Wind Energy Part III:

Making Electricity from Wind

The purpose of this lesson is to show how energy from the wind can be converted into electricity for everyday use. Students will construct a working wind generator from common materials and observe its generating power in a variety of situations. The activity is designed for students who have a basic understanding of electricity and magnetism and are familiar with the power of wind.

Included in this packet:

California Curriculum Standards

This lesson addresses or expands on the following California State Science Curriculum Standards for Earth Science (ES) and Physical Science (PS):

Third Grade

PS1. Energy and matter have multiple forms and can be changed from one form to another. As a basis for understanding this concept:

PS1a. Students know energy comes from the sun to Earth in the form of light.

PS1c. Students know machines and living things convert stored energy to motion and heat.

PS1d. Students know energy can be carried from one place to another by waves, such as water waves and sound waves, by electric current, and by moving objects.

PS5b. Differentiate evidence from opinion and know that scientists do not rely on claims or conclusions unless they are backed by observations that can be confirmed.

PS5d. Predict the outcome of a simple investigation and compare the result with the prediction.

Fourth Grad

PS1. Electricity and magnetism are related effects that have many useful applications in everyday life. As a basis for understanding this concept:

PS1d. Students know the role of electromagnets in the construction of electric motors, electric generators, and simple devices, such as doorbells and earphones.

PS1g. Students know electrical energy can be converted to heat, light, and motion.

ES5. Waves, wind, water, and ice shape and reshape Earth's land surface.

ES6c. Formulate and justify predictions based on cause-and-effect relationships.

ES6f. Follow a set of written instructions for a scientific investigation.

Fifth Grade

ES4. Energy from the sun heats Earth unevenly, causing air movements that result in changing weather patterns. As a basis for understanding this concept:

ES4a. Students know uneven heating of Earth causes air movements (convection currents).

Sixth Grade

ES4. Many phenomena on Earth's surface are affected by the transfer of energy through radiation and convection currents. As a basis for understanding this concept:

> **ES4d**. Students know convection currents distribute heat in the atmosphere and oceans.
>
> **ES4e**. Students know differences in pressure, heat, air movement, and humidity result in changes of weather.

PS6. Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for their formation. As a basis for understanding this concept:

> **PS6a**. Students know the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.
>
> **PS6b**. Students know different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and know how to classify them as renewable or nonrenewable.

PS7a. Develop a hypothesis.

PS7d. Communicate the steps and results from an investigation in written reports and oral presentations.

PS7e. Recognize whether evidence is consistent with a proposed explanation.

Lesson Summary

- *Estimated Time*: 80 minutes

- *Student Prerequisite Knowledge*: Wind has power and energy to move or alter objects; electricity and magnetism work together; electromagnetism is the physical property that allows motors and generators to work

- *Concepts Learned*: Energy from the wind can be converted to electrical energy through the use of turbines, magnets and wires in a configuration that is similar to a motor.

Background Information for Teachers

Capturing the Energy in Wind

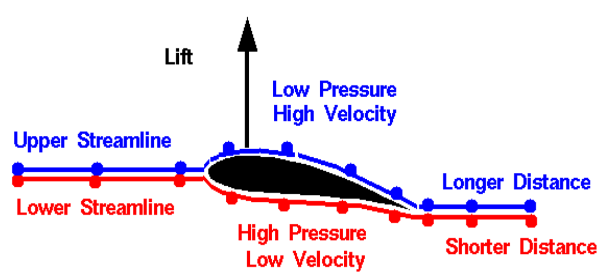
Humans have been harnessing wind energy for centuries. Techniques date back to the first sailing vessels which used the wind's energy to push a boat, and to early windmills which used the wind's energy to turn a rotating fan which then ground (milled) grain or raised water from a well. Harnessing wind to accomplish modern tasks involves a technique similar to that used in early windmills.

Solar radiation from the sun heats the earth's surface and atmosphere, causing variations in the temperature from place to place over the surface and from one altitude to another. Hot air tends to rise, leaving an open space of low pressure below it and forcing cooler air to rush in and fill the low pressure void. The fluctuation of high and low pressure in the air causes the air to move, often in one direction for extended periods, and this movement is what we call wind.

Good examples of these are the land and sea breezes observed near the ocean or large lakes. During the day, soil on land heats up far more than water; the hot air over the land rises, leaving a low pressure area that the cooler air over the sea rushes in to fill. As the hot air travels above and drifts out over the water, it cools again and drops down to the water. Meanwhile, the cool air that had rushed in over the land to fill the low pressure void has become warm. The newly-warmed air rises, leaving another low pressure void, and newly-cooled air over the water rushes in to fill it; the cycle continues. This is the sea breeze. When the sun sets, the soil becomes colder than the water, and the wind is forced in the other direction out to sea as a land breeze. Wind occurs under similar though less predictable circumstances across the surface of the earth.

Air that is moving, namely wind, has energy in the form of mechanical kinetic energy, as do all moving bodies. There are many other forms of energy than can be made by converting kinetic energy, but the simplest and most useful conversion is from kinetic energy to electrical energy via a generator. However before we make electricity from wind, we need to understand exactly how moving air can perform work.

When wind hits a propeller or turbine blade, it must go around the blade on both sides. One side of the blade is flat and the other is rounded (see picture next page), forcing the wind to move faster around the rounded side than along the flat side. According to *Bernoulli's Principle*, moving air creates low pressure. Around the turbine blade, the air is moving faster along the rounded side, so there is lower pressure on that side than on the flat side. Pressure creates force, and the blade moves towards the lower pressure. This is the fundamental principle that explains how bird and airplane wings create lift (see diagram below).



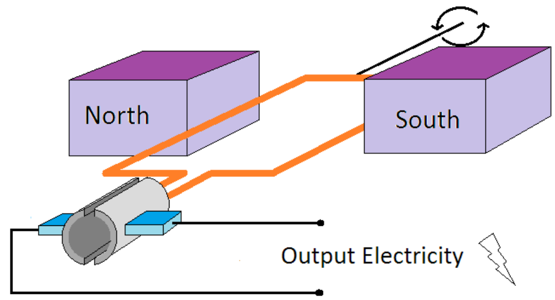
By connecting several blades to a central hub that can turn around an axle, and by making the rounded sides of the blades all face the same direction, either clockwise or counterclockwise, you create a machine that rotates in one direction when the wind blows against it. If wind around each blade causes low pressure on the clockwise side of the blade, for example, all the blades will move clockwise, thereby turning the hub. At this point, the wind's energy has been converted into rotational kinetic energy, or the energy involved in turning the hub.

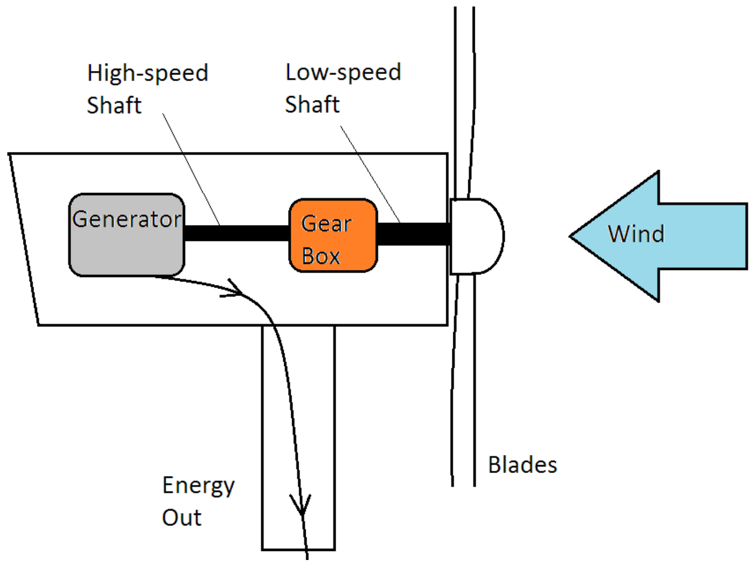
Converting Kinetic Energy to Electrical Energy

Now that the hub is turning for free due to the energy of the wind, it is a simple matter to produce electricity using basic electromagnetism. By now Fourth Graders will have learned that electricity and magnetism are two sides of the same coin: electric current creates magnetism, and a moving magnet creates electricity in a wire. When these concepts are used together we can create motors, which turn electricity into motion (electrical energy into kinetic energy) or generators, which turn motion into electricity (kinetic energy into electrical energy - the opposite of a motor). Here are the basics of the generator inside the body, or nacelle, of a wind turbine.

Connected to the hub, which rotates as wind pushes the blades in a circle, is a long shaft that extends back through the nacelle. Attached along the length of the shaft is a series of magnets with their North and South poles facing in opposite directions radially away from the shaft. Around this rotating mechanism is a large coil of wire that has been wound in concentric circles perpendicular to the rotating shaft. As the magnets rotate inside the wire coils, the natural magnetic field passes through each piece of wire in the coil. The reverse is also used: by having the magnets be stationary around a rotating wire coil, the same effect occurs (see diagram).

As we know, a moving magnetic field creates current in a wire (output): the rotating magnetic field on the shaft creates an electric current in the large wire coil. The mechanism that uses this technique to create electric current is the generator. That electric current is connected directly to the electrical grid and is used to power our homes!



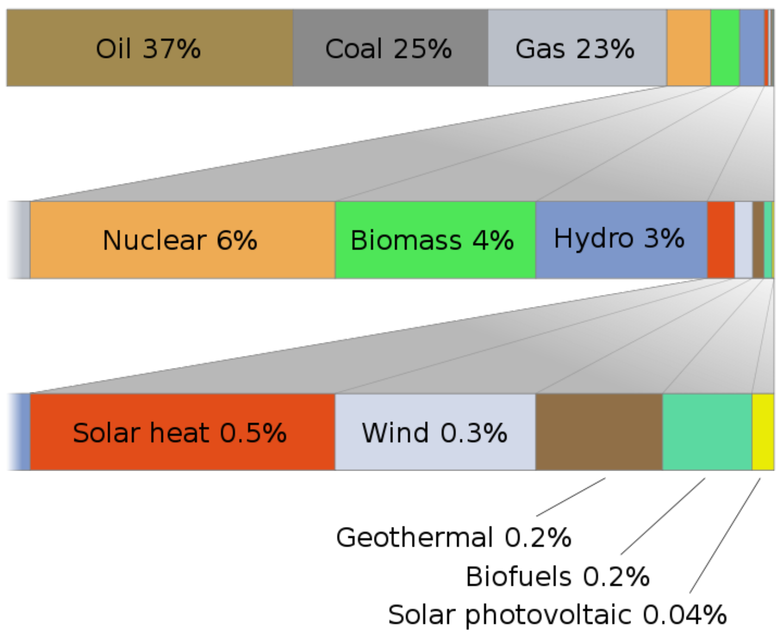


Currently, wind turbines are widely used across the world, including China and East Africa, and are especially effective along coasts and in the great plains of the USA where wind speeds are high and relatively constant. However, the output is variable and many utilities still prefer fossil fuels (oil, natural gas, and coal) as they tend to be cheaper. The most efficient wind turbines today convert about 47% of wind energy to electrical energy, and the price of a turbine is still high. However, technology and cost is improving constantly, and the added advantage of a wind turbine is that it requires minimal upkeep, has little effect on the surrounding environment, and has no pollution emissions. As such, wind power stands as one of the most effective, clean, and completely renewable sources of energy available to us.

Non-Renewables

The vast majority of our energy does not come from wind. In fact, if you look at the 2011 global energy resource chart below you can see that wind doesn't even appear as its own category; it is combined with others like concentrated solar, photovoltaics, hydrogen and others under the common name "Renewables." While hydro power is also renewable it is more commonly used than the others, for instance in large dams like Hoover Dam and Three Gorges Dam, or in tidal and wave generators. We call all of these renewable because they depend only on sources of energy that are in infinite supply. The sun produces energy of its own (solar) and also directly affects wind. The moon's gravity causes tides and the earth's gravity causes river flow: neither the sun nor gravity itself will ever run out, at least not as long as humans are around.

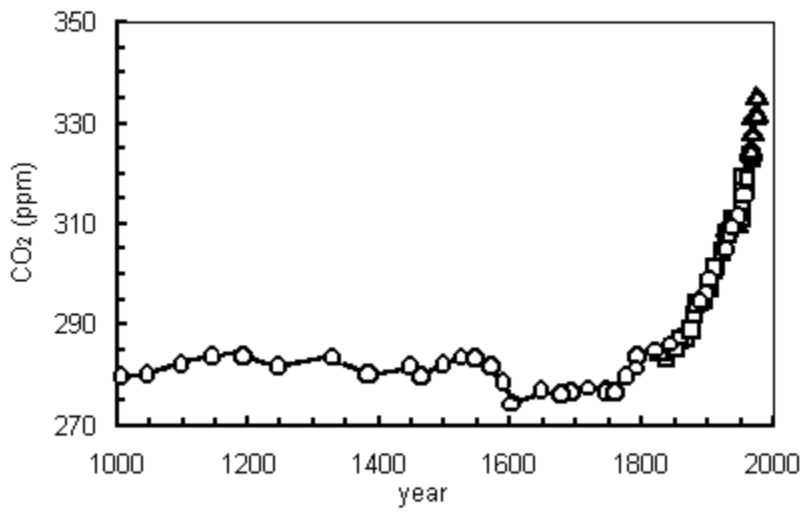
Most of our energy, however, comes from what we call "Non-renewables," meaning energy sources that are not infinite like coal, oil, gas, uranium, plutonium, and others. An added characteristic of non-renewables is that they tend to be extremely harmful to the environment. Nuclear, while it is clean to use for energy production, produces nuclear waste which must be stored underground in order to keep its harmful effects away from any ecosystems. The big three – coal, oil, and gas – are a different issue altogether.



Combined, coal, oil, and gas account for almost 90% of the world's energy supply, and for very good reasons. They are plentiful, relatively simple to extract, and contain more energy per gram than any other accessible and abundant substance on Earth. For example, a kilogram of coal contains more energy than a kilogram of TNT (the difference is power – TNT burns much faster than coal even though it produces less energy). Extracting and burning a single kilogram of coal is not only cheap, it produces almost 30 MJ of energy that is used to heat water, thus producing steam to turn a turbine and creating electricity. A typical coal plant can burn over 4000 kilograms of coal every minute. By comparison, one minute of average wind carries less energy than a kilogram of coal. Oil and Gas are even more energetic than that, at times carrying up to twice the energy of coal per unit mass. This is the reason that oil, the most energetic source we have, is used to power cars; solar cars simply cannot get enough energy to be effective.

The problem with these fossil fuels, of course, is that they pollute extensively. Oil and coal are the fossilized remnants of carbon-rich organisms that lived, died, and decomposed millions of years ago, depositing their stored energy in chemical bonds in the form of oil (hydrocarbons), gas (small hydrocarbons) and coal (almost pure carbon). Energy is most readily extracted through burning, but when burning fossil fuels a natural product is always carbon dioxide, which is the bonded carbon and oxygen in the air. Carbon dioxide is greenhouse gas, meaning it thickens the atmosphere, trapping the sun's and earth's thermal energy inside the atmosphere where normally it would escape into space as radiation. As more thermal radiation gets trapped inside the greenhouse blanket, the temperature of the earth rises, resulting in what we now call global warming.

Normally carbon dioxide is not a concern as the greenhouse effect is a natural phenomenon that, in fact, keeps us alive; and excess carbon dioxide is captured by plants, limestone and the ocean, to name a few. However, human industry has created such an increase in carbon dioxide, among other greenhouse gases, that the earth can no longer recapture it at the rate we produce it. On the graph below you can see the sudden increase in carbon dioxide levels coinciding with the rise of industry.



Other types of pollution are also a problem; carbon dioxide is but one of substances that have substantial negative effects on our atmosphere. Others include water vapor (greenhouse gas), carbon monoxide (a poison), methane (leaked into the air through natural gas wells), chlorofluorocarbons that destroy the protective ozone layer, excess ozone itself which is a poison in the lower atmosphere, and thousands of others. The main sources of pollutants are transportation, energy plants burning fossil fuels, manufacturing waste, and agriculture.

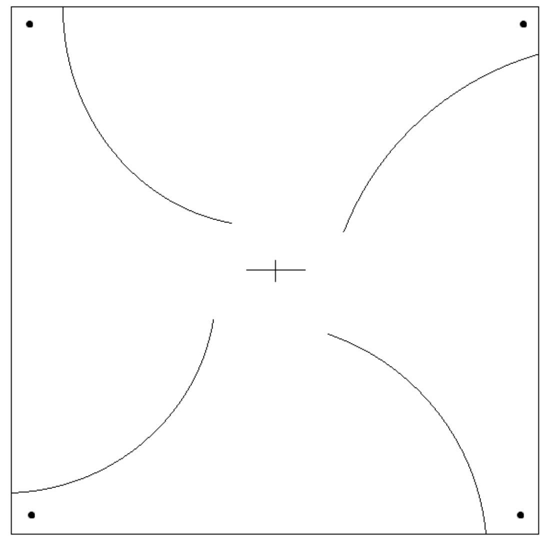
The push for renewable energy as the dominant source of energy is hindered by several factors. First: the price of fossil fuels for the energy produced is much more attractive to industries, tax-payers, and especially developing countries. Second: the infrastructure for and habit of depending on fossil fuels has been in place long enough for people to accept it over newer technologies. Third: the environmental effects created by burning fossil fuels have been overlooked by voters and policy makers as a potential side-effect rather than a definite, measurable, and growing problem.

*For more information, videos, or pictures of wind energy, wind turbines, renewable technology or electromagnetism, visit the Tape and Scissors website: (__)

Materials

Tape and Scissors Provides:

- Small 12 V Motor (1 per group)
- 6" x 6" pinwheel with cutting scheme (1 per group)
- LED (1 per group)
- Push pins (2 per group)
- 1" x 1/3" piece of eraser (1 per group)
- Written and illustrated instructions for creating wind generator (1 per group)
- Illustrated vocabulary list (1 per group)
- Wire leads



You Provide:

- Stapler (1 per group or share)
- Scissors (1 per group)
- Window fan (recommended for use inside or in areas where there is little reliable wind)

For teachers preparing the wind generator kits independently, the following additional guidelines are recommended:

- Copy (or have the students copy) the pinwheel cutting scheme onto a square piece of stiff paper. The design does not need to be exact, but sides of 7 inches or less are recommended.
- The "hub" can be made easily from any eraser. Cutting 1" x 1/3" segments from a standard large pencil eraser has proven to be the easiest method.
- Simple LEDs (Light-Emitting Diodes) can be found at most electronic supply or surplus shops for very little money. They can also be retrieved from broken radios and phone chargers.
- Small motors can be found at electronic supply or surplus shops, or ordered in bulk online. 12 V motors are recommended for their small size and appropriate power output but, in general, smaller is better. You shouldn't need anything priced over $2 or $3.

Preparation

Before facilitating this lesson, the teacher should be familiar with the steps, the end result, and potential problems with the activity. It is highly recommended that the teacher construct and test a wind turbine before attempting the lesson with students.

In this lesson students will build on their understanding of wind as a force and of the connection between a natural process and the electricity they use at home and in school. The most difficult concept is the conversion of rotational energy to electrical energy via electromagnetism. Before the lesson students will remove the back of the small motor to look inside and see what is happening, or look at the pictures of motors provided in the instructions. As they turn the axle of the motors, they will see several coils of copper wire rotating inside the motor case. On the inside surface of the case is a black band around its inside perimeter - the magnet. As the wire coils rotate inside the magnetic field, electricity is created inside the wire. Students may notice that there are several coils and several connections with wire "brushes" on the bottom. The brushes and multiple contact points on the rotating coils are called, together, the *commutator*. The commutator allows the motor to work using DC - direct current (current that runs in one direction only) - or the generator to produce DC. Without a commutator the generator will only produce AC - alternating current (current that changes direction many times per second, typically 60 times per second in the US) and the motor will not turn at all.

If you are using small bulbs there will not be any difficulty, but if you are using LEDs you will need to explain to the students that LEDs only accommodate electric current that is flowing in one specific direction; current in the opposite direction is stopped. LED stands for Light Emitting Diode: a diode is an electrical device that acts as a one-way gate for current to flow through. Therefore if the LED does not light at first while the turbine is spinning, they should remove the LED and reverse its direction before trying again.

- Students should work in small groups: prepare workstations around the room that are easily accessible so that students can see you and you can help when necessary.
- Throughout the lesson students should record the procedure steps, any observations they make and possible explanations for the observed phenomena. They will need to consult their notes to answer the discussion questions.
- Extra wind energy resources like videos, pictures, diagrams, and interactive web applications are available on the Tape and Scissors website (___) to help illustrate any part of the lesson.
- Optional class and take-home projects are given at the end of the lesson; feel free to perform the projects as a class, assign them as homework, or adapt the project into the lesson.
- Provide the given list of new or difficult vocabulary and help students to understand the new words before and during the activity.

Activity

1. Begin by sitting with the students and having them recall what they know about wind – where it comes from, what it feels like, the effect it has on the environment, homes, the students themselves, etc. Have one or two draw for the class what they imagine "wind" looks like.

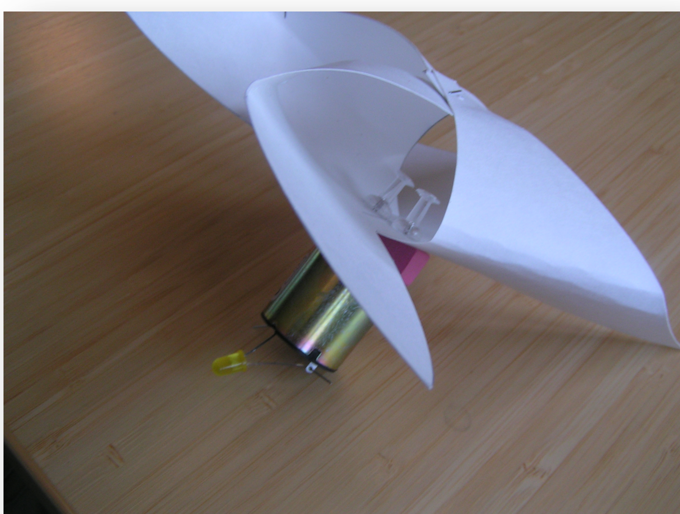
2. Review or discuss briefly the meaning of electricity and magnetism. What are the differences and similarities? Where have they seen electricity used? Magnets? Note that magnets and electricity affect each other. If students have not yet studied the 4th Grade Electricity and Magnetism unit, or have not performed the Tape and Scissors *Motor* activity, do not dwell on electromagnetism longer than it takes to explain that, in order to create electricity – the goal for the day – moving magnets are needed.

3. If available (see the Tape and Scissors website), show relevant pictures and videos of wind generators.

4. Discuss briefly the goal for the day – to create electricity/turn on a light bulb using only the wind. Show and explain the materials that each group will be using. Answer any questions they may have before beginning.

5. As students go to their workstations, pass out materials, instructions and vocab lists (if necessary) to each group.

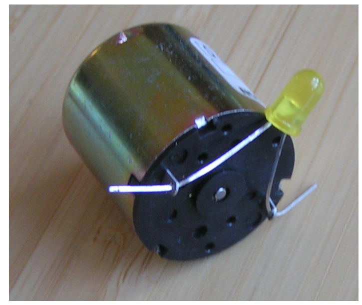
6. If students rely on oral instructions, read aloud from the sheet. Otherwise let the students navigate the instructions together. Walk around and help when they get stuck.



Wind Turbine Instructions

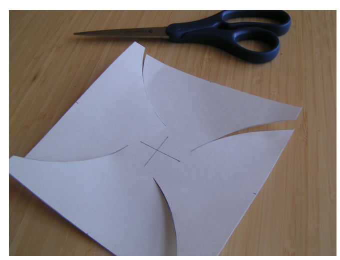
A. Collect all materials

B. Find the LED: bend its legs so that each leg fits into each lead on the back of the motor without sliding out. The motor's leads are the metal tabs with small holes in them.

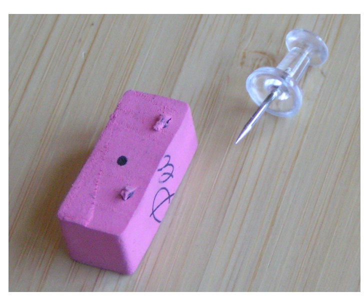


C. Test the LED by spinning the motor axle clockwise between your fingers quickly. The LED should blink once with each spin you give it. If the LED does not blink, reverse its direction by switching its legs to the opposite lead on the back of the motor. Then try again.

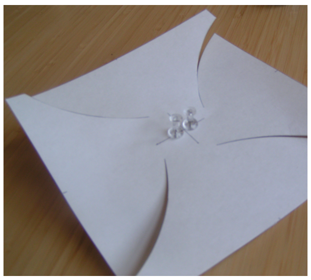
D. Find the square piece of stiff paper. There should be a design printed on one side. Cut along the curved lines on the paper.

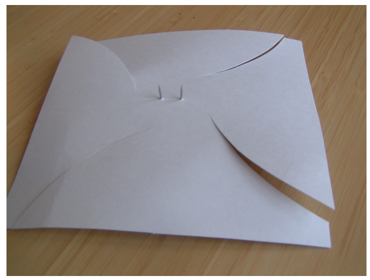


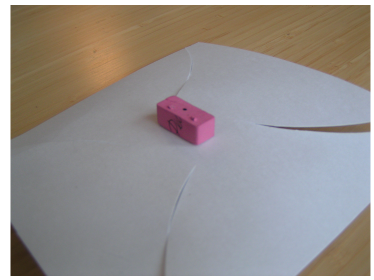
E. Find the piece of eraser: insert a pushpin into one of the long sides and then remove it. It should leave a thin hole in the eraser.



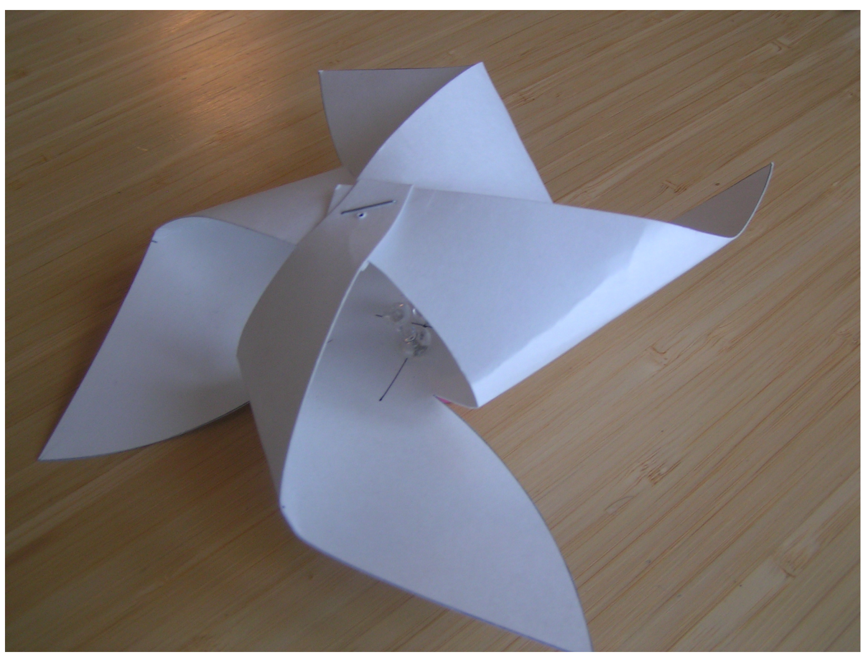
F. Attach the eraser to the back of the paper as follows: first, find the two push pins and insert them through the front of the paper to either side of the center so that they are about $\frac{1}{2}$ inch apart. Then stick the eraser onto the push pins in the back so that the hole in the eraser faces away from the paper, as shown.



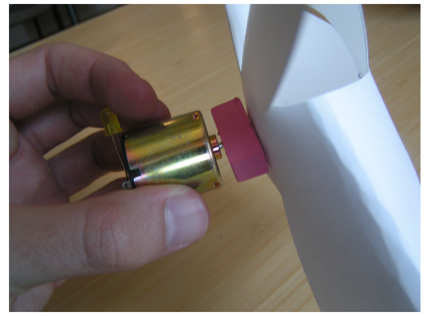




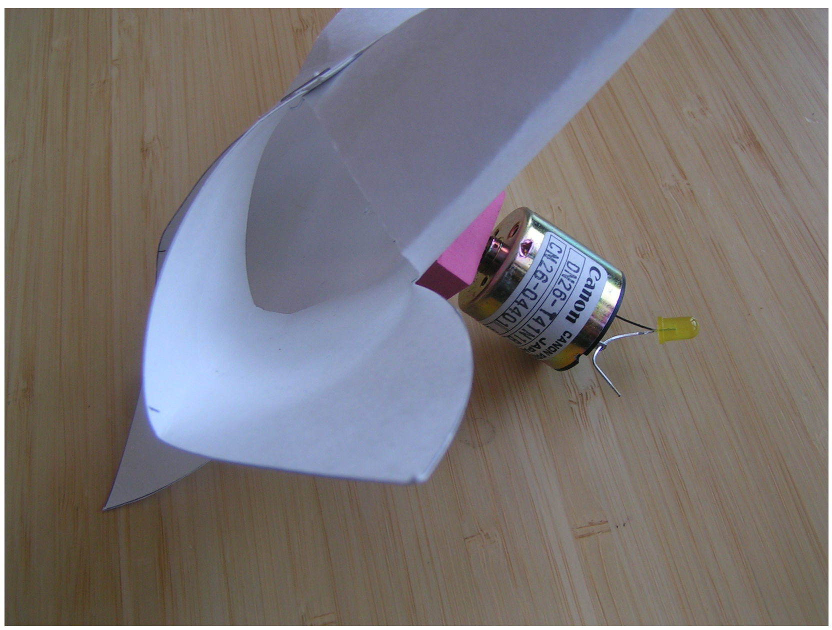
G. Holding them between your thumb and forefinger, bend each of the four paper corners (marked with a dot) into the center so that the dots overlap. Staple the four tabs together. The paper should now resemble a pinwheel.



H. Turn the pinwheel/eraser combination over so that you can see the hole you made in the center of the eraser. Insert the motor axle into this hole all the way.



I. The wind turbine is now complete! Hold it upright into the wind or in front of a fan and the pinwheel will turn quickly, creating electric current through the LED. If the LED does not light, find a stronger source of wind or try reversing the LED leads. *Note that the turbine should be facing the fan, not lying horizontally or facing away.



What Do You Think?

1. Hold your wind generator up into the wind or in front of a fan. Does the LED bulb turn on?

2. Try moving the wind generator to different positions: close to the fan, far away, behind the fan, to the side. What is the *best* position for the wind generator to spin quickly? Why?

3. What could you do to improve the wind generator? What are some problems with the wind generator?

4. Today we made a small wind generator. Draw and explain how you would make a bigger one.

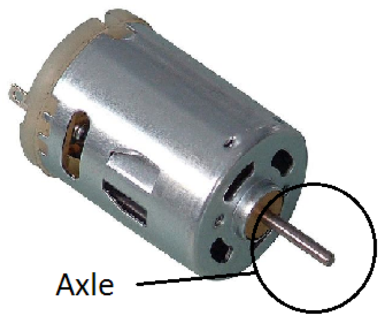
5. Could wind power be used to bring electricity to your school? How?

6. Today we used wind to create electricity. What are some other uses of wind that you have seen?

New Things!

Motor

A machine that uses electricity to *turn* an axle. Motors come in all shapes and sizes, but they always have a magnet, wire, and an axle.



Generator

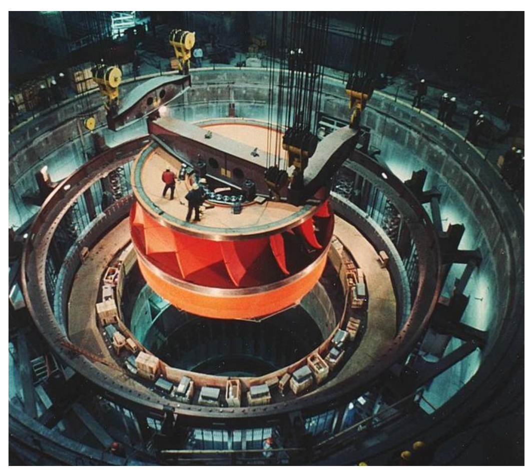
A machine that *creates electricity* from other sources of energy, like hydro (water), wind, gas, coal, oil, and nuclear

Turbine

A machine that is forced to turn because of moving air, steam, or water

OR

A machine that spins in order to move air, steam, or water



Wrapping up

As students test their generators and work on the questions, help those who were unable to get their generators to work or are having trouble with the questions. If the generator does not work it is often because the LED is connected backwards. If students finish early, they can help clean up or continue testing their generators.

When everyone is ready, the workstations have been cleaned and materials returned, have a few students share their answers to the questions. When answering the question about using wind to bring electricity to the school, help move the discussion towards ideas of how using wind might be possible or not. The more creative their answers, the better! Ideas might include the lack or abundance of wind in your area, design ideas for bigger and better turbines or generators, environmental concerns, etc.

Now that they've seen the basics of turning wind into electricity, it's time to show them how engineers are doing it! On the Tape and Scissors website are helpful videos and pictures of real wind turbines that are being built and used to power the national grid and, in turn, homes and schools. Especially notable is the size of industrial turbines.

If time permits, and if students have discussed energy previously, help them compare wind energy production to traditional energy production methods like oil, natural gas, and coal. What are the advantages and disadvantages of each? What are the respective impacts on the surrounding environment?

*Many students have heard that wind turbines sometimes kill birds, and you should be prepared to address that concern. There are several ways to approach this important issue. One consideration is that wind energy is meant as an alternative to other types of energy production like coal, oil, and gas, all of which produce such vast quantities of pollution that entire habitats and bird populations are wiped out, causing not only an immediate loss of life but a continuously compounding problem as habitats fail to recover. As an alternative, wind turbines have a drastically reduced impact on the environment and native or migratory species, and none of the impacts are continuous. Another helpful answer is that engineers work very closely with naturalists to avoid building in major migratory bird routes so as to minimize the chance that a large number of birds might come across the turbines. As it is, very few birds are killed by wind turbines, but engineers continue to try to reduce the chances.

If using the extension projects, address the work required at this time. The generators are theirs to keep.

For Engineers

After building the wind generator, you have seen that the wind carries energy which can be converted into electricity. How much energy does the wind have and how much electrical energy are we producing?

Often we are much more interested in calculating the power instead of the energy. Power is defined as the *rate that energy is used or transformed over a period of time*. Consider the example of a battery-powered radio or MP3 player. Once charged, the battery holds a certain amount of energy. If you play music at a low volume, you'll generally find that the battery lasts much longer than if you're shaking the walls at high volume. This is because at high volume the power used by the radio is greater than the power used at low volume. In either case, the radio has used the same amount of *energy* when its battery runs out, but the *rate* at which it used this energy, the *power*, was different.

Calculating the power of the wind through a turbine depends on three factors: the area that the turbine blades sweep out (A_s), the density of the air (ρ), and the cube of the speed of the air (v^3). The equation to find the power is

$$\boxed{P_{wind} = 1/2\ A_s\ \rho v^3}$$

1. Calculating the area that the turbine blades sweep out can be done by measuring the length of one of the blades. Be sure to convert this length to meters! This length is a radius of a circle; the area swept out can be calculated by $A_s = \pi r^2$. Measure the length of your turbine blade and calculate the area swept out by the blades below.

Radius (r) = _____ m **A_s = _____ m^2**

The density of air (ρ) is known to be around 1.2 kg/m^3. Use this value for ρ.

$$\boxed{\rho = 1.2\ kg/m^3}$$

2. Finally, we want to know the speed of the wind passing through the turbine. If you're using a fan, a typical wind speed might be around 12 mph or 5 m/s. Try using 5 m/s for *v* in the equation. Finally you're ready to calculate the power of the wind! Show your work below.

Wind Power = _____ Watts

How much power did you find? In reality, only a fraction of the wind's power is converted into electricity. Some of the wind makes it around and past the turbine. There are also losses in the gear system of the turbine due to friction and in the generator that converts the mechanical energy into electricity. Of course, the energy is not actually 'lost,' it is actually turned into waste heat which is then dissipated into the atmosphere.

3. How much of the wind's energy is converted into electricity depends on the generator's **efficiency**. Altogether, only about a quarter to a third of the wind's energy is captured and converted into electricity. Let's assume our system is 25% efficient (one quarter). Multiply your answer for wind power above by ¼ to find out how much electricity your turbine generates.

Electrical Power = _____ Watts

4. A typical energy-efficient light bulb uses about 13-20 Watts. Could your wind turbine power that? Redo your calculation using a stronger wind speed like 8 m/s (which is about 18 mph). Don't forget to multiply by your answer by ¼ to account for the efficiency. How much power did you find now? Why did the power increase so much with such a small increase in wind speed?

Electrical Power = _____ Watts

Extra Credit: An industrial wind turbine sweeps out an area of 4000 m^2 and operates best at a wind speed of 13 m/s (29 mph). How much power does the wind have passing through the turbine? How much electric power does the turbine produce? How many 20 Watt light bulbs could you power with one of these turbines?

Wind Power = 5,272,800 Watts

Electric Power = Wind Power/4 =1,318,200 Watts

Number of Light Bulbs =Electric Power/20 =65,910 light bulbs!

Project Extensions

- **Grades 4 +**

  In the great scheme of things, the energy produced by the paper wind turbines to light an LED is not much energy at all. To put it in perspective, you use more energy in the same amount of time walking up stairs than it takes to keep an LED lit. How can we harness more energy from the wind?

  Individually or in groups, have students work over the course of one or two weeks after school or at home to redesign the generator or turbine. They may use the pieces from the generator they created in class plus any other locally available materials to produce and test new designs. What can they power with their generator besides an LED? New designs might involve an altered turbine shape and size, a different motor or generating device, a different gear ratio, or anything else they might invent.

  Moving from the level of LEDs to bigger bulbs and other electronics can be difficult, so grade the students on effort and creativity even if they cannot produce a world-class generator. Give prizes for the best designs and best attempts and implementation.

- **Grades 4 +**

  For this activity the LED was attached directly to the motor's leads. Being relatively unfamiliar with the inside of the motor and the purpose of wires, students may want to investigate what happens when we don't connect the LED and motor directly.

  Have students disconnect the LEDs and instead attach the wire leads (speaker wire) to the motor and then to the LED, effectively extending the LED's legs. How long can you make the wires (by adding more lengths of wire) before the LED will not light? Does the length matter?

  Now try attaching multiple LEDs (have the fan on high for this one). Make sure that you've determined the direction of each LED. How many LEDs can the generator support? What would need to change in order for the generator to light more LEDs? Does it need greater force, higher speed, a stronger magnet, more wire coils?

- **Grades 3 +**

  All generators (except for nuclear power plants and photovoltaic solar panels) depend on some kind of rotation to get the coils spinning inside the magnet. Wind is merely one force that can be harnessed to cause rotation. Other common sources are rivers, tides, the movement of hot gases, and gravity itself. What else rotates or has motion that could be converted into rotation in some way? And how might you attach a generator or the motor used in this lesson so as to get free electricity from the force you're observing?

  As an exercise in observation, creativity, and mechanical imagination, have students find some force they notice in everyday life that could be harnessed and used to make something turn. When they have found something, help them make the connection between that force and the production of electricity. If you want to take the project a step further, encourage them to design and/or construct whatever mechanism they think would be needed to turn that force into electricity: they can use the motors provided in this lesson.

Examples are everywhere if you look for them. Some example gadgets that inventors and engineers have been playing with for years harness the force wasted by people in their day-to-day lives. One is a small-angle/high-torque see-saw placed under the pavement at busy intersections that pivot slightly back and forth as each car passes of it, turning a flywheel under a high gear ration to turn a generator. Another device sits in the central column of rotating doors and turns the force of the people pushing the door into rotation for a small generator. Perhaps the most common example is the mechanism in a hybrid car that steals some of the rotation of the wheels to return electricity to the car battery for later use. One device even promises to deliver a little electricity every time you sit on the toilet!

If you have used or are planning to use the water generator lesson, consider connecting the water wheel to the generator to see if it will work. For small motors like the 12 V motor used in this activity, speed is more important than torque (rotational force), so a fast rotation is more likely to light the LED than a strong one.

- **Grades 4 +**

  Now that students have seen wind produce electricity, it's time for them to think about how such technology could be implemented. Inform them that their task is to prepare a plan for the school to adopt wind energy. The plan will include three stages:

  1. Research: Give the students a few days to find out anything they can about wind turbines from their parents, teachers, the internet, etc. When they have an idea of what kind of turbines they need, they will then need to determine *where* the turbines need to be. Have them discuss and/or find the best locations around the school for capturing wind. Also have them consider the times of day when wind is strongest: perhaps the places they know to be windy are actually relatively still in the afternoons or evenings.

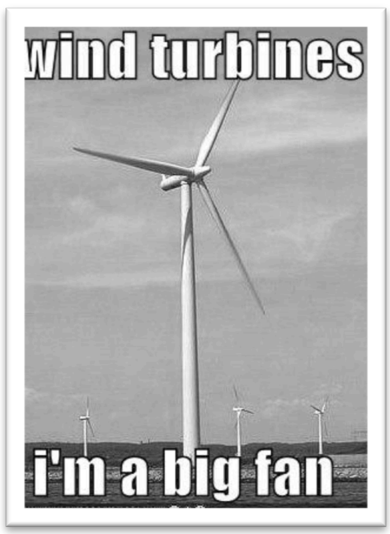
     *If the *Anemometer* lesson has already been done, or if students know what an anemometer is, consider building a few and taking measurements at the recommended sites. This is a great way to get outside, work in groups, take data, and reach a real conclusion. Data can be taken by different pairs each day and recorded on the board in class until a definite trend can be seen.
  2. Planning: Provide the class with a budget and a price list (you can make this up using numbers suitable to your students) of various components they will need to "purchase" for the school. These should include the wind turbines, generators of various output (one per turbine), distribution center (need only one), and lengths of wire. Also provide a map of the school with rough distance estimates and power needs of each classroom.

     Based on the map, price list, and generator output options, students should determine the best use of the budget to bring the most power to the school from the various locations determined in Step 1: Research.
  3. Writing: Now that the students have all the information they need, it is time to write the proposal. Help them prepare a written proposal and perhaps a presentation explaining

the benefits of wind energy, the needs of the school, and how their plan will meet those needs. They should include the complete budget, the expected power output, and the map of the school showing the locations of the components.

*If your school does not provide its energy consumption statistics, assume an average school requires 50 kW of power (that is 50 kWh of energy every hour).

*The power output of a wind turbine depends on the speed and reliability of the wind as well as the diameter of the wind turbine. The peak outputs of 10 m and 17 m wind turbines are 25 kW and 100 kW respectively – keep in mind that the average output will be much lower depending on how much wind is available.

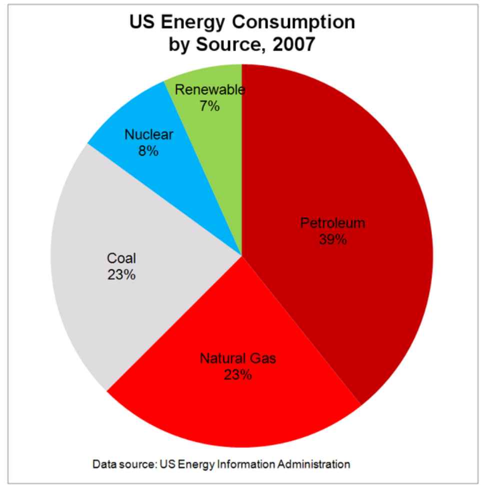


Information Letter for Parents

(Copy and paste the opening description as well as any relevant section that follows)

Dear Parent or Guardian,

This week in class we will be exploring the power of wind and its practicality as a source of energy. Currently the US relies largely on the burning of fossil fuels (coal, oil, and natural gas) for 86% of its energy needs. Meanwhile, research into renewable forms of energy has shown that wind and solar may be suitable alternatives.



The problem we face is that the extraction and burning of fossil fuels produces an enormous quantity of pollution, and the effect the pollution has had on our atmosphere and ecosystems is becoming increasingly dangerous. So that our students will consider the role that energy plays in our lives, as well as the responsibility we have to use our energy wisely and protect our environment, we will look at the nature of wind and the process of turning its energy into energy we can use. Related science topics include the use of electromagnetism; measurement and calculation of energy and power; and the process of collecting, graphing, interpreting, and presenting data.

In order to understand the basics of wind energy, students will construct and use a mechanical wind turbine to lift an object. By taking measurements and performing basic calculations they will be able to determine the energy that has been captured by the wind.

Mimicking engineers and researchers, we will build simple anemometers and use them to measure wind speed. These data are what engineers use to decide where to install wind turbines, so we will practice graphing and understanding the data we collect.

Bringing all the physical and earth science concepts together, students will build and test an electrical wind generator, allowing them to see each step in the conversion of energy from wind to electrical.

As a capstone to the lesson in wind energy we will be doing a class project; it may involve some work for your child at home. Please be sure to ask them about what they're learning about wind and help them find the information they need for their project.

All the best,