Wind Farm: Feasibility and Environmental Impacts

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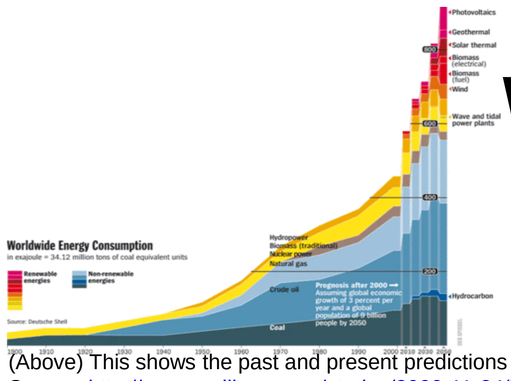

(Above) This shows the past and present predictions of energy sources.
Source: http://www.resilience.org/stories/2009-11-24/how-not-resolve-energy-crisis

(Above) Enercon E53 500 kW wind turbine.
Source:http://www.renewablesfirst.co.uk/windpower-wind-turbines/

Abstract

I have been taking a statistical approach to figuring out the feasibility of a wind turbine on site for energy production and research. I was given wind speed per minute data recorded over the last 20 years at a parcel of land located next to the Fire Department. I analyzed the data using graphing and analysis software on Microsoft Excel and Minitab. Additionally, I was able to find the potential power production of a wind turbine. This showed me that only slightly more than half a megawatt can be produced on the windiest day. The installation of a wind turbine on site would provide a great tool to explore mechanical improvements to the turbine hub and for analyzing the power produced. As a result of my work this summer, I have gained a grasp of renewable resources limitations as well as gaining incredible knowledge on the use of statistical programs.

Methods and Materials

- The information I focused on was the wind speeds for each minute at the 85 meter height. I did this because this is the height at which there would be the strongest winds and would provide the most power.
- For comparative measures I analyzed the wind speeds at 10 meters for 2014 and 2002, which is the lowest level of recorded wind speeds, the least windy year, and the windiest year respectively.
- When I analyzed the data I used a program called Minitab. This allowed me to import the data which was stacked in a row of 525,600 points and Minitab would take those points and organize them into rows and columns. These where separated by the 1440 minutes each day and 365 days in each year.
- To find the potential power produced, I assumed the wind turbine has a blade diameter of 10 feet, about 3 meters, and a swept area of 80 square feet or exactly 7.4322432 square meters. This formed my power conversion equation (in Watts), W = 0.625 *(7.4322432)*6^3. Using the formula I converted all my average wind speed measurements to watts and then to kilowatts and megawatts. As I wanted the most accurate results I multiplied all my power production potential values by .42 or 42% efficiency.

Discussion

- The installation of a wind farm on BNL site would go a long way to offset carbon emissions and provide vital research opportunities as the new wave of energy production takes root. When the wind farm is installed it would be very powerful in the daily energy offset at BNL. Although the wind farm would be ideal and easily paid off the space needed for a small wind farm is not readily available here. As there are limited places available for installation realistically only one turbine would be able to be installed.
- The bird and bat population would need to confirm to be steady and not in decline as the inevitable fatalities of the wind turbine could damage a potentially declining bird or bat population.
- The wind speeds are the best higher up and the Enercon E53 500 kW wind turbine, which I used for analysis, can reach 100 meters when at its highest point, so it can be provided with the strongest wind available.

Acknowledgement

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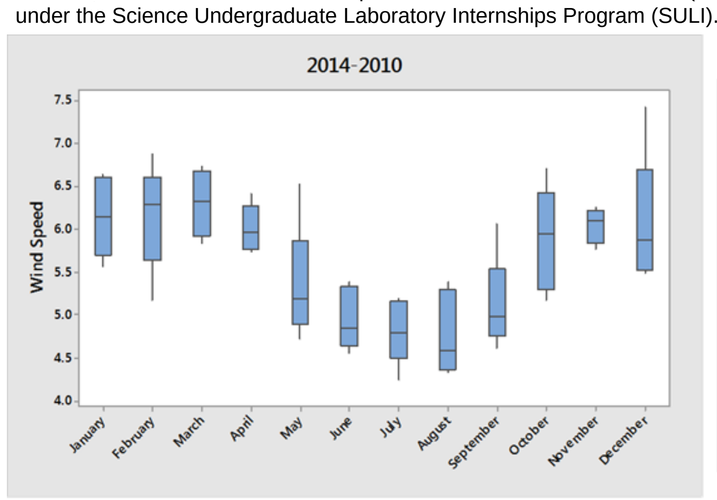
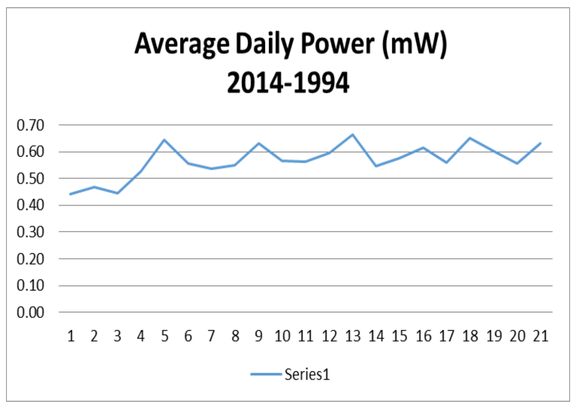
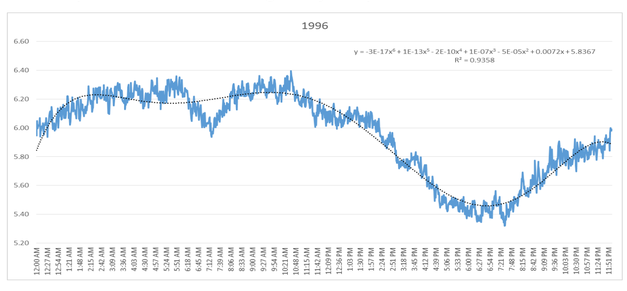


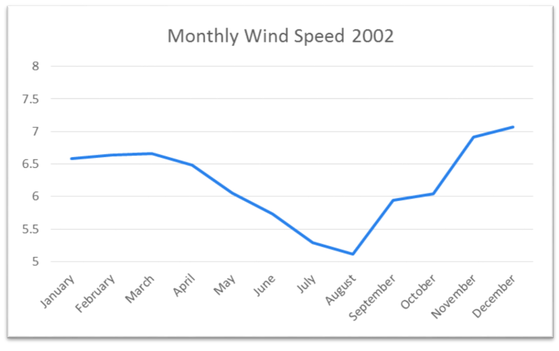
(Above) Box plot showing the average monthly wind speed variation during a 5 year period



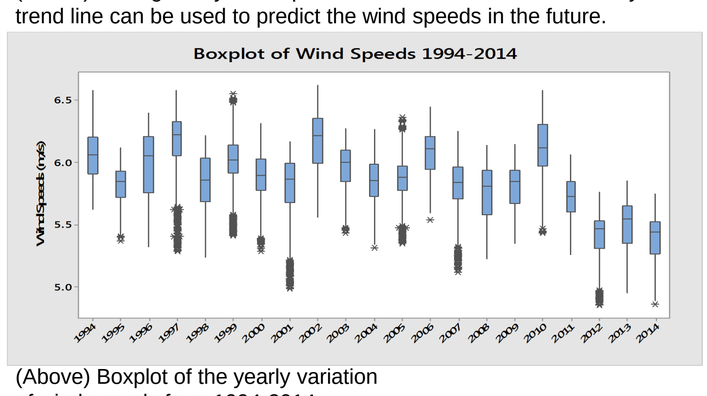
(Above) Average power produced each day between 2014 and 1994



(Above) Average daily wind speed and trend line of 93% accuracy. The trend line can be used to predict the wind speeds in the future.



(Above) Monthly wind speeds of 2002, windiest year



(Above) Boxplot of the yearly variation of wind speeds from 1994-2014

Introduction

- The scope of the energy infrastructure is changing. The new wave of energy innovation is heavily focused on the use of renewable energy systems, and the global production of renewable energy in 2013 was only 22%.
- Wind Power is taking off in the United States with a projected 30% growth rate.
- Brookhaven National Laboratory (BNL) currently produces less than 1 MW from the solar research array on site, not even achieving 1/20th reduction on the lowest power production days.
- I will explore the feasibility of installing a wind turbine and wind farm onsite at BNL.
- Globally there has been an increase of 383,000 GWH of renewable energy production from 1980 to 2006.

Results

A. Bird and bat effects

- BNL is located along the Atlantic Flyway which stretches from Canada along the east coast and down into the Caribbean islands. This causes trouble for migratory birds and given the height of 100 meters at the highest or about 300 feet the birds will be impacted. Although many times birds tend to fly well above 328 feet.
- There was a recent installation of a wind farm in Texas was installed in the direct path of a major bird migratory path and they used avian radar technology developed and used by NASA and US air force that could sense the approaching birds as far out as four miles. When this happened the turbine would shut off completely and allow the birds to pass. Once these birds passed the turbine would unlock itself and resume normal operation.
- If upon further research it is found that BNL is in a major hotspot for bird activity then a type of wind turbine with avian radar could be considered.
- I found that at night the wind is stronger consequently moving the wind turbines faster when the bats are most active.
- Due to the bats use of echolocation the reported impact on bats has been significantly lower than that of birds. The one risk that has been reported with many wind turbines has been the current it creates which can pull bats into the turbine and kill them.

B. Power production potential and pay back period

- The only viable source of wind here at BNL is at 85 meters and the analysis I performed was based off wind at that height.
- Upon analyzing this data I found that the windiest year on record was 2002 and the least windy year was 2014 taking into consideration the completeness of the data set.
- To analyze the data I found I had to find a wind turbine to use. This is because every turbine has different cut-in, rated, and cut-off speeds. I found the Enercon E53 500 KW wind turbine and used this for further analysis. The cut-in speed starts at 2.5 m/s which even on the least windy of days we are able to achieve. The rated speed starts at 10 m/s which can be achieved, and the cut-out speed is 25 m/s which in the 21 years of data was never reached. This means we would on average make between 200 kW and 500kW.
- The locations I was given as a possible location for installation were the former landfill, the met field, and when the smoke stack is taken down installation in its place.
- Due to the fact that the Enercon E53 500 kW, which has a hub height of 73 meters and blade length of 23 meters, produces maximum power at up to 10 m/s I calculated how many days continuously in a year the turbine could produce maximum power given wind speeds at BNL.
- The results showed that the best year was 1996 with 32.68 days and the worst year was 2013 with 15.97 days and the average was 24.14 days.
- Using the 18.8% return on investment achieved by the Enercon E52 500 kW turbine I found the pay back period to be 5-7 years for each turbine and with the Incentive from the New York State Energy research and Development Authority (NYSERDA) of $174,000 the pay back period is 3-5 years

C. Noise and health impacts

- Shadow Flicker refers to the constant shadow that the turbine casts during the day time. This constant flicker of light has rarely had a substantial affect on people. Although in rare cases it has been reported to cause epileptic seizures and symptom, mental illness, and irritability.
- Another noticeable affect is noise pollution. The noise emitted is a constant hum that sound louder when close but still at a safe decibel level and at a distance is almost unnoticeable.
- The sight of wind turbines for some people is just visual pollution. This can sometimes make the installation of wind turbines more difficult because of the people who do not want to see it.
- A recent example of this was with the Cape Wind offshore wind turbine project in long island sound. There were a select few people who were upset about their view being obstructed by these wind turbines and eventually these people derailed the project from coming into fruition.

D. Wind Pattern Forecast

- The wind speeds at BNL were shown to drop from early morning to early afternoon, while being at their highest between late afternoon to early morning. The Peak wind speed on average occurred around sunset
- Using trend lines of 90% and up we can accurately predict the wind speeds of each day.
- With the trend line the wind speed forecasts can tell us when the most power will be produced, what time of day the wind turbines will cause most harm to birds or bats, and much more.

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