Testing a Windmill Generator & Wind Power Basics

Target Grade Levels
Ninth - Twelfth

Time
Two 1-hour periods

Materials
- small electric fan or hair dryer
- small DC toy motor
- cork (at least 2 cm in diameter)
- DC voltmeter
- stiff ruler
- 50 cm of thin electrical wire with alligator clips
- rubber band
- scotch tape
- paper clips
- wire cutters
- scissors
- piece of cardboard
- goggles

Knowledge and Skills (TEKS)
- Science:
  - Describe energy systems, observe change and consistency, and make inferences and predictions;
  - Analyze effects and record data of heating and cooling; and
  - Explain different types of climate and the factors that influence climate regions.
- Math:
  - Show relationships using tables; and
  - Construct graphic organizers.
- Language Arts:
  - Gather credible information; and
  - Develop drafts, revise, edit.

Overview
Students will learn the best locations in Texas for utilizing wind power. Students will construct and test a windmill to observe how design and position affect the electrical energy produced. Appreciation for the benefits of renewable energy sources is a focus.

Background Information
Wind power is one of the oldest renewable technologies. Wind is caused when warm air rises, and cooler air rushes in to fill the space. The turbines change this wind energy into mechanical power. Turbines require a minimum wind speed of about 15 miles per hour to generate electricity economically. As wind speed doubles, power generation capability increases eightfold, and the higher the turbines are placed, for example, on a tall hill or tower, the greater energy production. Unlike fossil fuels, wind power cannot be depleted and produces little pollution.

Suggested Reading
- *Wind Energy and Wind Turbines*. Vaughn Nelson, AEI, Revised September 2000. (Available from the Alternative Energy Institute)
- *Introduction to Wind Energy*. Vaughn Nelson, Earl Gilmore and Kenneth Starcher, AEI Report 94-2. (Available from the Alternative Energy Institute)
- *Wind Characteristics, An Analysis for the Generation of Wind Power*. Janardan Rohatgi and Vaughn Nelson, 1994. (Available from the Alternative Energy Institute)
- *Wind Energy Basics, A Guide to Small and Micro Wind Systems*. Paul Gipe, Chelsea Green Publishing, 1999.

Procedure

1) Vocabulary

a) ammeters
b) convection
c) current
d) direct current (DC)
e) electrical power
f) electricity
g) fossil fuel
h) gearbox
i) kinetic energy
j) mechanical power
k) renewable energy
l) turbines
m) variable
n) voltage
o) voltmeter

2) Activities

a) The teacher should read the student activity first. This activity presumes that students can connect a small direct current (DC) motor and voltmeter (an electrical connector clamp can be used). 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.). Students should read W*ind Power Basics*, before reviewing the activity. 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.

b) 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 W*ind Power Basics* handout. Students can draw a concept map for the wind turbine and the functions of its parts.

c) Students should outline the instructions, before class, 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. Discuss the advantages of using a renewable energy source, rather than fossil fuels. Point out (from the W*ind Power Basics* handout) 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.

d) 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, changing wind velocity, and using different angles for the blades. Students should record their variables and results in a data chart they create

during the activity. As students change blade length, width, weight or angle, they should predict whether the amount of voltage will increase or decrease.

e) Students can share and compare the variables they used and the effects on electricity generation. 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 two weeks and consider if wind power would be beneficial as an investment there.

f) Constructing the Windmill Generator (wear goggles)

   i) 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.

   ii) If the motor doesn't already have wires attached, cut the piece of wire into two pieces and add these two wires to each of the motor's outlets.

   iii) Follow your teacher's safety instructions and attach the two wires to a DC voltmeter using the alligator clips.

   iv) Take four paper clips and straighten out the lower part of each clip. Clip off enough of this straight part, so that only one centimeter (cm) sticks out.

   v) Cut out four pieces of cardboard two cm by 25 cm. Tape these four blades onto the central part of each paper clip.

   vi) Using the one cm part of the paper clip that sticks out, insert the blades into the sides of the cork, .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.

   vii) Place the large cork end, which is furthest away from the wind blades, into the motor shaft. Make sure the shaft goes into the exact center of the cork.

g) Performing the Experiment (wear goggles)

   i) Rotate the blade in the cork so that it is at a 45^{o} angle to the flat plane of the edge of the ruler. 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 or hair dryer. Measure the voltage produced. Try rotating the blades of the windmill to see which angle produces the greatest voltage.

   ii) 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 a data chart.

   iii) Determine the most efficient blade size and shape (sketch and record the dimensions). Next explore how wind velocity affects the amount of electricity produced by changing the fan speeds. (Be sure to keep the windmill at the same distance each time.) Record your measurements in a data chart. Discuss with your teacher other variables you might use.

3) Review
Discuss results.

4) Evaluation

a) Short Answer Questions

i) What changes to a windmill can improve its efficiency?

ii) Draw a map of Texas and shade in the areas where wind power is best generated.

iii) Cite three reasons for using wind power, now and in the future.

b) Answers for Short Answer Questions

i) 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.

ii) 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. Students can describe the kinds of environments they have shaded by doing some research, using a variety of sources.

iii) 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.

c) Multiple Choice Questions

i) As an engineer working with renewable energies you would:

(1) place wind farms in valleys and low lying areas

(2) place wind farms where weather fronts are calm

(3) place wind farms on elevated sites

(4) build wind farms everywhere

ii) Wind power turns the kinetic energy of wind into:

(1) direct heat

(2) solar energy

(3) hydroelectric power

(4) both mechanical and electrical power

iii) Wind power:

(1) is one of the oldest renewable technologies

(2) was used by early sailors

(3) is used to pump water

(4) all answers a, b, & c

iv) Wind:
    (1) is moving air
    (2) is created by the sun's energy
    (3) has power proportional to the cube of its speed
    (4) all answers a, b, and c

v) You will likely most often see wind turbines:
    (1) on rivers
    (2) on hilltops
    (3) on lakes
    (4) in cities

vi) Learning about renewable energy sources:
    (1) is necessary for the future
    (2) will help future decision making
    (3) shows you other ways to create electricity
    (4) all answers a, b, and c

vii) Wind energy is:
    (1) an important energy source
    (2) kinetic energy
    (3) movement of energy from the air
    (4) all answers a, b, and c

viii) Some of the devices used in wind power are:
    (1) turbines
    (2) sails
    (3) windmills
    (4) all answers a, b, and c

ix) Wind is:
    (1) caused by convection
    (2) a determiner of weather
    (3) a form of fossil energy
    (4) a and b

x) Hot air:

(1) is heavier than cold air

(2) rises

(3) sinks

(4) a and c

d) Answers to Multiple Choice Questions

i) Question #1, 3

ii) Question #2, 4

iii) Question #3, 4

iv) Question #4, 4

v) Question #5, 2

vi) Question #6, 4

vii) Question #7, 4

viii) Question #8, 4

ix) Question #9, 4

x) Question #10, 2

5) Extension

a) Have a representative of the local electric utility discuss their wind energy program.

b) Have a representative of a windmill manufacturer visit to discuss construction and use of windmills nationwide.

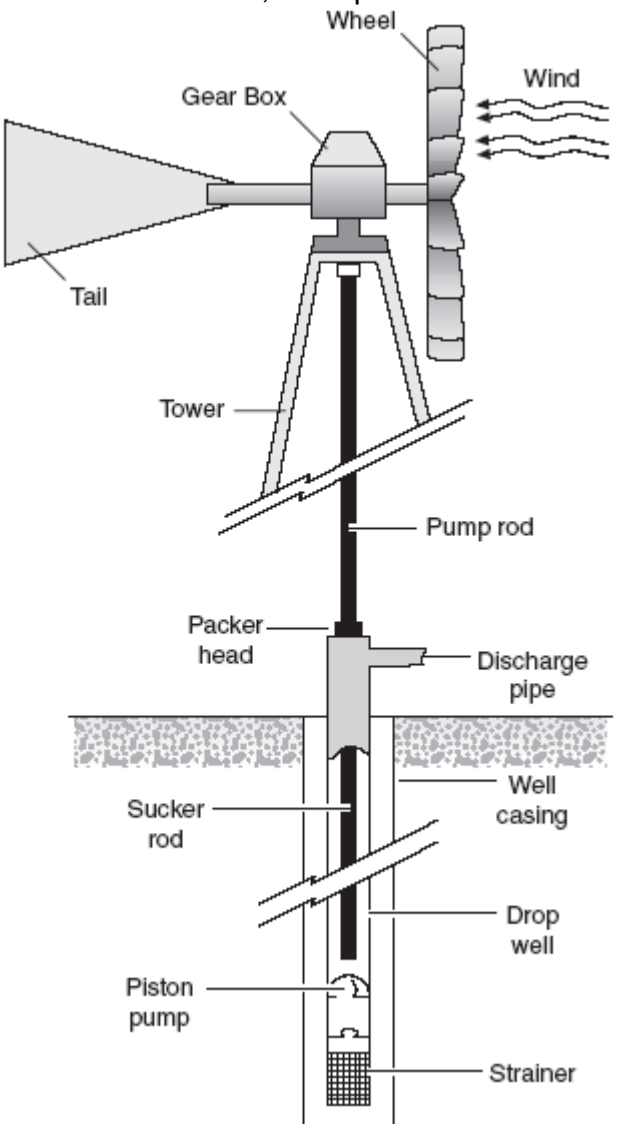
c) Have students research the drawbacks (bird kill, noise, etc.) of wind power and write a comprehensive paper citing pros and cons.

Adapted from: "Researching renewable Energy" *Texas State Energy Conservation Office.* www.infinitepower.org/lessonplans.htm.

Wind Power Basics

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
- Unlike fossil fuels, wind power cannot be depleted and produces no pollution



Mechanical pump windmill
These simple wind-driven machines, which utilize a long sucker rod to pump underground water to the surface, were a creitical tool in settling the West.

SUMMARY

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. Wind offers an inexpensive, clean and reliable form of power.

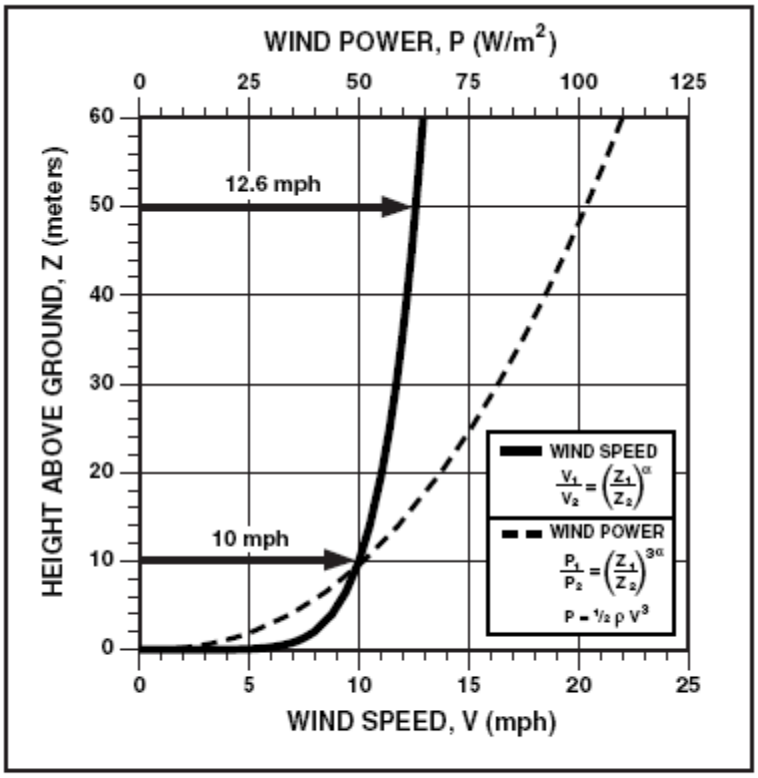
WIND ON THE WATER

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.

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. Why? 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 to 8,000 Watts.

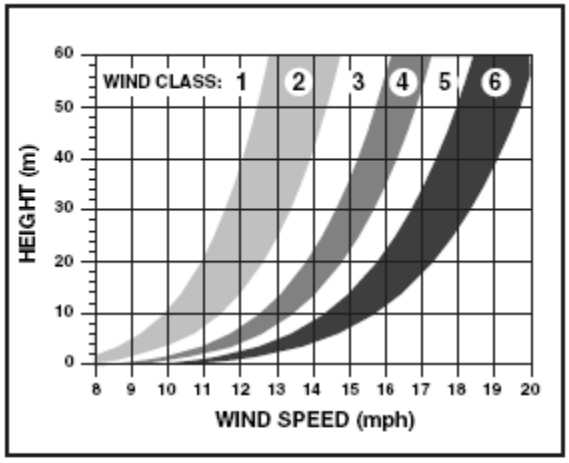


Typical wind shear profile *Speed and power available in the wind increases with increasing elevation. The relationship is commonly referred to as the one seventh power law (a=1/7)*

One easy way to access higher wind speeds is simply to go up. 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 must 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 meters (m) height. Wind farms are located in the most windy areas and close to utility power lines. In Texas, the best locales are found in West Texas and the Texas Panhandle.

Air temperature is also an important factor in wind power generation. Cold air is more dense 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.



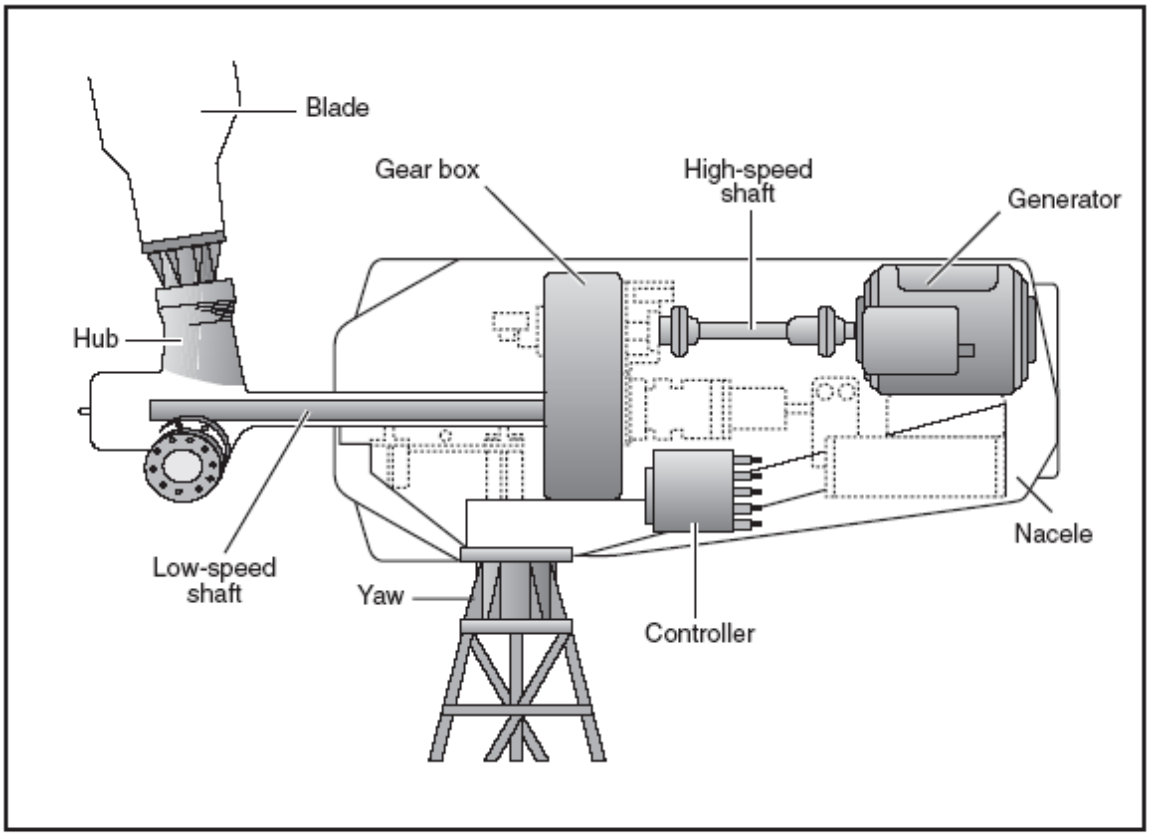
Wind power depends on elevation and wind speed *Wind Class is a relative scale used to characterize wind potential of any location. Wind Class of 3 and above are generally regarded as being suitable for commercial wind farm development.*

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 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 egg beaters.



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.*

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 photovoltaic systems. Several vendors sell readymade towers and turbines that are easily installed.

RESOURCES

FREE TEXAS RENEWABLE ENERGY INFORMATION

For more information on how you can put Texas' abundant renewable energy resources to use in your home or business, visit our website at www.InifinitePower.org or call us at 1-800-531-5441 ext 31796. Ask about our free lesson plans and videos available to teachers and home schoolers.

ON THE WORLD WIDE WEB:

Wind Energy Association
www.awea.org/faq/index.html

Danish Wind Turbine Manufacturers Association
www.windenergy.dk

For home owner size wind turbines homepower.com/download2.htm#Wind

ORGANIZATIONS

Alternative Energy Institute
Box 60215, WTAMU
Canyon, TX 79016
(806) 651 2295
www.wtamu.edu/research/aei or
www.windenergy.org

American Wind Energy Association
122 C Street, N.W.
Washington, D.C. 20001
(202) 383-2505
www.awea.org

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1617 Cole Blvd
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(303) 275-4373
www.caddet-re.org

National Renewable Energy Laboratory
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Texas Solar Energy Society
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Austin, TX 78767-1447
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