UNIT PROJECT

Build a Wind Turbine

Humans have used wind energy for thousands of years. Wind provided the energy to the blades of early windmills, which were attached to machinery that ground grain or pumped water. It was not until the late nineteenth century that people started to use wind turbines to generate electricity. Engineers have continued to optimize the design of wind turbines to make them more efficient. You may have seen large "farms" of wind turbines with their blades turning in the wind. California and other states have invested a lot of resources in optimizing their use of wind energy to reduce their dependence on fossil fuels.

It takes several steps to produce electricity from wind energy. First, wind turns the blades of the turbine, which are attached to a central hub called a rotor. The rotor connects to a shaft that spins. This shaft is connected to a series of gears, the final gear of which is connected to another shaft that spins the mechanisms in the generator. The series of gears varies in different wind turbine designs, but in all designs their main purpose is to regulate rotational speed of the generator shaft, so it rotates at the proper speed to work the generator. As the generator shaft spins, mechanical energy is changed into electrical energy as a wire coil and a magnet rotate to induce an electric current.

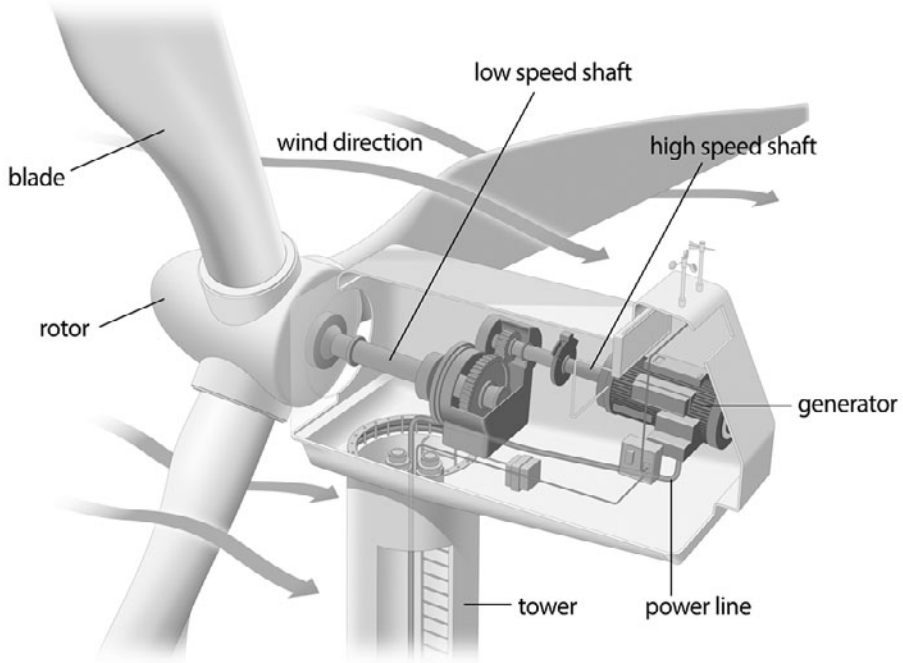
MATERIALS

- indirectly vented chemical splash goggles

POSSIBLE MATERIALS

- cork stopper
- DC motor to act as generator
- fan
- LED light bulbs, red, white, and blue
- scissors
- construction materials: plastic piping, cardboard tubes, cardboard, wood or metal rods, tape, wire

Blade design is particularly important for wind turbines. The number of blades, material, shape, size, and the angle the blades are attached to the rotor all impact how well the turbine will be able to convert wind energy to electrical energy. This is because all of these factors impact how quickly the blades turn. If the blades turn too slowly, they allow too much wind to pass through without harnessing that energy. If they turn too quickly, they may create drag and will not harness the maximum amount of energy.



Wind energy is a renewable energy source because there is an endless supply of wind. Wind is also a clean energy resource, as it does not release pollutants or excessive amounts of carbon dioxide gas into the atmosphere. This doesn't mean generating electrical energy from wind energy doesn't have drawbacks. Large wind farms are expensive to construct, can detract from the aesthetics of the landscapes they occupy, and be a hazard for flying animals such as birds and bats.

Your team is tasked with designing, building, testing, and optimizing the blade design for a scale model prototype of a working wind turbine. You will decide how many blades to use, what to make the blades out of, the shape and size of the blades, and the angle to attach them to the rotor. Your blades will need to attach to a rotor that will attach to a spinning, DC motor. The motor will connect to wires that will connect to the wires from the LED. Your teacher will help you set up your circuit.

A fan set to low or medium speed, set 0.5 meters away from the prototype, will be used to simulate wind conditions on a mildly windy day. The best wind turbine designs will be able to harness power even on days with very little wind.

DESIGN CHALLENGE Your model wind turbine must be able to produce enough electrical energy to power red, white and blue LEDs. The red LEDs require the least amount of energy to light, and blue LEDs require the most amount of energy. You will test each LED individually and optimize your design to increase its performance.

SAFETY INFORMATION

- Wear indirectly vented chemical splash goggles during the setup, hands-on, and takedown segments of the activity.
- Do not make the wind turbine blades out of metal or any material with sharp edges, as they could cause cuts while spinning.
- Do not touch the spinning blade or try to stop or slow down the spinning blades with their hands or other objects.
- Use caution when working with the light bulb connected to generator, because it can get hot and burn your skin.
- Use caution when using sharp tools, which can cut or puncture your skin.
- Use only GFI protected circuits when using electrical equipment, and keep away from water sources to prevent shock.

DEFINE THE PROBLEM

1. Write a statement identifying the problem you are designing a solution for. How will you evaluate your design?

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2. Identify the criteria for a successful solution. Explain your reasoning.

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3. Identify the constraints that will impact a successful solution. Explain your reasoning.

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CONDUCT RESEARCH

Research the history of wind turbines. Consider the following in your research:

- Are different designs used for different purposes?
- How have the designs of the blades changed over time?
- What materials are used to build wind turbines?
- How have engineers optimized the design of modern turbines to increase their efficiency?
- Are there any environmental concerns associated with wind turbines? How can these be handled?

DESIGN SOLUTIONS

1. In small groups or as a class, brainstorm potential designs and materials and evaluate them against your defined problem and criteria. Consider the following questions as you brainstorm:
   - How many blades will you construct for your wind turbine?
   - What materials will you use to make your blades and what shape will they be?
   - At what angle will you attach your blades and how will you attach them?
2. In your Evidence Notebook, make a decision matrix to use to choose the solution design that best meets the criteria.
3. Make a conceptual model of your selected design in your Evidence Notebook that includes the problem your wind turbine will solve, the components of your wind turbine, and the materials you will use for the prototype.
4. Have your teacher approve your design before you begin building your prototype wind turbine.

TEST

1. In your Evidence Notebook, develop a plan for testing your prototype. Write out a description of your plan and make sure to include the following:
   - how many trials you will perform
   - how long each trial will last
   - how you will identify design aspects to optimize to produce more energy
2. Consult with your teacher and get approval of your testing plan before carrying it out.
3. Test the red LED first, and document how well your design performed. If the red LED lights up, test the white LED using the same procedure. If the white LED lights up, move on to testing the blue LED.
4. Document the testing process using data tables and using digital photos or videos and/or drawings. This documentation will also be useful for your presentation at the end of the project.

OPTIMIZE

If you were unable to light up the blue LED during the initial testing phase, how could you optimize your design to produce more energy? Return to your original plans and consider changing the blade shape, material, angle, or number of blades. Use the observations you made in the testing phase to influence your decisions. Continue to optimize your design until you light the blue LED.

Once your design lights up the blue LED, consider how you could optimize your design to make it more economic. Could you use fewer materials to achieve the same results?

ANALYZE

Review the data you collected. Answer the following questions to describe the effectiveness of your efforts to optimize the design of your wind turbine.

1. How did your design changes affect the performance of the wind turbine?

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2. Which parts of your model could be further changed to increase its performance?

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LESSON 1: HUMAN POPULATIONS AND ENERGY USE

In your Evidence Notebook, make a table that lists the advantages and disadvantages of wind energy. List at least three advantages and three disadvantages. Do you think wind energy is a long-term solution to the increasing energy needs of California? Explain your answer.

LESSON 2: ENERGY FLOWS AND FEEDBACK IN THE EARTH SYSTEM

In your Evidence Notebook, draw a simple model of how convection causes air in the atmosphere to move as wind.

Answer the following questions in your Evidence Notebook:

1. What characteristics would engineers look for when choosing areas to build wind turbines to generate electricity?

2. In 2010, California generated about 4 percent of its electrical energy from wind energy. Research the percentage of electric power that California generated with wind energy more recently. What are the benefits California gains from using wind energy to generate electrical energy?

LESSON 3: SOLUTIONS TO ENVIRONMENTAL PROBLEMS

In your Evidence Notebook, draw a diagram explaining how excess electrical energy from a wind generator can be stored for later use. What are advantages and disadvantages of storing energy in this way?

DRAW CONCLUSIONS

Write a conclusion demonstrating your findings from this investigation. In your conclusion, answer the following questions:

Claim How are the blades of wind turbines designed to maximize the amount of wind energy converted into electrical energy?

Evidence Give specific examples from your data to support your claim.

Reasoning Explain how the evidence you collected supports your claim. Describe, in detail, the connections between the evidence you cited and the argument you are making.

EXTEND

Wind turbines are used in a variety of environments and are developed to harness different types of wind. In addition to being used on land, wind turbines are also used at sea and in areas with extremely high wind speeds, such as where typhoons are common. Some wind turbines are even modified to be bladeless so they don't endanger local wildlife. Investigate at least three other wind turbine designs. How are the blade designs and construction materials different for each type? Do they all work the same way?

COMMUNICATE

Develop a presentation that describes your design process. Be sure to address these points in your presentation:

- how you designed your wind turbine
- which variables you considered in your original design and then during optimization
- how you tested your designs
- how you optimized your design and whether and how its performance changed
- how you considered the needs of your users during the design process

Use evidence gathered over the course of the project to support your claims in your presentation. Photos, drawings, data tables, and graphs may be useful ways to present evidence in your presentation.