THE POWER OF THE WIND

YOUTH GUIDE
Acknowledgments

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THE POWER OF THE WIND

The 4-H Youth Development Program promotes learning by doing and focuses on developing skills for a lifetime. This project is designed to teach youth about the wind and its uses while introducing them to engineering and engaging them in doing and reflecting on the activities.
Wind has provided power for centuries.

Sail boats were one of the earliest uses of wind power, and windmills have been used throughout the world for more than 2000 years. The word “windmill” literally means “mill (or machine) powered by wind.” Windmills have been used to pump water and grind grain. Some have been used to power saw mills and paper mills. In the late 1800’s windmills began to be used to make electricity. In the 1970’s when people started to be concerned about pollution and availability of fossil fuels, interest increased in windmills as a source of electricity.

As you explore the activities in this book you will learn about the wind and its uses. You will learn how the energy of the wind is transferred to machines to do work for us. (Note: bold words appear in the glossary on pages 52-53).

You will also learn to design and improve your projects. There are photos of possible designs for some of the projects in this book, but these are not the only designs. Use your engineering skills to perfect designs of your own.

While working with your partners and helpers you may get some new ideas about using the power of the wind. Record your thoughts and ideas in your engineering notebook. (It’s in the appendix.) Then as a final project create a wind powered device of your own.
If you could create anything using the power of the wind, what would it be?

List some of your best ideas here.

The possibilities are up to you!
Have you ever felt cold air coming in through a window or door on a cold windy day? How can you stop this air from entering? Putting tape around the edges of a window would help, but it wouldn’t look nice, and tape around a door would make opening and closing the door tricky! How effective would it be to roll up a rug and put it next to the door? How effective would it be to cover a window frame with clear plastic?

It turns out that there are many solutions to the problem of air leaking into a building. Hardware stores sell weather stripping—strips of plastic that can be nailed to a door frame to help seal the space between the door and frame. Putting in new windows can take advantage of modern energy saving technologies. Even a simple fabric tube filled with sand placed against the bottom of the door can help stop cold air from coming in.

Think of more ways to stop cold air from coming into a house.

Write or draw some of your solutions
Have you ever made something you were extremely proud of?

Maybe it was something that you really had to plan and think hard about. Perhaps you even had to change things as you were creating in order to make your idea work, but you ended up with something really great. If you ever made anything, especially if you planned it from scratch and adjusted it along the way, you have designed something.

Design is in practically everything people make. Some design is fairly simple, like planning and making a birdhouse or a tote bag. Some design is pretty complicated, like making an artificial heart or building a bridge. And some design looks simple, and is anything but, like making a doorknob, escalator, or water faucet.

There’s a certain kind of designer called an engineer. Engineers use science and math and a lot of common sense to solve people’s practical problems. When engineers talk about design, they’re usually talking about how to make something that solves a problem. One interesting thing about design is that there’s often more than one answer to a problem. To get a good solution, designers spend a lot of time thinking and asking a lot of questions. Designers may figure out many possible solutions to a problem before deciding on one to use. Engineers are no different.

Think about your day today. Was there something you used that was developed or improved by “engineering design.”

<table>
<thead>
<tr>
<th>Talk About It</th>
</tr>
</thead>
<tbody>
<tr>
<td>What did you use or see today that could be improved if it was re-designed?</td>
</tr>
<tr>
<td>What skills do engineers use to solve problems?</td>
</tr>
</tbody>
</table>
How Can We Design a Wind Powered Boat?

Design and Build

a “sailboat” that will travel in a straight line a minimum of 75 cm on a smooth surface. Your constraints are to use a Styrofoam tray (see below for examples) for the body, and to attach a mast with a sail to the tray.

Try It

• Simulate the wind with a fan.
• Position the fan on the floor or a table top.
• Mark a starting line about 30 cm from the base of the fan.
• Fasten a tape measure to the table or floor.
• Place your boat at the starting line with the fan on low.

In Your Engineering Notebook

write or sketch answers to questions you find important or interesting.

What forces influence your boat?

Where should you put the mast? How do you know?

Think about the best shape and size of the sail. Where should you attach it to the mast?

Take a picture of your best design and include it in your notebook.

You Will Need:

• Small Styrofoam tray (part of an egg carton or a supermarket tray)
• Flexible straws
• Cardboard or index cards
• Tape
• Straight pins
• Scissors
• Tape measure
• Box fan

Other Possible Materials:

• Pencils
• Stop watch with second hand
• String
• Paper cups
• Paper clips
• Pennies
• Miscellaneous hardware and office supplies

These photos show one possible design for this project, but it is probably not the best design. Use your engineering skills to invent and perfect a design of your own.
Wind Power

The Power of the Wind: How Can We Think Like an Engineer?

Wind Power for Sailboats

Early sailboats had square sails. These sails were pushed by the wind. The sailboat had to go in the direction of the wind’s push. Sails with larger areas were able to use more wind power. Later triangular sails became popular. These sails were able to use the wind to push or pull the boat. Modern sailboats use different shapes and combinations of sails to maximize the force of the wind.

Some of the first wind powered machines for pumping water used cloth sails to catch the wind. Some of these are still in use today on the island of Crete.

Talk About It

• How far did your sailboat travel?
• How fast did it go?
• Did it go straight?

Try Something Else and Test Again

• Make the sail larger or smaller. What happens?
• Change the shape or material for the sail. What happens?
• What changes did you make in the design? What happened? What shape is the best sail?
• Where should the mast be attached to the body?

Learning from Others

• What ideas did you get from seeing the designs of others in your group?
• What other design changes could you make that might change the speed?
• How does the wind move a sailboat?

Wind Power Timeline

- Evidence of sails on boats
- 4000 BCE
- 3000 BCE
- 2000 BCE
- 1000 BCE

Engineering Design with Sue Larson

Engineers design to solve problems—that means that engineers make things that serve some purpose or meet some objective. The solution has to meet certain criteria, but should be reasonable. For the previous problem of air infiltrating a leaky door or window, criteria could include: (1) must keep cold air from leaking in around the door, (2) must allow the door to be used and (3) must be attractive. You also want a solution that isn’t too expensive. Restrictions like “not too expensive” are called the constraints on the design. Many constraints deal with performance, cost, and even the schedule of when a design will be completed. Anything an engineer designs will be the result of choices and trade-offs—balancing the criteria and the constraints.

In what other situations might you need to balance choices and trade-offs?
Learn More About Engineering Design

Think About It
Think about the Wind Powered Boat activity as you discuss the Engineering Design Process and answer the questions on page 9.

Engineering Design Process

Step 1
What is the challenge?

Step 2
How have others solved this?

Step 3
What are the design criteria and constraints? Brainstorm possible solutions.

Step 4
Which of the possible solutions do you choose?

Step 5
Build prototype.

Step 6
How does it work? Try it and test again.

Step 7
How do you learn from the designs of others?

Step 8
How can you use your new ideas to improve your design?

**Talk About It**

- What was the challenge?
- How did you get your first ideas?
- What were your constraints?
- Describe your first prototype.
- How did your prototype differ from your final result?

**Learning from Others**

- How did you use the ideas of others?
- Why do you think the engineering design process on page 8 is circular?

**Restrictions** like “not too heavy” or “not too expensive” are called constraints on the design.

Anything an engineer designs will be the result of choices and trade-offs — balancing the options and the constraints.

Engineering design always contains some “do-overs” (they’re called iterations) where you learn something valuable from something that went wrong and you go back and fix it.

Part of design is testing what you’ve made to see how it works and being willing to adjust as necessary—even to the point of “going back to the drawing board.”

It’s all part of getting something that works just like you want it to.
EXPLORATION

How Do We Observe and Measure the Wind (Part I)?

A method for estimating wind speed based on observations was developed in 1805 by Sir Francis Beaufort.

**Learn about and use the Beaufort Scale**

by making this tool. Cut out the tetraflexagon in Appendices D and E. Cut on the heavy black lines and crease on the red vertical lines.

After you cut out the tetraflexagon, follow the instructions under the photos.

Draw illustrations in each of the squares that contain small print.

Fold the center flap over and under the right-most vertical column.

Fold the left-most column over the second column.

Fold both over onto the third column.

Now the wind speeds from the Beaufort Scale are matched up with their illustrations.
**WIND FACT**

*Tornadoes* make the highest wind speeds. 

*Scientists think some tornadoes may produce 400 mph winds*, but they don’t know for sure because the tornadoes destroy their wind instruments.

Flip the whole tetraflexagon over and tape. 

The Beaufort Scale showing the least wind speeds is face up.

Turn the tetraflexagon over to show the next higher group of wind speeds. 

Now the flexagon is ready to flex. Bend it in the middle. 

Let the next group of wind speeds fall open. 

Bend it in the middle again. 

Open to see the highest group of wind speeds. 

**Flex your tetraflexagon to see all four sides showing the twelve Beaufort Scale categories and their illustrations.**
How Do We Observe and Measure the Wind (Part 2)?

Record observations in your engineering notebook.

Go outside to observe the wind. Although you can’t see the wind, what can you observe that tells you how windy it is?

What do your other senses tell you about the wind?

Observe the wind at regular time intervals for several days. Make a chart and record your wind observations. Include the date and time of day. Use your Beaufort Wind Scale tetraflexagon to estimate the wind speed.

Beaufort Wind Scale
Developed in 1805 by Sir Francis Beaufort

<table>
<thead>
<tr>
<th>Force</th>
<th>Wind Speed (miles per hour)</th>
<th>WMO Classification</th>
<th>Appearance of Wind Effects On Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Less than 1</td>
<td>Calm</td>
<td>Calm, smoke rises straight up</td>
</tr>
<tr>
<td>1</td>
<td>1-3</td>
<td>Light Air</td>
<td>Smoke moves in the direction of the wind, wind vanes don’t move</td>
</tr>
<tr>
<td>2</td>
<td>4-7</td>
<td>Light Breeze</td>
<td>Leaves rustle, wind can be felt on face, wind vanes begin to move, flags stir</td>
</tr>
<tr>
<td>3</td>
<td>8-12</td>
<td>Gentle Breeze</td>
<td>Leaves and small twigs are constantly moving, light flags blow out</td>
</tr>
<tr>
<td>4</td>
<td>13-18</td>
<td>Moderate Breeze</td>
<td>Dust, leaves, and loose paper lifted off ground, small tree branches move, flags flap</td>
</tr>
<tr>
<td>5</td>
<td>19-24</td>
<td>Fresh Breeze</td>
<td>Small trees in leaf begin to sway, flags ripple</td>
</tr>
<tr>
<td>6</td>
<td>25-31</td>
<td>Strong Breeze</td>
<td>Larger tree branches move, umbrellas are hard to use, flags beat</td>
</tr>
<tr>
<td>7</td>
<td>32-38</td>
<td>Near Gale</td>
<td>Whole trees moving, hard to walk against the wind, flags extended</td>
</tr>
<tr>
<td>8</td>
<td>39-46</td>
<td>Gale</td>
<td>Twigs break off trees, walking is very difficult</td>
</tr>
<tr>
<td>9</td>
<td>47-54</td>
<td>Strong Gale</td>
<td>Slight structural damage occurs, shingles blow off roofs</td>
</tr>
<tr>
<td>10</td>
<td>55-63</td>
<td>Whole Gale</td>
<td>Whole trees are uprooted, severe damage to buildings</td>
</tr>
<tr>
<td>11</td>
<td>64-73</td>
<td>Violent Storm</td>
<td>Widespread damage</td>
</tr>
<tr>
<td>12</td>
<td>74+</td>
<td>Hurricane</td>
<td>Violent destruction</td>
</tr>
</tbody>
</table>

How does a wind vane work like the rudder on a wind mill?
• What indicators of wind speed do you observe today?
• What is the speed of the wind today?
• How do your observations compare with the official weather information?
• Can you observe different wind conditions in different areas of your neighborhood at the same time? Explain how that is possible.
• Where does the wind blow at the steadiest speeds? The fastest speeds? The slowest speeds?
• Is today a good day to fly a kite? How do you know? Use the Beaufort Scale to determine the wind speed.

Learning from Others
• What members of your community need to know the speed of wind?
• How can you teach others to observe the speed of wind?
• What projects could you do together to observe the wind and gauge its speed?

Wind Facts
June 5, 1805 a massive tornado started in Missouri and then crossed the Mississippi River into Illinois. Fish were scattered all over the countryside of Illinois. Reports were that clothing from one home that was hit was carried 8 miles.

Jet streams form more than 9 km above the Earth. They travel at speeds of 92 km/hr or more.

High Winds
All of these are names of storms that have high winds. What are the characteristics of each? How do they differ from each other?

Hurricane
Tornado
Cyclone
Tropical Storm
Typhoon
Tsunami

Use the Beaufort Wind Scale to determine the approximate wind speed in these photos of flags.

Investigate other tools for measuring the wind.
How do they compare to using the Beaufort Scale?
How Does a Pinwheel Use Wind Power?

Try It

- Cut out one of the square pinwheels in Appendix A or B.
- Cut on the lines from the corners to the center circle.
- Curl the dots at the corners to line up with the dot in the center circle.
- Push the pin through all five dots and into the eraser of a pencil.
- Blow straight into the front of the pinwheel and see it turn.

Pinwheels are easy to make and are fun toys that turn when air blows on them. A pinwheel is a turbine. The energy of the moving air becomes **mechanical energy** when the pinwheel turns.

You Will Need:

- Scissors
- Straight pins
- Pencils with erasers
- Pinwheel pattern from Appendix A or B
Talk About It

- When the wind blows straight into the front of the pinwheel, it turns. What happens when the wind blows into the back of the pinwheel or if it blows into the sides? Try both sides.
- Does your pinwheel turn easily?
- What could be improved? How could you alter your pinwheel design?

Try Something Else and Test Again
- Make another pinwheel from a larger square. What happens? Does it turn faster or slower?
- What other changes could you make to the design that might change the speed? What happens when you try out your changes?
- What adjustments can you make in the design to make your pinwheel turn better?

Learning from Others
- What determines the direction of the turning?
- How is your pinwheel like the working windmill in the picture?
- How does the pinwheel use the power of the wind?
- Your pinwheel and your boat both use wind power. How are they alike? How are they different?
- How can you help younger children learn to design pinwheels? How can you teach them how pinwheels work? Create a short lesson for children in your neighborhood.

Rotational Symmetry
The pinwheel pattern looks the same in multiple positions as it turns. This is an example of rotational symmetry. The windmill blades in the photo also have rotational symmetry.
How Can We Design a Better Pinwheel?

Try It

• Cut out the triangular pinwheel in Appendix C.

• Make a design on the pinwheel that has rotational symmetry.

• Cut on the lines from the corners to the center circle.

• Curl the dots at the corners to line up with the dot in the center circle.

• Push the pin through all three dots and into the eraser of a pencil.

• Design and build another pinwheel with more blades. Start with a hexagon, octagon or other polygon.

You Will Need:

• Scissors
• Straight pins
• Pencils with erasers
• Paper (various weights—construction paper, index cards, cardboard)
• Pinwheel patterns from Appendix C

Other Possible Materials:

• Paper plates
• Aluminum pie plates
• Paper clips
• Coffee stirrer
• Popsicle sticks
• Miscellaneous hardware and office supplies

In Your Engineering Notebook

write or sketch answers to questions you find important or interesting.

Make several pinwheel variations.
What other aspects of the design change the way the pinwheel works?
How well do other pinwheel shapes work?

Vary the number, shape, and size of the blades.
What materials work best? Is stiffer paper too heavy?
Record your observations about the various designs in your engineering notebook.
Make sketches or include photos.
• How did your group define “best?”
• Why is it important to change only one thing or variable at a time?
• Which pinwheel designs turn faster using wind energy? How do you know?

**Learning from Others**

• Which pinwheel designs does the entire group think are the best? What does your entire group mean by “best?”
• What other changes could you make to the design that might change the speed?
• Why might speed be important in working windmills and wind turbines?
• What do you observe about the blades of working windmills and wind turbines? Think about their shape, length, and speed.

**Wind Facts**

• Normal breathing causes a 5 mph “wind.”
• Sneezes can travel at a speed of 100 mph.
• The ancient Greeks thought wind was the breath of the earth.
How Can We Use Wind To Lift a Load?

Design and Build

a wind turbine that uses wind power to lift a minimum of four pennies in a small paper cup.

Try It

- Simulate the wind with a box fan.
- Position the “wind” near your turbine.
- Lift the load from the floor to a table top.

You Will Need:

• Pennies
• Cardboard or index cards
• Round pencils
• Straws (sturdy straws)
• Cardstock
• String (cotton or poly works best)
• Paper or plastic cups
• Paper clips
• Tape
• Box fan
• Stop watch or watch with a second hand

Other Possible Materials:

• Rubber bands
• Poster board
• Plastic beads for spacers
• Miscellaneous hardware and office supplies

In Your Engineering Notebook

Write or sketch answers to questions you find important or interesting.

Describe all of your attempts.
What is the maximum number of pennies your machine is able to lift?
How long does it take your machine to lift four pennies?
How long does it take to lift eight pennies? Is it twice as long?
We know that windmills were used to do work in Persia at least 3,000 years ago (Persia is now Iran). These windmills looked somewhat like modern day revolving doors. The wind pushed against the door-like paddles and turned a center shaft. The shaft was connected to a pump or to a millstone used to grind grain. These were vertical axis windmills which work no matter which direction the wind blows.

Early European windmills first appeared about 800 years ago. These horizontal axis windmills had large blades that faced into the wind like a pinwheel. The blades were often wood frames covered by cloth sails. When the direction of the wind changed the windmiller had to turn the blades to face the wind. Later, inventors developed ways for the wind to do this turning. Notice the small set of blades on the windmill in the photo.

In the later 1800’s smaller windmills were invented to help farmers in the American West pump water. These windmills were mounted on towers and had many thin blades. There was also a fantail or rudder to turn the blades into the wind. These windmills were used by American farmers to do many chores. Over time, improvements were made in the shape of the blades. Some were made of steel. During the years 1880 to 1935, several million windmills operated in the American West.

Describe your first design. What works well? What do you want to improve?

Try Something Else and Test Again

• What improvements did you make in your initial windmill?

• Which adjustments to your design made the windmill work faster and which made it stronger? Discuss your design with your partner or group. Explain the adjustments you want to make and explain why you want to make them.

Learning from Others

• Observe the turbines built by others in your group. How are they similar? How do they differ? What are some features of the turbines that lift the most pennies?

• We need energy to do work. Moving or lifting something is work. Lifting 4 pennies 20 inches is twice as much work as lifting 4 pennies 10 inches. Describe how your turbine uses wind energy to do work.

Have you ever heard the phrase “go back to the drawing board?” It means that something has gone wrong with a design and it’s time to start over. Engineering design always contains some “do-overs” (they’re called iterations), where you learn something valuable from something that went wrong and you go back and fix it. Some of these iterations happen early in the design process and some happen much later—even after something is made and the designer sees how people use it. Part of design is testing what you’ve made to see how it works and being willing to adjust as necessary—even to the point of “going back to the drawing board.” It’s all part of getting something that works just like you want it to.
Which Turbine Design Is Better for the Job?

**Design and Build**

two wind turbines. One turbine should have high **solidity** and the other should have low solidity.

**Try It**

• Simulate the wind with a box fan.
• Position the “wind” near one of your turbines.
• Test each design first with no load.
• Record revolutions per minute for five trials for each.
• Test each design lifting a paper cup containing four pennies.
• Record the time needed to lift the load 40 cm.
• Gather data for five trials for each.

**Possible Materials:**

- Pennies
- Pencils
- Straws
- Cardstock or index cards
- Box Fan
- String (cotton or poly works best)
- Paper cups
- Paper clips
- Tape
- Tape measure
- Stop watch or watch with a second hand
- Aluminum pie plates
- Miscellaneous hardware and office supplies

The blades of this older-style water pumping windmill nearly fill the circle. It has high solidity and a high turning force (high **torque**), but lower speed. The blades are about 18 inches long.

The blades of this modern electricity producing wind turbine in McLean County, IL are only a small part of the circle. The diameter of the **swept area** is 328 feet and the three blades are very long and narrow; it has low solidity. Even though it turns only 20 **rotations per minute** (rpm), the tip of one of the blades travels faster than 100 miles per hour.

The word “solidity” contains the word “solid.” Which turbine in the photos below has higher solidity?
The Power of the Wind: How Do We Use the Wind?

### Talk About It

<table>
<thead>
<tr>
<th>Trial</th>
<th>Without a Load Low Solidity RPMs</th>
<th>Without a Load High Solidity RPMs</th>
<th>With a Load Low Solidity Seconds</th>
<th>With a Load High Solidity Seconds</th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<tr>
<td>5</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Avg.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Compare your two devices. How do they perform differently? How do they perform the same?
- Which of your devices turns faster with no load?
- Which lifts the load faster?
- What happens if you increase the load?
- What forces act against the load?

### Learning from Others

- Using what you’ve learned here, what changes might you make to the device you made in the previous activity?
- In what situations would a strong turbine be important? In what situations would a fast turbine be important?

### Wind Power Timeline

- Working windmills in Persia: 1000 BCE
- Windmills in China for pumping water: 500 BCE
- Horizontal axis windmills in Western Europe: 1000
- Windmills in the Middle East used for food production: 1500
- Windmills in the American West: 2000
How Can We Use Wind Power to Produce Electricity?

Design and Build

a wind turbine that uses wind power to create electricity.

Try It

• Create rotor blades.
• Connect your blades to a cork hub.
• Insert the shaft on the motor into the cork.
• Attach the leads on the motor to the multimeter.
• Simulate the wind with a box fan.
• Position the “wind” near your device.
• Measure the electricity produced.

You Will Need:

• Cardstock or index cards
• Paper clips
• Tape
• Cork (natural or synthetic)
• Multimeter
• Box Fan
• Small motor
• LED (a string of tiny holiday bulbs, cut apart, works well)
• Wire stripper

Other Possible Materials:

• Plastic drink bottles or aluminum pie plates
• Rubber bands
• String
• Paper cups
• Miscellaneous junk, hardware and office supplies

Faster turning rotors produce more electricity. Use a systematic method for testing and developing your designs. Adjust the number, position, shape and size of the rotor blades. Refer back to the Engineering Design Process on page 8 and write about how your design evolved.

How many volts can it produce?

Can it produce enough electricity to light a small LED?

Take a picture of your best design and include it in your notebook.
Describe your first design. How much electricity did it produce? What works well? What do you want to improve?

Try Something Else and Test Again
• What improvements did you make in your initial wind turbine?
• Describe the solidity, speed, and power of your turbine.
• Which adjustments to your design made the turbine produce more electricity?
• Describe your best design. How much electricity did it produce?
• Compare your electrical output with others in your group. How is each designed to produce maximum output? What are the characteristics of the turbines that produce the most electricity?
• How much wind is needed for a wind turbine to produce electricity? How much is too much wind?

Learning from Others
• Compare this turbine to the device you made in the Lift a Load activity. How are they similar? How are they different?
• Describe how the energy of the wind becomes electrical energy.
• Describe some of the turbines built by others in your group. Can you tell what makes them work well? What other design factors are important for electricity-producing turbines?

You can think about a wind turbine as the opposite of a fan. Electricity turns a fan to make wind. Wind turns a turbine to make electricity.

In any wind machine, the wind turns the rotor. Because wind is steadier and stronger at higher elevations, the rotor is mounted on a tower. The rotor turns a generator which is housed in the nacelle. This makes electrical current. The current flows through wires or cables. A transformer increases the voltage at the turbine so the electricity can be transported over long distances. Other transformers will reduce the voltage.
How Do Motors and Generators Work?

Try It
• Connect the leads on a small electric motor to a AA battery. What happens to the shaft? What could we use this motor to do?
• Switch the electrical leads. What happens to the shaft?

Try It
• Remove the battery and connect the leads to the multimeter.
• Spin the shaft with your fingers. How much electricity, measured in volts, did your device produce?
• Spin the shaft in the opposite direction. How does the display on the multimeter change? When we use the device to produce electricity, we call it a generator.
• If a motor converts electrical energy to mechanical energy, explain what a generator does and how it is opposite of a motor.

You Will Need:
• Small motor
• Leads (with alligator clips)
• AA Battery (Caution: other batteries, such as a 9V, may cause a shock.)
• Multimeter

Electricity

When electricity moves through the wire coil creating an electromagnet, the opposing poles of the magnets push and pull causing the shaft to turn.

When you turn the shaft, it turns the coil of wire inside the magnet to produce moving electrons or electricity.

In Your Engineering Notebook
write or sketch answers to questions you find important or interesting.

Explain how a motor and a generator are related.
Sketch what you see inside the case of the motor.
• Chemical energy is found in batteries and in the food we eat. How can both be used to make a motor shaft turn?
• How can the wind be used to make the shaft of the generator turn?
• How do other energy sources produce electricity?

Learning from Others
• When you turn the shaft of a generator it produces electricity that lights a bulb. Energy is transferred at least three times. Tell where this happens and how the energy changes form.

Career Connections
• Research a career related to renewable power and energy. Both professional and skilled workers are needed in a variety of fields such as: meteorology, turbine manufacturing, construction, environmental engineering, computer programming, energy analysis, project management, green electricity sales and law.
• In a news or journal article, describe what that person might do during a typical day.
• Write about what interests you most in this career field.

Wind Power Timeline
- 1880: Six million windmills with steel blades pumped water in the American West.
- 1910: The first large electricity-producing windmill built in Ohio.
- 1940: Small turbines built to produce electricity in rural areas of U.S.
- 1970: Widespread extension of power grid makes rural turbines less necessary.
- 2000: Oil prices climb because of the OPEC Oil Embargo.

Wind Facts
- 55 megawatts (MW) of wind power offsets the pollution produced by about 10,000 cars.

An operating wind turbine 350 yards away sounds as loud as a refrigerator.

Talk About It
- Stored energy is called potential energy.
- Kinetic energy is moving energy.

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Where and Why Does the Wind Blow?

**Examine the map and the key.**

Wind power classes from 1 to 7 designate the potential wind energy available for a geographic area. Most sources say that class 2 sites or higher are needed for small wind generators and at least class 3 is needed for wind farms.

Go to the U.S. Department of Energy’s Wind Powering America web site and find a more detailed wind map for your state.

There are dynamic wind energy resource maps and Geographic Information Systems (GIS) data available from National Renewable Energy Laboratory (NREL) Regional maps are also available. Visit The Power of the Wind online at www.4-H.org/curriculum/wind.

**In Your Engineering Notebook**

write or sketch answers to questions you find important or interesting.

Which colors on the map indicate greater wind resources?
Which areas of the U.S. have average wind speeds higher than 6.4 m/s?
Which parts of the Midwest have wind speeds greater than 7.5 m/s?
Which states have low average wind speeds?
Why are wind power density and wind speeds on the map given at 50 meters?
The Power of the Wind: How Do Geography and Community Influence Wind Power Projects?

Talk About It

- Why is the wind near the coast of Florida different from the interior?
- What do you know about the geography of California that might explain the variety of wind speeds in that state?
- Examine the map in Appendix G to discover how the wind blows in Illinois. Find similar maps of your state.
- What is the average wind speed near your community?
- How could wind turbines transfer the energy from the sun into electricity? Draw a diagram in your engineering notebook.
- What did you learn from the turbine you built about the importance of wind speed for producing electricity? What other factors are important?

Learning from Others

- How can you share information about wind energy potential in your state with members of your community?
- Why would this information be important to share?

Thinking about Wind Power as Solar Power

Wind power is really a form of solar power. Winds are caused by uneven heating of the surface of the earth. Land heats up more quickly than water and water keeps its heat longer.

Air expands as it warms. When this same mass of air expands, it takes up more space and becomes less dense. Cooler and denser air then pushes in below the warm air mass and pushes it up.

Wind Power Timeline

- Higher oil prices spurred search for cheaper energy sources
- First large U.S. wind farm at Altamont Pass, CA
- U.S. installed more new wind energy capacity (2,431 megawatts) than any other country in the world
- Global wind energy capacity reached 31,000 megawatts
- In U.S. 16,596 megawatts of wind energy are produced in 36 states
- More than 2,200 megawatts of wind energy capacity installed in California
- 1970
- 1980
- 1990
- 2000
- 2010
Where Are the Wind Turbines?

Examine the map and the key.

View an animated version of this map and other maps of installed wind capacity at www.4-H.org/curriculum/wind

Get information about wind energy in individual states by visiting The Power of the Wind online and searching for the Wind Powering America’s State Wind Activities.


How does this map compare with the Wind Resource Map on page 26? Compare this information with the information on the Wind Powering America web site, found at www.4-H.org/curriculum/wind. Why has this information changed over time? What social, economic, and environmental factors might have influenced this data?

Which states have the most installed wind power capacity? Why do you think these states have the most wind installations? What factors, other than available wind, influence where wind turbines are built?

North Dakota has good wind resources. Why do you think there are fewer wind turbines there?

Go to the Wind Powering America State Wind Activities web site and view the information for your state or another state. Write about wind-related news.
Talk About It

• Suggest some places in your state or community that could be considered for a wind farm. What places might not be ideal locations for a wind farm? Explain your choices.

• Why might people in your community be for or against the development of a wind farm in these areas? Are there social reasons? Economic? Cultural?

• How might community members from different professions collaborate to bring wind energy to their area?

• How can you help community members understand wind as a renewable energy source? Compose a news article for your local paper that would help community members learn about wind power.

• Wind is variable and does not always blow when electricity is needed. This is one of the reasons that wind cannot be our only power source. Scientists are working to find a practical method for storing electricity, but for now nearly all of our electricity is generated when we need it. Do research to find out more about how electricity is generated and distributed to meet the demands of communities.

Learning from Others:

ORGANIZE A DEBATE

Work with your facilitator or adult leader to organize a debate or town hall meeting to explore the issues associated with building and operating wind turbines in your community.

• Choose a topic such as sound, aesthetics, habitat protection, construction of turbines, economic impacts of turbines, or your local electrical supply needs.

• Take a pro or con position on the topic and research the facts that support each side of the topic.

• Write a logical argument in your notebook.
What Are Some Facts About Wind Farms?

The Mendota Hills Wind Farm

near Paw Paw, Illinois was the first Illinois wind farm. It began operating in November, 2003 and consists of 63 turbines that have a total capacity of 50.4 MW. Each tower is about twenty-five stories tall, and the nacelle or housing is about the size of a small school bus. For more information on Illinois wind power, see Appendix G.

The turbines are located on land owned by several area farmers. The wind farm is spread over 2,600 acres, but the turbines and roads to them use only thirty-one acres.

Each year the wind farm developer, Navitas Energy, pays the landowners $1200–$1500 per megawatt of electricity produced. It is estimated that this wind farm produces approximately 125,000,000 kilowatt hours (kWh) of electricity every year, which is sold to Commonwealth Edison.

Research a wind farm in your state or a nearby state.

How many turbines are there?

How tall are they?

How long are the blades?

What is the total power capacity?

How many houses do they provide power for?

Where are they located?

Twin Groves Wind Farm

is located in eastern McLean County, Illinois. Its 240 (1.65 MW) turbines have the potential to power about 120,000 homes. However, because wind is variable, wind turbines cannot be the only generation source. The best solution to high electricity need is a variety of energy sources.
Talk About It

- The person standing near the wind turbine is six feet tall. About how tall is the tower?
- Use a ruler and calculator to estimate the height of the tower. Calculate the length of the blades.
- How far does the outer tip of the blade turn in one revolution?
- If the turbine is spinning at 25 rpm, about how fast is the tip of the blade turning?
- Why are wind turbine towers so tall?
- Is this a high or low solidity turbine? What does this tell you about its ability to lift a load or produce electricity?
- View a turbine in action at 4-H.org/curriculum/wind

Learning from Others

- List some ways that wind farms could be important to a community.
- Would you like a wind farm like the one in Mendota Hills located in your community? Why or why not?

Career Connections

Make a brochure of different careers that are required to build a wind farm. Include descriptions of careers, technologies they used, and educational requirements. Include other interesting facts that you think are important.
How Do Schools Use Wind Power?

Read

about three school districts that have installed wind turbines to produce all or part of their electricity. Look for important data about the schools and fill in the School Wind Power Table below.

School districts in several states have recognized the advantages of installing wind turbines.

They have received grants from governmental and commercial sources to help with the projects.

CASE STUDY 1

Forest City, Iowa

The wind turbine at Forest City Community School District began as a physics project. Students and their teacher became interested in exploring the possibility of installing a turbine during a study of wind power. They were able to install an anemometer at the top of their water tower and collected wind data for one year.

The data showed that the wind speed at this site was high enough to support a wind turbine, so they did more studies. One student did a study of the costs and benefits of installing a turbine, and he and his teacher made a presentation to the school board. The school board continued the project in cooperation with the Forest City government and the Forest City Municipal Utility, and the 600 kW turbine began producing electricity in January, 1999.

The turbine supplies approximately 65% of the school district’s electricity. As of August, 2006 the turbine produced electricity valued at approximately $434,500. Continuing its commitment to renewable energy, the district has installed a geothermal heating and cooling system.

School Wind Power Table

<table>
<thead>
<tr>
<th>School Name</th>
<th>Number of Turbines</th>
<th>Production Capacity of Turbines</th>
<th>Value of Electricity Produced Per Year</th>
<th>% of District’s Electricity Needs</th>
<th>Year the Turbine Began Producing Electricity</th>
<th>Benefits from the Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest City Community</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erie Community Unit School District</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spirit Lake Community</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CASE STUDY 2
Erie Community Unit School District, Erie, Illinois
completed the construction of a 1.2 MW wind turbine in September 2008. The turbine will provide energy to all four school district attendance centers. The project is extraordinary because it will use only one wind turbine to generate energy for an entire school district with several buildings. Erie Schools plan to become nearly 100% powered by wind.

Each year Erie CUSD #1 needs approximately $170,000 to pay for electrical energy. It estimates that as the cost of electricity goes up, the expenses for electrical energy for the next thirty years will be approximately $7.8 million dollars. The Erie superintendent, Mike Ryan, thinks the wind turbine will produce enough electricity to save about 9 million dollars during those same thirty years.

The wind turbine project also included installing air conditioning in three of the school buildings. The whole project cost 5.1 million dollars. The schools received $745,000 in grant money from the Illinois Clean Energy Foundation to help pay for the project. So after paying for the turbine, the air conditioning and expenses involved with taking care of the turbine, the district thinks it will save about 4 million dollars over thirty years.

The school district is also using lessons involving the turbine in math and science classes. According to the superintendent, “data will be ‘streamed’ into our classrooms and the students can study ‘live’ wind energy information from a turbine right outside of their window.”

For more information about wind turbines and schools go to: www.4-H.org/curriculum/wind.

Offloading sections of the tower.

Setting the Inbed Ring to construct the tower.
How Do Schools Use Wind Power?

CASE STUDY 3
Spirit Lake, Iowa

Spirit Lake Community School District is the first in the United States to be wind powered. In July, 1993, the 250 kW turbine installed at Spirit Lake Elementary School began producing electricity. This turbine was so successful that the district installed a second larger turbine. This 750 kW turbine has been producing electricity since October, 2001. The two turbines provide enough electricity to power all of the school district’s facilities and athletic fields. The school district has agreements with Alliant Energy for net billing. In other words, when the turbines produce more energy than the school district uses, Alliant purchases the excess. When the district needs more than the turbines produce, it purchases it from Alliant. There are two different contracts for the two turbines, but in each case Alliant purchases the energy for less than it sells it. The money that the school district saves pays for the turbines. When the loans are completely paid back the district expects to have over $140,000 per year from the turbines to use for the educational program.

Turbine activities are a part of the educational curriculum at every grade level and in most curricular areas.

The turbines save the school district money and reduce pollution. By using electricity that is not produced by burning coal or oil, the Spirit Lake Community School District reduces carbon dioxide emissions by over 2.5 million pounds per year. Carbon dioxide is a greenhouse gas produced when fuels are burned and scientists believe that it contributes to global warming. For more information about wind turbines and schools go to: www.4-H.org/curriculum/wind.

Career Connection
Iowa Lakes Community College at Estherville, Iowa installed a 1.65 MW turbine in 2005. The main reason for the turbine is to offer students the opportunity to become skilled technicians for the wind industry.

The college offers an Associate in Applied Science degree in Wind Energy and Turbine Technology.
Talk About It

- How did the students and teachers get started thinking about using wind turbines for energy?
- What community groups were involved with the students and teachers? Why is it important to have community support?
- What important skills or information do you think the students learned from the school wind projects?
- Analyze the data you recorded in the School Wind Power Table on page 32. How are the school projects similar? How are they different? Which school seems to be getting the most out of its wind power project? Justify your answer.
- Use some of the data from your table to make bar graphs to help illustrate important facts.

Learning from Others

- What are some benefits to a school that installs a wind turbine?
- What limitations might they consider before installing a wind turbine?
- What are some environmental benefits of wind power?
- What are some environmental concerns of wind power?
- How could you use the experiences of these schools to begin investigating wind power as a possibility for your school?
- How can you make sure that everyone’s opinion is respected as you explore wind energy options?

Wind Facts

At the end of 2007, schools and colleges in Iowa owned 5.6 MW of wind installations. There were ten school wind projects in the state.

California, Texas, and Iowa are the states with the most total installed wind power.

South Hardin High School, Eldora, Iowa
The Power of the Wind: How Does Wind Inspire Creativity and Design?

Who has seen the wind?
Neither I nor you:
But when the leaves hang trembling,
The wind is passing through.
—Christina Georgina Rossetti (1830–1894), British poet

Always restless
Always free
Can open doors
and fell a tree
— From Tales Told in Tents by Sally Pomme Clayton, illustrated by Sophie Herxheimer, published by Frances Lincoln Ltd. © 2004

Wind and wind machines have been painted and photographed by many well-known artists.

Rembrandt van Rijn (1609–1669) was the son of a windmiller. Look in a book of paintings to find his engraving, “The Mill”. You can find out more about Rembrandt and “The Mill” at the web site for the National Gallery of Art or see it at the Gallery in Washington D.C.

You may also find these works by other well known artists.
• Tulip Fields with Windmill, Claude Monet
• Windmill on Montmartre, Vincent Van Gogh
• Les Vieux Moulin de Montmartre, Maurice Utrillo
• The Windmill, Henri Matisse
• View of Montmartre with Windmills, Vincent Van Gogh

Try and capture your feelings about the words and the poem.

“Windmill” is the name of a traditional early American quilt pattern. Why do you think it has this name? You might like to sew a small quilt or pillow using this quilt square pattern. How does it look when you put several squares together?
Create wind inspired art work of your own.

WIND PHRASES
References to the wind are part of our language. What do these phrases mean? List some others.

“Free as the wind”
“Any way the wind blows”
“Winded”
“Sail close to the wind”

Read Wind Child by Leo and Diane Dillon (Harper 1999). Write and illustrate your own myth about the wind.

In Your Engineering Notebook
write or sketch answers to questions you find important or interesting.

Describe the wind. How do you know the wind is blowing?
When is the wind helpful?
When is the wind harmful?

Name the Wind
All of these words name or describe winds. Add more words to the list.

Blustery
Breezy
Squall
Hurricane
Tornado
Eddy
Whirlwind
Cyclone
Gusty
Gale
Zephyr

How do you think these sculptures move when the wind blows?
Design and Build

**a wind powered device.** As you have been working on the activities in this project book, you have been listing and sketching some ideas for using wind power in your engineering notebook. Choose one of your ideas and build a wind powered machine, vehicle, or sculpture using the design process.

Conduct a wind fair to showcase your group’s wind projects. Make a poster that shows how your machine uses wind energy and include some photos. Invite members of your community. Explain what you have learned. Work with another community partner like a museum, library, or school club to conduct the fair.

As you choose an idea and work through the engineering design process to create solutions, think about these questions:

- What problem would you like to solve?
- What are the criteria for a successful solution?
- What are the constraints?
- What research do you need to do before you get started?
- What alternative solutions can you come up with before deciding on one to try?
- After you build a prototype, how can you test it against the criteria for the problem?
- What redesign is suggested by the tests?
- How will you communicate your solution?

Explain how your machine uses wind energy. Include some photos.
**Make it Happen**

- Make a presentation about what you have learned to your 4-H Club, PTA, local power company or other group interested in wind power.
- Gather a group of civic leaders to determine if wind power is a reasonable source of energy for your community.
- Research similar projects in your state or in other states that have been tried in communities of your size.
- Contact local organizations or Wind Powering America, a program of the U.S. Department of Energy. This agency publishes state specific guides for those interested in pursuing wind power projects. If wind isn’t a reasonable alternative energy source for your area, what alternative fuel and energy sources are possible?

**Research the Potential Future of Wind Energy**

How can we more efficiently distribute wind energy and electricity in our communities? Across your state? Across the United States?

**Research Other Careers Available in the Wind Power Industry**

- What kind of work do they do?
- What skills do they need to be able to do the work?
- What classes would you need to take if you are interested in doing this kind of work?
- Talk to your guidance counselor to find out what courses you will need and make an educational plan to become an energy professional.

It’s best to learn about design by doing. For example, some engineering students at the University of Illinois at Urbana-Champaign, designed a house powered by the sun! The house’s refrigerator, dishwasher, heater, and air conditioner will all be solar powered. You won’t see any electricity lines connected to this house! While the students will have to use many things that they’ve learned in their engineering classes, they’ll learn many things about engineering design just by working together to reach their goal.

As you have worked on the activities in this project book, you’ve had an experience like those college students: you’ve learned a bit about engineering and design by doing some yourself! You have learned some of the science of wind and how to harness wind power to achieve something – like pump water or generate electricity. You figured out a design, tested and adjusted it, and experienced the unforgettable thrill of seeing your device work. You have been a designer and an engineer!
Appendix A
Pinwheel With Rotational Symmetry Template
Appendix C
Triangular Pinwheel Template

Draw a design on this pinwheel using rotational symmetry.
Appendix D
Beaufort Wind Scale – Tetraflexagon (Front Template)

- Cut on the heavy black lines and crease on the red vertical lines.
- Draw illustrations in each of the squares that contain small print.
- Follow the instructions for folding on pages 10–11.

<table>
<thead>
<tr>
<th>4</th>
<th>4</th>
<th>3</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>47–54 mph</strong>&lt;br&gt;Strong gale</td>
<td><strong>13–19 mph</strong>&lt;br&gt;Moderate breeze</td>
<td><strong>32–38 mph</strong>&lt;br&gt;Moderate gale</td>
<td><strong>55–73 mph</strong>&lt;br&gt;Whole gale/Violent storm</td>
</tr>
<tr>
<td>antennas break</td>
<td>umbrellas hard to use</td>
<td>leaves move</td>
<td>trees uproot, widespread damage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4</th>
<th>4</th>
<th>3</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>more than 74 mph&lt;br&gt;Hurricane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hurricane</td>
<td>difficult walking</td>
<td>leaves move</td>
<td>trees sway</td>
</tr>
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</table>
# Appendix E

Beaufort Wind Scale – Tetraflexagon (Back Template)

<table>
<thead>
<tr>
<th>Wind Force</th>
<th>Speed (mph)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>less than 1</td>
<td>Calm</td>
</tr>
<tr>
<td>1</td>
<td>1–3</td>
<td>Light air</td>
</tr>
<tr>
<td>2</td>
<td>4–7</td>
<td>Light breeze</td>
</tr>
<tr>
<td>3</td>
<td>8–12</td>
<td>Gentle breeze</td>
</tr>
<tr>
<td>4</td>
<td>13–19</td>
<td>Moderate breeze</td>
</tr>
<tr>
<td>5</td>
<td>19–24</td>
<td>Fresh breeze</td>
</tr>
<tr>
<td>6</td>
<td>25–31</td>
<td>Strong breeze</td>
</tr>
<tr>
<td>7</td>
<td>39–46</td>
<td>Strong breeze</td>
</tr>
</tbody>
</table>

- **Smoke rises**
- **Flags extend**
- **Branches move**
- **Smoke drifts**
Appendix F
Using a Multimeter

Measuring Voltage
You can test even a very small amount of generated electricity using a moderately priced digital multimeter. If the turbine you created is spinning, that means you can measure its voltage. The voltage is one measure of how fast the turbine is spinning.

- The multimeter has a red test lead cable and a black test lead cable. To measure voltage attach the red to the VΩmA jack and the black to the COM jack.
- Select 20V on the DCV part of the dial.
- Attach the leads to the generator and place your turbine in the test wind.
- Depending on your turbine design and the wind speed, your voltage readings should be between 0.1 and 1.0 volts.
- Turbines that generate voltage readings near 1.0 volts can light a small LED.
Appendix G
Where the Wind Blows in Illinois

- Where are areas in Illinois designated “good” for wind power?
- Which of these areas have operational or proposed wind farms?
- Why are the wind power density and wind speeds on the Wind Resources Map given at 50 meters?

This map shows counties in Illinois. The shaded counties are sites of existing and/or proposed utility scale wind turbines. The numbers show MW of proposed capacity for new projects in these counties.

Larger versions of these maps can be found at www.4-H.org/curriculum/wind.

Illinois Rural Electric Cooperative
Owns a 1.65 MW turbine in Pike County, Illinois. The hub is 235 feet tall and at its highest point the turbine is 365 feet tall. It generates enough electricity to power about 500 homes. It operates when the wind blows 5–55 mph. Where is Pike County? What does the wind map of Illinois show us about the Pike County area?

Twin Groves Wind Farm
This project is located in eastern McLean County, Illinois. Its 240 (1.65 MW) turbines have the potential to power about 120,000 homes. What does the Wind Resource Map show about the site of this wind farm? The best solution to high electricity need is a variety of energy sources.
**Anemometer**
an instrument used to measure wind speed.

**Axis**
the line about which a rotating body, such as the rotor of a turbine, turns.

**Beaufort Scale**
a scale that uses numbers from 0 to 12 to categorize wind speed based on observing. The scale was created by the British naval commander Sir Francis Beaufort around 1805.

**Biodiesel**
a renewable fuel for diesel trucks, cars, buses, and tractors that is made from plants.

**Chemical Energy**
energy that can be released by a chemical reaction. A chemical reaction takes place inside a battery when the battery is part of a complete electrical circuit.

**Constraint**
a restriction on a design, such as performance, cost, and scheduling.

**Criteria**
the rules used to judge something.

**Cyclone**
any storm with circulating winds (a “twister”) formed over water. Also refers to a hurricane that occurs in the Indian Ocean.

**Electrical Energy**
energy made available by the flow of electric charge through a conductor.

**Electron**
an elementary particle of an atom with negative charge.

**Energy**
refers to the ability to do work. It is defined as power over time. The unit of energy that appears on your electrical bill is kilowatt hour (kWh). A 1000 watt hair dryer uses one kWh of electricity if it is on for one hour. Different forms of energy include electrical, solar, wind, thermal, mechanical, and chemical.

**Engineering Design Process**
a process used by engineers to help develop products.

**Force**
a force is a push or a pull that results in a change of an object’s velocity or direction.

**Generator**
a device that converts mechanical energy into electrical energy.

**Hurricane**
a storm with very fast circulating winds (a “twister”) formed over water near North or South America.

**Kilowatt**
1,000 watts is equal to 1 kilowatt (kW). The unit of energy that appears on your electrical bill is kilowatt hour (kWh). A 1000 watt hair dryer uses one kWh of electricity if it is on for one hour.

**Kinetic Energy**
the energy of an object in motion.

**LED**
light-emitting diode: a semiconductor diode that emits light when conducting current and is used in electronic equipment (e.g. a string of holiday lights).

**Machine**
a device that does work and uses energy.

**Megawatt**
1,000,000 watts is equal to 1 megawatt (MW). One MW is enough power to light 100,000 standard 100 watt light bulbs or to operate 10,000 hair dryers.

**Mechanical Energy**
the energy an object possess due to its motion or its stored energy of position.

**Motor**
a device that converts electrical energy into mechanical energy to do work.

**Multimeter**
a device consisting of one or more meters used to measure two or more electrical quantities in an electric circuit, such as voltage, resistance, and current.

**Nacelle**
the housing that contains the generator and gear box of a wind machine mounted on top of the supporting tower.

**Potential Energy**
the energy stored in an object because of its position.
Power
energy transferred or work done per unit of time. It is measured in watts. A watt is a measure of power at a specific instant. A 100 watt light bulb changes 100 watts of electricity to 100 watts of light and heat.

Prototype
an early attempt at a working model for an idea.

RPM
stands for revolutions per minute.

Rotational Symmetry
an object with rotational symmetry is an object that looks the same after a certain amount of turning.

Rotor
a rotating part of an electrical or mechanical device.

Rudder
A blade at the rear of the turbine that keeps the turbine turned into the wind.

Shaft
a revolving rod that transmits power or motion.

Solidity
the ratio of rotor blade surface area to the area that the rotor blade passes through; the amount of swept area occupied by the blades.

Swept Area
the area of the circle that the blades of a turbine pass through.

Tetraflexagon
in geometry, flexagons are flat models made from folded strips of paper that can be folded, or flexed, to reveal a number of hidden faces. A tetraflexagon has four faces.

Tornado
a storm with very fast circulating winds (a "twister") formed over land.

Torque
force which causes something to rotate, turn, or twist.

Tower
column upon which the nacelle is supported.

Transformer
converts high voltage to low voltage or low to high.

Tropical Storm
a group of thunderstorms with fast wind speeds rotating in a spiral formed over water.

Tsunami
an unusually large sea wave produced by a seakeep or undersea volcanic eruption.

Turbine
any of various machines having a rotor, usually with blades, driven by the pressure and movement of water, steam, or air. A turbine converts kinetic energy of a moving substance (such as air) into mechanical energy.

Typhoon
a storm with very fast circulating winds formed over water in the South Pacific Ocean.

Voltage
the force or pressure pushing the electrons. It is measured in volts.

Wind
air in motion, ranging from still (no wind) to a breeze (slight wind) to a gale (strong wind) or hurricane.

Windmill / Wind Turbine
a device that converts wind energy to other forms of energy such as mechanical or electrical.

Wind Farms
a collection of wind turbines located on the same area and used to generate electricity.

Wind Energy
energy harvested from moving air in the atmosphere. Wind energy is dependent on atmospheric conditions such as temperature and pressure differences.

Work
occurs when a force is applied over a distance.
**Print Resources**


**Internet Resources**

For Internet Resources, please go to The Power of the Wind online at [www.4-H.org/curriculum/wind](http://www.4-H.org/curriculum/wind)
4-H Pledge

I Pledge my Head to clearer thinking,

my Heart to greater loyalty,

my Hands to larger service,

and my Health to better living,

for my club, my community, my country, and my world.