Lesson 7: Around and Around They Go

Turbines

Overview

Turbines are a common component in most forms of electricity production. During this lesson, students explore turbines by designing and building blades for a simple wind turbine.

Teacher Background

This lesson has two major goals: the first is to take a closer look at how turbines work in terms of their role in electricity generation. The second is to provide students with the opportunity to experience working through a technological design process as they observe, design, and build blades for a simple paper wind turbine.

When a force from something such as wind, water, or steam hits the blades of a turbine, the blades turn freely. It is this energy of motion that is used to do work such as spinning a generator to produce electricity or rotating great stones for grinding grain or lifting water from a moving stream to irrigate crops. Wind, water, and steam turbines have all been used throughout Maine to generate electricity.

The harnessing of wind has a long history. Early records indicate that wind was being used to push on the sails of a boat as a way to move the boat across water. This was followed by the advent of people attaching sails to wheels perched atop tall structures. As the wind moved the sails, shafts connected to the sails would turn and grind or mill grain into flour, thus the name "windmill." The modern-day interest in wind is focused on figuring out ways to conveniently harness it for the purpose of generating electricity to meet the increasing energy demands of society. People often use the words windmill and wind turbine interchangeably when talking about wind energy. Traditionally windmills refer to structures that grind or mill grain and wind turbines are devices that harness wind to generate electricity. Windmills and wind turbines may vary in their appearance, but they operate using essentially the same basic design.

Wind energy can be thought of as a form of solar energy since the Sun is the ultimate source of wind. Wind is, very simply, moving air. Air moves due to the uneven heating and cooling of the Earth's surface. The Sun will shine for billions of years so wind energy will be here for a very long time. This is why wind energy is considered renewable. The wind keeps blowing! There are places on Earth that have more wind than others, such as near the oceans, along the open plains, and on the tops of hills and mountains. The availability of wind is one factor that needs to be considered when people think about erecting wind turbines. Other considerations include the migratory patterns of birds and bats, aesthetics, noise pollution, and shadow flicker.

The opening paragraph of the *Maine Learning Results: Parameters for Essential Instruction* states "…it is important for students to learn how science and technology connect with the demands of society… It is equally important that students are provided with learning experiences that integrate tools, knowledge, and processes of science and technology. Instruction should support students in asking questions and making inquiries, to help them understand and solve problems that require the integration of knowledge and processes in authentic contexts." The study of our society's energy needs and the wind power available in Maine sets the stage for an engaging opportunity to combine inquiry and technological design into the study of energy. By designing, building, and testing the blades of a model wind turbine, students are able to put into practice the skills of scientific inquiry and experience technological design in a hands-on and meaningful way. Building a model turbine using blades that they design will aid in the students' understanding of how turbines work and some of the complexities they entail. Whether you refer to this as technological design or engineering, this is a real life use of a design process to study the generation of electricity using a renewable energy resource that is becoming more popular in Maine, the United Sates, and throughout the world.

Key Ideas

- Wind can be used to make things happen. In the context of generating electricity, wind energy can be used to spin a turbine.
- Technological design involves using scientific principles to solve problems.
- Predicting, observing, designing, building, testing, analyzing, and retesting are all part of technological design.

Lesson Goals

Students will:

- describe how wind, water, or steam can be used to make things happen.
- identify different uses of windmills and wind turbines.
- observe and describe how different blade materials and shapes harness wind.
- analyze turbine designs for strengths and weaknesses and implement some of their improvement ideas.

Vocabulary

turbine: a device made up of a series of blades that is turned by a fluid (gas or liquid) and as it turns, converts mechanical energy into electrical energy.

Preparation

- Construct the model steam turbine following the directions found at the end of this lesson. **Practice before doing this demonstration with students!** An alternative method for showing steam power can be found at Combustion Demonstration: http://teachengineering.org/view_activity.php?url=http://teachengineering.org/collection/cla_/activities/cla_activity2_energy_conversion/cla_activity2_energy_conversion.xml
- Collect materials and prepare a materials area for students to construct their model wind turbines.
- Make your own model wind turbine that lifts pennies using the blow dryer following the procedure students will follow.
- Elicit the help of parent volunteers for testing days.
- Post/have on hand PowerSleuth puzzles if previously taken down.
- Preview and bookmark websites used in this lesson:

  http://www.teachersdomain.org/resource/phy03.sci.phys.matter.wind/

  http://cr.middlebury.edu/es/altenergylife/turbinecutaway.gif

  http://www.jpmorganclimatecare.com/media/images/low_cardbon_technologies/WindTurbine_diagram_WEB.jpg_

  http://www.teachersdomain.org/asset/phy03_vid_zmill/
- Consider taking digital photos. Taking photos throughout this lesson to capture each stage of students at work provides an opportunity to capture a snapshot of students at a particular phase of their work and document their progress. Students can write about and discuss what they were thinking, learning, and doing at that time. This provides another opportunity for individual and group reflection. Photos may be added to students' notebooks or to a wall dedicated to the photos.

Materials

Item	Quantity
Model steam turbine demonstration: • 4 disposable metal pie pans • lightweight metal washer (approximately ½ inch) • heat resistant (metal) funnel • electric hot plate, extension cord, 3 prong adapter • oven mitt • unsharpened pencil • push pin • safety goggles	1 for teacher, assembled in advance. Includes additional pans for making replacement turbines
Blow Dryer	At least 1 for the class
A variety of pinwheel making materials, such as • Heavy duty aluminum foil • Index cards (4 X 6) • File folders • Wax paper • Plastic bags	1 per student (Have spare materials on hand)
Plastic straw	1 per student pair
Unsharpened pencils	1 per student pair
Push pins	1 per student pair
Washers	1 per student pairs
Scotch and masking tape, scissors	Enough for the class
String	Enough for the class
Small paper cups (3 ounce)	1 per student pair
Pennies	Enough for all the cups (approx. 100)
Computer with internet & LCD projector	1 for class
Store bought pinwheel (optional)	1
Pinwheel template (optional)	1
Miscellaneous materials such as: wax coated hanger wire, dental floss, paper, different weight papers, plastic 2 L soda bottles, etc. (optional)	For an extension for students who finish early or want to be challenged further
Scientist's Notebook	1 per student
From Lesson 6: *PowerSleuth* Puzzles	1 set posted
Digital camera (optional)	1 per class

Time Required: 2-4 sessions

Session 1: Steam demonstration and drawing initial design.

Session 2: Constructing and testing turbines.

Session 3: Redesign and test turbines.

Session 3: Debrief design process and discuss real world issues about wind power.

Connection to *Maine Learning Results: Parameters for Essential Instruction*

- Propose a solution to a design problem that recognizes constraints including cost, materials, time, space, or safety. MLR B2 (3-5) b
- Evaluate their own design results, as well as those of others, using established criteria. MLR B2 (3-5) e
- Modify designs based on results of evaluations. MLR B2 (3-5) f
- Present the design problem, process, and design or solution using oral, written, and/or pictorial means of communication. MRL B2 (3-5) g
- Explain that natural resources are limited, and that reusing, recycling, and reducing materials and using renewable resources is important. MLR C3 (3-5) c
- Predict the effect of a given force on the motion of an object. MLR D4 (3-5) a

Teaching The Lesson

Engage

1 Observe and discuss the nature of steam.

Set up the materials for the model steam turbine demonstration in a safe area away from students. Bring a partially filled pot of water to a rolling boil until steam escapes through the funnel.

Call students' attention to the demonstration by asking them what they think it might feel like if they were to put their hand over the pot of boiling water.

> **Safety Note and Caution:** *Prepare and practice this demonstration prior to class. Do not leave the pot of boiling water unattended at any time. Use extreme care in working with students during this demonstration! Electric hot plates and steam are very hot and this is designed as a teacher demonstration for that reason. Students should not be allowed near the hot plate or steam device.* ***Students should not put their hand over the steam!*** *Be sure the demonstration is set up so that the handle of the pot is faced away from the class and that the cord placement eliminates the risk of students tripping.*

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> **Note:** *Scientifically, steam is vaporized water which can't be seen. As used in common every day language, steam typically refers to the white mist that is often visible above boiling water. This mist is visible because the cooler air above the boiling water causes the water vapor escaping from the boiling water to condense, forming tiny droplets of water, which are suspended in the air. In this exercise, the every day use of the word steam will be used since it is familiar to students at this age.*

Students may say that their hand would get hot or become wet. Use this observation to segue into the notion that steam is "stuff." (If steam wasn't "something," it wouldn't collect on hands.) In more scientific terms, steam is matter and is made up of molecules of water.

> **Note:** *Very often children do not see steam as being "something" or made up of molecules so they struggle with the idea that steam is capable of exerting a force on something.*

Explain that steam is very hot water escaping from the pot. Caution students about this point, noting that steam is very hot and capable of causing severe burns.

> **Note:** *The steam is formed by water molecules being heated so much that they begin to move faster and faster as they get hotter. This causes some of the molecules to break away, change state, and become water vapor (gas). As the water vapor comes into contact with the cooler air above the boiling water, the water vapor cools down, causing the water molecules to slow down and condense, changing back into tiny droplets of liquid water.*

2 Demonstrate model steam turbine.

Show students the model metal turbine. Ask students to predict what they think will happen if the turbine was held over the rising steam and why. Most students may not have thought about steam as a force and may not offer the idea that steam can exert enough force to turn the turbine. Accept students' ideas at this point.

With your hand inside an oven mitt, hold the model (metal pie pan) turbine face down several inches above the steam device and carefully allow the steam to turn the turbine. Ask students to share what they observe and any questions they may have. It may be beneficial to record their questions for further investigation or discussion.

After discussing students' observations, refer to the *PowerSleuth* puzzles used in Lesson 6. Ask the students how the spinning turbine they observed relates to the power generation methods depicted in the puzzles. Remind students of the idea that turbines are key components in electricity generation as evidenced by their presence in all the different electricity generation scenarios pictured. Explain that steam is often used to turn those turbines just like the steam used here turns this model.

> **Safety Note and Caution:** *Immediately following this demonstration, unplug the hot plate and move the pan of hot water and the hot plate to a safe place out of the way where students can't accidentally bump into it while it is cooling.*
>
> **Note:** *An alternative method for showing steam power can be found at Combustion Demonstration:*
> ***http://teachengineering.org/view_activity.php?url=http://teachengineering.org/collection/cla_/activities/cla_activity2_energy_conversion/cla_activity2_energy_conversion.xml***

3 Discuss energy technologies in the news.

Say something like: *Energy is a topic that is frequently in the news these days. There is a lot of troublesome news related to energy lately, but what have you read or heard that highlights innovative energy technologies?* Students may be quick to offer energy news that is related to the high cost of energy or that focuses on some of the challenges in meeting society's energy demands. Acknowledge these issues, but maintain focus on the innovative technologies people are introducing as possible solutions to the energy crisis. (Alternately, the teacher can pre-select an "exciting energy news" article to brief students on.) Use this opportunity to explain that humans are amazing at designing solutions to problems. It is very important that students at this age see that problems have solutions and that each problem encountered also offers an opportunity to create an innovative solution.

4 Introduce wind as a resource.

Hold up the model steam turbine and ask students what else besides steam could be used to spin a turbine like our model turbine. Most will have had experiences with pinwheels and will be able to cite wind for an answer. Blow gently on the model turbine. Guide students' discussion by asking how the use of wind to spin the turbine relates to the electricity generation process. Explain to students that in Maine and around the world people have been and are continuing to design and build creative solutions such as wind turbines to address our energy needs. For example, in some places wind farms (a collection of wind turbines in one area) or wind "power plants" are being used to generate electricity. Remind students that wind is an example of a renewable resource.

8

5 Discuss technological design.

Engage students in a conversation about technological design. Ask about what they have designed and/or built? Extend the conversation by asking if anyone has designed and built something to solve a problem. Accept all answers and encourage creativity in ideas. Explain that humans are still exploring different designs of wind turbines. They are trying to design and build the "most effective" turbine; the ones that will harness the most wind energy, have the safest design, and generate the most electricity. Tell students that they will join this challenge by designing and building blades for a model wind turbine.

6 View "Windmill Gallery."

Say: *Describe what you think a windmill looks like.* Explain that they are about to view a collection photographs showing a variety of styles of windmills and wind turbines. Ask students to pay particular attention to the blades of the turbines in this collection.

View the gallery of photos with students at: http://www.teachersdomain.org/resource/phy03.sci.phys.matter.wind/

Ask students to share what they noticed about the windmills and wind turbines and what they noticed about the blades of the turbines. Consider showing the slide show twice, directing students to pay particular attention to the blades.

Explore

7 Design a wind turbine.

Introduce students to the challenge of designing blades for a model wind turbine that will perform a task. Explain to students that instead of generating electricity, the wind energy captured by their model turbine will be used to lift a paper cup filled with pennies. The challenge is to design a turbine using the materials available to lift as many pennies as possible. Explain that a hair dryer will be used as the "wind."

Diagrams of wind turbines are available online:

http://cr.middlebury.edu/es/altenergylife/turbinecutaway.gif

http://www.jpmorganclimatecare.com/media/images/low_cardbon_technologies/WindTurbine_diagram_WEB.jpg

The following clip from the popular public television show ZOOM, can be used to introduce the activity:

http://www.teachersdomain.org/asset/phy03_vid_zmill/

To initiate the process of students designing and building a model wind turbine have students work in pairs to brainstorm suggestions for the following:

- *What do the blades of the wind turbine have to do?*
- *What will they look like?*
- *How can we use the available materials the best way possible?*

Give students time to discuss and record their thinking in their notebooks. Encourage students to try out a few designs by sketching their ideas in their notebooks. Additional instruction on how to capture the details of their design in drawings or diagrams may be needed. Model for students how to draw something using different perspectives and/or close up or cut away views of various parts. Ask students to decide on one design and make a detailed drawing of the turbine that they would like to build. Students' design plans should include labeled drawings and a materials list.

Note: *Each student should record in his or her own notebook.*

8 Peer review.

When students are done designing their wind turbines they will share their designs with another pair of students. During this time, students work together explaining their designs. Peers write constructive comments and questions they have on sticky notes and then post the notes in the reviewed notebook. It may be necessary to define a "constructive comment" or question as those that would help the designer think about their model in a new way and make improvements upon or enhance some aspect of their model. Consider requiring each student to offer one constructive comment and/or one question for the design that they review.

> **Note:** *Review each notebook to get a sense of students' ideas before students begin to build.*

9 Build and test the blades of the turbines.

Provide time to review their designs before they gather materials and build the blades for their turbines. Encourage students to follow their design. As students are working, circulate among students. Ask guiding questions and support students in constructing their models as needed.

10

> **Note:** *Guiding questions about students' designs are appropriate and helpful. However, it is often tempting to correct a flawed design. Part of the design and building process is the experience of making something that may not work and redesigning and rebuilding it until it does. Be careful not to take that learning experience away from the students.*
>
> *It is easy to place too much emphasis on having students follow their designs rigidly. While following a plan is important, it is also important to balance students' need to experiment with the building process. Often children at this age get so excited with the building process that they don't exactly follow their design or remember to record the changes they make to their designs. Encourage students to keep good records without squelching their excitement, enthusiasm, and creativity that this type of activity brings out. Excitement, enthusiasm, and creativity are all scientific traits that should be encouraged. If students are struggling with following the design/build process then consider allowing a certain amount of time for less structured "free" exploration with the materials prior to the building. Keep in mind that "free" exploration may not be practical if materials are limited and/or if involves cutting or activities that are challenging for teachers to safely monitor.)*

10 Test the blades of the wind turbines.

Coordinate supervised opportunities for students to use the blow dryer(s) to test the blades of their wind turbines as they are being constructed. Consider having each team carefully try their model wind turbine without the lifting of pennies initially. If their model is successful, add pennies to the cup, starting with a penny or two and gradually increase to the maximum number of pennies the turbine will lift.

> **Safety Note:** *Most hair dryers have a cool setting; if so use this setting. If not, be mindful that blow dryers may get hot! Use the utmost caution when using a blow dryer in the classroom especially when students are encouraged to interact with it as they are in this lesson. Go over safety rules with students, including not pointing hair dryers in anyone's face.*
>
> **Note:** *It is rare for a first design to be entirely successful. Repeated attempts are part of the engineering process. When students' trials aren't as successful as they would like them to be, use the opportunity to ask guiding questions to aid in the redesigning of their turbine's blades. Questions can focus on any areas of their turbines that appear to be problematic, such as the quality of the turbine base and blade construction, attachment points of blades, number of blades, size and weight of blades, angle of blades, base height and stability, etc. This is also a good opportunity to remind students that many inventions begin with partially successful or unsuccessful attempts. This is part of the designing and building process and is to be expected. Encourage students to think of these attempts as learning opportunities!*

11 Redesign, rebuild, and retest.

Guide students to use both words and sketches to record their thoughts on what aspects of their first model worked and didn't work. Students can then begin to "tweak" their design on paper using labeled drawings. Once their new designs are entered into their notebooks, they may partner up with their peer reviewers to discuss any new design elements. As before, peers use sticky notes to add constructive comments and/or questions to their peer's notebooks. Once students have reviewed their new designs with peer reviewers, they may move on to rebuilding and retesting.

> **Note:** *As tempting as it may be to eliminate this step due to time, the redesigning, rebuilding, and retesting process is an integral component of the design process.*

Reflect And Discuss

12 Reflect in notebooks.

Once building materials have been cleaned up and put away have students take a few minutes to reflect and write about their experiences in their notebooks. Include the following:

- *What parts of my model turbine worked well* _________
- *If I could redesign the blades of our wind turbine again I would* _________ *because* _________
- *How do you think that wind energy could be used to generate electricity for a community?*
- *What else besides blade design would need to be considered before building wind turbines in a community?*
- *If you were asked to build a turbine that utilized the energy from falling water, how would the turbine blades be similar to and different from the turbine blades you constructed for wind?*

13 Debrief the experience as a large group.

12

After students have finished writing in their notebooks, have them bring their notebooks to the group area for a class discussion. In addition to discussing the questions above, ask questions that focus students on their designing and building experiences. For example:

- *What were some challenges you and your partner experienced during this process?*
- *What parts of the designing and building process were most challenging or difficult?*
- *What was the purpose of having the chance to redesign your model?*
- *What are some design characteristics that made turbines successful?*

14 Bring lesson to a close.

Compare students' designing process and their models to "real world" applications of energy issues and solutions. Explain that there are and always will be problems with all types of electricity generation; there are always positive aspects and negative aspects for every resource and design used. Problems include finding enough resources to generate electricity in nonpolluting and safe ways as well as designing new machines that use new types of resources. The exciting part is that there are people who have jobs studying energy and designing machines like wind turbines. They work together creatively to solve our world's energy crisis.

> **Note:** *This is a nice time to make the connection to careers. Use the careers section of the Energy Lights Maine website to look for ideas to include in this discussion/exploration.*

Extensions

Student may:

- improve their models using additional materials. Aluminum foil, wax paper, different weight papers, tissue paper, manila folders, various plastics (recycled milk jugs and/or butter tubs) allow for added creativity.
- engage in additional activities related to using wind as an energy source. The 4-H Youth Development Program has developed an in-depth curriculum called *The Power of the Wind*. Materials can be accessed at and are available for use at no charge at: http://projects.4-hcurriculum.org/curriculum/wind/
- make a waterwheel. Simple waterwheel instructions can be found on the ZOOM website: http://pbskids.org/zoom/activities/sci/waterwheel.html or at http://www.youtube.com/watch?v=x8xow_R0YRI
- visit a wind turbine site in Maine.
- measure the wind speed around the school's campus to determine best place for a wind turbine at school. Directions for making a simple wind anemometer can be found at: http://www.ciese.org/curriculum/weatherproj2/en/docs/anemometer.shtml
- investigate where and why does the wind blow. Study the two wind resource maps found on the US Department of Energy's website: http://www.windpoweringamerica.gov/wind_maps.asp *What do these maps tell us about wind as a resource in different parts of the country?*
- find the locations of wind turbines in Maine.
- measure the weights of the coins lifted by their models.
- explore the uses of wind energy in schools:

  MSAD 3 considers using wind turbine to cut energy costs: http://www.unity.edu/News/wwind107.asp

  US map showing states with Wind Energy for Schools Project Locations: http://www.windpoweringamerica.gov/schools_projects.asp#ME

Connection to Maine Agencies

MEEP (Maine Energy Education Program) has PV Fan and Mini-Wind Turbine activities where students make electricity from renewable resources. A representative from MEEP will come to interested schools, free of charge. The MEEP website is: http://www.meepnews.org/classroomactivities

For schools in Aroostook County, a Maine Public Service (MPS) representative will come to interested schools, free of charge, to guide and support concepts developed in this lesson. A description of programs is available at www.mainepublicservice.com. Click on the education section of the site. To schedule a visit contact Nancy Chandler at 207.760.2556 or nchandler@mainepublic service.com.

The Power of the Wind is part of a 4-H national curriculum designed for middle school aged youth. This comprehensive guide examines wind power in-depth through hands-on investigations and is applicable to the classroom setting. Guides and additional support materials can be accessed through:
http://projects.4hcurriculum.org/curriculum/wind/.

Website includes information about 4-H wind power afterschool clubs in Maine.

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Constructing a Model Steam Turbine

This model steam turbine uses a small, partially filled pan of water, a hot plate, two aluminum pie pans, a pushpin, a small metal washer, and a heat resistant funnel. When the pie pan and funnel are put over a small pan of boiling water, steam from the boiling water is forced up through the top opening of the pie pan and through the funnel. The force of the steam exiting through the top of the funnel turns the blades of the model turbine constructed out of a metal pie pan. The step by step directions that follow include two parts: 1) how to set up and construct steam emitting device, and 2) how to construct the model steam turbine.

Safety note: *Use caution when cutting metal pie pans–edges are sharp!*

Construct steam directing device

1) Use the funnel to trace a circle onto the center of one aluminum pie pan. The hole should be approximately ½" smaller than the traced circle. This makes the hole smaller than the funnel itself. This is important so the funnel can sit on top of the pie pan without falling through the hole. The top of the pie pan also needs to be flush with the funnel, to prevent steam from escaping between the pie pan and funnel.

2) Refer to diagram – Cut a small opening to allow a spot for the pot handle to go. This will allow the pie pan to stay level with the pot of boiling water while being used.

Construct model steam turbine

1) Cut the circular bottom off of the second metal pie pan. Discard sides.

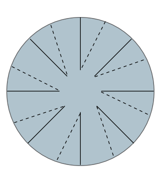
2) Refer to the diagram of the model steam turbine blade arrangement – Using a ruler and pencil; divide the cut circular pie pan bottom into halves, then fourths, then eighths. Create eight blades by cutting partway up the lines, stopping at the inner circle markings found on most pie pans.

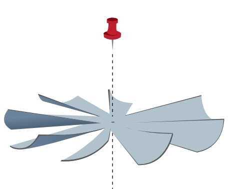
3) Take one side of each blade and carefully it bend up (as indicated by the dashed lines in the diagram) so that all of the blades are curved up on the same side of the blade. The blades may need adjusting as the turbine is being used.

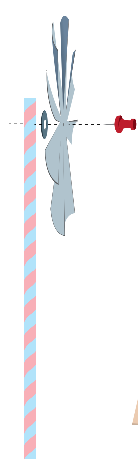
> **Note:** *Consider making a spare turbine out of the extra pie pans in advance. After use, the models can become bent and somewhat difficult to use.*

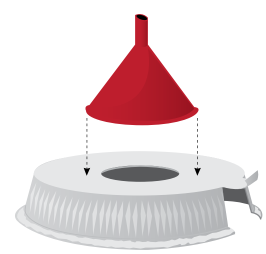
4) Place a washer between the pencil and turbine before securing the turbine to the pencil. This maintains a small gap between the turbine and pencil allowing the turbine to move freely. Use a pushpin to attach the turbine to the eraser of an unsharpened pencil as shown in the diagram.

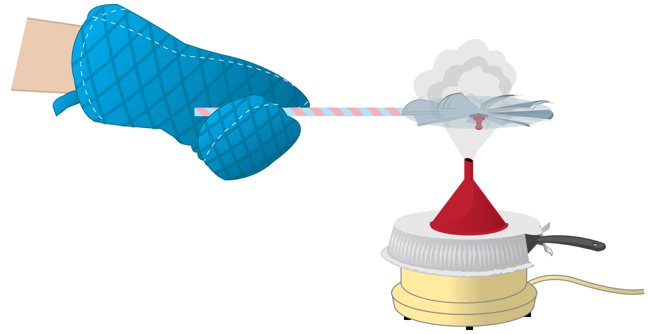
5) To demonstrate steam turning the turbine, hold (cover hand with oven mitt) the turbine blades down over the steam escaping from the funnel.











Online References and Resources

Energy Education Group. (2005). *Energy for Keeps: Electricity from Renewable Energy.* Tilburon, CA: Energy Education Group. www.energyforkeeps.org

Energy Quest:
http://www.energyquest.ca.gov/story/chapter16.html

KidWind Project:
http://www.kidwind.org/

Wind with Miller:
http://www.windpower.org/en/kids/index.htm

Wind with Miller's Crash Course:
http://www.windpower.org/en/kids/intro/

Additional Print Reference:
A first energy grant: ***Pinwheel electrical generation*** article in NSTA's *Science Scope* magazine, October 2007, Volume 31, Number 2, page 74-76