Avian Mortality - Wind Energy

Anthony Seto
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The United States has developed a dependency on various fossil fuels in the past years. It is important that we begin to merge into a new era of renewable resources. One of the top choices on interest include wind energy. However, there are many problems with wind energy that must be addressed. In this paper, supporting detail for wind energy's potential is provided as well as avian mortality problems associated with wind turbines.

1. Abundance

The main advantage of wind energy is its high abundance in the United States. In Figure 1, the National Renewable Energy Source Lab (NREL) created a map of potential locations for wind turbines at a height of 110 meters. The amount of potential locations for wind energy is extremely high, even at areas where current wind sources are not located. The darker blue regions represent areas of higher potential as a building site. NREL also recognizes that there are areas where wind turbine energy is not feasible, such as urban areas, national parks, and also federal regulations on certain locations. These locations are already accounted for the map. Although the United States has many urban areas, the map shows the high potential of wind turbine implementation at the mid-western part of the country. It's important to note that the average wind turbine size is around 110 meters. The map in Figure 1 is a model of wind turbines at a higher than average height. However, when the NREL produces the same type of map with a different wind turbine height, it is still clear that the United States can expand their investments in wind technology.

In Figure 2, the NREL produces a similar map as Figure 1. This graph shows the potential wind capacity at a much higher height of 140 meters. While this type of wind turbine is not mass produced yet, it represents a near future technology that could well increase the potential for wind turbine energy. In the map, the proportion of dark blue areas is much higher than the amount represented in Figure 1. Again, the NREL attempts its best to account for the urban areas where wind turbines cannot be installed.

Figure 1 – Graph of Potential Wind Capacity at 110-Meters Hub Height[1]

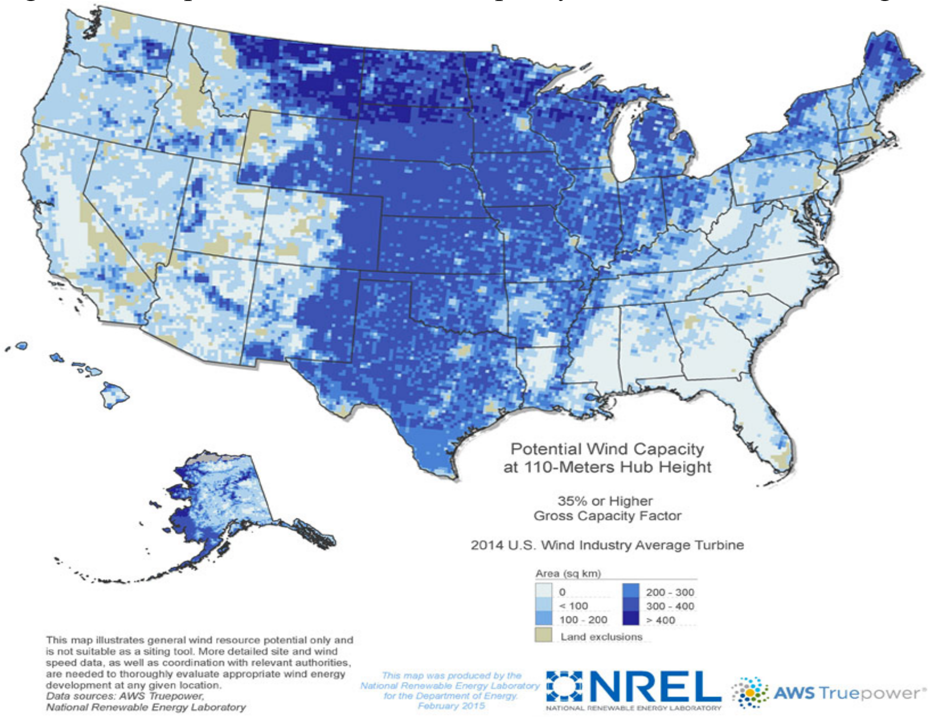
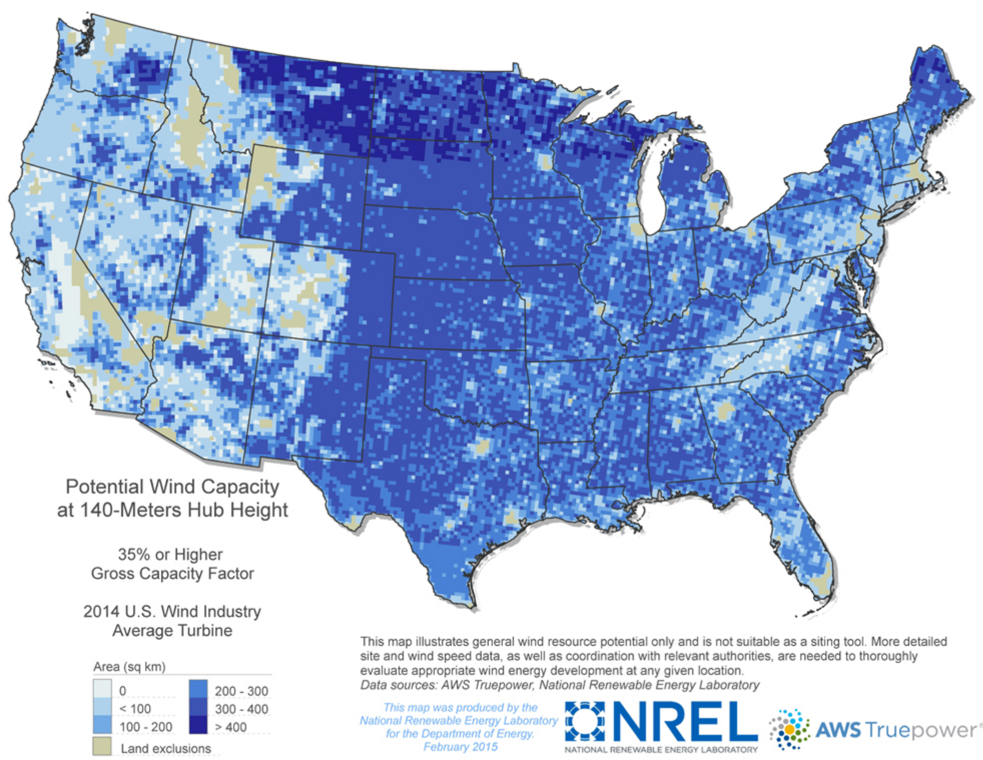


Figure 2 – Graph of Potential Wind Capacity at 140-Meters Hub Height



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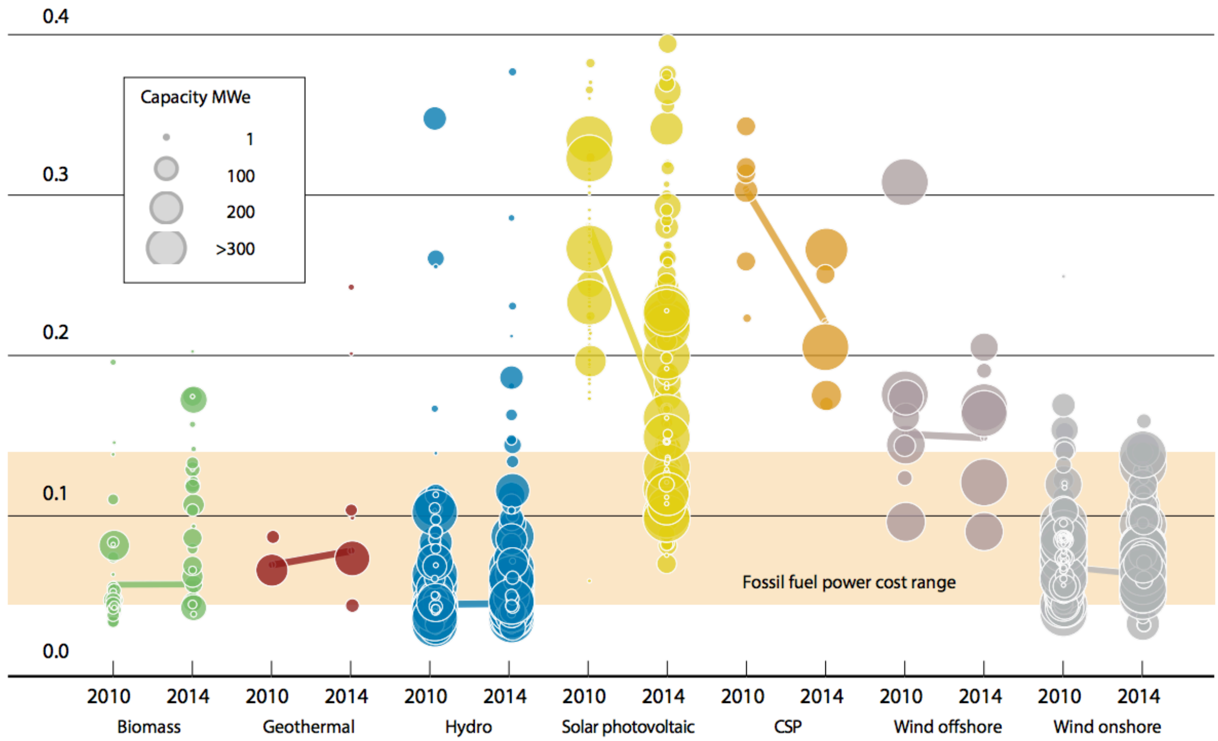
[1] "WIND RESOURCE ASSESSMENT AND CHARACTERIZATION." *Energy*n.d. http://energy.gov/eere/wind/wind-resource-assessment-and-characterization.

2. Cost

The main problem with renewable energy sources is its high costs. However, wind energy seems to be around the same price range as fossil fuels. This is partly due to recent improvements in wind energy. The improvements in optimization electricity generation contributes greatly towards the price of wind energy. When comparing wind energy to the prices of the other renewable energy sources, it seems that wind is significantly cheaper than the other renewable energy sources. Figure 3 shows the cost of wind energy in comparison with other energy sources. Primarily, looking at onshore wind, it lies at the same price range as the fossil fuel cost range, but at the same time, it Is fairly low compared to the other energy sources.

Figure 3 – Price History of Renewable Energy Sources[2]



3. Technology

It is important to understand the technology behind wind turbine before recognizing its high potential for improvements in the future. The wind turbine has a very simple mechanism. It has only one input, and that is the wind in the air. When wind meets the turbine blades, the blades rotated which effectively spins a shaft connected to a generator. The generator utilizes the rotating motion to produce electricity. Because wind turbines must be able to capture wind with its best efficiency, there is a lot of room for research in wind turbines. Factors such as capturing air optimization and also creating the electricity are reasonable areas of interest.

There are many different factors that affect the efficiency of wind turbines. The height of wind turbine can affect the speed of the turbine. At a higher height, the wind turbine is able to capture

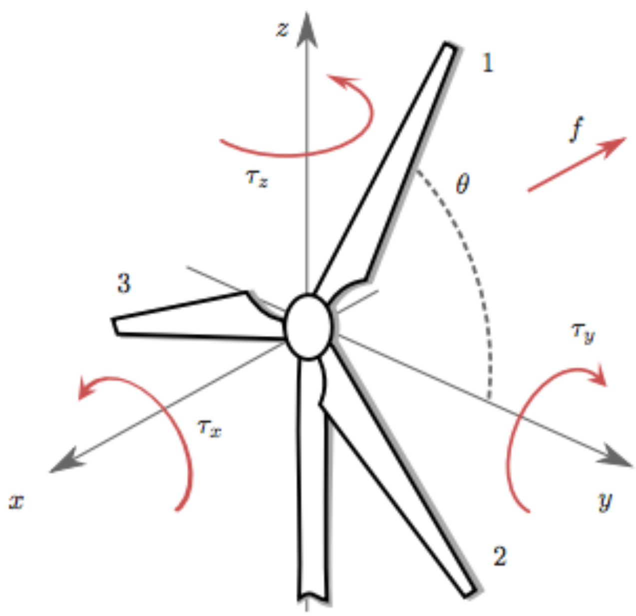
[2] "Renewable Power Generation Costs in 2014." *International Renewable Energy Agency*. 2015.

more air. This is useful because more air would lead to a faster rotating blade creating more energy. The length of the turbine blades also affects how fast the blades are able to spin. This is because a larger surface area captures more air, thus creating a faster motion. Even without a faster motion, a higher turbine and longer blades increase the likelihood of creating a rotating motion in the blades because wind is not always present.

4. Pitch Angle Optimization

One recent publication on research of wind energy produced by the NREL involves the pitch angle of the wind turbine. The pitch angle is the angle of the rotary blades with respect to the turbine itself. The blades are not located directly perpendicular to the ground because it is not the best optimization angle. Researchers have found that by changing the pitch angle, the overall power output is directly affected. This is useful in knowing because wind energy can further be improved upon in the future. In Figure 4, the angle Ø represents the pitch angle on a 3 bladed horizontal axis wind turbine.

Figure 4 – Diagram of a Wind Turbine and its Pitch Angle[3]



The research on pitch angle has begun several years ago. However, only until recently, the NREL finally made great progress. The idea is simple. During turbine operation, two periods of rotations will be analyzed for its power output. The data obtained will be useful in understanding the best pitch angle for the wind turbine. When the second period produces a higher power output, a pitch increment will be made to the blades. On the other hand, if the second period of rotation generates less power than the first, a pitch increment will be subtracted. By understanding the periods of rotation and the power output, a control signal can be produced activating blade pitch actuators. The actuators are responsible for adjusting the pitch angle of the

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[3] Biegel, Benjamin, Morten Juelsgaard, Matt Kraning, Stephen Boyd, and Jakob Stoustrup. “Wind Turbine Pitch Optimization”2011.

wind turbine. This process is extremely useful. It can increase the power output of the wind turbines, and it can also limit the amount of power needed in case of an over supply of energy.

5. Avian Mortality

Bird mortality in wind turbines has become a very large problem. In particular, raptors and birds have relatively lower mortality rates annually. However, bat mortality is over a hundred times higher. There have been estimates of bat mortality rise over a hundred thousand per year and up to 600,000 per year[4]. Because bats are nocturnal creatures, their reliance on sound to travel places them at a disadvantage when looking at wind turbines. As a result, concerns have risen over limiting the bat mortality rates. Furthermore, wind turbines often interfere with raptors and birds that are being protected by the federal government. It is important to protect the birds and bats in the environment and limit the impact caused by wind turbines.

5.1 Altamont Pass Wind Resource Arena

One of the main concerns with wind turbines is its complications with bird traffic. Future projections of wind energy show an increase in turbine size that may intuitively lead to a higher bird mortality rate. Despite wind farms claiming low bird mortality rates, in reality, bird traffic is almost unavoidable.

California generates over 500,000 megawatt hours of wind energy each year, or about a quarter of the nation's total wind energy[5]. One of the wind farms residing in California is the Altamont Pass Wind Resource Area (APWRA). It is a 165 km^2 wind farm in western California that generates over 550 megawatt hours total. With over 5,400 wind turbines, bird traffic is a major concern in the wind farm, and there have been lots of controversial opinions of the effect on birds. In a study of the Altamont Pass wind farm, bird mortality in the Altamont Pass was analyzed to visualize the impact of the wind turbines. The results of the study showed that 434 raptors and 1,058 birds were killed annually. However, factoring in birds that may not have been counted due to human error, the estimate of bird deaths rose up to 1,127 raptors and 2,710 birds. It is important to note that these estimates are from the wind turbines alone. Because wind farms are located far away from the cities, high voltage electricity lines are often wired to the city. The bird mortality due to these energy lines are not added onto the estimates for bird deaths in the wind farm. Furthermore, the study only analyzed the bird deaths caused by 4,074 turbines of the 5,400 total turbines.

Although the numbers are not very high considering there are a total of 4,074 turbines analyzed in the study. The problem lies within the species of the birds killed. In the Altamont Pass area, the birds killed are often less common species of hawks, eagles, and owls. For example, the golden eagles, though are not endangered, are federally protected to prevent it from becoming an endangered species. Bird mortality due to turbines can be problematic as it can drive different bird species to be endangered. Furthermore, there are also studies on other wind turbines throughout the nation that have affected endangered species of birds. It is important to

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[4] "Bat Fatalities at Wind Turbines: Investigating the Causes and Consequences." United States Geological Survey. 2016.

[5] *US Energy Information Administration*. "Electric Power Monthly with Data for February 2016," May 82016. https://www.eia.gov/electricity/monthly/pdf/epm.pdf.

understand the impact wind farms have on bird species, and make the appropriate adjustments for prevention.

5.2 Electromagnetic Fields

Bats are at a large disadvantage in travelling when there are wind turbines present because of their reliance on sound to travel. In comparison to birds, there have been solutions to bird mortality by using visual stimuli. However, similar methods do not work for bats. One such method is utilizing electromagnetic fields to alter bat traffic. Although there are no concrete studies showing bats can detect electromagnetic fields, a research team has conducted field trials to analyze bat traffic in areas with and without electromagnetic fields.

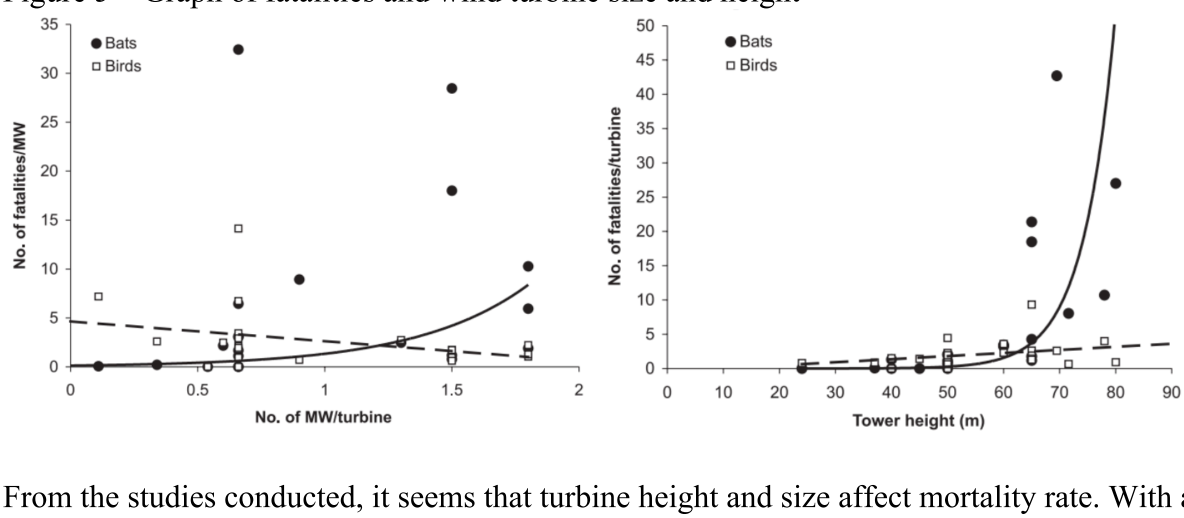
Three different stations were analyzed to understand bat traffic with respect to electromagnetic fields. The results are clear showing that bats can indeed detect electromagnetic fields. In fact, areas where the electromagnetic fields are present reduced the amount of bat traffic. This can be useful in that less bat mortality will occur at these locations.

Although areas with a higher electromagnetic field can decrease bat traffic in the certain area, it also raises concern to why these areas are avoided by bats. The main suggestion is that the bats are affected by the radiation emitted from radio frequencies. The radio frequency was a main form of the electromagnetic fields caused by radars. However, it turns out that radio frequencies are known to cause thermal responses in organisms. In humans, there have been responses in radio frequencies resulting in increases in body temperature. Further analysis shows that bats may also be affected in such a way due to electromagnetic fields.

5.3 Turbine Height and Size

In Figure 5, two graphs show the relationship between fatalities and turbine size and height. On the left, the graph represents the relationship between the size of turbine blades in relation to the number of fatalities of both birds and bats. On the right, it is a graph of fatalities based on the height of the turbine. The studies of this data ranges from various parts of the United States wind farms.

Figure 5 – Graph of fatalities and wind turbine size and height



From the studies conducted, it seems that turbine height and size affect mortality rate. With a larger turbine blade size, the number of bird deaths decrease. Furthermore, at higher turbine heights, the bad mortality rate increases exponentially. The results of these studies can be used to develop the ideal wind turbine height and size to limit avian mortality.

5.4 Variable Turbine Speeds

Wind turbine speeds can greatly affect the mortality rate of both birds and bats. In a study conducted on the Casselman Wind Project in Pennsylvania, it turns out controlling the wind turbine speed does not result in significant losses in energy output, yet it also mitigates the bird mortality rate caused by the wind turbines. Since wind turbines' efficiency is dependent on wind speed, it is interesting to see a relationship between wind speed, efficiency, and its effect on aviation mortality.

In order to analyze the effects of bat mortality based on the wind speeds, bat deaths were counted and the wind turbine speeds were analyzed throughout the time period. The results showed a clear relationship between the two variables. The cut-in speed of a wind turbine is defined to be the starting speed of the blades. It turns out that with a higher cut-in speed, the bat mortality rates increase significantly.
Relating the turbine cut in speeds with bat mortality, wind farms can significantly reduce bat mortality by limiting the turbine cut-in speed to 5 meters / second. At this cut-in speed, the average bat mortality over 25 nights was 0.73 in comparison with a fully operation turbine that had an average bat mortality of 2.29 [6]. Although limiting the cut-in speed of wind turbines may result in a loss of power, it turns out that a limit of 5 meters / second will only result in a loss 0.3 % of the annual energy output. Thus, curtailing the wind turbine speeds can have a very large impact on bat mortality, and possibly even bird mortality without losing much energy generation.

6. Ideal Wind Turbine

With a growing investment in wind energy, it is important to establish an ideal set of features in a wind turbine. These features must produce the largest amount of energy, yet it must mitigate the effects on avian mortality.

In the current wind farm technology, pitch angle optimization has yet to be introduced in the industry. Despite lack of investment, laboratory studies on pitch angle control proves that it is in fact very important in maximizing energy output. By incorporating pitch angle optimization in a future wind turbine, it can definitely increase the energy output. Because pitch angle optimization lies on the basis of variable speed turbines, it is also possible to monitor its cut-in speed. In particularly, wind farms can ensure that turbines do not spin at maximum speed, and only begin spinning when there is enough wind to generate electricity. Although this can result in losses in total annual energy output, it will be able to limit the annual bat and bird deaths.

There are also alternative methods that should be added onto the ideal wind farm. In order to limit bat mortality, one excellent method is the use of electromagnetic fields. In particular, radio frequency's lie on a very safe zone of the electromagnetic spectrum. This can prevent bat traffic

[6] Arnett, E. B., Huso, M. M., Schirmacher, M. R. and Hayes, J. P. (2011), Altering turbine speed reduces bat mortality at wind-energy facilities. Frontiers in Ecology and the Environment, 9: 209–214

from the wind farms which can limit the bat mortality rate. Furthermore, the total diameter of the wind turbines should be less than 70 meters, with a height of 70 meters. Although the results of the studies shown in section 5.3 suggest a height of 70 meters, I propose a much higher wind turbine, at 140 meters. By utilizing a much higher wind turbine, the turbines can capture more air over time, and the chances of reaching cut-in speeds would be much higher. Furthermore, in Figure 2, it is clear that higher wind turbines are more likely to be installed due to the larger amount of ideal areas for 140-meter wind turbines.

7. Final Remarks

Wind energy has many benefits. Its low cost can be a main deciding factor when choosing between different energy sources. Because it is a renewable energy source, wind energy will never run out. It has little to no emissions, and more importantly, there are lots of concurrent improvements being made and investment in wind energy to optimize energy output. Furthermore, of these different improvements, there really needs to be a method of combining the improvements into one single wind farm. This will amplify the effects of the newer technologies maximizing efficiency in wind turbines, yet also mitigate the avian mortality problem.
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