ACTIVITY 4

Designing Model Wind Turbines

LABORATORY

v 1.0

Maintenance workers repel
from a large wind turbine.

4 : DESIGNING MODEL WIND TURBINES

GUIDING QUESTION

How can understanding a model wind turbine help make a decision about using turbines in a community?

INTRODUCTION

There are many types of energy sources that can be used to generate electricity. Common sources include fossil fuels (such as coal and natural gas), hydroelectric, thermal, nuclear, and tidal. Generating electricity from any of these sources relies on energy transformations. An energy transformation is the change of energy from one type to another, such as from chemical to thermal energy.

In this activity, you will investigate how to design a model wind turbine to generate more power during its energy transformation. You will play the role of engineers developing expertise in energy transformations and wind turbine technology. As you design your model wind turbine, you will consider how people with firsthand experience with experimentation in a particular subject are more likely to know facts about that subject than other people. Then, you will have the opportunity to put your expertise into the context of a decision for Vanwick.

Engineers inspect a wind turbine blade at a testing facility in Denmark. Photo courtesy of Moog.

If you need to review the concept of energy transformations, you will find a Science Review at the end of this activity.

CONCEPTUAL TOOLS

WEAVING FACTS & VALUES IN DECISION-MAKING

MATERIALS LIST

FOR THE CLASS

- FAN STATION

FOR EACH GROUP OF FOUR STUDENTS

COMPONENTS NEEDED TO BUILD A MODEL WIND TURBINE:

- 1.5 V – 3 V MOTOR-GENERATOR
- TURBINE HUB THAT FITS ON THE SHAFT OF THE MOTOR
- 5–10 SMALL DOWELS
- SHEET OF CARDSTOCK OR THIN CARDBOARD
- RING STAND OR SIMILAR
- 2 WIRES WITH ALLIGATOR CLIPS
- VOLTMETER OR MULTIMETER
- PROTRACTOR
- RULER
- SCISSORS
- TAPE

FOR EACH STUDENT

- STUDENT SHEET 4.1 "Wind Turbine Design Testing"
- SURVEY RESULTS FROM ACTIVITY 3

PROCEDURE

PART A: DESIGNING A WIND TURBINE

1 In your group, discuss reasons why one wind turbine might generate more power than another. Record your ideas in your science notebook. You may want to draw a diagram or picture to illustrate your ideas.

2 Your teacher will provide your group with one variable to test in your wind turbine design. A variable is a feature, factor, or result that can change or vary. Record your variable in your science notebook and discuss how you might test that variable.

3 In your group, design a wind turbine model to maximize the voltage produced by changing only your assigned variable. Your model should have a similar setup to the following diagram. Follow your teacher's instructions for building the model.

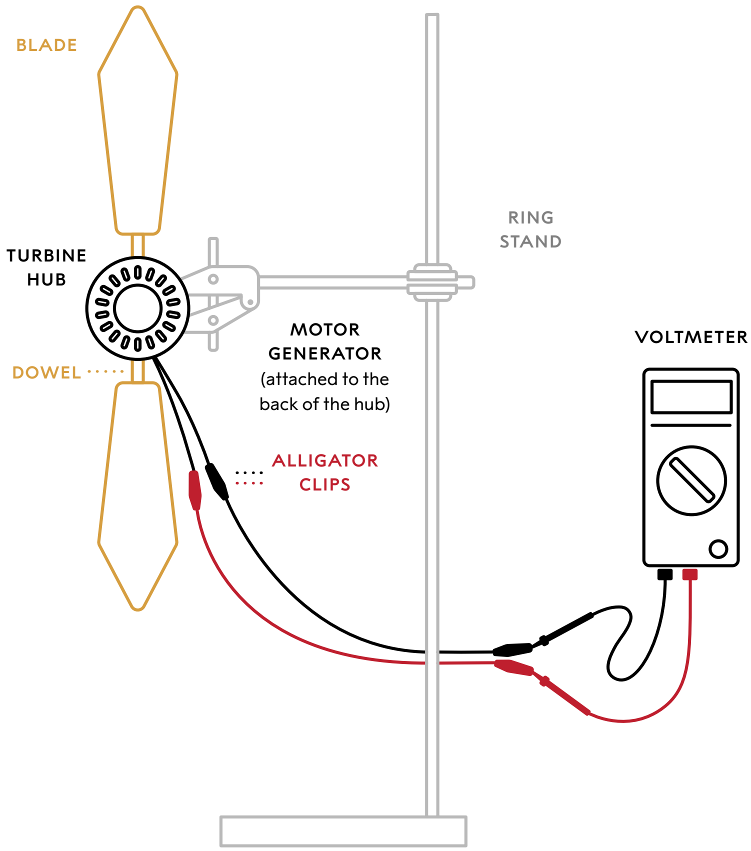


FIGURE 4.1
Wind turbine model setup

4 Before testing your model, consider your reasoning for the design. Record your ideas in the first row of Student Sheet 4.1, “Wind Turbine Design Testing.”

5 Test your first design at the classroom fan station. For every test, make sure that
- the turbine is at the same distance from the fan.
- the fan is on the same speed setting.
- the turbine faces directly into the fan.

Record the peak voltage on your student sheet. It is not important if the voltage reads “+” or ”–”; just record the number.

6 With your group, discuss possible changes to the design in order to maximize the amount of electrical power (measured by the voltage) your model wind turbine can produce.

7 Revise your model wind turbine design based on your test results two or three more times. Each time, complete a row of the table on Student Sheet 4.1.

8 Follow your teacher’s instructions to meet with another pair from another group who experimented with the same variable. Share your findings about the variable you were testing and the designs that led to the best results. Discuss similarities and differences in your designs and how those led to similar or different voltage readings.

9 Follow your teacher’s instructions to meet in a group in which each member experimented with a different variable. Share your findings about the variable you were testing and the designs that led to the best results. Discuss which aspects of each group’s design might be combined for a better model wind turbine.

10 With this new group, redesign the model wind turbine to incorporate the expertise from each member. Build and test this version. Record your work on Student Sheet 4.1.

11 Use the test results from the previous step to make a final design. Build and test this version. Record your design, voltage readings, and observations on Student Sheet 4.1.

12 As a class, compare the similarities and differences in the designs. Summarize the variables that did or did not contribute to increasing the measured voltage. Discuss how the design could be changed further to possibly improve results.

PART B: CALCULATING POWER

13 Use the highest voltage reading from your designs to calculate the power output of the turbine. The power of a device is the rate at which energy is transformed. It is calculated using the formula:

$$P = IV$$

where **P** is the power output of the turbine (in watts, W),
I is the current generated by the turbine (in amps, A), and
V is the voltage generated by the turbine (in volts, V).

For the model turbine, the estimated current coming out of the turbine is 0.1 A. Conduct your calculation in your science notebook and check your answer with your group members.

14 A typical laptop needs a power source of about 60 W. Calculate the approximate number of your model turbines that would be needed to power a laptop. Record this information in your science notebook. Check your estimate with your group members.

15 Look at the data (in the following table) about small and large wind turbine technologies. Calculate the number of units that would be required to meet Vanwick's power needs for each kind of turbine. Compare this to Vanwick's current electrical generation of 500 megawatts (MW) to the area. Record your calculations in your science notebook.

TABLE 4.1
Power Generation of Wind Turbines

SOURCE	TYPICAL LOCATION	APPROXIMATE MAX POWER (MW)	NUMBER OF POSSIBLE TURBINES IN VANWICK
SMALL TURBINE	RESIDENTIAL, SMALL FARM, RANCH, CITY LAND	0.010 MW	5
LARGE TURBINE	UTILITY COMPANIES	8 MW	52

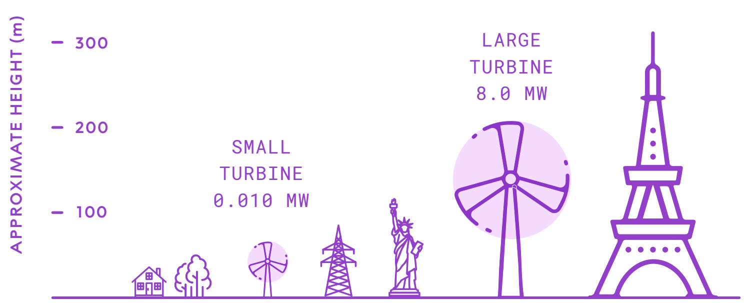


FIGURE 4.2
Scale of small and large wind turbines

16 Discuss what your calculations mean for Project REV. Specifically, how do wind turbines support, or not support, Project's REVs goal of reducing greenhouse gas emissions.

BUILD UNDERSTANDING

1. Some community members think that Vanwick should use only wind turbines to power the city. If this were the case, some of the wind turbines would need to be located close to residences, near the school, and in the city park. Review the stakeholder values surveyed in Activity 3. Do you think Vanwick should decide to use all the wind turbines possible to power the city? Explain your decision, including the following:
   - the relevant facts and stakeholder values and how they affected your decision.
   - the predicted outcome(s) of your decision.

2. Facts about the maximum amount of power generated by different-sized wind turbines were presented in this activity. However, the actual power generated at any given moment is usually lower than the maximum generation rate. For example, the average power generated by a wind turbine is 20%–40% of the maximum.
   - **a** Make a list of variables that can affect the amount of power produced by wind turbines.
   - **b** How would these variables affect the number of turbines needed to meet Vanwick's power needs?

CONNECTIONS TO EVERYDAY LIFE

3. Imagine you know someone who has an electric car. It is charged by plugging it into an electrical grid. The grid is powered by a coal power plant. They make the following claim of fact: ***This vehicle provides zero emissions to the atmosphere.***
   - **a** Do you agree or disagree with their claim of fact? Explain.
   - **b** Suppose the person provided an information source for their claim of fact. Would that change your thinking about the claim of fact? Explain why or why not.

EXTENSION

Wind farms kill an estimated 140,000 to 328,000 birds every year in North America. Birds can fly into the wind turbine's spinning blades and die instantly. Design a solution to this problem. You may consider making a diagram, writing a description of your solution, or building a model to add to your model wind turbine from this activity. Share your ideas with someone. Then, investigate how engineers are trying to solve this problem and compare your idea with theirs.

KEY SCIENTIFIC TERMS

energy transformation
power
variable

SCIENCE REVIEW

Energy Transformation

Energy can cause objects to change, move, or do work and appears in many forms. From our everyday experiences, energy seems like it is something that people use up or consume. Although it often appears that energy is used up, it has not gone away. Instead, it has been transferred to another part of the system or transformed into another type of energy. For example, when chemical energy stored in the food we eat gets released, it enables our bodies to perform the processes that allow us to survive and grow. Or when the chemical energy in wood is released by burning the wood, it is transferred to the environment as thermal energy and light.

These forms of energy are grouped into two types—kinetic and potential. Potential energy is stored energy that has not yet been used, such as energy stored in the oil in a furnace, a buildup of electric charge on your clothes, or a rubber band that is fully stretched. Kinetic energy is associated with movement, such as when a roller coaster travels down its tracks or when a ball is thrown in the air. There are many forms of potential and kinetic energy, such as chemical, electrical, thermal, sound, light, and nuclear. The table that follows provides a short description of different types of energy. The unit for energy in the International System of Units (SI) is the joule (J), which is used for all kinds of energy types.

While we cannot observe energy directly, we can detect when it is transformed from one form to another. For example, when an object falls, its gravitational potential energy is transformed into kinetic energy of motion. When hot water is mixed with cold water, thermal energy is transferred into the cold water. We can observe that the cold water warms up, and the hot water cools down. Whenever energy is transformed or transferred, the total amount of energy beforehand must be equal to the amount afterward, regardless of the process or energy types involved. This is known as the Law of Conservation of Energy.

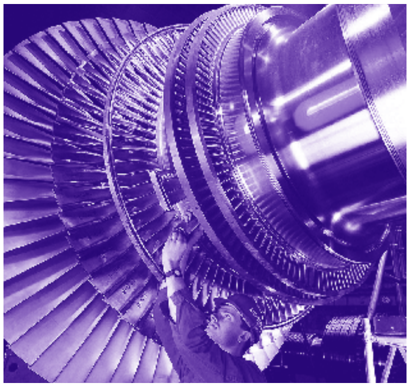
TABLE 4.2
A summary of energy types

ENERGY TYPE	NAME	DEPENDS ON	DESCRIPTION	EXAMPLE
Potential energy	Chemical	Type of substance	Energy stored in the bonds of atoms	Energy stored in fossil fuels and food
	Elastic	Springiness of object	Energy stored by stretching or compressing	Energy stored in a stretched rubber band or compressed foam
	Electric (static)	Electric charge buildup	Energy stored by the buildup of charges (electrons or ions)	Charge building up on a person walking on a rug or combing fine hair
	Gravitational	Height and mass	Energy stored due to an object's mass and position	Energy stored due to the mass and position of a train on the top of a roller coaster or water at the top of a waterfall
	Nuclear	Atomic structure	Energy stored in the nucleus of atoms	Energy stored in uranium-238 atoms, or energy stored in the nucleus of hydrogen atoms in the center of the Sun
Kinetic energy	Electric (current)	Charge, conductivity	Movement of charge and energy from one place to another	Lightning, or electricity through wires
	Light	Intensity and frequency	Energy transferred by the rapid movement of electromagnetic fields	Sunlight or X-rays
	Motion (kinetic)	Mass, speed	Movement of an object from one place to another	Wind or a moving train
	Sound	Loudness	Energy transferred by the vibration of an object	Music in air or voices under water
	Thermal	Mass, material, and temperature	Energy transferred in transit from a hot to a cold object	Hot plate heating up water, or hot water cooling to room temperature

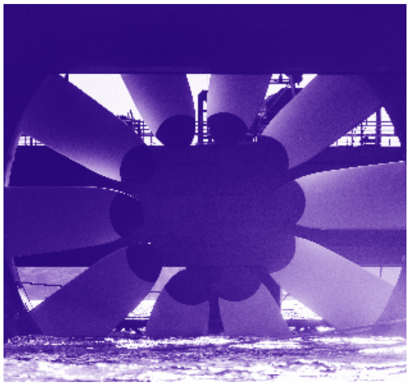
Motors and Generators

A generator converts mechanical energy into electrical energy; a motor does the opposite and converts electrical energy into mechanical energy. In a simple generator, a coil of wire spins inside a magnetic field. This produces an electromotive force (known as voltage) that results in an electrical current when connected to devices. A motor is similar to an electric generator but in this case, an electric current makes a coil move in a magnetic field. Often, a motor can also be used as a generator, provided there is some way to make the coil spin.

The most common way of making the coil spin in a generator is by pushing a gas at high velocity through the blades of a turbine that is connected to the generator. The most common gas for this is steam, which is produced by the boiling of water. The heat needed to boil the water may come from a variety of sources, such as burning fossil fuels or nuclear power. Some turbines are rotated by other moving fluids, such as water and air. Hydroelectric and tidal power stations harness the movement of water, while wind turbines harness the movement of air.



Steam turbine



Hydro turbine

Wind turbine

The word *generate*, while used by experts and laymen alike, is a misnomer. The electrical energy that comes out of a generator is not made, or generated, from nothing. It is a result of an energy transformation, so no energy was created or destroyed in the process.

Electrical Power

When generators provide electrical energy, the amount of generation is measured by the rate that the device can provide energy. Power is the rate that energy is moved or used. While the SI unit for energy is joules (J), power is measured in joules/second (J/s), which is equivalent to watts (W). Electrical devices are also rated by the amount of power they need to run properly, either in watts or kilowatts (kW).