Wind Energy Part I:

Wind Does Work

The purpose of this lesson is to observe and calculate the work done by wind. Students will construct a simple wind turbine capable of lifting a weight under the influence of power from the wind. This activity is designed for students with any prior knowledge of wind energy and basic math skills, though the lesson can be adapted to higher levels of math.

Included in this packet:

California Curriculum Standards

This lesson addresses or expands on the following California State 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 Grade

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*: 60 minutes
- *Prerequisite knowledge*: Wind has power and energy to change or move objects
- *Concepts learned*: Energy can be changed from one form to another; wind can cause a propeller/turbine to rotate; work is done when an object is moved from one place to another

Background Information for Teachers

Wind is air in MOTION

Air moves in unpredictable ways, but it usually starts moving because of the way the sun heats different parts of the atmosphere – whenever one parcel of air is hotter or colder than its neighboring parcel of air, there will be wind.

You can see a good example of this for yourself whenever you are on a beach. During the day, the sun heats the land on the coast, and the warm air above it rises. The air over the ocean is colder, so it rushes towards the land. This daytime sea breeze is a very consistent source of wind, which we can depend on for anything from making electricity to windsurfing. If, for example, we want to use these consistent sea breezes to generate electricity, we turn the kinetic energy of the wind into power. Another way to use the wind's kinetic energy is to turn it into mechanical power, which can then be used to pump water. Whatever we decide to use the wind for, it is an inexpensive, clean and reliable form of power.

There is ENERGY in the wind

Kinetic energy of the wind is the amount of energy in the wind due to the motion of the air. We describe the air's motion by its velocity, which specifies its speed and its direction. We measure velocity as:

$$v = \text{distance} / \text{time}$$

We measure kinetic energy as:

$$\text{Kinetic Energy} = \tfrac{1}{2}\, mv^2$$

where ***m*** is the mass of the moving object (in this case, the air parcel) and *v* is the velocity of the moving object. We use the velocity of the wind to calculate the kinetic energy because it accounts for both the speed of the wind and the direction that the wind is traveling.

When it comes to changing the wind's kinetic energy into electricity, stronger breezes are better. The power available in the wind is measured as:

$$\text{Power} = \tfrac{1}{2}\rho A v^3$$

where **ρ** is the density of the air, ***A*** is the area covered by the wind turbine blades, and ***v*** is the velocity of the wind. We can see that the power available in the wind is proportional to the cube of the wind's velocity (v^3). That means that if the velocity of the wind doubles, the power we get from a wind turbine increases by a factor of eight! In general, power is calculated as the rate at which energy is used, or as energy divided by time. This is the calculation students will use in this activity to determine the work done by the wind.

Some notes on UNITS

- Mass (*m*)is measured in g (grams) or kg (kilograms)
  - one kilogram = 1,000 grams
- Distance (*d*) is measured in m (meters)
- Time(*t*) is measured in s (seconds)
- Velocity (*v*) is measured in m/s (meters/second)
- Kinetic Energy is measured in J (Joules)
  - one Joule = 1 $kg*m^2/s^2$
- Power is measured in W (Watts)
  - one Watt = 1 Joule/second

What can Wind Energy do for us?

In order to generate enough electricity from the wind to actually replace older technologies (like electricity from fossil fuels), we need to find the best locations to build collections of turbines, called wind farms. So what are we looking for in that location?

First, turbines need to be exposed to fast wind speeds, usually in the range of 16-20 mph (or 7-9 m/s), which is why we build turbines so tall - wind velocities increase as you go higher in the air. A 50-meter-tall wind turbine will experience much faster winds than a 5-meter-tall wind turbine. Also, areas along the coast are good places for wind energy (the California coast is a great example). As discussed earlier, the sea breezes that happen every day at the beach are reliable, which is why coastal and offshore locations are being considered more and more for wind turbine installations.

Second, the electricity that we generate from wind farms has to travel through power lines to reach us. And just like we wouldn't want to build new roads to transport our everyday supplies, we don't want to build new power lines to transport the electricity that powers our towns. Therefore we want to build wind farms close to power lines that already exist. Besides large-scale wind farms, normal residents all over the country have been installing small wind turbines to get electricity from the wind – especially people who live in rural or agricultural areas. Several companies sell ready-made towers and turbines that are easy to install, so you can start benefiting from the wind!

Why Wind?

Besides the fact that it's just cool to get electricity from the wind, some other reasons behind wind energy are…

- Wind energy is clean: there is no pollution resulting from generating electricity using the wind.
- Wind energy is renewable: we will never "use up" all of the wind.
- Wind energy is one of the cheapest ways of producing electricity.
- Wind energy is a replacement for older electricity-generating technology like coal, natural gas and oil, which are expensive and heavily pollute our surroundings.

Materials

Tape and Scissors Provides:

- Bottle (1 per group)
- Paper (1 per group)
- One dowel with pushpin inserted (< 20cm if using small soda bottles); the 1-meter string is already taped onto dowel and wound around it
- 10 g washer weight (1 per group)
- 1-meter measuring tape (1 per group)
- “back” piece of paper (1 per group)

You Provide:

- Tape
- Scissors (1 per group)
- Watch or clock with a second hand (1 per group)
- Fan (1 per group)

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.

Depending on the level of your students, you will either be distributing materials and instructions to their workstations or you will be directing the construction and activity yourself. Arrange their workstations so that they can see you easily should you need to demonstrate the steps.

This lesson was designed to be a potential precursor to two other wind lessons: Measuring Wind and Making Electricity from Wind. Students do not need much knowledge of wind and power prior to this activity, but should have a basic understanding of the concepts of work, energy and power, and should be able to perform simple calculations given some data. By the end of the lesson they will understand the ability of wind to do work and will understand how its power can be harnessed and compared to other sources of power.

The activity involves some measurements and calculations, followed by some questions that students can work on in class or at home. The questions are meant for the sake of discussion and encouraging creativity and new ideas. In order to help students with measurement and calculation, be sure that you have tried the activity once yourself.

Activity

1. Begin by sitting with the students and having them recall what they know of 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. Discuss with them the meaning of *energy* and *power*. How are these terms related and how are they different? As a summary: *energy* is the ability to do work; *power* is the rate at which energy is used.

3. What ideas do they have for how wind is used to do work in daily life? Can they point to examples? How might wind be used to generate *electric* power for everyday use?

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

5. Discuss briefly the goal for the day – to create a wind machine that is capable of moving an object/doing work and to measure and calculate its power. Show and explain the materials that each group will be using. Answer any questions they may have before beginning.

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

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

(Pictures to be added when kit materials become available for demos)

Wind Turbine Instructions

A. Collect all materials.
B. Find the square piece of stiff paper. There should be a design printed on one side.
C. Cut along the curved lines on the paper. Be careful not to cut beyond the end of the lines.
D. Stick the push pin through the back of the paper through one of the dots in the corners. Fold each dotted corner into the center and push the pin through all four.
E. With each corner held by the pin, push the pin through the center of the paper so that it comes out the back. The paper should now look like a pinwheel.
F. Stick the pin into one end of the wooden dowel so that it holds. If you let go the pin should stay in the dowel, holding the pinwheel in place.
G. Find the end of the thread that's wound around the wooden dowel. Tie this end to the metal washer so that the washer hangs freely.
H. Find the plastic bottle with the two windows cut into the sides. Tape the bottle near the edge of the table so that the windows are level with each other and one of them is near the table edge.
I. Now tape the piece labeled "Back" to the bottle so that it sits about an inch behind the back window of the bottle (not the one near the table edge).
J. Insert the wooden dowel (with turbine attached) through the front window of the bottle. Let the end of the dowel come to rest at the "Back" piece. The dowel should be able to turn freely without falling out.
K. Let the metal washer hang freely from the dowel so that it is off the edge of the table.
L. Your turbine is now ready for experimenting! Hold the fan in front of it to test that it can spin freely. Then continue to the activity.

Wind Power Lab Activity

In this activity you will be finding the *energy* and *power* of your wind turbine. In order to do this you will need to do an experiment, take some data, and then use your data to calculate the answer. Follow the steps below to find out how powerful your turbine is!

1. Begin by pulling the metal washer down so that it hangs exactly 50 cm below the wooden dowel. During the calculations, 50 cm will be the distance, ***d***.

2. Scientists prefer to use meters (m) instead of centimeters (cm) when describing distance. To change your distance to meters, divide 50 cm by 100: ***d* = _____ m**

3. Now you are going to measure the time it takes for the wind to raise the washer back up to the dowel. Using the fan as your "wind," allow the wind turbine to spin in front of the fan, raising the washer as it spins. Record the time it takes for the washer to reach the top in the table below next to "Trial 1"

4. Also write down any observations you made while the washer was moving up. Did it move slowly or quickly? How did the wind turbine work?

5. Now return the washer to 50 cm below the dowel and time its motion back up to the dowel. Do this four more times, recording each time in the table.

6. When all five times have been recorded, add them up to find the Total Time.

7. To find the Average Time, divide your Total Time by the number of trials (in this experiment we did five trials).

No. 8 **STUDENT DATA SHEET**

Lab Report Form: Building and Testing a Pinwheel

Date ____

Purpose of this lab is to ____

____

Instructions:
Follow the instructions listed in the Lab Activity and record your measurements in the Data Table below. Once you have completed all the measurements and calculations, answer the questions at the end of this form.

DATA TABLE

Trial	Time	Observations
1		
2		
3		
4		
5		
Total time		
Average time		

To calculate the average: Take the amount of total time and divide this number by the number of trials. Round your answer to one decimal point. This number is the average time in seconds for your data.

1. In order to calculate the energy used to lift the washer, you first need to know its velocity *v*. To calculate velocity we divide the distance it traveled (***d***) by the Average Time it took to travel. Calculate your velocity and record it here (be sure to indicate the correct units):

   ***v* = _____**

2. Because the washer is moving, you will be finding its Kinetic Energy, meaning the energy of motion. The equation for Kinetic Energy is:

   $$KE = \frac{1}{2}mv^2$$

   where ***m*** is the mass of the washer and ***v*** is its average velocity. Assuming the mass of the washer is 0.01 kg (10 g), calculate its kinetic energy and record it here; the standard unit of energy, the *Joule*, has been given (if your units did not include only meters, seconds, and kilograms, then check your work above):

   ***KE* = _____ Joules**

3. The *power* of a machine is the rate at which it uses energy. To calculate the *rate* of something you can simply divide by its time. Therefore, to calculate the power of the turbine, divide the Kinetic Energy it used by the Average Time. Record your answer here; the standard unit of power, the *Watt*, has been given:

   ***Power =* _____ Watts**

4. What do you think would create greater kinetic energy in this activity?

5. Does the power output of your wind turbine seem small or large?

6. Considering that an average light bulb uses 40 Watts of power (that is 40 Joules of electricity every second!), how many of your wind generators would you need to power a light bulb?

7. How would you explain the difference between *energy* and *power*?

8. In this activity you used the power in wind to lift a washer. What else could you do using wind?

9. Engineers are currently trying to use wind to create electricity to use in our homes and schools. Why do you think wind might be better than the oil, gas, and coal that we use today? How might it be worse?

Wrapping Up

As students finish up their lab activities and questions, help any who need assistance with the calculations or measurements. For the calculations units are important; if students end up with anything other than seconds, meters, and kilograms, their answers will not make much sense.

When everyone is ready invite them to share their results. Did everyone have an answer within reason? What did they think of their values for power compared to what a light bulb uses? Students should share some of the answers they had for the post-activity questions. Encourage inventive, creative ideas for improving the wind turbine or explaining why wind energy might be effective or not as a major power source.

To expand on their ideas in their answers, show them some of the pictures or videos of full-scale wind turbines provided on the Tape and Scissors website (___). Take some time to talk about wind energy production as it compares to methods using fossil fuels. Between high-energy fossil fuels and clean wind, which would they choose? Given the effects of climate change on their environment, how important is it to stop polluting?

Project Extensions

- The in-class activity was designed to give a taste of how data is collected and calculations are done to arrive at a meaningful answer. Students were able to observe the power of their turbines under a given amount of wind.
  In order to see the range of possibilities with their turbines, try varying the wind speed for more trials. Turn the fan speed up or down, adjust its distance from the turbine, and change the weight hanging on the thread. How does the turbine react?
  Especially important to wind energy is its speed. In a normal wind power calculation the velocity is raised to the third power, making even a small increase in wind speed noticeably effective. Try a few precise trials varying the wind speed each time. Each setting on the fan corresponds to a linear increase in wind speed, but the students will see an exponential increase the power for each increase in speed.

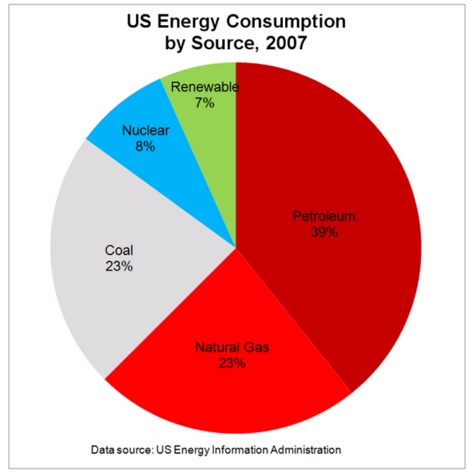
- The pinwheel design for the wind turbine is just one design that works. There are many styles of not just lateral turbines, but also of vertical turbines. What other designs can the students come up with, and which is the most effective? Have a contest to see who can make the best wind turbine; offer small prizes for the best ideas.

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 roughly 85% 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,