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A3 5 Harnessing Hurricane Power

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Abstract

This paper investigates the effectiveness of using wind turbines in hurricanes to generate power. We use power equations to find out how long it would take a large turbine, in different hurricane strength categories, to generate enough power to meet the University of Leicester's yearly campus power usage. We find that for the strongest hurricanes (Category 5), it would take 30 hours to match the 2020/2021 energy usage of UoL's campus.

Introduction

In this article, the power generated by a hypothetical wind turbine inside a hurricane is investigated. We find the time taken for a wind turbine to generate enough power, in a hurricane, for the yearly usage of the University of Leicester's campus. To investigate this, we derive an equation which includes the energy usage of the campus and the power generated by a wind turbine, which we then use to find the time required. As hurricanes are categorised depending on strength, we calculate results for all five different strength categories, which yield different results. We make the assumptions that the hurricane has constant wind speeds throughout its body and that the wind turbine will not be damaged by the hurricanes. Any further assumptions are listed throughout the method.

Method

To find the time required for a wind turbine to generate enough power to meet the University of Leicester's yearly energy consumption, we must form an equation. We start with Equation (1), which gives the power attained from a wind turbine.

$$P = \frac{1}{2} C_p \rho R^2 v^3 \tag{1}$$

Within this equation, C_p is an efficiency coefficient, ρ is the density of air, R is the length of the wind turbine arm, and v is the wind speed. The energy used by the University of Leicester campus was approximately 84,500,000 kWh [1] in the 2020/21 academic year. Therefore, we have a value for energy, and an expression for power, which can be substituted into Equation (2) to give time.

$$t = E/P, \tag{2}$$

Where P is power generated by the turbine, E is the universities energy usage and t is time required. Equation (1) can be substituted into Equation (2), giving an expression for the time required. This is shown in Equation (3).

$$t = \frac{2E}{C_p \rho R^2 v^3}, \tag{3}$$

In this equation, we must find values for its constituents. Turbines usually have an efficiency between 20% and 40% [2] and so we take the value of C_p to be the mean, 0.3. For the value of ρ (air density), we take the density of air at 25°C, as this is roughly the temperature required for hurricanes to form [3]. The density of air at this temperature is 1.168 kg m^{-3} [4]. For the length of the wind turbines arm, we took this to be 107 m, as this is the arm length which the largest offshore turbine has [5]. Now the final variable which we need is the velocity of different category hurricanes which is shown in Table 1. Therefore, we can substitute all these values into Equation 3 to give our results.

Results and Discussion

Hurricane Class	Wind Speeds (km/h) [6]	Time Taken (hours)
Category 1	153	175
Category 2	177	113
Category 3	208	70
Category 4	251	40
Category 5	275	30

Table 1: The time taken to power UoL's campus using wind turbines in different hurricane strength categories

The results from these calculations find that using wind turbines in hurricanes to generate power is an effective method as the entire campus of the University of Leicester could be powered for a year, based on previous data, with a maximum of 175 hours and a minimum of only 30 hours. In reality, wind turbines would incur significant damage in a hurricane, especially in the higher categories. However, if the technology was available to build hurricane resistant turbines, this could prove to be a valuable method for generating power. It is also worth mentioning that the 2020/21 energy usage data used in this report may not be entirely accurate when compared to recent years. This is because the academic year of 2020/21 was in the midst of the COVID-19 pandemic, when students were not on campus. The energy usage of this year would have been much less. For more accurate results, wind speed dynamics should be looked at in more depth as our assumption of constant wind speed throughout the hurricanes, may have led to an error in our results.

Conclusion

To conclude, we find that if the University of Leicester's campus were to be powered for a year by wind turbines, it would take between 30 and 175 hours to generate this energy. We acknowledge, however, that our results are simplified due to the assumptions we made in our method. We also find that wind turbines harnessing the natural force of hurricanes could be an effective way of generating power in the future.

References

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