As the world's demand for clean energy sources increases, so has the interest in wind power. The 2011 National Science Experiment Wired for Wind helps youth better understand the physics of wind energy and how it can be used to conserve energy and save our planet from the pollution and harm caused by burning fossil fuels.
4-H PLEDGE

I pledge my Head to clearer thinking,
my Heart to greater loyalty,
my Hands to larger service,
and my Health to better living,
for my club, my community,
my country and my world.
On October 5, 2011, millions of young people across the nation will become scientists for the day during the fourth annual 4-H National Youth Science Day (NYSD). NYSD is the premiere national rallying event for year-round 4-H Science programming, bringing together youth, volunteers and educators from the nation’s 111 land-grant colleges and universities to simultaneously complete the National Science Experiment.

The 2011 National Science Experiment, Wired for Wind, will explore how to engineer renewable energy technologies and the positive impact that they can have in communities across the country and the world.

Why Wind?

Energy is one of the top concerns for our nation today. The United States consumes 22% of the world’s electricity, yet represents only 4.5% of the world’s population. Most of energy we use today comes from nonrenewable resources. The United States produces most of its electricity (almost 50%) from coal.

Wind power is a clean, renewable energy source:

- According to the U.S. Energy Information Administration, wind power has been growing at an average rate of 25% per year, making wind the fastest growing source of energy today.
- Nearly every one of our 50 states has locations that could be good for the development of wind power.
- In fact, the National Renewable Energy Laboratory (NREL) identified only six states that have little or no wind energy potential – Mississippi, Florida, Delaware, Connecticut, Rhode Island, and Kentucky.

While many young people today are aware of the issues associated with carbon-based fossil fuels and the dangers of our nation relying on foreign oil, they may not fully understand how scientists and engineers decide how to design and deploy alternative energy sources. Wired for Wind provides young people with an engaging, hands-on introduction to the engineering design process utilizing renewable energy as the centerpiece.

Wired for Wind — The Experiment

In the 2011 National Science Experiment, Wired for Wind, participants will use the engineering design process to design and test their own renewable energy wind turbines in three parts:

**Part One: Design & Build a Wind Turbine**
Youth will design and build two types of wind turbines, then test them to determine which design is more effective in harnessing wind.

**Part Two: Put a Pitch On It**
Youth will experiment with different blade pitch angles to determine how each one affects the wind turbine’s rotor speed and performance.

**Part Three: Where to Wire for Wind**
Youth will identify the best location for a wind farm in their state using the same data, maps and social and environmental considerations that real scientists use today.
By expanding on the principals taught in *The Power of Wind* curriculum and adding more physics and critical thinking, the *Wired for Wind* experiment will provide young people with an engaging, interactive introduction to wind power that will ultimately lead to an increased level of interest and engagement in science, physics and engineering.

**Objectives and Outcomes**

- Increase interest in science and engineering through a series of hands-on, highly visual experiments that examine the potential of wind power to serve as a viable renewable energy resource
- Introduce the engineering design process and its associated terminology by applying it to common wind energy challenges
- Understand the purpose of a wind turbine, its essential parts and mechanisms, and how it works to convert wind power into electricity
- Comprehend key electrical engineering principles as they relate to motors and generators and how turbines generate renewable electricity
- Use physics and formulas to calculate wind power
- Employ critical thinking skills to identify appropriate locations for wind farms using physical, environmental, and social factors

**Using this Guide**

The *Wired for Wind* Facilitator Guide features information found in the Youth Guide as well as additional information that can assist you in teaching and overseeing each part of the experiment. Throughout the guide you will find:

- **Talk About It** - Questions that can be used to facilitate group discussions
- **Leader Notes** - Suggestions and tips for facilitating each experiment
- **Take the Lead** – Instructions for performing various experimental tasks
PRE-EXPERIMENT

Generate a Conversation: Electricity Basics
Before participants begin to experiment with wind power as an alternative energy choice, it's helpful to understand a few basics about energy and electricity in general.

Energy Synergy

What is energy?
Energy is what makes things happen. Scientists define it as “the ability to do work.” It's what moves cars along the street, keeps food cold in the refrigerator, lights up a room so that we can see—it's even what our bodies use to think, grow and move.

What is electricity?
Electricity is the flow of electrical power or charge. Electrical energy is generated using resources like coal, nuclear and natural gas then travels through transmission lines to reach the destinations where they will be used.

The most common type of electricity is the flow of electrons through a conductor, which is a material consisting of atoms which allow electrons to move freely through it. An example of a good conductive material is copper, which is used in most common electrical wiring.

Despite the important part it plays in our everyday lives, few of us probably ever stop to think what life would be like without electricity. Because we don’t see it, we tend to take electricity for granted—unless of course it disappears.

How is electricity generated?
Generating electrical energy is not simple. We have to convert it from primary sources of energy like fossil fuels, wind, and sunlight. Primary energy sources are typically converted into electricity using an electrical generator. Using generators, we are able to capture the mechanical energy of a primary source and convert it to electrical energy, powering the electrical devices we use in our homes, schools, and communities.

A typical generator uses powerful magnets and many coils of copper wire. Faraday’s law tells us that a magnet moving within a coil of wire has the potential to cause electrons to flow in a circuit. It is also possible to move the coil of wire within a magnetic field to generate electricity.

Most generators consist of a rotating shaft to which coils or magnets are attached. In the case of a wind turbine, rotating blades designed to catch wind are fixed to this shaft.

Talk About It

- Consider all of the things in our world that require electricity to operate. Can you think of anything that doesn’t require electricity?
- What do you think life might be like if there were no electricity?
Nonrenewable vs. Renewable Energy

While we need electricity to keep us warm, cool us off and power our devices, some of the processes used today to get that energy to us can be limited and/or bad for the environment. The energy we use to make electricity falls into two different categories: nonrenewable and renewable.

Nonrenewable Energy Sources
Nonrenewable means that these sources—such as coal, nuclear and natural gas—will eventually run out and cannot be replaced in a short period of time. For example, coal is a nonrenewable energy source because it takes millions of years to create.

Renewable Energy Sources
Renewable sources of energy are sources—such as wind, the sun, and biomass—that can be easily replenished, meaning that we are able to create them again and again without worrying when they might run out.

The five most commonly used renewable resources today are:

1. **Wind** – Wind power created from the sun heating the earth unevenly
2. **Solar** – Energy from the sun converted into other forms of energy such as heat and electricity
3. **Biomass** – Heat energy and biofuels created from burning organic materials made from plants and animals (microorganisms)
4. **Geothermal** – Heat that generates in the Earth’s core and is brought to the surface in the form of steam or hot water
5. **Hydropower** – Electricity created from moving water like a river, waterfall or dam or ocean waves and tides

**Talk About It**

Have youth complete the activity on page 5 of the youth guide

- Name some of the things surrounding you that use energy. Can you identify their energy sources? Are they renewable or nonrenewable?
- Can you think of examples of how we use renewable energy sources?

**Did You Know?**

**Facts About Nonrenewable Energy Sources**

- Most of energy we use today comes from nonrenewable resources. The United States produces most of its electricity (almost 50%) from coal.

- Coal fired power plants exhaust pollution in the form of carbon dioxide, sulfur, and mercury. Electricity production from coal also requires a large amount of water for cooling to condense steam after it has powered the steam turbine.

**Facts About Renewable Energy Sources**

- The U.S. currently produces about 13% of its electricity from renewable sources, 10% from hydroelectric (energy from flowing water) and 3% from wind and very small amounts of other types (solar, wood, etc.).

- Renewable energy sources allow us to produce energy with little or no pollution.
Wind is Energy in Motion

Wind power is air (energy) in motion. It is caused by the uneven heating of the Earth’s surface by the sun. Because the Earth’s surface is made of very different types of land and water surfaces of variable elevations, it absorbs the sun’s heat at different rates.

- Wind power is clean, widely available, low cost compared to other technologies, and uses no fossil fuels or water making it an excellent renewable energy choice.
- Wind is a renewable energy source because as long as we have a sun, we will have wind. Every day new wind is created by the heating and cooling of the earth.
- Nearly every state has the potential for wind power production either on land or off shore in the lake or ocean.

Think Like An Engineer

The Engineering Design Process
In the experiment, participants will use the engineering design process to solve a series of problems pertaining to wind energy. The engineering design process includes seven basic steps:

1. Identify the problem.
   Determine what constraints (or drawbacks) limit your choices in solving this problem.

2. Generate ideas.
   Brainstorm possible solutions that might address those constraints.

3. Evaluate and compare possible solutions.
   Decide which of the possible solutions are the most logical or make the most sense.

4. Build a prototype.
   A prototype is a first attempt at a design and is built to test your hypothesis.

5. Test the prototype.
   Conduct a series of experiments to see if your prototype works.

6. Tell your story.
   Record your data and share what you learn with others.

7. Refine your design.
   Explore how you can use what you’ve learned to improve or change your design.

As part of the engineering design process, engineers may repeat these steps over and over again—refining and changing their designs until they get it just right.

Talk About It:
Ask your group to provide examples how the engineering design process can be applied to solve different problems.
The 2011 National Science Experiment, *Wired for Wind*, consists of three parts. Parts One and Two require similar materials and set up, including a KidWind turbine kit and a testing station. To complete Part Three, download the maps and materials for your state at www.4-H.org/NYSD.

**Setting Up**

1. Assemble the KidWind small wind turbines generators according to the instructions. One to two turbine assemblies can work for groups of 5 to 10 participants.

2. Designate an area in the room for turbine testing. Shared by all groups, the testing location will include the following items (not included in the turbine kit):
   - Fan
   - PVC assemblies
   - Turbine hub
   - Multimeter

**Leader Notes**

- When constructing the blades in Part One, hot glue works better than tape because it secures the blades more tightly to the dowels. If your group plans to use hot glue, we recommend setting up a gluing station.

- For this experiment, separate youth into equal sized groups (group sizes of 2-5 work well). Have groups seated together or close so they can collaborate.

- To build additional turbines, a simple PVC turbine base can be easily constructed using 3 PVC tees, 4 PVC elbows and 4 six inch pieces of PVC pipe.

**SAFETY FIRST!**

- Use a fan that has a safety guard to prevent fingers and objects from coming in contact with the fan blades.

- Also, remind participants that spinning turbine blades can hurt. They should keep their hands and face away from blades when they are in motion.
PART 1

DESIGN & BUILD A WIND TURBINE

Time Required: 45 minutes

OBJECTIVE

Design and build two types of wind turbines (one with a vertical axis and one with a horizontal axis), then test them to determine which design is more effective in harnessing wind.

MATERIALS

BLADE MAKING MATERIALS

- Poster board, cardboard or other thick paper*
- Paper cups*
- Blade protractor or standard protractor
- Dowels
- Hot glue or packaging tape*
- Scissors*
- Pencil*

TURBINE TESTING AREA

- KidWind turbine kit
  (consisting of hub, PVC tee, PVC handle, small generator with wires, multimeter)
- Box fan or other fan*

*(not included in the turbine kit)

INTRODUCTION

As future engineers, it is important that participants understand the form (the parts) and function (the purpose) of a wind turbine. A wind turbine is a machine that turns moving air (wind) into spinning motion (energy). This is then used to turn a generator, which creates clean electricity without polluting the earth.
Take the Lead: Know Your Parts
Wind turbines come in many shapes and sizes. Some have three blades, others have six. Big or small, they all share the same parts:

1. **ROTOR**: The section of the turbine consisting of the hub and blades
2. **Blades**: Catch the wind and turn wind power into mechanical energy
3. **Hub**: Hold the blades together and spins as the blades turn
4. **NACELLE**: The section of the turbine that encloses the generator
5. **Generator**: Converts spinning motion (mechanical energy) into electricity we can use
6. **Gearbox**: Used in large wind turbines to increase speed of spinning motion to run the generator
7. **TOWER**: The section of the turbine that supports the machine

Two common types of turbines are:

- **Vertical axis turbines** have blades that go from top to bottom and look like a giant eggbeater. *(These blades will be simulated by paper cups attached to dowels.)*
- **Horizontal axis turbines** have blades like airplane propellers and looks like a windmill. *(These blades will be simulated by using paper blades attached to dowels.)*

**STEP-BY-STEP**
Using the engineering process we discussed earlier, let’s design, build and test blades for a vertical or horizontal axis wind turbine.

**Talk About It**
What might be some of the constraints that could limit you in building your wind turbine?
Step 1
IDENTIFY THE PROBLEM.
The problem: How can we turn wind into electrical power?

Step 2
GENERATE IDEAS.
The blades on modern turbines “catch” the wind and use it to rotate the shaft of a generator. The spinning shaft of the generator converts mechanical energy into electricity. How well you design your blades can greatly impact how much power your turbine produces. Brainstorm possible designs for wind turbine blades.

While most utility-scale wind turbines all look pretty similar, don’t let that limit each group’s designs. Encourage participants to experiment with the possibilities and draw their ideas. Be sure to include at least one blade idea for a horizontal axis turbine and one for a vertical axis turbine.

NOTE: The vertical axis blades will be simulated by using paper cups cut in half, and attached to a dowel. The horizontal axis blades will be simulated by using paper blades attached to dowels.

Step 3
EVALUATE AND COMPARE POSSIBLE SOLUTIONS.
Let each group decide what type of turbine to make. Make sure there are at least one vertical axis and one horizontal axis design created.

Leader Notes
• The number of blades a turbine uses is not critical for success.
• Limit the team to 2, 3, 4, or 6 blades (not 5 because hub does not have correct pattern for 5)
• Six blades are a lot to make and will slow some groups. If time is a factor, limit groups to use 4 blades or less.
• For a vertical axis turbine more than 3 or 4 blades are preferable.
• Medium sized blades tend to work the best – the total blade diameter should not be larger than the fan
Step 4
BUILD A PROTOTYPE.

Instruct participants to construct a set of blades using the materials supplied.

1. Draw one blade on the paper or paper cup to create a blade
2. Cut out the blade
3. Trace blade for however many blades you need and cut them out
4. Using hot glue or tape, attach your blades to the dowels (make sure all of your blades are the same length!)

Step 5
TEST THE PROTOTYPE.

Test the prototype to determine how much power each design generates. A multimeter will be used to measure the voltage their turbine is producing.

Take Charge: Measuring voltage

1. Take your turbine blades to the testing location
2. Attach the blades to turbine. To do this:
   a. Loosen the hub nut by twisting the knob.
   b. Insert the dowel end of blade.
   c. With your fingers, grip the dowel at the base of the blade and turn it slowly to your desired blade pitch. Using a blade protractor, set the blade at 10 degrees. Do not grip the paper blade material or you may break the glue or loosen the tape. (See inset above)
   d. Tighten the hub nut so that it’s snug, but not too tight.
3. Attach the turbine wires to the multimeter (match up red to red and black to black).
4. Turn on the multimeter and set it to the 20-volt setting.
5. Turn on the fan.
6. Hold the turbine about 12-18 inches in front of the fan in either a horizontal or vertical position. You may want to move the turbine or fan to see if you can get the turbine to spin faster.
7. Record the voltage output achieved. This is the number that appears on the multimeter. If the voltage number bounces up and down a bit, record the number you see the most.

Take the Lead: How to Use a Multimeter

1. Attach the wires from the generator to the multimeter.
2. To check the voltage, select DC volt (V) and set the number to 20.
3. Place your turbine out in the wind or in front of a fan and let it spin.
   It is normal for the voltage readings to fluctuate. Voltage output is often unsteady because of the inconsistent nature of the wind or unbalanced blades.
**Leader Notes**

- For the first time, it helps to have a facilitator or older youth assist with attaching the blades to the hub and adjusting the pitch.
- When making a pitch adjustment, grab the dowel at the base of the blade. Do not grab the paper part of the blade or you will break the glue or loosen the tape. Do not over tighten the hub nut.
- The direction the blades spin does not matter, yet it will affect the multimeter reading (polarity). If the multimeter is reading negative numbers, do not adjust the blades. Simply reverse the polarity by switching how the red and black wires are attached to the multimeter. The multimeter will read the same absolute number, regardless of whether it is negative or positive, so if you prefer, you can simply choose to ignore the negative.

**Step 6**

**TELL YOUR STORY.**

Collect the data from each group and create a chart so that everyone can see the results.

**Talk About It**

1. Which type of turbine had the highest voltage output?
2. Which type had the lowest?
3. Which type of turbine spun the fastest?
4. Did rotor speed correspond with voltage output?
5. Which design most resembles a large-scale turbine?

**Leader Notes**

- Voltage output is related to rotor speed. The faster the rotor speed, the higher the voltage output.
- The horizontal axis turbine should have the higher voltage output because it has the larger swept area (more wind hitting the blades), than the vertical axis turbine. The vertical axis turbine also always has part of it moving against the wind, which slows its speed.
- Most large-scale wind turbines built in the United States today are horizontal axis because this design has a large swept area and high rotor speeds which translate to more electricity.
- Large wind turbines look like they are spinning slow, due to their size (the tip of the blade travels a long way to go around). However the blade tips are moving in excess of 130 miles per hour. They also have a gearbox to increase generator speed inside the nacelle.
- There may be situations where the blades created are too small, too large, unbalanced or poorly designed and the expected outcome is not achieved. In this case, you may have to explain what was supposed to happen or have a set of properly made blades on hand to demonstrate the desired outcome.
Step 7

Refine your design.

As a team, brainstorm ways to improve your design.

Talk About It

1. What might your next design look like?
2. What design features would keep the same?
3. What design features would you change?

Leader Notes

• Worldwide engineers and designers have chosen the three blade horizontal axis design for large wind turbines. Yet small wind turbine designers have chosen many different designs including 2, 3, 4 or more blades. Small wind turbines are generally simpler and have less moving parts than their large wind turbine relatives.

• In general, to improve on these designs youth would want to spin the generator faster. One way to accomplish this is with gears. Adding gears to these turbines can be fairly simple and could be a good experiment for further investigation.
**PUT A PITCH ON IT**

**Time Required:** 35-45 minutes

**OBJECTIVE**

Building upon some of the principles learned in Part One, participants will observe how a turbine’s blade pitch (angle of the blades) influences its rotor speed.

**MATERIALS**

- A SET OF HORIZONTAL AXIS BLADES (use blades made in Part One)
- TURBINE TESTING AREA (KidWind turbine kit, box fan)

**INTRODUCTION**

What is blade pitch?

The blade pitch refers to the angle at which the wind turbine blade is turned into or out of the wind. On a large-scale wind turbine, the control system will adjust the blade pitch as the wind changes to keep the rotor speed within operating limits. In this experiment, the blade pitch angle will be our variable.

**Leader Notes**

- Large wind turbines can change their blade pitch depending on the wind speed. The reason they change their pitch is to catch the wind at lower wind speeds in order to get started (they need about 10-15 miles per hour for startup).
- Small wind turbines like the ones we are using for our experiments have a set blade pitch angle. We want the blade pitch angle to be set so the turbine is able to create the most electricity.
- Wind turbines with a set blade pitch have to protect themselves from high wind. They accomplish this by turning sideways to the wind, also known as furling, or with power electronics and dynamic braking, or an aerodynamic stall.
- Wind turbines also use pitch at high wind speeds to shed energy and slow down which protects the generators from damage.
- Large turbines slow down to protect themselves by turning sideways to the wind which reduces their swept area thus less wind is hitting the blades.
**STEP-BY-STEP**

Using the engineering process we discussed earlier, let’s find out how the changing the blade pitch will affect the rotor speed and voltage output of a horizontal axis turbine.

**Step 1**

ASK A QUESTION.
For this experiment, our question will be:

How will changing the blade pitch affect rotor speed and voltage output?

**Step 2**

GENERATE IDEAS.
Create a hypothesis. A hypothesis is an educated guess about what will happen when we change the variables. What do you hypothesize will happen when you test the different blade pitches?

**Step 3**

EVALUATE AND COMPARE POSSIBLE SOLUTIONS.
We will be testing blade pitch variables of 10, 30 and 60 degrees. How do you think changing the blade pitch will affect your wind turbine performance?

**Talk About It**

- As blade pitch increases rotor speed will ______________.
- As blade pitch increases voltage output will ______________.
- ______________ degree blade pitch angle will have the highest voltage output.
**Step 4**

**BUILD A PROTOTYPE.**

For this experiment we will use the prototype blades you made for your horizontal axis wind turbine in Part One. If you do not have horizontal axis, take a moment to make a set now.

**Step 5**

**TEST THE PROTOTYPE.**

Perform the same instructions for testing the blades that you followed in Part One. Only this time, test blade pitch angles for 10, 30 and 60 degrees. Determine if your hypothesis is correct by recording your observations. Look for any patterns in your data and record what changes occur.

**Take the Lead**

**How to Change the Pitch Blade Angle**

Demonstrate the proper way to change blade pitch angle on experimental turbines:

1. Loosen the nut on the front of the hub
2. Grip the dowel at the base of the blade and turn slowly
3. Once you have all the blades adjusted tighten the nut on the hub until snug (not too tight)

**Step 6**

**TELL YOUR STORY.**

Instruct participants to record their observations on a poster board, chalkboard or whiteboard so that it may be shared with the other groups:

**Talk About It**

- What patterns do you see in the data?
- Which angle had the highest voltage output?
- Which had the lowest?
- From your observations at which angle did the rotor spin the fastest?
Leader Notes

- Blade pitch angle affects how fast the rotor spins - the less of an angle, the faster it spins. However, if the angle is zero the rotor will not spin at all.
- Voltage output is related to rotor speed. Faster speeds result in higher voltages outputs. Generally turbines that spin faster put out more electrical energy.
- Real turbines are attached to a load which uses the electricity. If a load is present then the voltage reading can be used to calculate the turbines power.
- While these small turbines do create electricity, the calculation of how much electricity they can create is more complex than we can do here.
- Some wind turbines have twisted blades with a different pitch angle at the tip than they do the base. This is so the blades will begin to spin at lower wind speeds yet can still spin fast.

Step 7

REFINE YOUR DESIGN.

As a young scientist and engineer, analyze your data and draw a conclusion.

Talk About It

- Which blade pitch angle would you choose for your small turbine design?
- What changes would you make and why?
- What would you keep the same?
PART 3
WHERE TO WIRE FOR WIND
Time Required: 40-50 minutes

OBJECTIVE
Is there potential for wind power in your state? Nearly every state has some location—either on land or offshore in the ocean or a lake—where wind power is possible. However, there are several factors to consider when choosing a location. In this experiment, we will explore some basic steps in choosing the best locations in your state.

MATERIALS
Resource materials for your state downloaded from 4-H.org/NYSD

These materials will include:

• State wind map
• State transmission map
• Population density map

INTRODUCTION
Location is extremely important for a successful wind farm. What type of location is needed for a wind farm to be successful? One that:

• Has high average wind speeds
• Is close to transmission lines
• Isn’t too close to endangered birds or bats
• Not located in areas with high population of people

As of 2011, all of the wind farms in the United States are on land. In Europe, many wind farms have been built out in the sea—miles away from land. Steady, fast and smooth, offshore wind means that these wind farms can make a lot of power.
**Where to Wire for Wind**

**STEP-BY-STEP**
Using the materials and steps provided, work together to choose the best locations for a wind farm in your state.

**Step 1**

**CONSIDER THE FOLLOWING FACTORS.**
There are four important factors to consider when choosing an appropriate location:

1. **Wind speed.**
   Wind speed greatly affects the power in the wind, so it makes sense to build wind farms in places that are very windy. Some of the windiest places on land in the U.S. are the Great Plains (the “wind belt”), mountainous areas and coastal regions.

   **Look at the wind map for your state with your group.** Ask participants to choose two locations in your state that may make a good wind farm location. The two locations should not have the same wind speed. Mark the locations on the map so you will remember them. Record their wind speeds in the chart in Step 2.

2. **Transmission lines.**
   Can your location go with the flow? Electricity uses power lines or transmission lines to flow from where it’s made to where it’s used (our schools, our homes, etc.). Having no transmission lines is like driving a car in a town with no roads.

   Use the national or state transmission map to compare your selected wind farm locations. Are their transmission lines close? Or are they far away? Ask participants to record their findings in the chart in Step 2.

3. **Environmental considerations.**
   Birds and bats are a common problem for wind farms. They can get stuck in the spinning blades. In situations where a species may be endangered, this is an even greater concern. An endangered species is a plant or animal species existing in such small numbers that it is in danger of becoming extinct.

   *Can you think of ways that we can protect endangered species from wind turbines?*
   Record your answers in the chart on the next page.

4. **Social considerations.**
   Turbines also need to be kept a safe distance from humans. Use the population density map to compare your two locations and determine if your sites would cause disruption to homes, schools or other community areas.

   In the box on page 23 marked Population Density, write your solution for how you keep your wind farm from bothering people.
**Step 2**

**RECORD YOUR OBSERVATIONS.**

Use the data you collected in Step 1 to complete the chart.

<table>
<thead>
<tr>
<th>Table: Siting a Wind Farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVERAGE WIND SPEED</td>
</tr>
<tr>
<td>LOCATION #1</td>
</tr>
<tr>
<td>LOCATION #2</td>
</tr>
</tbody>
</table>

**Step 3**

**POWER UP AND DO THE MATH.**

To compare the potential each of the locations has for producing wind power, calculate the physics of wind speed for both locations.

**Take the Lead:**

**Calculate the Physics of Wind Speed**

The equation for determining the physics of wind speed is: $$P \text{ (Watts)} = \frac{1}{2} p A V^3$$

- **p = AIR DENSITY** (Use 1.2 if your location is near sea level or 1.0 if your location is on land)
- **A = AREA OF A TURBINE** (using the equation $A = \pi r^2$
  - For this example use a 1.5 MW turbine which has a radius = 42 meters
  - Unit should be measured in meters
- **V = VELOCITY OF THE WIND**
  - This number can be found on your state wind maps
  - Unit should be measured in meters per second (m/s)
**Step 5**

**DRAW A CONCLUSION.**

Compare and discuss your group’s data to determine which location would make a better destination for a wind farm.

**Talk About It**

- What did you learn?
- Which location would you pick and why?
- Using what you learned, are there other locations in your state that might make a better location?
**Blades**: Part of a wind machine used to catch the wind and turn wind power into spinning motion

**Constraints**: restrictions, limitations, regulations, within prescribed bounds

**Electricity**: the flow of electrical power or charge. Electrical energy is generated using renewable or nonrenewable resources

**Endangered Species**: a plant or animal species existing in such small numbers that it is in danger of becoming extinct

**Energy**: defined by scientists as “the ability to do work.”

**Engineering design process**: a plan or series of steps an used to assist an engineer in creating a product or solution

**Environmental**: relating to the ecological impact on the earth’s environment

**Experiment**: the act of conducting a controlled test or investigation

**Gearbox**: used in large wind turbines to turn increase speed of spinning motion run the generator

**Generator**: Converts spinning motion into electricity using magnets and coils of wire

**Horizontal axis turbines**: Wind turbines with blades like airplane propellers that look like windmills

**Hub**: part of a wind machine used to attach blades together

**Load**: a device to which power is delivered (anything that uses electricity is a load)

**Mechanical energy**: is the energy associated with the motion or position of an object - it is the sum of kinetic (energy of motion) and potential (stored energy) energy of a mechanical system

**Nacelle**: part of a wind machine that encloses the generator

**Nonrenewable resources**: energy sources such as coal, nuclear and natural gas that will eventually run out and cannot be replaced in a short period of time

**Polarity**: electrons flow from the negative pole to the positive pole.

**Prototype**: the first attempt at a design—built to be tested so that the design can be changed if necessary before the product is manufactured for regular use

**Renewable resources**: energy sources like wind that can be replenished, meaning that we are able to create them again and again without worrying when they might run out.

**Rotor**: part of a wind machine consisting of hub and blades

**Social**: relating to human society and matters affecting human welfare

**Tower**: part of a wind machine that holds it up many wind machines have very tall towers

**Transmission (of electricity)**: movement of electricity from one place to another using wires

**Variable**: a factor or condition that is subject to change, especially one that is allowed to change in a scientific experiment to test a hypothesis

**Vertical axis turbines**: Wind turbines with blades that go from top to bottom and look like looks like giant eggbeaters

**Voltage**: the difference in electric charge between two points expressed in volts

**Wind**: moving air; wind is caused by the uneven heating of the earth’s surface by the sun

**Wind turbine**: a machine that converts wind energy into mechanical energy to produce electricity
The 2011 Experiment was designed in conjunction with the University of Nebraska-Lincoln and the University of Nebraska-Lincoln Extension Program.

For more than 100 years, 4-H has been at the forefront of teaching youth about science, engineering and technology. 4-H National Youth Science Day is an annual event—and is part of 4-H's national One Million New Scientists, One Million New Ideas™ campaign, with a bold goal of attracting one million new youth to science, engineering and technology programs by the year 2013.

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