From: Laura Smith
To: Aaron Anderson, Brian Cian [poster teammates in fall 2007]
Re: Wind Energy—Mechanics, Issues, and Current State of Affairs in Washington State

Currently, more than half of all electricity produced in the United States is generated by burning coal.[1] Given the several health effects, consequences to the natural environment, and contributions to global warming burning coal creates, it is imperative that cleaner forms of energy be developed and implemented. Harvesting the wind's energy through wind turbines proves to be an ideal candidate for producing electricity. When used in conjunction with other forms of power generation, wind energy has the ability to meet the electricity demands of American citizens.[2] Wind farms can provide clean and efficient energy; however, their construction raises several ethical and social questions. These issues must be addressed thoroughly through proper policy and government regulations before the country can fully invest and commit to the use of wind turbines.

Since most of the controversy surrounding the use of wind turbines arises from construction concerns and economic factors, it is important to understand the mechanics and placement requirements of turbines before any policy decisions are made. There are two main types of wind turbines—vertical axis mills and horizontal axis turbines.[3] Vertical axis mills have existed for centuries and physically resemble egg beaters. Given this complex design, they are not as efficient as horizontal axis turbines at collecting the wind's energy at high elevations and speeds.[4] For this reason, horizontal axis turbines are more commonly used today. They generally consist of two or three blades that rotate parallel to the wind's flow.[5] The turbines can be constructed to operate up or down wind. Several design characteristics allow the horizontal axis turbines to effectively collect and transform the wind's energy into usable forms of power.

Mechanics and Scientific Aspects

In order to obtain optimal efficiency and remain safe, horizontal axis turbines only operate between wind speeds of 8 to 55 miles per hour (mph).[6] An anemometer measures the oncoming

wind speed and communicates with a controller. If the wind exceeds 55 mph or reduces below 8 mph, the controller engages a brake and stops the turbine.[7] However, once wind speeds are within range, the controller disengages the brake and the blades are free to rotate. As the wind blows over the blades, it forces them to "lift" in a manner similar to wings of an airplane.[8] The rotation power of the blades is channeled by a hub which spins a low-speed shaft. Depending on the force of the wind, the shaft turns between 30 and 60 revolutions per minute (rpm).[9] However, since most generators require between 1000-1800 rpm to produce electricity, a gearbox is needed to connect the low-speed shaft to a high-speed shaft.[10] The high-speed shaft, which is connected to the generator, increases the rotational speed to the proper specifications. The generator transforms the energy, created by the rotational speed, into electricity which is fed to a central grid and then to homes and businesses through transmission lines.[11] Since the amount of electricity that is generated depends on rotational speed, and rotational speed depends on the wind speed, correct placement of the turbine is essential for optimal power generation.

The amount of power that can be harvested from the wind is a function of the cube of the wind's speed ($P = S^3$).[12] Thus, by simply doubling the wind's speed, the power output increases by a factor of eight. The prevailing winds produced by regional pressure patterns ultimately determine the amount of wind an area will receive.[13] However, factors such as elevation and terrain can enhance the wind's speed. Since wind speed increases with altitude, the taller the turbine, the greater the power generation.[14] Placing the turbine atop a hill or plateau will also increase its height and access to faster air. Mountain ridges also enhance wind speed by acting like a ramp which launches and propels the air forward.[15] The high specific heat capacity of water also makes costal regions ideal for turbine placement.[16] Since the ocean will heat and cool much slower than the land mass, land-sea breezes are consistently created. Regions that should be avoided for placement include the leeward side of mountains and those areas with dense vegetation and built structures.[17] These areas have increased friction which creates turbulence and drag, thus reducing the wind's speed. The placement

of turbines in valleys can be beneficial; however, caution must be exercised. Valleys have the ability to channel and enhance wind speed only if they have elevation breaks and run parallel to the wind's direction.[18] Carefully assessing these factors will ensure the turbine operates at optimal efficiency.

Ethical and Social Issues

Given the design characteristics of a turbine, properties of wind, and terrain features, it is clear that specific locations will be more appropriate for the erection of wind farms. Placing a constraint on construction locations creates several ethical problems. Wind turbines are extremely tall and require large areas of unobstructed land. An average industrial 1.5 megawatt turbine can range from 260-425 feet tall and need up to 82 acres of land for best performance.[19] Given these specifications, concerns regarding the destruction of the land's aesthetic beauty arise. The turbines can also compete with other uses of the land, such as hiking. By placing turbines on public lands which cater to recreational activities, citizen outcry may occur. Aside from being unsightly, wind turbines are also noisy and require safety lights so they are visible to aircrafts at night.[20] Noise and light pollution thus becomes a problem when turbines are built in close proximity to homes. Tenants may be forced to deal with the turbine's constant humming and light production, while their landlords, who lease the land to wind companies, receive income from the turbines. Questions of whether turbines will be constructed in regions dominated by minority populations or in the pathways of migrating birds also raises concern. These ethical issues are only part of the problem surrounding the construction of turbines. Transitioning from coal generated electricity to wind generated electricity also has several social implications.

The construction of wind turbines in certain regions has the ability to lower real estate values.[21] In Michigan, there have been reports of properties near turbines dropping up to eight thousand dollars in retail value.[22] Switching to wind energy also severely impacts the workforce. It is true that labor will be required for the installation and maintenance of turbines, however, jobs related to the mining and burning of coal will be lost. These individuals, some of which will have worked

with coal their whole lives and have little other job skills, will suffer terrible economic and emotional losses. The fact that wind farming also requires excessive amounts of money and space to transport and erect the turbines also raises several questions. How much pristine environment will be destroyed to pave the roads necessary for trucks needing access to the construction site? What additional costs will this destruction introduce? The fact that wind farms only receive small government subsidies also forces some to wonder about the success of wind energy. Combined, these social problems and questions hinder the construction and use of wind turbines in America. In order to address each of these issues, as well as those discussed above, certain policy and regulatory decisions must be made regarding the placement of turbines.

Given the multitude of ethical and social concerns, it is tempting to compartmentalize the problems and address them separately when making policy decisions. Although this is helpful for understanding the specifics of each situation, it is important to utilize a holistic approach since solving one problem may worsen another. For example, instituting mandates for maximum allowable decibel outputs may reduce noise pollution and the issues associated with it, however, may introduce extra construction costs. These expenses would raise production costs and thus, the overall price of electricity for consumers. Similarly, restricting zoning areas to those away from recreational regions, migratory paths, and minority lands may require the turbine be placed in an area with below par wind speeds. As a result, the turbine would operate at non-optimal levels, thus lowering the amount of power generated and raising the cost of electricity. Policy decisions must weigh the costs and benefits of specific regulations and mandates before any decision is made. Leaders must acknowledge that these decisions will involve trade-offs and that the goal is not to please everyone, but to ensure the greatest benefit for the most people.

Wind in Washington State

Debates surrounding several of the issues discussed above are currently raging in the state of Washington given the governor's and citizens' desires to become more environmentally friendly.

According to the latest figures from the Department of Energy, Washington is ranked third in the nation among states with the fastest growing renewable energy development plans.[23] The state already has six major wind farms which produce 818 MW of electricity annually.[24] The most productive areas for wind farms are in the central part of the state, in the Kittitas Valley and ridges of the Columbia River basin, and along the coast.[25] Much controversy has recently swelled over the proposed construction of 65 turbines near Ellensburg.[26] Residents voted against the project, stating loss of aesthetics and property values as reasons for their objections.[27] However, in September, the governor overturned the city's decision, allowing the construction of the wind farms. Controversies, such as this one, are expected to increase given the fact that in 2006, voters approved I-937.[28] This initiative requires that 15% of electricity used by all major utilities come from renewable resources by 2020.[29] To meet this goal, many utility companies are expected to draw on and advocate for the development of more wind farms.

Conclusion

Harnessing and transforming the wind's energy into a viable form of power is a realistic solution to burning coal. The technology is sound and has progressed from an unproductive vertical axis wind mill, to a more efficient horizontal axis turbine. Given the promises of clean and renewable energy, it is however easy to overlook problems associated with the development of wind farms. It is critical that the ethical and social issues be addressed prior to any major construction. Residents, animals, and natives tribes have equal rights to the land and their concerns need to be heard and respected. Policy makers have the ability to institute zoning and technology regulations to better satisfy all stakeholders, however, they must utilize holistic approaches when making their decisions. Washington State is expected to expand its use of wind energy in the near future. In order to avoid future controversies, it is important that state leadership, companies, and citizens collaboratively develop a strategy which ensures the responsible construction of new turbines in areas that maximize benefits and minimize costs.

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