is that wherever the site location is determined to be, a comprehensive study of the factors surrounding that particular situation must be obtained. It can be imagined that in further studies on and off the campus of Worcester polytechnic institute will bring together the growing collection of data set by projects of the past.

THE TIPPING POINT OF WIND POWER

A major component of this project was to evaluate whether or not wind power generation has reached its "tipping point" in the United States as defined by Malcolm Gladwell. Gladwell places importance on three separate aspects that judge if a tipping point has been reached. These are the presence of a few motivated and well connected people, an atmosphere that calls for action, and a message that is known by the vast majority of the country. [Gladwell]

Two people making a significant difference in the fight to improve America's renewable energy generation are T. Boone Pickens and President Barack Obama. These two men are acting not only as the connectors to spread interest in wind power, but also as information specialists and as the driving force behind the movement. According to Gladwell these three types of people are all necessary for a tipping point to be reached. The connectors spread awareness that wind power is indeed a feasible idea in America. Information specialists enhance this step by informing both people and more importantly the connectors about the facts behind wind power generation. The final step is having someone to act with this information. President Obama is forcing renewable energy forward and looking to increase the production of clean energy. He has already begun by putting forward stimulus packages that provide funding for wind energy and tax incentives for those who invest in turbines. [Szakonyi] T. Boone Pickens is also pushing for wind power by attending conferences and raising awareness using all forms of media available to him. One major resource of information is his web site, pickensplan.com, where he lays out his plan to generate up to 22 percent of Americas energy using wind. He also posts news reports on events relevant to the renewable energy initiative. [PickensPlan] The only problem with this type of media is the sheer size of the internet today. If you type in wind power or renewable energy

into the Google search engine on the internet there are so many results and only a few are actually valid websites with current information about the move to renewable energy in the United States. Regardless, with the push for wind power by these two men this project finds that in regards to Gladwell's idea of needing connectors, the tipping point of wind power is almost here.

As oil prices in the United States began to fall after a summer of record high prices, so did the concern to move over to renewable energy. The second aspect needed for wind power to reach its tipping point is the so called, "atmosphere of change". People need to be motivated by necessity rather than by good intension so that any action can be taken. When the oil prices in America skyrocketed, everyone in the U.S. was calling for a better source of energy that would break the U.S. dependence on foreign oils. However, now that the oil prices have come down to the point where most Americans do not mind filling up at the pump, most of the drive that was in the general populous just disappeared. President Barack Obama has also noticed this trend. He has stated that now is the time for breaking our dependence on foreign oil. Obama stated that America has gone through this very cycle many times where oil prices go up and panic makes people act. Then when the prices drop, everyone is lulled into thinking the crisis is over and goes back to their old habits of wasting energy and ignoring the need for change. [Szakonyi] With President Obama forcing renewable energy forward, the tipping point is likely to happen within the next few years.

The final step in preparing America for the tipping point of wind power generation is the idea of stickiness. The notion that wind power is a real, reliable, safe, and clean power source needs to stick in the mind of the general populous. Today the only way this seems to happen is by using popular internet sites or by broadcasting interesting commercials on cable television.

America has begun seeing commercials on the television in support of wind power which is a very good sign. One in particular from General Electric portrays a young boy who brings his grandfather some wind in a jar to help blow out his birthday candles and ends up sending a huge gust of wind through the room. More companies are beginning to see this trend rising and will eventually jump to action to keep up with new profitable venues. A slight problem with this is that the economy has yet to recover. Although the economy crisis has not caused many working in the field of renewable energy to lose their jobs, without an economy to support wind power, the tipping point is unlikely to occur. [Isaacs and Salerno]

Considering all of these facts about the current state of wind power this project has decided that wind power generation is coming very close to its tipping point. It seems that all that is holding it back is the poor state of the economy and the mindset of some car and oil companies whose income depend on America's dependence on oil. Over the next few years it will be seen if President Obama, alongside T. Boone Pickens and other supporters, can push wind turbines past the tipping point and make America's dependence on dirty, pricy energy sources a thing of the past.

The wind turbines examined in this project have all be standard horizontal axis wind turbines with a single tower and a blade that spins in the wind. Although these designs are proven to work it is important to examine any alternatives to the normal to see if they could better fit the situation. One company this project found in its search is Mass Megawatts Wind Power Inc. This company has devised a jungle gym vertical axis design for harvesting wind power that can be seen below in Figure 37. Although the company hasn't actually produced any final models of this turbine design it has high hopes that it will reduce maintenance costs by only including small parts rather than large blade. The system should also work in lower wind conditions than conventional wind turbines and as such supply much more consistent power at a cheaper cost to the consumer. Overall the company looks promising however their design is limited in height since it cannot incorporate a tower like standard turbines. [Mass Megawatts Wind Power]

FIGURE 37: MASS MEGAWATTS DESIGN [MASS MEGAWATTS WIND POWER]

Another company that appears to be up and coming is Magenn Power Inc. This system is very unique when compared to both standard turbines and the Mass Megawatts design. Magenn's turbines are horizontal axis generators placed on the edge of an inflatable cylinder with blades along the side of the device to catch the wind and spin it thereby generating electricity. The design can be seen below in Figure 38. The power generated by the device is then carried down a tether cable that also keeps the cylinder from flying away. This design has a number of advantages over other designs on the market today. The use of a tether rather than a rigid tower allows the Magenn Air Rotor Systems (MARS) to reach heights up to 305 meters, more than double the tallest existing wind turbine heights. This added height allows the MARS to gain access to much higher wind speeds than conventional turbines in the same location. The MARS is also a portable system and thereby can be moved to better wind locations and even taken down during bad weather conditions which reduces the costs of maintaining it. This design even widens the wind range generating power from 1.8 meters per second to speeds greater than 27 meters per second, or 60 mph. [Magenn Power Inc.]

FIGURE 38: MARS WIND GENERATOR [MAGENN POWER INC.]

According to the company they should be producing 10 to 25 kilowatt versions in 2010. Although this is a much smaller size than the 2.5 megawatt turbine this project is considering, many more of these small turbines could be placed all over Worcester rather than being constrained to the best wind farm locations. Current prototypes have been releasing impressive data that makes the company look very promising. Many of the problems discussed later in this project are the vision, noise, and animal life impact turbines have. Based on prototyping Magenn estimates the MARS system to improve greatly upon all of these areas. First of all the sound the system generates will be just above that of a whisper since the system will be so high up in the air. The height along with placement ability also reduces the problems with people complaining about the turbine blocking their view. Lastly, the impact on animals is estimated to be significantly less than the already small impact turbines made since the system is more three dimensional and softer. Overall this system could drastically increase wind power generation and decrease dependence on nonrenewable energy solutions across the globe. [Magenn Power Inc.]

In the coming years Worcester and all of the Unite States should see mass improvements in generating electricity from wind and other green energy sources. During its research this project has found many different companies who wish to reinvent the way wind power is converted to electrical energy. Whether it is Mass Megawatts with their jungle gym style device with multiple vertical axis turbines or it is Magenn with their balloon style horizontal axis turbine, wind technology is improving day by day. To facilitate this legislation is also improving at a similar rate. Recently on April 22nd Cape Wind announced that the Obama administration has set up guidelines for acquiring offshore leases that can be used in installing offshore wind farms that are extremely productive and efficient. In the future even more legislation could help wind power grow faster than it ever has.

A man named Paul Gipe released an essay on April 16th, 2009 detailing a plan for government incentives known as feed-in tariffs. Gipe believes that "the cutting edge of renewable energy is not the technology, but policy. It's the policy revolution that is going to make renewable energy possible." He is suggesting these feed-in tariffs that have been used in Germany since they were first introduced 20 years ago. These tariffs will give different rates to different energy suppliers based on how easily obtained energy is from that area. This system would pay an incentive to companies who put up large scale wind farms in prime locations but would then also pay individuals who put up smaller wind turbines in areas where wind is not as prevalent a higher rate per kilowatt hour of electricity generated. This legislation would give everyone a reason to implement wind and solar power where up until now it has been very cost inefficient for individuals to set up wind turbines or solar cells on their own.

Overall the future of wind power and green energy as a whole appears promising. New inventive ideas for designs and recent pushes in legislation are moving this country into a situation where it is possible to greatly reduce the adverse effects of using fossil fuels to generate our electric power.

CONCLUSION

This report has explored the feasibility of a wind turbine farm in Worcester County, MA by examining the possible locations, current technology, social implications, environmental impacts, and political as well as economic aspects of implementation of a wind farm. A wind farm could be very beneficial to this area, with the main drawback being that the wind speeds are just marginally high enough to produce electricity.

In terms of locations, Green Hill was the clear choice due to ownership, elevation, and wind speed evaluation. If a wind farm was built on the Green Hill Park and Green Hill Golf Course, eight to ten wind turbines could generate a substantial amount of electricity, approximately 60 to 75 thousand megawatt-hours of electricity per year, providing for approximately 25,000 people in Worcester. This would be best implemented using GE's 2.5 megawatt wind turbine model.

Socially, the public is receptive to wind energy in general. Through surveying, this study found that the vast majority of people at the Holy Name School are accepting and appreciative of the turbine recently erected at the school. Also through surveying it was found that the general public is receptive to a more commercialized wind farm, whether it is at Green Hill or elsewhere. Environmentally, such a farm would not impact the environment in an excessively negative way; quite the contrary, it would be environmentally beneficial, especially when compared to a traditional oil or coal factory.

There is vast political support for alternative energies, both locally and nationally. Economically, such a wind turbine farm would involve a large initial investment with a long

return on investment period; however recent economic and political developments could lessen the initial investment.

Prior research has been conducted and has been evaluated in this report, as well as the concept of the “Tipping Point”. Powerful people and sociological conditions can lead to widespread support of wind energy, and the current state of mind around the world has the potential to expand the concept of alternative energies such as wind to a rarely implemented concept to a common occurrence.

Overall, this report found that it would be feasible and beneficial to the community if a wind farm was built in an area such as Green Hill. Alternative energy is on the rise, and if current trends continue, using these energies could soon become a way of life.

APPENDICES

APPENDIX A: SURVEYS

HOLY NAME SCHOOL SURVEY

	Not favorable				Favorable
What are your general feelings about wind turbines?	1	2	3	4	5
How do you feel about the turbine when it is not moving?	1	2	3	4	5
When it is moving?	1	2	3	4	5

Did you support the decision for the turbine to be placed? Yes No

Do you think it retracts from the natural beauty of the campus? Yes No

Have you experienced any adverse health effects that you have related to the turbine? (If yes, please elaborate) Yes No

Have you noticed any wildlife being affected by the placement? (If yes, please list the animals affected) Yes No

Are you aware of the percentage or approximate percentage of electricity the turbine provides?

Are you aware of the opinions of people in surrounding neighborhoods?

Do you think the any negative aspects are outweighed by the benefits the turbine provides? Yes No

What do you think is the greatest benefit of wind turbines?

WORCESTER CRAIGSLIST SURVEY

	Not favorable				Favorable
What are your general feelings about wind turbines?	1	2	3	4	5
How do you feel about turbines when they are not moving?	1	2	3	4	5
When they are moving?	1	2	3	4	5
How would you feel if a wind turbine site was placed in the Green Hill park area?	1	2	3	4	5

Do you think it would retract from the natural beauty of the area? Yes No

Are you aware of how much electricity a wind turbine site would provide? Yes No

Are there any wildlife in the area that you feel would be affected? Yes No
If so, please list:

Do you think other neighbors feel the same as you do? Yes No

Do you think that the benefits of wind turbines outweigh any negative aspects? Yes No

What do you think is the greatest benefit of wind turbines?

WORKS CITED

Archer, Cristina L., and Mark Z. Jacobson. Evaluation of global wind power. Tech. 2005. Stanford University. Mar. 2009 <http://www.stanford.edu/group/efmh/winds/global_winds.html>.

"Bat Population Database." February 2009. USGS Fort Collins Science Center. Ed. Laura Ellison. <http://www.fort.usgs.gov/Research/research_tasks.asp?TaskID=2217>.

BGN: Domestic Names. 21 April 2009. 23 April 2009 <http://geonames.usgs.gov>.

Brahic, Catherine. "Wind Turbines Make Bat Lungs Explode." 25 August 2008. New Scientist. <http://www.newscientist.com/article/dn14593>.

Cape Wind. 22 April 2009. 24 April 2009 <http://www.capewind.org/>.

City of Worcester, Massachusetts. 23 April 2009. 23 April 2009 <http://www.ci.worcester.ma.us/air/>.

Clipper Windpower. 2008. 04 April 2008 <http://www.clipperwind.com>.

Community Wind. 11 11 2008 <http://www.masstech.org>.

Craig, Mathias. "Wind Turbines are Billboards." 28 January 2008. Social Edge. <http://www.socialedge.org>.

GE Energy. 23 April 2009. 04 April 2009 <http://www.gepower.com>.

Gladwell, Malcolm. The Tipping Point. Little, Brown and Company, 2000.

Google Maps. 2009. 5 April 2009 <http://maps.google.com>.

Holloway, Bruce. "Build It.. Just Not Near Me." 4 December 2007. Industrial Wind Action Group. <http://www.windaction.org/news/13021>.

"How Products are Made - Wind Turbine." 1 May 2006. eNotes. Ed. Stacey L Blachford. <<http://www.enotes.com/how-products-encyclopedia/wind-turbine>>.

Isaacs, Jessica and Elizabeth Salerno. Renewable Energy World. 17 April 2009. 24 April 2009 <http://www.renewableenergyworld.com/rea/news/article/2009/04/the-economic-reach-of-wind>.

Jensen, Hans Erik, et al. Holy Name High School Wind Feasibility Study. IQP Report. Worcester, MA, 2006.

Magenn Power Inc. 04 Arpil 2009 <http://www.magenn.com>.

Mass Megawatts Wind Power. 04 April 2009 <http://www.massmegawatts.com>.

MORI Scotland. "Tourist Attitudes towards Wind Farms." September 2002. Scottish Renewables Forum & the British Wind Energy Association. <http://www.bwea.com/pdf/MORI.pdf>.

"New Scientist." 7 May 2005. Wind Turbines a Breeze for Migrating Birds. <http://www.newscientist.com>.

Norwin | Wind Turbine Energy. 04 April 2009 <http://www.norwin.dk>.

PickensPlan. 20 March 2009 <http://www.pickensplan.com/theplan/>.

Proof of Betz' Law. 12 May 2003. 23 April 2009 <http://www.windpower.org/en/stat/betzpro.htm>.

"Renewable Energy." Massachusetts Technology Collaborative. 20 April 2009 <www.mtpc.org/RenewableEnergy/>.

Szakonyi, Mark. Jacksonville Business Journal. 24 April 2009. 25 Arpil 2009 <http://jacksonville.bizjournals.com/jacksonville/stories/2009/04/27/story1.html?b=1240804800^1816408>.

"The Nutty Birdwatcher." February & March 2009. Migration Flyways: Atlantic Flyway. <http://www.birdnature.com/atlantic.html>.

Vestas. 04 April 2009 <http://www.vestas.com>.

Weather Underground. 23 April 2009. 23 April 2009 <http://www.wunderground.com>.

Williams, Nigel. "Turbine Troubles." 22 August 2006. Science Direct. <http://www.sciencedirect.com>.

"Wind Energy." Microsoft® Encarta® Online Encyclopedia 2009. http://encarta.msn.com © 1997-2009 Microsoft Corporation. All Rights Reserved.

"Wind Energy and the Environment." November 2008. American Wind Energy Association. <http://www.awea.org/faq/wwt_environment.html>.

Wind Plants of California. 9 May 1999. 24 April 2009 <http://www.ilr.tu-berlin.de/WKA/windfarm/tehcal.html>.

Wind Turbine Syndrome - Nina Pierpont's Research. November 2008. <http://www.windturbinesyndrome.com/>.