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# Turning Turbines

**Target Grade:** 4<sup>th</sup> - 8<sup>th</sup>

## Overview

In this lesson, students will design wind turbine blades to help understand how the wind can be harnessed to provide the energy needed to generate electricity, and to experiment with changes that might be made to the blades that would make them more effective at generating electricity.

The lesson may be adapted for multiple grade levels. It may also be adapted for use in concert with social studies lessons as wind power use has figured prominently throughout history.

## Objectives

- Students will understand the relationship of potential and kinetic energy in relation to wind energy.
- Students will investigate the process through which a wind turbine produces electrical energy.
- Students will work together to discover the factors influencing how well a wind turbine converts wind energy into electricity.
- Students will explore the uses of wind power throughout history.

## Background

- Energy and Wind Power- See Appendix I
- Scientific Method - See Appendix II

## Materials

- Wind Power Turbine (available at [www.kidwind.org](http://www.kidwind.org); and see resources for other options)
- Multi-meter - to measure the voltage produced by the turbine
- Fan - box fans work best for this experiment!
- Cardboard for Blades - used boxes work great!
- Dowels - these are attached with tape to the blades to be inserted in the turbine's hub
- Duct Tape/Strapping Tape/Masking Tape
- Scrap Paper - try using tissue paper as it is lighter!

**Prep Time:** 10 minutes

**Activity Time:** 60 minutes

## Nevada/California State Standards

- E.12.C.4 - Students know process of obtaining, using, recycling of renewable and nonrenewable resources.
- E.2.A.1 - Students know the Sun is a source of heat and light. E/S
- E.5.A.1 - Students know the Sun is the main source of energy for planet Earth. E/S
- E.12.A.1 - Students know the Sun is the major source of Earth's energy, and provides the energy driving Earth's weather and climate. E/S



- N.8.A.6 - Students know models are tools for learning about
- N.5.B.3 - Students know the benefits of working together with a team and sharing findings.
- GS 5.8.6 - Identify and locate examples of renewable and nonrenewable natural resources.
- GS 5.12.6 - Analyze the patterns of use changing distribution, and relative importance of Earth's resources.
- H3.[6-8].14 - Analyze the social impact of technology, i.e., ships, iron, water delivery systems, wheel, and the printing press.

### Key Vocabulary

- **Wind**- air that gets put into motion in order to balance out unequal pressures.
- **Wind Speed**- Increases with altitude and over open areas with no windbreaks, measured in miles per hour.
- **Turbine**- Rotary engine that converts the energy in a continuous stream of fluid (gas, liquid, or wind!) into mechanical energy by passing the stream of fluid through a system of fixed and moving fanlike blades.
- **Mechanical Energy** - energy of an object created by its movement position or both (Example: pulley system, pencil sharpener, door handle)

### Activity

**Introductory Discussion:** Brainstorm with the students about wind and wind energy. Some potential discussion questions: Where was the windiest place you have ever been? Where you live is it windier in the winter or the summer? Is it windier on the top of a mountain or in the valley? Is it windier on a lake, ocean, field, or forest? Is it windier in the city or in rural areas? Have you ever seen a wind turbine? Have you ever seen a wind farm? What kind of factors do you think would affect the effectiveness of a wind turbine? What are some ways wind has been used in the past?

**Step 1.** Divide the class into design team groups of 3-5 students. Begin by showing the class the wind turbine and letting them know they are going to design blades for the turbine. Their goal is to make blades that utilize the power of the wind most effectively; generate the most electricity! Students will compare their blade design to that of their classmates to ultimately determine which design is most effective. Blades should be made out of any reasonably lightweight material. Cardboard boxes cut to use as frames for blades made of tissue paper is common and quite successful. However students should be encouraged to get creative if they have other ideas, or if a wider variety of materials is available.

**HINT 1:** Student groups can often work more efficiently in groups for this activity if they are given individual roles. **EXAMPLE:** one student in charge of obtaining supplies, one in charge of recording ideas, etc. The instructor can decide how their students would work best to successfully undertake this activity.

**Step 2.** Student groups will decide by consensus upon the design for their blades. They should consider shape, materials, number of blades, size of blades, and ultimately the angle/pitch at which blades are attached to the turbine to best harness the wind energy. Students can use tape to attach the small dowels to their blades to insert into the hub of the wind turbine. Students should



be allowed 15 - 30 minutes (depending upon time availability) to design the blades for their group. The instructor should monitor student groups to gauge readiness.

HINT 1: If desired, the instructor can have student design teams draw their blade designs and obtain instructor permission, prior to beginning construction. To improve students' blade design have them consider blade length (are they bigger than the fan?), number of blades, weight of materials, smoothness of surfaces, edges, curvature of the blade itself, and angle/pitch at which the blade is attached to the hub.

HINT 2: This may be an ideal opportunity for an instructor to introduce graph paper for student design teams to use for drafting their potential blade designs.

**Step 3.** Once blades are completed, the instructor can call the groups up to the turbine to begin testing effectiveness. OR, the instructor can begin calling groups to the turbine as soon as the first group is ready, therefore staggering the testing process for better time management. When testing their blades, students should record the amount of energy generated and make observations on their blades' effectiveness. The accompanying handouts can be used for this purpose. (For safety purposes, have students stand to the front or back of the turbine rather than to the side during testing, in case blades come loose as the turbine turns.)

*NOTE: It is possible to get a negative volt reading if the wires from the multimeter to the turbine are connected incorrectly; therefore the turbine is using electricity instead of generating it. Of course be sure to check your circuit connections; however instructors can let the students figure out the proper adjustments to make in order to achieve a positive volt reading (electricity generation). To achieve this, students generally need only to reverse their angle/pitch of the blades. As this is an actual struggle of scientists and wind farmers it is an opportunity for a teachable moment to allow the student design teams to discover how to solve the problem.*

HINT 1: Instructors can allow student groups to make adjustments (such as attachment angle, connection materials) to their blades while testing. OR, Multiple rounds of testing can be done by the class if time permits, and the instructor can have students return to their desk to make adjustments to their blade design. All adjustments and subsequent effects upon energy generation should be recorded by the students.

HINT 2: Recording the angle/pitch of the blade, and the blade positions around the hub, (Part A.2. on the Student Handout) may be confusing for students. It may be helpful for the instructor to go through an example for the whole class on the board of how to record the angle/pitch of the blade selected by the student design teams.

**Step 4.** After all groups have received adequate testing and adjustment time, invite student groups to share their design and results with the class. The instructor can record these results on a white board for comparison.

**Step 5.** Once results have been revealed students should discuss in their groups which blades they think were most effective. The instructor can then invite groups to share their consensus with the class.

## Review Questions

- What is wind? What are some ways that wind was used in the past?
- How does a wind turbine work? What are the parts of the wind turbine?



- What is a renewable energy source? Name some. Why is wind considered a renewable energy source?
- Why is wind energy so important? What are some challenges of wind energy?
- What factors affect how a wind turbine works? What factors must be considered when building a wind farm?
- Which type of blade worked best? Why do you think there was a difference in the way different blade shapes worked?

(Review Questions are based on the lesson as well as on the Background Information in Appendix I)

### Assessment/Evaluation

- Have student groups imagine that they were a consulting firm designing blades for a wind turbine on top of their school. What blade design from their class would they recommend? Why would that blade design be best? Write at least three sentences describing the blade design they would recommend and why.

### Constructed Response

a. This activity was similar to conducting an experiment as a scientist does. You created turbine blades, tested them for effectiveness, made adjustments, then re-tested your turbine blades. Then you compared the effectiveness of your blades with your classmates' and determined which design was most effective for your class.

- Describe a situation when you may have used, or could use, a trial-and-error thinking process similar to that of a scientist.
- Explain why you think using this process worked well, or could work well, for you as you tried to solve your problem or answer your question.

b. During this activity you were given and/or brainstormed information about the usage of wind power.

- Describe two ways wind power has been used by people in the past.
- Explain whether you think this knowledge influenced the design of your blades. Write two sentences why thinking about past usage of wind power was, or was not, important to creating effective blades for the wind turbine.

### Cross-Curricular Extension

- **Math:**
  - Graph the energy generated by each groups' blade design
  - Graph the changes in electricity generated at different angle/pitch intervals.  
EXAMPLE: How many volts were generated at 15, 30, 45, 60, 75 and 90 degrees?
  - Graph multiple design teams' results at different angles/pitches to determine which angle/pitch would be most effective for each blade design.
  - Students can investigate common appliances that could be powered by the wind turbine using their blade design, or calculate how many turbines it would take to power common appliances (TV, Video game console, hair dryer, laptop computer).
- **Social Studies**
  - Brainstorm ways that wind power assisted in the emergence of ancient civilizations (Egyptian, Mesopotamian, Roman, Greek, Norse) and modern countries (British Empire, Victorian Spain, Dutch, United States).



## Differentiation

### Learning Intelligences addressed

- Verbal/Linguistic; Bodily/Kinesthetic; Intrapersonal and Interpersonal; Visual/Spatial

### Gifted and talented

- Research the strength and frequency of wind patterns in at least two areas (such as Washoe County and Clark County, the state of Nevada and Arizona, etc.). Graph wind strength and frequency together on the same grid for each area then determine which area is a better location to build a wind farm. Consider distance of transmission to urban centers, potential detrimental environmental factors (EXAMPLE: migratory bird pathways), construction cost potential, and any other factor you might think would influence a wind farm's effectiveness in that geographic area (EXAMPLE: if it is too cold snow and ice may accumulate on the turbine blades so electricity cannot be collected). Give a presentation to convince your classmates why the location you determined would be better than the other.
- Examine wind power use in your local community and state. What are some ways it is being used? Make some recommendations on how wind power could be used more efficiently and frequently? Give a presentation on your findings to your classmates.
- Investigate further the history of wind power, especially its use in generating electricity. Who are some pioneers in wind turbine engineering? What are some of the advances they made? What is some of the new technologies that make our turbines more effective? How did wind power affect the emergence of ancient civilizations, and modern countries? (HINT: Wind powered water wells assisted in the settlement of the American west) Give a presentation on your findings to your classmates.

### English as second language

- Investigate, in your primary language, the translations for the following vocabulary words: wind, wind energy, windmill, turbine blades, turbine, electricity, transmission, and generator.
- Investigate wind power use in your home country. How does it compare to wind power use in the United States?

## Appendix I

### Energy and Wind Power

Energy is defined as the capacity to do work. Potential energy is energy that is stored, and kinetic energy is the energy possessed by a moving object. Energy comes in many forms including thermal (heat), electric, radiant (light), nuclear, chemical, mechanical, and elastic. Energy cannot be created or destroyed, only changed from one form into another. For example when a light bulb is turned on, that energy is changed from electrical energy into light and heat!

The sun itself creates energy through nuclear fusion, when hydrogen nuclei pair up to form a helium atom, and releases huge amounts of energy in the form of heat and light! The sun provides the earth's inhabitants with energy that drives our carbon cycle; providing energy to green plants through photosynthesis, and subsequently to other living things who eat the green plants and organisms that eat the organisms who eat green plants. Through the carbon cycle the sun is also responsible for giving us the fossil fuels and natural gas that we utilize as a non-renewable energy



resource. A renewable energy resource means it is naturally regenerated within a useful amount of time such as a lifetime, therefore making it renewable. Renewable energy resources include solar, geothermal, hydropower, wind, and biomass or plant materials.

Wind energy is a mechanical energy force created by moving air. Wind is the flow of the air on Earth on a large scale; it is caused by differences in atmospheric pressure as air is accelerated from areas of high pressure to those of low pressure. On Earth wind is driven mostly by the differences in temperatures between the equator and the poles, and the rotation of the planet itself. Wind speed is measured in miles per hour, and described by the direction it is blowing from. For example a *northerly* wind blows from north to south! The potential for wind energy generation is gauged by determining wind strength AND frequency, and wind farm locations are determined by finding areas with the right combination of both.

Wind has been used by people as a source of energy for thousands of years, first to power sailboats and then to drive windmills. In fact wind was used to power smelting furnaces in Sri Lanka as early as 300 B.C. Today wind is used to power wind turbines to create electricity by "capturing the wind's kinetic energy" and converting it to electrical energy (Walker, 2007). The basic parts of a wind turbine are the blades, tower, and gearbox. The wind blows against the blades and through the force of lift causes them to turn. The blades are attached to the hub, which turns the main shaft attached to the gearbox. The gearbox "is connected to a generator made up of magnets inside coils of copper wire. When the shaft spins, the magnets spin which creates an electric current," that is then carried to a storage device such as a battery for use as needed (Walker, 2007). Most turbines begin to turn with wind speeds of around 12 mph, but when building a wind farm the frequency of the wind must be considered as well as the strength of the wind. Wind turbines can be used as stand-alone power plants which make them very effective for powering buildings in remote locations, as no transmission lines need be built.

Wind turbines are built in areas best suited to the harvesting of wind, and it is an attractive form of renewable energy because it is very clean as turbines can create electricity without burning fossil fuels. When many turbines are built close together this is called a wind farm. Wind farms store power which they then sell to local power companies for use by their customers. Costs for wind farms have decreased significantly, and efficiency has increased significantly. Storage of generated electricity can be a challenge but battery technology has improved drastically. This is important because we want to be able to store excess electricity when the wind is really blowing for use when the wind is not blowing. Another challenge of wind power is transmission of the generated electricity as often wind farms must be located in remote areas for efficiency, such as north of Elko, NV. As people have become increasingly more concerned about pollution and fossil fuel availability, wind power has become very popular and wind technology innovations are occurring rapidly, currently providing nearly 20% of all power in Denmark (International Energy Statistics, 2008).

## **Appendix II**

### **The Scientific Method**

The scientific method is a series of steps used to investigate phenomena, attempt to solve a problem, to find answers to questions, and ultimately to acquire new knowledge. Conclusions are reached through asking questions, formulating guesses, creating and performing experiments, and analyzing the results. Often scientists will repeat this process until they achieve an adequate volume of data to analyze, or find an answer to the problem they are investigating. It is important



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to remember that the scientific method is used to find answers to unknowns; and ethically a scientist must use their experiments not to gather evidence in order to prove a point they already believe is true, but to explore without bias the consequences of their experiments and then through analyzing the results determine a conclusion whether it confirms or rejects their original beliefs. The thinking process involved in the scientific method can also be applied to other walks of life, and once an individual learns to approach issues in this way they will have the power to solve any problem!

#### Steps to the Scientific Method:

- **Ask a Question/Find a Problem/Query a Phenomenon** - this must be related to something that can be observed so that the answer is about something that can be measured
- **Do Background Research** - this is necessary in order to properly craft your experimentation to yield results that can potentially answer the question you are asking; also you want to ensure you are not repeating past failures, though making adjustments to a past experiment to potentially yield different results would be valid!
- **Construct a Hypothesis** - formulate an educated guess as to the possible answer to your question. Try using "If \_\_\_[I do this]\_\_\_, then \_\_\_[this]\_\_\_ will happen." Your hypothesis should be stated in a way that you can easily measure its acceptance or rejection.
- **Do an Experiment to Test your Hypothesis** - this is a test of the validity of your hypothesis, whether you can accept or reject it. Craft your experiment so that all conditions are the same except one (have only a single variable) that way you know it is that single difference that is affecting the results. For example, if you are examining how light affects the speed at which a type of plant grows, every plant in your experiment would get the same type and amount of food, and water; be planted in the same soil and containers; and be kept at the same temperature etc. BUT they would each receive different amounts of light each day, that way you would know their differing growth rates were dependent only upon the different amounts of light they were given. Repetitions should be done as well to add to the validity of your results and provide as much evidence as possible for your conclusions, and to prove your results weren't just accidental.
- **Record your Results** - it is important for scientists to keep very complete, timely, and accurate record of the results of their experiments, and their observations, usually by keeping a journal. If you were doing the plant experiment you should measure the height of the plant, count the leaves etc.; and write observations as to the plant's observable qualities; at very regular intervals, daily for example, to provide as extensive a picture possible of your experiment as it progresses.
- **Analyze your Results** - do an unbiased examination of the results you have achieved.
- **Draw a Conclusion** - here is where you examine the meaning of your results, speculating on why certain data resulted from your experiment.
- **Accept or Reject your Hypothesis** - look carefully without bias at your results and your conclusions, can you confirm your hypothesis with the data you collected? Was your experiment extensive enough to accept your hypothesis? If your hypothesis is rejected, or is shown to be true but not to a significant degree, restructure your hypothesis, make adjustments to your experiment, and test your hypothesis again!
- **Share your Results!** - prepare a written report, and/or presentation board for your experiment. Be sure to include some of your background information, hypothesis, data, analysis, and conclusion.



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It is important to remember that though the scientific method seems to be a rigid series of steps that must be performed in an orderly fashion, new information can be integrated into the experiment at anytime, and one can also back up and repeat steps if needed. Just remember to record everything! Then those to whom you present your findings can judge for themselves whether they think your experimentations and conclusions are valid. When a question or problem is repeatedly experimented on and yields the same or significantly similar results and the analysis always leads to the same conclusions... you finally have an answer, which is also known as a theory!

## Resources

*International Energy Statistics*. (2008). Retrieved December 29, 2009, from US Energy Information Administration:

<http://tonto.eia.doe.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=37&aid=2&cid=&syid=2005&eyid=2007&unit=BKWH>

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