The Effect of Changes in Air Pressure and Temperature on Wind Energy Production

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Research Topic

Research focus

This study assesses how weather conditions, namely temperature and barometric pressure, affect the amount of energy produced by wind turbines in Union Township. The variance of weather patterns in the Great Lakes Region prompted this study. Fluctuating weather conditions could cause wind turbines to produce more or less energy. All data was collected at a constant wind speed of 10 miles per hour. Data was collected and analyzed over a 60 day period.

Hypothesis

At a constant wind speed of 10 miles per hour, temperature and barometric pressure directly correlate with the amount of energy produced by the wind turbines collectively.

Null hypothesis

At a constant wind speed of 10 miles per hour, temperature and barometric pressure have no impact upon the amount of energy produced by the wind turbines collectively.

Background Information

Air pressure, temperature, and wind

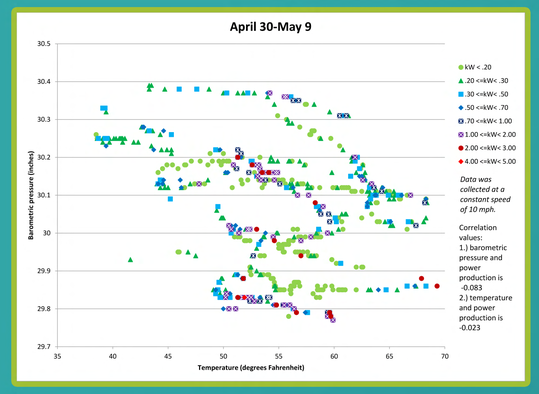
Air pressure, temperature, and wind are inter-related, thus, changes in any of these elements will affect the others. The surface of Earth is heated unequally which creates constant pressure differences. As a result, solar radiation is the prime source of energy for wind. Roughness of the Earth's surfaces cause friction, resulting in variations in air movement. Earth is continually rotating, causing the Coriolis Effect. If these forces did not exist, air would flow directly from high to low pressure areas, but because these features do exist, wind is regulated by an amalgamation of forces. These forces include the pressure-gradient force, friction, and the Coriolis Effect (Lutgens & Tarbuck, 2007).

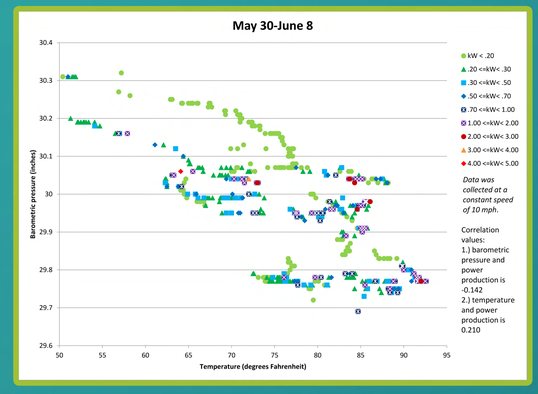
Residential scale wind turbines

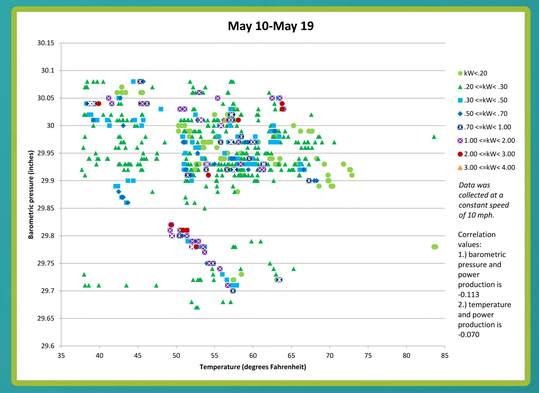
Union Township Hall of Isabella County, MI has three wind turbines installed on site for energy production and a study fellowship with Central Michigan University. Two of the three turbines are Skystream 3.7 model horizontal-axis wind turbines (HAWT). The third turbine is a Windspire standard model vertical-axis wind turbine (VAWT)..

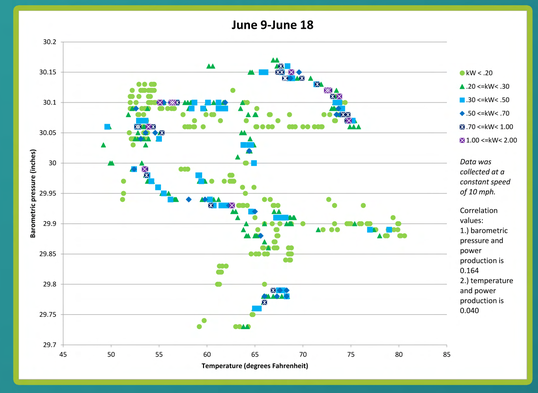
Skystream 3.7 is a residential scale wind turbine manufactured by Southwest Windpower. They are most commonly used for individual homes or small businesses within a residential area. HAWTs must be facing the wind in order to begin capturing energy because the rotor system, this includes the blades and the hub that connects them to the shaft of the turbine, and the electricity generator are at the top of the tower mechanism (Jain, 2011).

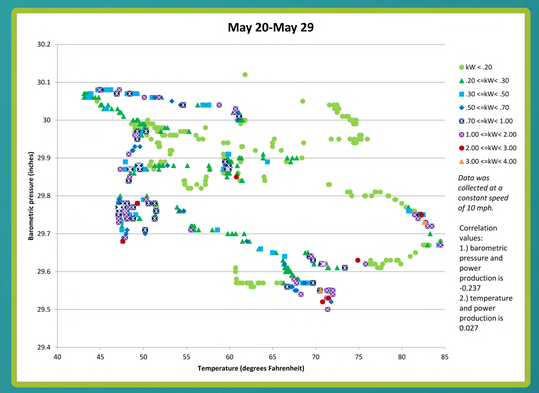
Windspire standard model wind turbines are a subtype of vertical-axis wind turbines (VAWT) classified as a low-speed Giromill or H-rotor VAWT. These unique turbines are designed and manufactured by Windspire Energy Inc., formerly Mariah Windpower (Windspire Energy Inc., 2010). VAWTs function in a different manner than HAWTs, mainly because blades of the turbine run parallel to the main shaft or axis of rotation. These turbines are viewed as easier to maintain than HAWTs because the main components of the turbine mechanism are on ground level as opposed to HAWTs that have these components at the top of the tower (Jain, 2011).

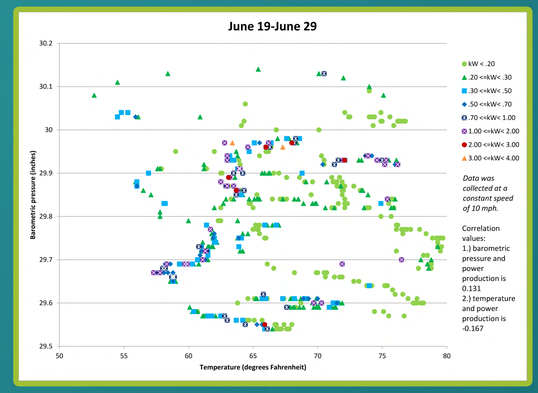












Energy production

Wind turbines are used to harness wind and convert it into electricity. The way in which these machines turn wind into power is a simple process. Blades of wind turbines are used to capture energy from the blowing wind by rotating around a rotor. The rotor of a turbine is connected to the main shaft of the machine, and in turn spins a generator which creates electricity. Electricity produced by wind turbines can be used for a single home or business or be connected in a grid of wind turbines to provide energy for multiple infrastructures (Jain, 2011).

Union Township Wind Energy Research

Research objectives

This study aims to determine whether changes in air pressure and temperature affect the amount on energy produced by wind turbines at Union Township Hall. Varying weather conditions inherent in the Great Lakes Region may contribute to an increase or decrease in wind turbine energy production. The effects of air pressure and temperature are aspects of wind energy for which little research exists.

Materials

The materials used to conduct this study were hardware and software necessary for weather and power production data collection. At Union Township Hall there is an anemometer and weather station located 825 feet away from the wind turbines that reaches 58 feet high. Figure 3.1 in the Appendix displays an image of weather station's location in relation to the turbines. The weather station measures weather data such as temperature, wind speed, wind direction, and barometric pressure. Davis Vantage Vue virtual weather station collects data once every minute. The virtual weather station logs the data and is stored on a computer at Union Township Hall. Stored weather data is accessed through Microsoft Excel spreadsheets.

Power data collected is performed in a similar manner to that of weather data. AcquiSuite A8810 data acquisition server collects power production data. A Dent Power Scout 18 power meter then reads data and is logged by Obvious Power Data Logger on a computer at Union Township Hall. Data is recorded every minute. This data can then be accessed through Obvious Building Manager Online and opened as a Microsoft Excel spreadsheet.

Procedures

Barometric pressure, temperature, and power production data was collected to analyze the possible effects on power production. Data was collected at a constant speed of 10 miles per hour which is enough speed to ensure that the turbines are producing power this resulted in 60 days of collection. After all data was compiled it was entered into Microsoft Excel in order to create graphs to display the data. On the x-axis temperature is displayed and on the y-axis barometric pressure is displayed. Data is separated into six graphs with 10 days represented on each graph. Every datum was put into a category based on the amount of power produced at that particular point. Data is represented with several different shapes and sizes in accordance with power production. A correlation equation was applied to all six sets of data and to all data together in Microsoft Excel.

Research findings

Correlation coefficients were utilized in this study to assess results. Correlation was used to compare both barometric pressure and temperature to power production in order to determine the relationship between the factors. The closer to 1 or -1 a correlation is, the stronger the relationship between the two sets of variables. A strong correlation is 0.80 or -0.80 or higher, whereas a correlation below 0.50 or -0.50 is considered weak. The analysis of barometric pressure and power production data and temperature and power production data collected, in Microsoft Excel, resulted in correlations of -0.064 and -0.016; both are weak correlations. Correlation was used to analyze each set of data separately as well. The results are as follows:

Time period	Correlation between barometric pressure and power production	Correlation between temperature and power production
April 30-May 9	-0.083	-0.023
May 10-May 19	-0.113	-0.070
May 20-May 29	-0.237	0.027
May 30-June 8	-0.142	0.210
June 9-June 18	0.164	0.040
June 19-June 29	0.131	-0.167
Total	**-0.064**	**-0.016**

The results of this study are inconclusive and the null hypothesis is accepted.

Recommendations for further study

This study shows that, for the period of this study, air pressure does not appear to have a relationship with power production by wind turbines at Union Township Hall. It would be beneficial to look at other weather-related factors that could potentially effect power production. One of these factors is wind direction in relation to each turbine. It would also be interesting to find out if there is a difference in power production in relation among all four seasons. Comparing the extreme seasons, summer and winter, would be noteworthy as well.

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