WIND ENERGY LESSON PLAN

Summary: Students will learn what an anemometer is and how it can be used to simulate effectiveness of wind turbine placement. In addition, hopefully students will understand what it really takes to produce power. Students develop an understanding of how engineers use wind to generate electricity. If no wind is present at the time of the activity, use a fan with variable speed, show the kids how the math works and how the anemometer works, and then tell them about how wind turbines need to be placed outside of cities for various reasons addressed below. (See disadvantages under Pre-Lesson Assessment)

Learning Objectives

- Explain how wind is used to generate energy.
- Explain how the use of anemometers is related to wind energy.
- Build and gather data from a model anemometer.
- Describe the relationship between changes in wind speed and changes in the rate of rotation of the anemometer.

Materials Needed (to build one Anemometer)

- 4 small paper cups, 6-ounce or smaller
- 1 push pin
- 1 sharpened pencil
- stopwatch/timer
- 1-2" diameter ball of modeling clay (for base)
- 2 pieces of stiff cardboard (3 inches wide by 14 inches long)
- 1 pair of scissors
- 1 stapler
- assorted color markers (fun for kids to draw designs on cups)

Outline of *Wind Power* Lesson

1. Introduction (Teacher)
2. Introduction to content (generally; more specific info in slideshow)

3. Wind Power slideshow (in conjunction with Pre-Lesson Assessment)[1]
4. Pre-Lesson Assessment [2]
5. Explain what an Anemometer is! How is it used?
6. Build anemometers [3]
7. Explain what calculations need to be made
8. Take anemometers outside and have students place them in varying locations
9. (OPTIONAL) Have kids complete calculations [4]
   (a) Might not be appropriate for all kids. In that case, use the general table below to see what feedback you can give, once they've given you their numbers.
10. Post-Activity Assessment [5]
11. Questions

Pre-Lesson Assessment:

- How can we get energy from the wind?
- Brainstorm with students some advantages and disadvantages of using wind power.
  - Advantages:
    - · Reduces consumption of fossil fuels for electricity production
    - · Reduces production of greenhouse gases
    - · Reduces production of pollution
    - · Wind is a *renewable* energy source
  - Disadvantages:
    - · Wind generators only work in certain areas (focus of project)
    - · Wind generators are tall and can block views of nearby scenery (they need to be outside of the city)
    - · Can have noise (outside of a mile you can;t hear it)

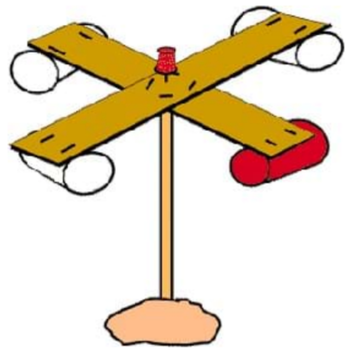
[1]See Github "Wind Pow er.pptx
[2]See following pages
[3]See "Building Anemometers" below
[4]Summary table below
[5]See below

What is an Anemometer?:

- The anemometers that engineers design are critical instruments for determining the best locations for wind-power generators.
- The direction and strength of the wind is very dependent on local terrain, so measurements must be made to determine the best site for wind turbines.
- Also, wind speed changes with height, so anemometers are necessary to determine the best height for the tower.
- It is essential that these wind speed measurements be very accurate, because the power generated by a wind generator is related to the cube of the wind speed (if the wind speed doubles, the power available to a wind generator increases by a factor of eight).
- Finally, wind machines can be very inefficient because the distribution of wind energy is uneven and unpredictable since the wind does not blow strongly all of the time.
- The ones you make will be very inaccurate, but will highlight the need for some form of measurement for wind power assessment.

Building Anemometer:

1. Divide the class into groups of four students each. Distribute a set of supplies to each group.
2. Direct students to cut off the rolled edges of the paper cups. This makes them lighter.
3. Ask one student in each group to color the outside of one of the cups with a marker.
4. Ask another student to form the two cardboard strips so they make a plus sign (+) and staple them together in the center where the two strips join. Each cardboard strip should be $\sim$12 inches long.
5. Ask a third student to find the exact center of the cardboard cross. An easy way to do this is by using a ruler and pencil to draw lines connecting the diagonal corners through the center (overlap) section of the cross. Where the pencil lines intersect is the exact middle of the plus sign.
6. Ask teams to staple the sides of the cups to the ends of the cardboard strips, making sure the cup openings all face the same direction.



7. Next, push the pin through the center of the cardboard (where the pencil lines intersect) and attach the cardboard plus sign to the eraser end of the pencil.
8. Direct the teams to gently blow on the cups to make sure the cardboard structure spins freely around on the pin. They may need to adjust their models slightly before proceeding.
9. Take the students outside with their partially constructed anemometers, second-hand timer and clay balls.
10. Have each group choose a different spot where they want to measure the wind speed.
11. Have teams place the modeling clay on a stable, horizontal surface (such as a wooden fence rail, picnic table, wall or flat rock). Ask them to stick the sharpened end of the pencil into the mound of clay so that the pencil stands vertically and the anemometer is free to spin.
12. Direct the groups to measure and record the wind speed by counting the number of times the anemometer spins around in 1 minute. (Note: To make this simple, advise them to count one rotation each time the colored cup to passes by the pencil.) Require groups to take at least three wind speed measurements at their locations.
13. Have students calculate the average wind speed for their locations. Consider calculating a class average as well. Discuss the minimum, maximum and average wind speed at the time of measurement.
14. Have students complete the worksheet and check their answers with another person in their group.

Calculations (For Student or Teacher):
(All in metric units. If kids don;t have ability to calculate wind speed, then look at table

below.)[6]

$$\text{Wind Speed} = \frac{(\text{Rotational Rate}) \cdot \pi \cdot \text{diameter}}{60s}$$

This is in meters/second.

$$\text{Kinetic Energy} = \frac{0.078 \cdot (\text{Wind Speed})^2}{2}$$

$$\text{Power} = (0.0006) \cdot (\text{Wind Speed})^3$$

This is measured in KILOwatts per hour.

Peak Efficiency $\sim$ 59%

$$\text{Real Power} = (\text{Peak Efficiency}) \cdot (\text{Power})$$

Notice that the real power of a wind turbine is exponential in nature. This may be interesting to students who understand this concept. You can also show them that that is why it's so important to place wind turbines in specific areas.

Here is that table I promised:

Rotational Rate	Wind Speed (mph)	(Total Output)/Year	Powers LED For " " Days
7	1	0.96 kWh/year	4.7
14	2	1.94 kWh/year	9.5
20	3	2.81 kWh/year	13.5
28	4	3.87 kWh/year	19
35	5	4.84 kWh/year	23.7
42	6	5.8 kWh/year	28
50	7	6.78 kWh/year	33.2
56	8	7.74 kWh/year	37.9
63	9	8, 71 kWh/year	43
70	10	9.67 kWh/year	47
105	15	14.52 kWh/year	71
140	20	19.36 kWh/year	94
175	25	24 kWh/year	117
210	30	29 kWh/year	142
280	40	38.2 kWh/year	187

You can read this is: "The student observed that the anemometer spun for an average of 20 rotations per minute. This meant the wind had a velocity of approximately 3mph. If a (standard[7]) wind turbine was erected at that spot, it would produce 2.81 kWh

[6] Diameter should be fixed at $\sim$12 inches for ease of calculation.

[7] 50 meters tall, 70 meter span, 59% efficiency (theoretically the peak efficiency)

per year. That amount of electricity could power a single LED bulb for 13.5 days."

Hopefully this enlightens students not only about placement of turbines, but about how much electricity we sue as well. See the GitHub resource "Calculations for Wind Power ECO-Kit" for some other interesting calculations.

Post Activity Assessment

- How does our model anemometer measure wind speed? (Answer: The wind hitting the cups of the anemometer causes the anemometer to rotate. The rate of the rotation of the anemometer is related to wind speed.)
- Why do engineers need to use anemometers in deciding where to put wind turbines? (Answer: Wind generators produce much more electricity where the wind speed is higher.)
- Where would engineers locate a small wind turbine used for generating electricity for a single home? (Answer: On a hill by the house, on its roof, or someplace high by the house where the wind would not be blocked by the home, other structures or trees.)
- From where does wind come? (Answer: Uneven heating of the atmosphere causes wind. Air is heated and its density decreases causing it to rise. This produces a low-pressure area. Cooler, denser air produces an area of high pressure and moves in under the warm air. This movement creates wind.)
- Is wind a renewable or a non-renewable resource? Why? (Answer: Wind is a renewable resource, because it is formed naturally in the atmosphere. This means that wind will always exist from which energy can be harnessed.)