Wind Power Feasibility at Westtown School
First Semester Computer Science Exam
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1. Introduction

A Wind Turbine, or informally 'wind mill', is a device that captures kinetic energy from the wind and converts this into electrical power. The wind blows a two or three bladed propeller, similar to which you'd see on an airplane which in turn drives an electric generator (Fig. 2). This propeller is often very large, in the case of the most common *GE Energy 1.5s,* this is 70.5m. In most cases a turbine is mounted on a large shaft thirty meters or more above the ground to have access to faster and less turbulent air. There are alternative designs of wind turbine, such as a vertical wind turbine (Fig. 1), but these are struggle to generate enough power for a house, not even a school, and such are not worth considering. The proposed instillation of a Wind Turbine would be to offset Westtown's usage of *dirty energy*, energy coming from coal or other greenhouse gas, that are a driving force behind climate change.

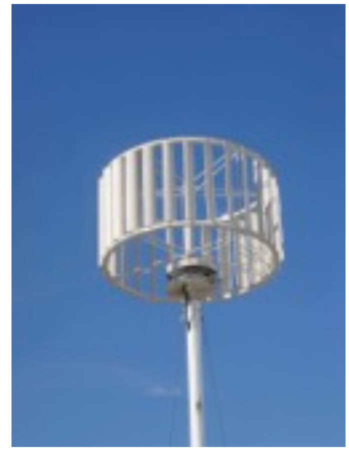

Fig. 1

2. Calculation of Possible Power Output

To calculate the possible power output of a traditional wind turbine we consider the following equation:

$P = 1/2 \rho A v^3$

where

P = power (Watts)

ρ = density of air (kilograms per cubic meter)

A = area wind passing through perpendicular to the wind (square meters)

v = wind velocity (meters per second)

Fig. 2

Power will be our hourly output from the turbine, this will change according to wind speed for each hour. Most other factors are considered to be constant, with blade area (A) at 3500 and air density at 1.225. The blade area is the area swept by the blades of the GE Energy 1.5s turbine, the smallest and most common commercial turbine (fig. 2). As only the smallest of commercial turbines could even be considered, this value is pretty close to all other feasible turbines. Air density changes based on altitude, time of year, weather, and many other complicated factors. Despite having so much variability as to its calculation, air density does not change that much. As such assuming air density as constant at 1.225 kilograms per cubic meters allows us to focus on how windspeed affects power production, without muddling it with such a little factor such as air density. 1.225kg/m^3 is standard air pressure for our altitude and standard weather. The wind speed is hourly calculation made from daily data taken from *wunderground.com*, and covers about five years of averages. This data is daily, but the calculation is made for each hour, assuming that that day's average is close enough to an hourly average. This is about five years of daily data, meaning about eighteen hundred data points.

More frequent data is available at cost from various three letter agencies but is not within the scope of this project. While this calculation is tedious to do by hand it has been automated for daily calculation by a program that can be found in the appendix alongside a sample dataset and output. Power output will vary greatly by the hour and time of year so calculations must be made for several years of data. Total understanding of this equation is not necessary for understanding of the rest of the report; in short, wind speeds change often, and with that power output, by considering wind speeds twenty four times a day we get a much more accurate picture what a wind turbine could do.

3. Efficiency and Betz's law

Due to the restraints of the physical world, turbines cannot capture the full amount of energy described in the equation below. Due to friction and other forms of energy loss, a wind turbine cannot capture much of the wind's energy. The physicist Albert Betz calculated in 1919 the absolute maximum efficiency that a perfect turbine could reach, now known as the *Betz's Limit*. The Betz's limit is 16/27 or 59.3%, meaning that an absolutely perfect turbine can only capture about sixty percent of the energy passing through it. Commercial turbines, such as the *GE Energy 1.5s*, are only able to reach about twenty percent efficiency in peak working order. This means our power yield as calculated above is multiplied by .2 to find the realistic energy output. As such our power yield will always be much lower, one-fifth, of what the equation gives us.

4. Zoning

Due to the disruptive nature of the operation of wind turbine, Westtown Township has heavily regulated their instillation. Turbines are loud, and operate at most hours of the day and therefore are ill-suited for residential areas like Westtown Township. In May of last year Westtown Township appended their Alternative Renewable Energy ordinance to include expanded definitions of what is and is not aloud as to the install of green energy devices. Under *Article 8* of the document Wind Turbines are limited to thirty-five, or a conditional seventy, feet in height. This regulation excludes all commercial turbines that could even begin to fill Westtown's energy need. Furthermore, the regulation limits wind farms to " ...No more than one (1) Wind Energy System (wind turbine) shall be permitted per lot..." meaning farm solutions are impossible. Zoning Code as such eliminates any chance of placing any turbine on this campus that could off possibly even offset a noticeable portion of Westtown's energy need.

5. Energy Usage

The main campus of Westtown School uses around 8.325 Megawatts of power per day, excluding energy usage of Faculty homes and other buildings off of the top of campus. While Westtown School is a leader in the usage of green energy in schools, it simply takes a huge amount of energy to fuel our campus. While energy usage totals are down over ten percent from 2007, we still have a long way to go as both a school and global community to finds ways to conserve energy. For context this is about two hundred and fifty dollars of energy per day to keep the school running. A single turbine instillation will struggle to offset even some of this. However Westtown is also doing a great job in ensuring the energy we do use comes from clean sources. Just this year the School transferred to one hundred percent wind energy, meaning turbines in better suited areas then our campus, are producing carbon neutral energy to fuel our campus.

6. Conclusions

In all respects a wind turbine instillation is ill-suited for Westtown. A GE 1.6 Energy Wind turbine instillation would only produce about one megawatt (1.0162) of power per day, only twelve percent of Westtown's total 8.325 megawatt usage. Furthermore, this area in Pennsylvania is far from optimal for wind energy, average wind speeds struggle to reach levels that could even spin the blades. Westtown Township's restrictive zoning would prevent both the instillation of a large commercial turbine, and heavily restricts the instillation of smaller systems. The huge cost of install of a single turbine, often reaching into the several millions, even further shows that a wind farm instillation is everything but a realistic option for Westtown School. More practical solutions include buying wind power from our existed energy supplier, increased purchase of solar panels, and further reinforcement of energy conservation practices.

7. Quick Stats

Average windspeed in Westtown Township is: 8.79 MPH
A singe GE 1.5s Energy Turbine would produce .0423 Megawatts of power per Hour
The same turbine would produce a little over one (1.016289) Megawatt of power a day
The same turbine would twelve percent of our energy needs.
This is about forty dollars ($40.04) worth of energy produced a day.
It would take about 136 years (136.84 years) to repay your investment by selling produced power

8. Appendix

Sources

http://energy.gov/eere/wind/how-does-wind-turbine-work
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Judy Asselin / Westtown Energy Conservation Results FULL Summary