Journal of Physics Special Topics
An undergraduate physics journal

# P3 6 Extraterrestrial Wind Turbines - Which Planet Is Most Suitable?

T. Miller, F. Astrophel, O. Simpson, E. Rodgers

*Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH*

December 15, 2023

**Abstract**

Wind power is a potentially essential form of sustainable energy, using the energy of wind to turn turbines and generate electricity. Wind turbines are usually found on the windiest places on Earth; however, there are windier places beyond Earth, in our own solar system. The winds of Neptune, for example, reach approximately 600 m/s, the fastest in the solar system. In this paper, a continuation of Tang et. al's work on the power generated by wind turbines, we find that the power generated by one turbine on Neptune is 235 GW, which means 13 Neptunian turbines are required to provide enough power for the world.

## Introduction

In 2022, global wind power production was 2,100 terawatt-hours (TWh) [1], for the whole year. Global energy consumption in 2022, however, was 25,530 TWh [2], meaning that wind power accounted for only 7.2 % of global power production in 2022. With the power generated by wind turbines limited by the wind speed of Earth, looking to other planets to build wind farms could be a viable option.

Tang et. al derived an equation for the power generated by a wind turbine in their 2023 journal article [3], and stated values for the power generated by assuming the wind speed to be 7 m/s on each planet, with differences in power arising due to differences in atmospheric density. In this paper, we expand upon this idea by considering the vastly differing wind speeds in the different planets across the solar system, and determining which planet is most suitable for an off-world wind farm, and how many turbines would be needed there to provide enough power for Earth for one year.

## The Turbine Equation

Wind turbines operate by converting the kinetic energy of wind into electrical energy by turning a generator connected to the blades of the turbine. The total power (in watts) generated by a turbine is given by:

$$P = 0.5 \times C_p \times \rho \times \pi \times R^2 \times V^3 \qquad (1)$$

Where $C_p$ is the coefficient of performance (a measure of efficiency), $\rho$ is the air density (in kg/m$^3$, $R$ is the blade length in m, and $V$ is the wind speed in m/s [3]. In order to calculate the power generated by a wind turbine on another planet, we need to determine $V$, $R$, $\rho$, and $C_p$. The maximum possible efficiency of a turbine is 56.9 % [5], as a result of Betz's law, so we shall use 0.569 as our value for $C_p$. A typical modern wind turbine has a blade length of approximately 52 metres [6], so we will use this as our value

| Planet | Wind Speed (m/s) | Air Density ($kg/m^3$) | Power (GW) |
|---|---|---|---|
| Venus | 1 [4] | 65 [4] | 0.00157 |
| Mars | 30 [4] | 0.02 [4] | 0.0009 |
| Jupiter* | 179 [4] | 0.16 [4] | 2.22 |
| Saturn | 400 [4] | 0.19 [4] | 29.4 |
| Uranus | 250 [4] | 0.42 [4] | 15.9 |
| Neptune | 600 [4] | 0.45 [4] | 235 |

Table 1: Physical Parameters of planets with atmospheres. *Jupiter's wind speed is taken from inside the big red spot.

for $R$. The wind speed V and the atmospheric density $\rho$ are the numbers that will determine the power generated from planet to planet.

**Windy Planets**

In order for a planet to host a wind farm, it must have an atmosphere; therefore Mercury has been excluded since it doesn't have an atmosphere. Additionally, no other atmospheric bodies (such as Titan or Triton) have been considered in this paper; these may be viable topics of future research.

All of the wind speed and atmospheric density data was taken from NASA's Planetary Factsheet series of webpages [4], with values selected for surface speed and density where possible to better represent the environment wind turbines would be in.

**Results**

Table 1 shows the power generated by a single wind turbine on each planet. It can be clearly seen that the turbine on Neptune generates the most power, at 235 GW, while Venus generates the least (0.00157 GW), despite the high air density. One turbine on Neptune running for a whole year (8760 hours) would produce a total of 2058.6 TWh of electricity. Thus, in order to totally power the Earth for a year, we would need to build 13 turbines total on Neptune.

**Conclusion**

Despite the theoretical potential of Neptune as a site for a wind farm, in reality Neptune is an undesirable candidate for a few reasons: firstly, it is a very distant planet, and therefore very difficult to reach, to the point that the power needed to build the wind farm would likely take years to be offset by the wind farm itself. Secondly, the structure of the planet means building a wind farm would likely be impossible. Of the terrestrial planets, where wind farms are easier to build, Earth actually has the greatest potential for wind power generation, since it has faster winds than Venus but a thicker atmosphere than Mars. Therefore, despite the huge potential for power generation on Neptune, Earth is actually the best planet (in the solar system) to build wind turbines for the time being.

**References**


[1] https://www.iea.org/energy-system/renewables/wind/.

[2] https://www.statista.com/statistics/280704/world-power-consumption/.

[3] Cheuk Tang, Lewis Armitage, and Matthew Alexander. Wind power on different planets. *Physics Special Topics*, 22, 2023.

[4] David R Williams. Planetary fact sheet, 2023. https://nssdc.gsfc.nasa.gov/planetary/factsheet/.

[5] Thunder Said Energy. Windy physics: how is power of a wind turbine calculated?, 2019. https://thundersaidenergy.com/downloads/wind-power-impacts-of-larger-turbines/.

[6] Wind Energy Technologies Office. How a wind turbine works - text version.