

Wind Power Basics



RENEWABLE ENERGY
THE INFINITE POWER
OF TEXAS

For High School

OVERVIEW

This unit introduces students to the concept of generating electricity from the wind. Students will familiarize themselves with these concepts through the Reading Passage, answering assessment questions, and by conducting a Lab Activity where they will construct and test a windmill to observe how design and position affect the electrical energy produced. Based on their lab results, students will also engage in a follow-up activity to measure the actual power generated by their windmill.

OBJECTIVES

See High School Teacher Resource Guide for TEKS objectives and additional information regarding this and other high school units.

SUGGESTED TIMEFRAME

Teacher will need to determine how many class periods to devote to each activity, based on the suggested timeframe and length of classes.

Time	Activity Description	Subject
60 minutes	1 – Introduction and Reading Passage	Science Vocabulary Reading
60 minutes	2 – Lab Activity – Testing a Windmill Generator	Science Mathematics
45 minutes	3 – Assessment	Science Vocabulary
30 minutes	4 – Follow Up Activity – Measuring Windmill Power	Science Mathematics Reading

REQUIRED MATERIALS

- copy of Reading Passage and Student Data Sheets for each student
- one equipment kit per group for the main Lab Activity containing:
 - small electric fan (or a hair dryer that has an “air only” setting)
 - small DC toy motor (from a science or electronic supply company)
 - cork (at least 2 cm in diameter)
 - DC voltmeter
 - stiff ruler or meter stick or other sturdy wood strip
 - protractor
 - 50 cm of electrical wire with alligator clips
 - rubber bands
 - scotch tape
 - paper clips
 - wire cutters
 - scissors
 - pieces of cardboard (use boxboard, or material thicker than an index card)
 - cork borer
 - goggles for each student
- one equipment kit per group for the Follow Up Lab Activity containing:
 - small electric fan
 - thick drinking straw, 18 cm long
 - dowel rod, approx. 3-5 mm wide, 25 cm long
 - thread
 - 2 short pieces of aquarium tubing 1 cm long that fit snugly around the dowel rod
 - 2 small washers that fit loosely around the dowel rod
 - a paper clip

TEACHER OVERVIEW

- small calibrated weights (Small paper clips can be used. They have a mass very close to one gram.)
- “warm” glue and glue gun
- stopwatch
- cork borer

See separate materials list for Additional Activities.

BACKGROUND INFORMATION

Windmills have been used for many hundreds of years to pump water, to grind grain and other materials, even to pump crude oil from shallow wells. While the concept of using wind to generate electrical power has been understood for a century or more, wind power has become a significant source of electrical power only in the last decade or so. Texas has several areas suitable for wind power generation. Most of the Panhandle region consists of high plains, where the wind blows fairly consistently. In far west Texas, there are several mountain ridges that run generally north and south. As wind blows over these ridges, it increases in speed making these mountain ridges ideal locations for “wind farms.”

Warm air is less dense than cool air. When warm air contacts cool air, the density difference can cause the warm air to rise. As it rises, cool air flows in to replace the rising air. This **convection current** is the source of wind. Since air is warmed, either directly or indirectly, by the sun, wind energy is really solar energy. Wind turbines transform this wind energy into mechanical energy and then to electrical energy. Turbines require a minimum wind speed of about 15 miles per hour to generate electricity economically.

SUMMARY OF ACTIVITIES

Activity 1 – Introduction and Reading Passage

Teachers should read the entire sequence of activities first, before starting the lab. Introduce the subject of wind power and explain to the class that during this unit of study, students will build and test a simple wind powered electrical generator. Teachers can include statements from the teacher background information section. Have students consider the following quote:

“Drill for oil? You mean drill into the ground to try to find oil? You’re crazy.” – *Drillers who Edwin L. Drake tried to enlist to his project to drill for oil in 1859*

Ask them how this relates to the idea of wind generating power, and how it might be initially difficult to “sell” people on the idea.

Each student will need a copy of the Reading Passage and the pages titled Student Data Sheet. Instruct students to study the Reading Passage, “Wind Power Basics,” and complete the questions and vocabulary. This activity will help them learn about wind energy and some of its applications. Key vocabulary words in the Reading Passage will assist them in understanding the Lab Activity instructions. For students who wish to learn more of the detailed mechanical and physics principles behind the design and operation of wind turbines, direct them to the appropriate resources. Refer to the Teacher Resource Guide for suggested resources. Appropriate safety guidelines should also be reviewed before beginning the lab activity.

Activity 2 – Lab Activity – Testing a Windmill Generator

This activity presumes that students can connect a small DC motor and voltmeter (an electrical connector clamp can be used). All small motors that operate with brushes (most “hobby” and toy motors) will also operate as generators. A small motor of this type is used as a generator in this activity. The manipulated variable in the lab is the angle and design of the rotor blades. Wind speed is held constant by fixing the distance between the fan and the generator.

Each student will need a copy of the Student Data Sheets. Instruct students to review the Lab Activity before beginning so they will understand the purpose and the goals. To enhance the class’ scientific inquiry in this lab, instruct each student to develop statements for the following: hypothesis, predictions, conclusions and finally significance/implications. Note that the hypothesis and predictions should be made before beginning the Lab Activity. Refer to the Teacher Resource Guide for more information. The students

can compile results of their findings, which can be averaged so that the class can draw conclusions.

Basic concepts of electricity, such as current flow, operation of a magnetic coil motor and generation of electricity can be discussed. Discuss the diagram of the major components for generating electricity in the Reading Passage. Students can draw a concept map for the wind turbine and the functions of its parts.

Discuss the advantages of using a renewable energy source, rather than fossil fuels. Point out (from the Reading Passage) the results of doubling wind speed, which increases power output eight times, and where to locate wind turbines. Using the Internet for more information, students can research wind turbines as to what they are, where they are found, what uses they have, when they are most effective, and how they work. Research on historical uses of wind power will enrich their understanding. How wind develops from sunshine is a major concept. Students can keep track of wind speed in your area for 2 weeks and consider if wind power would be beneficial as an investment there.

Students should outline the instructions, using very few words to summarize. Before performing the experiment, students should plan some of the variations they will change in the design. Extra cardboard will be needed for altering blade sizes. Once the instructions to the initial lab exercise have been completed, experimenting with the variables provides students with opportunities to enhance their understanding. Variables can include changing length and width of blades, using different weights of cardboard for the blades, and using different angles for the blades. Students should record their variables and results in the Data Tables. As students change blade length, width, weight or angle, they should predict whether the amount of voltage will increase or decrease. Students can share and compare the variables they used and the effects on electricity generation.

Safety Precautions: Emphasize to the class safety precautions when taking current and voltage readings

using volt- and ammeters. Use either meter leads that have alligator clips on the ends, or attach insulated alligator clips to the wire ends that come into contact with the meter leads. Students should never touch any bare or exposed metal in a circuit that is generating electricity (i.e. meter leads, bare wire, etc.). Safety instructions should be reviewed. Voltmeter readings should be taken safely. For example, attach insulated alligator clips on the ends of the wire to safely clip on to the voltmeter leads. Discuss safety procedures for using the fan.

Activity 3 – Assessment

Distribute a copy of the Assessment Questions to each student. Instruct each student to work alone and answer the short answer and multiple-choice questions. Collect the handouts, grade and return them to the students.

Activity 4 – Follow Up Lab

In the Follow Up Lab, students study the relationship between wind speed and the ability of a windmill to do work (lifting objects) using their best rotor design. A separate worksheet is included in this unit for the Follow Up Lab activity.

ADDITIONAL ACTIVITIES

1. Windsock

This activity involves constructing a windsock to estimate wind speed and direction. This information is relevant to the unit because a wind turbine must face directly into the wind, and the wind speed must fall within a certain range for optimum operation of the wind turbine. A separate worksheet is included in this unit for the windsock activity as well as a separate list of required materials.

2. Internet or library research

Some students may wish to investigate the uses of wind power systems in other countries and compare with the United States. They could also investigate debates that have arisen regarding the pros & cons of offshore wind development in the US and other countries.

Wind Power Basics



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HIGHLIGHTS

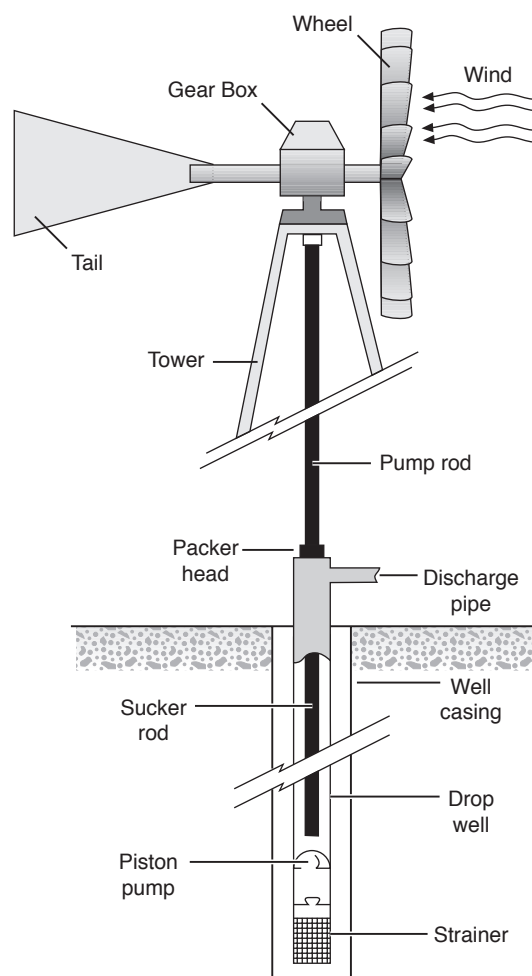
- Wind power is one of the oldest renewable technologies
- As wind speed doubles, power generation capability increases eightfold
- Higher is better: hilltops and tall towers lead to greater energy production

INTRODUCTION

What creates wind? Wind is created from differences between higher pressure and lower pressure caused by unequal heating and cooling of the Earth and atmosphere. Air always tries to flow from higher to lower pressure until the pressures are equalized.

The greater the difference in pressure between two points, the faster the wind speed will be. Other things such as mountains and valleys can affect the wind as well.

Humans have been harnessing the wind ever since farmers in ancient Persia figured out how to use wind power to pump water. Wind power turns the kinetic energy of the wind into mechanical or electrical power than can be used for a variety of tasks. Whether



MECHANICAL PUMP WINDMILL *These simple wind-driven machines, which utilize a long sucker rod to pump underground water to the surface, were a critical tool in settling the West.*

the task is creating electricity or pumping water, the wind offers an inexpensive, clean and reliable form of power. Wind farms are now part of the Texas landscape with 1,292 megawatts (MW) installed as of 2003.

WIND ON THE WATER

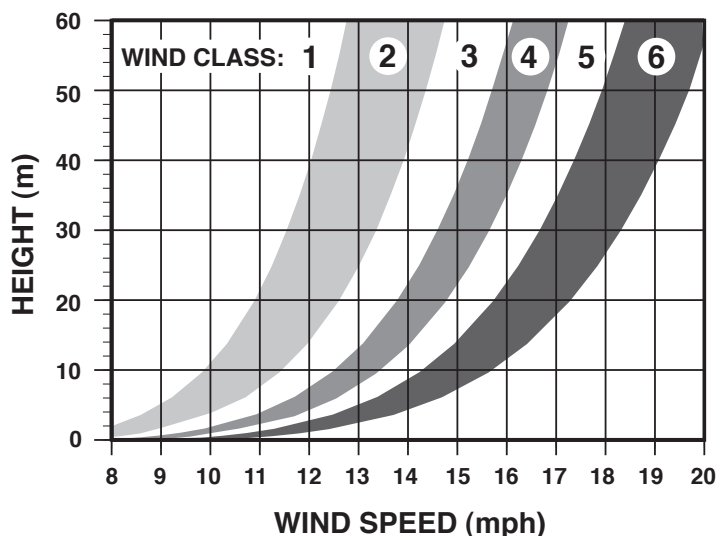
Whether powering sailboats across the surface of the water or pumping water from one location to another, the wind is a good source of power. Wind provided early explorers with the engine they needed to cross oceans and discover new lands. On land, the oldest and most widespread use of wind power is for pumping water. In virtually every country on Earth, humans are using wind power to either pump water from the ground or move it from one location to another. Here in Texas, where more than 80,000 windmills are in use, rural residents have long relied on windmills to provide water for livestock and human use.

THE HOWS AND WHYS OF WIND POWER

Wind is moving air. The engine that drives this movement is the sun. A good illustration is the sea breeze that blows along the Texas Gulf coast. As the coastal land soaks up sunshine, the air above it heats up and rises. Air over the cooler ocean water then rushes inland. The result is a very dependable wind source suitable for making anything from electricity to windsurfing.

Although modern wind turbines can produce some electricity in light winds, the stronger the breeze the better. The power available in the wind is proportional to the cube of its speed. That means that if the wind speed doubles, say from 10 to 20 miles per hour, the power available to a wind generator increases by a factor of eight, for instance from 1,000 Watts to 8,000 Watts.

One easy way to access higher wind speeds is simply to go higher above ground level.



WIND POWER DEPENDS ON ELEVATION AND WIND SPEED *Wind Class is a relative scale used to characterize wind potential of any location. Wind Class of 3 or above are generally regarded as being suitable for commercial wind farm development.*

Winds high above the ground are stronger than winds near the ground. On average a five-fold increase in elevation, say raising the height of the wind machine from 10 feet to 50 feet, will result in twice as much available wind power. That's why wind turbines are perched on tall towers and are often located on mountains or hilltops.

Given the need for strong winds, finding the best sites for commercial wind farms is critical. The location of power plants fueled by wind should be near existing power lines and in the windiest sites available. To compete head-to-head with fossil fuel generating technologies, wind turbines are best located in areas where wind speeds are 16-20 mph at 50 m height. In Texas, the best locales are found in far west Texas and the Texas Panhandle.

Air temperature is also an important factor in wind power generation. Cold air is denser than hot air. Thus, wind turbines are able to generate about 5% more power at any given

wind speed in the winter than they are during the hot days of summer.

MAKING WATTS FROM WIND

The blades on a wind turbine are similar to the propeller blades on an airplane. The rotor blades generate lift from the passing wind, causing them to rotate the hub of the turbine. The rotating action of the hub then turns a generator, which creates electricity. A gearbox is generally necessary to optimize the power output from the machine. That power is then either fed into the electric grid or stored in batteries for use on-site.

While wind speed is important, so is the size of the rotor. On a turbine, the power available to the blades is proportional to the square of the diameter of the rotor. In other words, simply by making the turbine blades



SOURCE: ALTERNATIVE ENERGY INSTITUTE

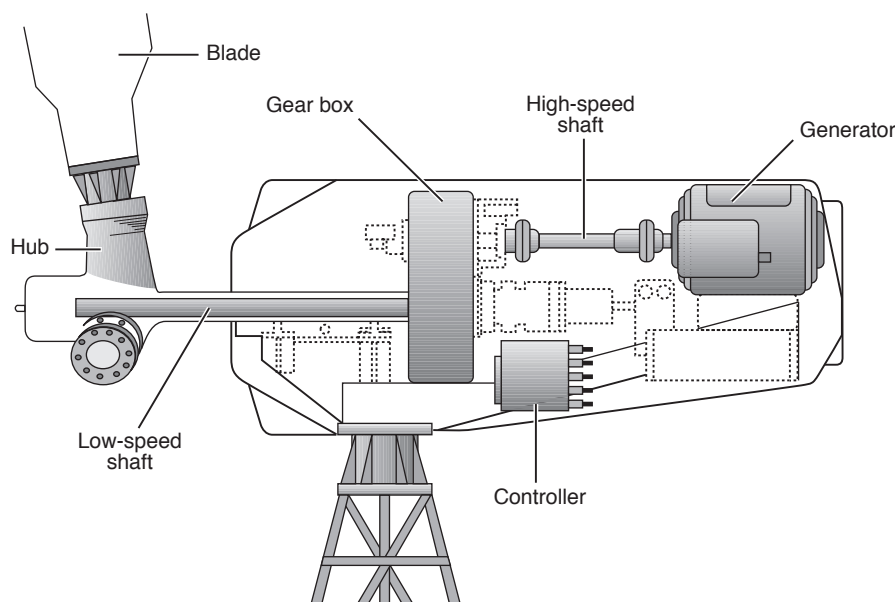
TEXAS WIND POWER In the Delaware Mountains, south of Guadalupe Mountains National Park, this wind farm's turbines are 330 kW each.

twice as long and beefing up the generator, you increase the power producing capability of the turbine by a factor of four.

Modern wind turbines come in two varieties: horizontal axis and vertical axis. Horizontal axis turbines have blades that spin on an axis that is parallel to the ground. These systems often look like the propeller on an airplane. Vertical axis systems have blades that spin

on a vertical axis giving them an appearance somewhat like giant eggbeaters.

Although large utilities are getting the most attention for their move into wind power, rural residents in all 50 states and dozens of foreign countries have quietly been installing small-scale wind generation systems. These systems can be obtained for as little as \$1,000 and are perfect compliments to solar photovoltaic systems. Several vendors sell ready-made towers and turbines that are easily installed.



ELECTRICITY GENERATING WIND TURBINE The major components of this device are the blades, shaft, gearbox and generator. On large machines, additional controllers and drive motors ensure that the machine is positioned for optimal capture of the wind.

Understanding the Reading Passage

1. Should wind energy be considered a form of solar energy?

2. Why does a five-fold increase in elevation result in more wind power?

3. How does a wind turbine create electricity?

Vocabulary

Based on the Reading Passage, write down your understanding of these words or word pairs and verify your definitions in a dictionary, on the Internet if available or with your teacher:

convection _____

electrical grid _____

electricity _____

kinetic energy _____

renewable energy _____

variable _____

voltmeter _____

LAB ACTIVITY – TESTING A WINDMILL GENERATOR

INTRODUCTION

The purpose of this activity is to construct and test a simple wind powered electrical generator and to observe how design and position affect the electrical energy produced. You will vary the angle and design of the rotor blades and observe the effect on the voltage output.

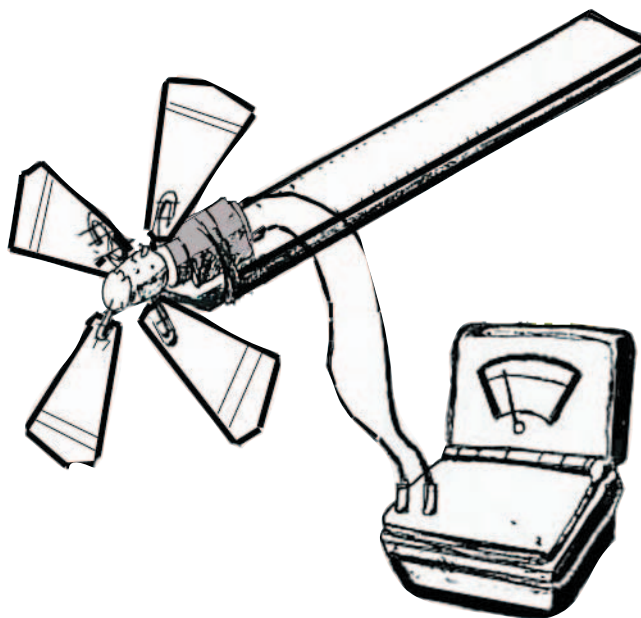
BEFORE YOU START

Review the vocabulary words from the Reading Passage. Ask your teacher if you are unsure of any of the meanings.

MATERIALS

Obtain a materials kit from your teacher. Check that it contains the following materials:

- small electric fan or hair dryer
- small DC toy motor
- cork (at least 2 cm in diameter)
- DC voltmeter
- stiff ruler or meter stick or other sturdy wood strip
- protractor
- 50 cm of electrical wire with alligator clips
- rubber bands
- scotch tape
- paper clips
- wire cutters
- scissors
- pieces of cardboard
- cork borer
- goggles



Step I. Constructing the Windmill Generator (wear goggles)

1. Use the rubber band to attach the small electric motor to the flat end of the ruler with the motor shaft extending towards the edge of the ruler.
2. If the motor doesn't already have wires attached, cut the piece of wire into 2 pieces and add these 2 wires to each of the motor's outlets.
3. Follow your teacher's safety instructions and attach the 2 wires to a DC voltmeter using the alligator clips.
4. Take four paper clips and straighten out the lower part of each clip. Clip off enough of this straight part, so that only 1 cm sticks out.
5. Cut out 4 pieces of cardboard 2 cm wide and 5 cm long. Tape these 4 blades onto the central part of each paper clip.
6. Using the 1 cm part of the paper clip that sticks out, insert the blades into the sides of the cork, 0.5 cm from the small end of the cork. Be sure to space the blades equally around the circumference of the small end of the cork.
7. Use the cork borer to make a hole in the exact center of the large cork end, which is furthest away from the wind blades. Make this hole slightly smaller than the motor shaft. Slide the cork onto the motor shaft. It should be tight enough so that the cork does not slip. If the cork does slip, use a small amount of rubber cement to hold it in place.

Step II. Performing the Experiment (wear goggles)

1. Set the blades in the cork to a 45° angle to the flat plane of the edge of the ruler (use protractor to position the angle). Place the windmill 30 cm away from the fan or hair dryer (your distance may vary depending on the strength of the wind source). Turn on the fan. Measure the voltage produced. Rotate the blades of the windmill to angles of 15°, 30° and 60° (use protractor for guidance) to see which angle produces the greatest voltage.
2. Design your own set of wind blades, discussing with your lab partner(s) which size and shape, and what number of blades, will work best. Attach these new blades to the motor and try adjusting them at various angles to produce the greatest voltage. Place the windmill at the same distance from the wind source. Measure the voltage again. Place all of your measurements in the Data Tables.
3. Determine the most efficient blade size, shape, and angle. Using this combination, explore how wind speed affects the amount of electricity produced by changing the fan speeds. (Be careful to keep the windmill at the same distance each time.) Record your measurements in the Data Tables. Discuss with your teacher other variables you might use.

Step III. Data Summary

Complete the data analysis by recording your measurements and answering the questions.

DATA TABLES**Table 1. Effect of blade angle on voltage output**

Angle of blade	Voltage
15°	
30°	
45°	
60°	

Table 2. Effect of blade design on voltage output

Blade design	Voltage
2cm x 5cm rectangle	

Table 3. Effect of fan speed on voltage output

Fan setting	Voltage

DATA SUMMARY

- Which angle of the blade produced the highest voltage? _____
- Which of your designs produced the highest voltage? What variables contributed to higher voltage? Sketch your design and record its dimensions.
- What is the approximate relationship between wind speed (fan setting) and voltage? Did increasing the fan speed increase the voltage output of your generator? _____

- On a separate piece of graph paper, select one variable from the activity and create a graph of its effect on the voltage output.

Assessment Questions

1. What changes to a windmill can improve its efficiency?

2. On the back of this paper, draw a rough map of Texas and shade in the areas where wind power is best generated.
3. Cite three reasons for using wind power, now and in the future.
1 _____
2 _____
3 _____

Multiple Choice Questions

1. As an engineer working with renewable energies you would:
 - a) place wind farms in valleys and low lying areas
 - b) place wind farms where weather fronts are calm
 - c) place wind farms on elevated sites
 - d) build wind farms everywhere
2. Wind power turns the kinetic energy of wind into:
 - a) direct heat
 - b) solar energy
 - c) hydroelectric power
 - d) both mechanical and electrical power
3. Wind power:
 - a) is one of the oldest renewable technologies
 - b) was used by early sailors
 - c) is used to pump water
 - d) all answers a, b, & c
4. Wind:
 - a) is moving air
 - b) is created by the sun's energy
 - c) has power proportional to the cube of its speed
 - d) all answers a, b, and c
5. You will likely most often see wind turbines:
 - a) on rivers
 - b) on hilltops
 - c) on lakes
 - d) in cities
6. Learning about renewable energy sources:
 - a) is necessary for the future
 - b) will help future decision making
 - c) shows you other ways to create electricity
 - d) all answers a, b, and c
7. Wind energy is:
 - a) an important energy source
 - b) kinetic energy
 - c) movement of energy from the air
 - d) all answers a, b, and c
8. Some of the devices used in wind power are:
 - a) turbines
 - b) sails
 - c) windmills
 - d) all answers a, b, and c
9. Wind is:
 - a) caused by convection
 - b) a determiner of weather
 - c) a form of fossil energy
 - d) a and b
10. Hot air:
 - a) is heavier than cold air
 - b) rises
 - c) sinks
 - d) a and c

FOLLOW UP LAB – MEASURING WINDMILL POWER

INTRODUCTION

You will use your optimized windmill from the Lab to measure the actual power.

MATERIALS

Obtain a materials kit from your teacher.

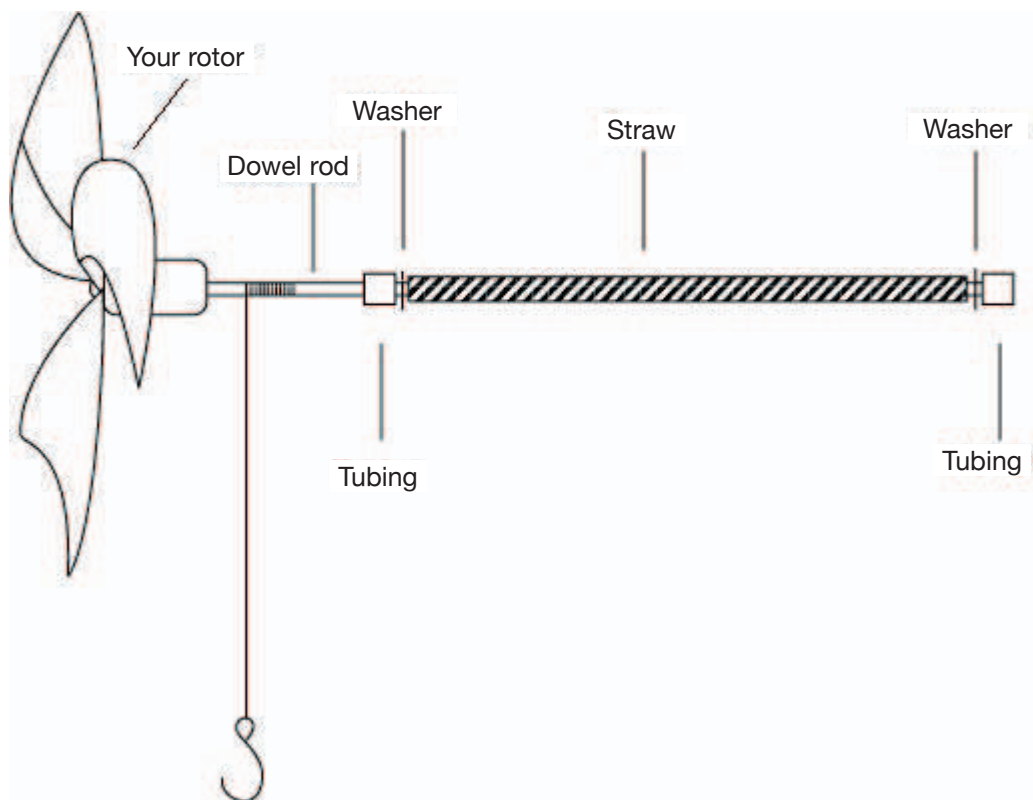
Check that it contains the following materials:

- small electric fan
- thick drinking straw, 18 cm long
- dowel rod, approx. 3-5 mm wide, 25 cm long
- thread
- 2 short pieces of aquarium tubing 1 cm long that fit snugly around the dowel rod
- 2 small washers that fit loosely around the dowel rod
- a paper clip

- small calibrated weights (Small paper clips can be used. They have a mass very close to one gram.)
- “warm” glue and glue gun
- stopwatch
- cork borer

PROCEDURES

1. Remove your optimized wind turbine from the motor shaft and place it on the dowel rod. It may be necessary to enlarge the hole. Do not force the cork on the dowel rod as the cork may split.
2. Assemble the apparatus. Slide a piece of tubing over the dowel to a position right behind the rotor. Add the other parts in this order: washer, drinking straw, the second washer and the other piece of tubing. Check to make sure the rotor and dowel



spin freely inside the straw. The rotor must turn the dowel, not spin on the shaft. Use a small amount of rubber cement or warm glue to attach the cork to the dowel if necessary.

3. Use the warm glue to attach the thread to the dowel. Bend the paper clip to form a hook and tie it to the end of the string.
4. Hang five small weights from the paper clip and turn on the fan. Hold the rotor assembly by the straw in front of the fan the same distance as in the laboratory portion of this activity.
5. Experiment with the number of weights until your rotor lifts the weights from the floor to the dowel in about five seconds.
6. When everything seems to be working, use the stopwatch to measure the time required

to lift the weight from the floor to the dowel. Record your measurement. Repeat five times. Calculate the average time.

CALCULATIONS

1. Calculate the power output of your rotor assembly.

Convert mass to kilograms:

Weight in grams $\times 0.001$ = weight in kilograms

2. Calculate work:

Work = mass $\times$ height $\times 9.8 \text{ m/s}^2$

3. Calculate power output:

Power = work/time

ADDITIONAL ACTIVITY – MAKE A WINDSOCK

INTRODUCTION

A wind turbine must face directly into the wind, and the wind speed must fall within a certain range for optimum operation of the wind turbine. Pilots of small airplanes have for years used windsocks to determine the wind direction and estimate its speed. You can make a windsock.

MATERIALS

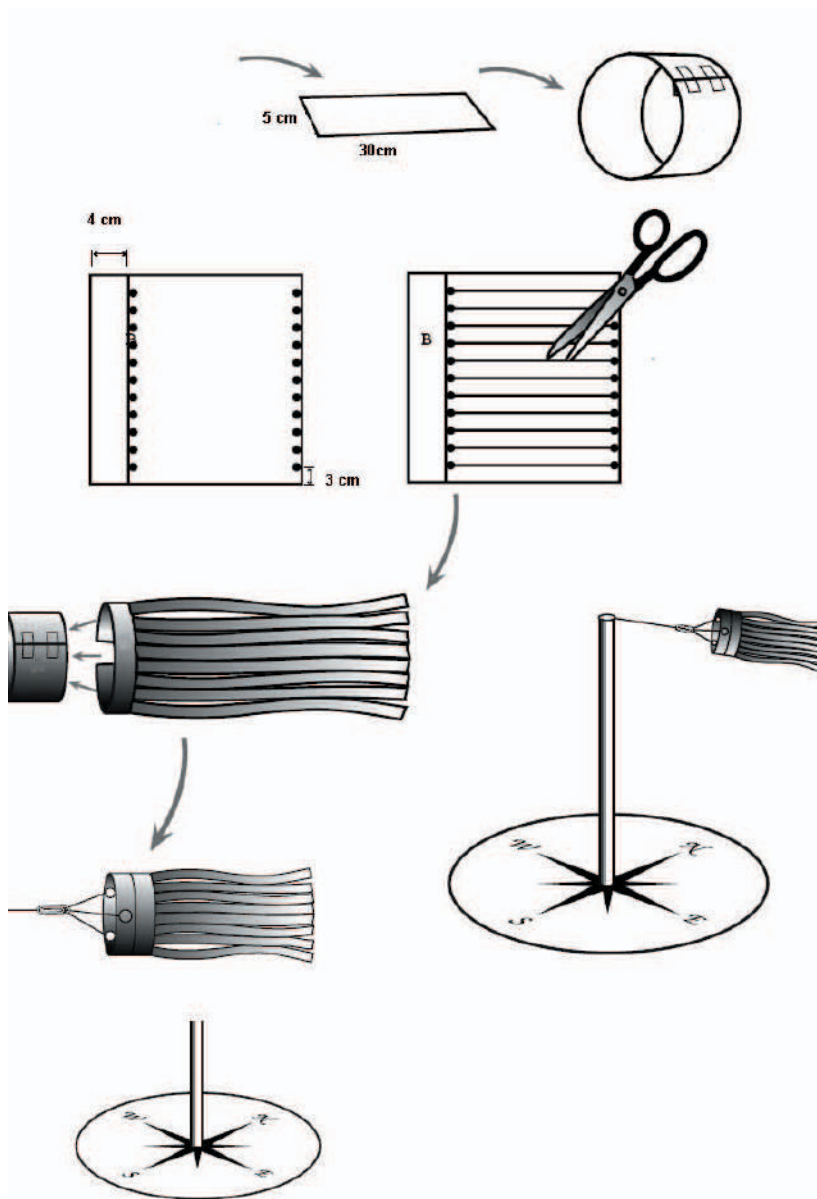
Obtain a materials kit from your teacher. Check that it contains the following materials:

- strip of poster board 5 cm × 30 cm
- 1 piece of tissue paper 28 x 28 cm
- glue
- adhesive tape
- scissors
- hole punch
- 1 paper clip
- metric ruler
- 1.2 m kite string
- six foot pole (wooden dowel rod, flag pole, tent pole, or 1" PVC)
- magnetic compass

Follow these steps to make the windsock:

1. Obtain a strip of poster board 5 cm × 30 cm.
2. Form a loop from the strip and glue or tape the ends of the strip together to make a paper ring.

3. On the tissue paper use a marker to draw a line all the way across 4 cm from one edge.
4. Begin at one end of the line you just drew and make a small mark every 3 cm all the way across the tissue paper.
5. Make small marks every 3 cm along the opposite edge of the tissue paper.



6. Using the marks as guides, draw lines on the tissue paper 3 cm apart. Use scissors to cut along these lines, making strips of tissue paper. Start at one edge and stop 4 cm from the other edge. Do not cut the paper into separate strips.
7. Glue the solid edge of the tissue paper to the paper ring. Allow time for the glue to dry.
8. Use a hole punch to punch three holes equally spaced around the paper ring.
9. Cut 3 pieces of string each 30 cm long. Tie one end of each string to the windsock at each of the 3 holes.
10. Tie the 3 loose ends of the string to a single paper clip. Tie another 30 cm length of string to the paper clip.

11. Tie the windsock to a pole and place it outside where it can be seen from the classroom. If desired, use the compass to mark directions on the ground with the pole at the center.

Using the windsock and the compass you can now measure the wind direction. You can also see how much wind there is, by looking at how high the wind lifts the windsock.

If you want the windsock to be weatherproof, you can use plastic bags or nylon fabric instead of paper.

Understanding the Reading Passage

1. Yes, since air is warmed by the sun, wind energy can be considered a form of solar energy.
2. Winds high above the ground are stronger than winds near the ground. Since the power of wind is proportional to the cube of its speed, stronger winds at high elevations produce more power.
3. The rotor blades on a wind turbine generate lift from the passing wind. This causes them to rotate the hub of the turbine thereby turning a generator that creates electricity.

Lab Activity Data Summary

1. Student answers will vary, but an angle somewhere close to 45 may produce the best results.
2. Student answers will vary, but should include blade size and shape, number of blades, angle of blades, distance from wind source.
3. Increasing fan speed should increase voltage.
4. Accept students' graphs.

Assessment Questions

1. Improving efficiency can be accomplished by changing length and/or width of the blades, changing the angle of the blades, altering blade weight and also insuring that the windmill is positioned on an optimum site where the wind is quite constant.
2. Students can practice drawing a map of Texas from memory, which also aids their ability to locate major Texas cities. The areas in the Panhandle and west Texas as well as part of the coast should be shaded.
3. Wind power is renewable, cost effective to use, will reduce our consumption of imported energy, does not pollute the environment and can be delivered through the existing power grid.

Multiple Choice Questions

1 c; 2 d; 3 d; 4 d; 5 b; 6 d; 7 d; 8 d; 9 d; 10 b

Vocabulary Definitions

convection – transport of heat by the movement of parts of a fluid (air or water); cool air is denser than warm air and as it settles the cool air pushes the warm air upward

electrical grid – the transmission lines and generating facilities that supply homes and businesses with electricity

electricity – created when a metal wire is moved through a magnetic field; a flow of energy involving electrons and other subatomic particles

kinetic energy – energy resulting from motion

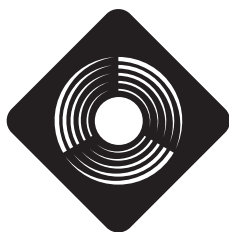
renewable energy – forms of energy that derive and quickly replenish from the natural movements and mechanisms of the environment, such as sunshine, wind, movement of the seas and the heat of the earth

variable – a value liable to change, as in size, number, degrees, etc.; one can manipulate variables in an experiment.

voltmeter – instrument for measuring electric potential; $\text{voltage} = \text{resistance (ohms)} \times \text{current (amperes)}$

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RENEWABLE ENERGY
THE INFINITE POWER
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