NSTA 2025
Philadelphia, PA

Eco Engineers: Introduction to Wind Turbine Design for All Levels

Projects

Maximum Energy Output

Blade Variables and Power Output

- Go Direct® Energy Sensor

Workshop Presenter

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SCAN ME

Project: Maximum Energy Output

Generating electricity from fossil fuels (primarily coal and natural gas) produces carbon dioxide (CO_2) and an array of other pollutants that are injected into the atmosphere each year. The Intergovernmental Panel on Climate Change (IPCC) estimates that 20–25% of the CO_2 produced by humans comes from the generation of electricity around the world. Increasing CO_2 concentrations in the atmosphere is one of the key drivers of climate change.

While electricity generation produces a significant amount of the CO_2 released by humans, there are millions of people around the world who do not currently have access to electricity. When individuals or communities seek out reliable electricity, they have a variety of options, including generators that run on gasoline or diesel. Developing ways to efficiently produce electricity from renewable sources, such as wind or solar power, can greatly improve people's quality of life and ability to sustainably support themselves and their communities.

Wind turbines are a rapidly maturing technology that can help reduce the carbon footprint of electricity generation and bring electricity to even the most remote communities. In this project, you will construct a small wind turbine that maximizes energy output at low and high wind speeds. This turbine could be used to provide energy that would charge small electronics or provide lighting. During the project, you will work with your group to design, test, and then optimize your wind turbine design. At the end of the project, you will submit a set of deliverables.

DESIGN REQUIREMENTS AND CONSTRAINTS

- Turbine diameter: No larger than 50 cm
- Wind speed range: 2–6 m/s
- Output: Unregulated Direct Current
- Generator: Any available DC generator or you can build your own generator
- Turbine must be robust enough to withstand outdoor conditions over time
- Turbine should track the wind direction (yaw)
- Do not exceed the project budget

DELIVERABLES

- Prototype
- Detailed design specifications (so the unit can be replicated)
- Expected energy output over a 24 hour period at wind speeds of 2 m/s, 4 m/s, and 6 m/s
- Social and environmental impact statement on the benefit of your design

Blade Variables and Power Output

The blades of a wind turbine are what capture the kinetic energy of the wind so it can be converted into electrical energy, and therefore, blade design and engineering is one of the most complicated and important aspects of wind turbine technology. When designing blades, engineers try to develop blades that extract as much energy from the wind as possible throughout a range of wind speeds. Engineers must also consider durability and affordability when selecting materials for the blades.

Over time, engineers have experimented with many different shapes, designs, materials, and number of blades to find what works best. In this experiment, you will experiment with different blade designs to maximize power output.

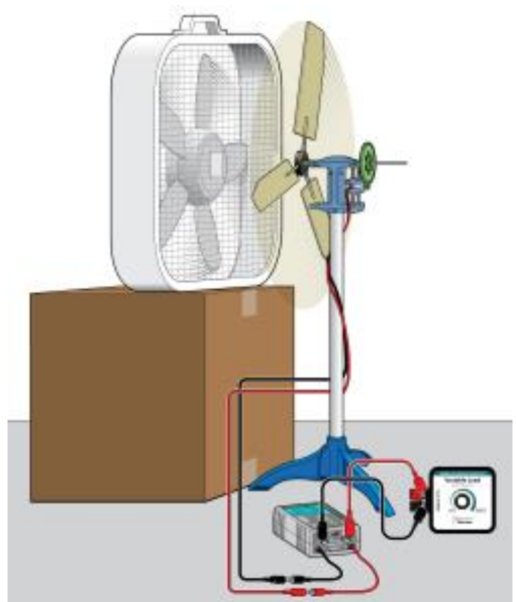

Figure 1

OBJECTIVES

- Test blade design variables.
- Understand how blade design variables affect power output.
- Evaluate data to determine which blade design is best at generating power.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Energy
Vernier Variable Load
items needed from the Advanced Wind Turbine Kit:
  Wind Turbine with Nacelle, Gears, and Generator, assembled
  Wind Turbine Hub
  Blade Pitch Protractor
  2 wires with clips
fan
ruler
blade materials
scissors and hot glue
safety goggles

PRELIMINARY QUESTIONS

1. What are some blade variables that may affect turbine performance?
2. What are some variables other than blades that may affect turbine performance and power output?
3. Choose a blade variable to adjust for improved turbine power output. Why did you choose that variable?

PROCEDURE

1. Create a plan to collect data for the blade variable you are testing. You will modify the blades 3–5 times for your blade variable. For example, if you are testing blade pitch, you will collect data for 3–5 different angles.
2. Set the switch on the Energy Sensor to External Load. Launch Graphical Analysis. Connect the Energy Sensor to your Chromebook, computer, or mobile device.
3. Set up the equipment.
   a. Connect the wind turbine to the Energy Sensor Source terminal wires.
   b. Connect the Variable Load to the Energy Sensor External Load terminals.
   c. Connect blades to the wind turbine based on your plan. For example, if you are testing blade length, your blades should be at the longest length that you will test.
   d. Position the equipment as shown in Figure 1. Align the center of the fan with the center of the wind turbine hub. Measure the distance between the fan and the turbine hub and ensure that the distance remains constant throughout the experiment.
   e. Clear off your area and make sure that when the fan and the turbine are moving, nothing will be in the way.

4. Check the current and voltage values.
   a. Put on safety goggles and turn on the fan. The wind turbine should be spinning. **Caution**: Do not stand in the plane of rotation of the rotor.
   b. Note whether the current or voltage values are positive, negative, or zero.
   c. Turn the fan off.
   d. The setup is correct if the values are positive. If the values are negative or zero, switch the wires connected to the Source terminal wires so they are connected to the opposite terminal wires.
5. Adjust the load.
   a. Turn on the fan to the highest setting. Wait 30 seconds, or until the fan and the turbine blades reach a constant speed.
   b. Note the Resistance value in the meter. Adjust the Variable Load until the resistance is approximately 40 Ω or equal to the internal resistance of the generator you are using.
6. Collect data and determine the mean power.
   a. Click or tap Collect to start data collection. Data will be collected for 30 seconds. When data collection is complete, graphs of potential *vs*. time and current *vs*. time are displayed.
   b. Click or tap View Options, ⊞, and choose 1 Graph.
   c. Tap the y-axis label and select Power only. A graph of power *vs*. time is displayed.
   d. Click or tap Graph Options, 📈, and choose View Statistics to determine the mean power value. Record the value in the data table.
7. Collect data for the second trial.
   a. Click or tap Collect to start data collection. Data will be collected for 30 seconds. When data collection is complete, turn off the fan.
   b. Click or tap Graph Options, 📈, and choose View Statistics to determine the mean power value. Record the value in the data table.
8. Collect additional data.
   a. Modify the blades according to your plan.
   b. Return the fan and wind turbine to the correct positions. Check the distance between the fan and turbine. This distance should be the same each time you collect data.
   c. Turn on the fan to the same setting. Wait 30 seconds, or until the fan and the blades reach a constant speed.
   d. Repeat Steps 7 two times to collect a total of two runs of data for this modification.
9. Repeat Step 8 until you have collected all the data that you need to test your variable.

DATA TABLE

Variable: ________________	Trial	Power (mW)	Average power (mW)
	1		
	2		
	1		
	2		
	1		
	2		
	1		
	2		
	1		
	2		
	1		
	2		

PROCESSING THE DATA

1. Calculate an average power value for each modification.
2. Create a graph of average power *vs*. the variable you tested.

ANALYSIS QUESTIONS

1. Which blade modification produced the greatest power output? The least?
2. If you had the opportunity to collect data again, how would you modify your blades while still testing the same variable?
3. Share your results with the rest of the class. When you do this, describe your testing plan, how you designed the blades, and your results. After you have heard all the results, use the information to write a paragraph explaining which variable has the greatest affect on power output.

EXTENSIONS

1. Summarize the group findings in a report. Answer at least some of the following questions in your summary.
   - What variable has the greatest impact on power output?
   - What type of blades were the most powerful at low speeds? High speeds?
   - What number of blades resulted in the most power output?
   - What shapes worked best?
   - What length worked best? Did longer blades bend in the wind? Was this a problem?
   - What problems did you encounter?
   - What happened when the diameter of the turbine rotor was bigger than the diameter of the fan?
2. Use the collected data to design wind turbine blades that result in the greatest power output and test what you predict will be the best combination.
3. Test blades at a different wind speed. Does this affect the power output?