

## Blowin' in the Wind

**Topic(s):** Renewable Energy

**Grade level(s):** 5<sup>th</sup> – 8<sup>th</sup> grades

**Time:** 60-80 minutes

**Maine Science and Engineering Standards:** MS-ESS3-3, MS-ETS1-1

### ACTIVITY OVERVIEW

In this hands-on STEM activity, students will design, build, and test wind turbine blades to investigate how different blade shapes, angles, and materials affect energy generation. Through the **engineering design process**, students will brainstorm ideas, create prototypes, test their designs, and refine them to optimize performance.

Students will work collaboratively to design and test wind turbine blades using tabletop wind turbines. They will measure energy output with multimeters, analyze the collected data, and evaluate the effectiveness of their designs. Based on their findings, students will propose improvements to enhance efficiency.

In addition to applying engineering principles, students will explore concepts of **energy transformation**, including how wind's **kinetic energy** is converted into **mechanical energy** and ultimately into **electrical energy**. They will also discuss the environmental and societal impacts of renewable energy, comparing wind power to nonrenewable sources and highlighting its role in sustainable energy solutions.

By the end of this activity, students will have a deeper understanding of renewable energy technologies, the importance of sustainable design, and how engineering can address real-world challenges related to energy production.

### ALIGNMENT TO STANDARDS

**MS-ESS3-3.** Apply scientific principles to design a method for monitoring-and minimizing a human impact on the environment.

**MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, considering relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

## LEARNING OUTCOMES

By the end of this lesson, students will be able to:

1. Apply the steps of the engineering design process, including brainstorming, prototyping, testing, and refining, to optimize blade designs for maximum energy output. Students will collaborate with peers to share findings, troubleshoot design challenges, and propose solutions to optimize energy generation.
2. Evaluate the effectiveness of their blade designs based on data collected during testing and make evidence-based recommendations for improvement.
3. Identify and describe the types of energy involved in wind energy systems, including kinetic energy and mechanical energy.
4. Demonstrate an understanding of the transformation of kinetic energy from wind into mechanical energy and subsequently into electrical energy.
5. Articulate why wind energy is classified as a renewable energy source and discuss its environmental benefits compared to nonrenewable energy sources and reflect on the societal and environmental impacts of renewable energy sources and the importance of sustainable energy solutions.

### Key Terms:

Energy, renewable energy, potential energy, kinetic energy, mechanical energy, friction, windmills, wind turbine, wind

## CAREER CONNECTIONS

1. **Climate Change Analysts** - Research and analyze policy developments related to *climate change*. Make *climate*-related recommendations for actions such as legislation, awareness campaigns, or fundraising approaches.
2. **Wind Energy Engineers** - Design underground or overhead *wind* farm collector systems and prepare and develop site specifications.
3. **Wind Turbine Service Technicians** - Inspect, diagnose, adjust, or repair *wind* turbines. Perform maintenance on *wind* turbine equipment including resolving electrical, mechanical, and hydraulic malfunctions.
4. **Wind Energy Operations Managers** - Manage *wind* field operations, including personnel, maintenance activities, financial activities, and planning.
5. **Wind Energy Project Managers** - Lead or manage the development and evaluation of potential *wind* energy business opportunities, including environmental studies, permitting, and proposals. May also manage construction of projects.
6. **Environmental Engineers**- Research, design, plan, or perform engineering duties in the prevention, control, and remediation of environmental hazards using various engineering

disciplines. Work may include waste treatment, site remediation, or pollution control technology.

## BACKGROUND INFORMATION

### Wind Energy and Wind Power

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun (nuclear energy), the irregularities of the Earth's surface, and the rotation of the Earth. Wind flow patterns are modified by the Earth's terrain, bodies of water, and vegetative cover. When "harvested" by modern windmills and wind turbines, this wind flow or kinetic energy can be used to generate mechanical power or electricity. Windmills and wind turbines differ in their function and design. Windmills convert wind energy directly into mechanical energy for tasks like milling grain—the source of the term “windmill”—or pumping water, which is usually the purpose of windmills one sees on farms. A wind turbine converts wind energy into electricity which can then be used to power electrical equipment, stored in batteries for later use, or transmitted over power lines. 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 students design the blades in this lesson can greatly impact how much power the turbine produces.

### Why Do Windmill and Wind Turbine Blades Move in the Wind?

Two important reasons wind turbine blades can spin in the wind are **Newton's Third Law** and the **Bernoulli Effect**.

1. **Newton's Third Law** states that there is an equal and opposite reaction for every action. In the case of a wind turbine blade, the action of the wind pushing air against the blade causes the reaction of the blade being deflected or pushed. If the blade has no pitch (or angle), the blade will simply be pushed backward (downwind). However, since wind turbine blades are set at an angle, the wind is deflected at an opposite angle pushing the blades away from the deflected wind. This phenomenon can be viewed on a simple, flat blade set at an angle. If you push the blade with your finger from the direction of the oncoming wind, the blade will deflect away from your finger.
2. **The Bernoulli Effect** tells us that faster-moving air has lower pressure. Wind turbine blades are shaped so that the air molecules moving around the blade travel faster on the downwind side of the blade than those moving across the upwind side of the blade. This shape, known as an airfoil, is like an uneven teardrop. Most wind turbines are upwind oriented, meaning they face into the wind. The downwind side of the blade has a large curve, while the upwind side is relatively flat. Since the air is moving faster on the curved, downwind side of the blade, there is less pressure on this side of the blade. This

difference in pressure on the opposite sides of the blade causes the blade to be "lifted" towards the curve of the airfoil causing the wind turbine blades to rotate.

- a. You can do a simple experiment to demonstrate the Bernoulli Effect. Take two small pieces of paper and fold them slightly in the middle. Hold the two pieces of paper in your hands so that the outside creases of the folds are facing each other. Then blow air in between the two pieces of paper. When you blow air between the papers, would you expect them to push apart or pull together? Were you surprised? When you blow air between the papers, the speed of the air is higher between the two pieces of paper than outside the papers. Bernoulli's Principle tells us that this higher velocity will lead to a lower pressure between the papers. That is why the papers are sucked in towards each other!

### **Drag, Lift, and Torque**

The efficiency of a wind turbine blade depends on the **drag, lift, and torque** produced by the blade. These factors are affected by the size and shape of the blades, the number of blades, and the blade pitch.

What is **Drag**?

**Drag**, or air resistance, works against the blades, causing them to slow down. Drag is always important when an object moves rapidly through the air or water. Airplanes, race cars, rockets, submarines, and wind turbine blades are all designed to have as little drag as possible. Drag increases with the area facing the wind—a large truck has much more drag than a motorcyclist moving at the same speed. Wind turbine blades must be streamlined to pass through the air efficiently. Changing the angle of the blades will change the area facing the apparent wind. This is why blade pitch angles of 10-20 degrees tend to have much less drag than greater angles. Drag also increases with wind speed. The faster an object moves through the air, the more drag force it experiences. This is especially important for wind turbine blades since the blade tips move through the air much faster than the base of the blade. The shape and angle of wind turbine blades change along the length of the blade to reduce drag at the blade tips.

What is **Lift**?

**Lift** is the aerodynamic force that allows airplanes and helicopters to fly. The same force applies to the blades of wind turbines as they rotate through the air. Lift opposes the force of drag, helping a turbine blade pass efficiently through air molecules. The main goal of a well-designed wind turbine blade is to generate as much lift as possible while minimizing drag. The amount of lift a blade or wing can generate is determined by several factors—the shape of the blade, the speed of the air passing around the blade, and the angle of the blade relative to the apparent wind.

What is **Torque**?

**Torque** is a force that turns or rotates something. Torque is equal to the force multiplied by distance. This means the longer your blades are, the more torque you can generate. On an actual wind turbine, the long blades give the turbine a lot of leverage to provide power to the generator.

### **Blade Design**

Blade Design and engineering are some of wind turbine technology's most complicated and essential aspects. Today engineers are trying to design blades that extract as much energy from the wind as possible throughout a range of wind speeds. In addition, these blades need to be durable, quiet, and affordable.

Experiments with blades can be simple or very complicated, depending on how deep you want students to go. Some things students can test about blades include:

- blade length
- blade number
- blade pitch (angle)
- blade shape
- blade materials
- blade weight

## **PRE-LABORATORY ENGAGEMENT**

### **Investigating Electricity**

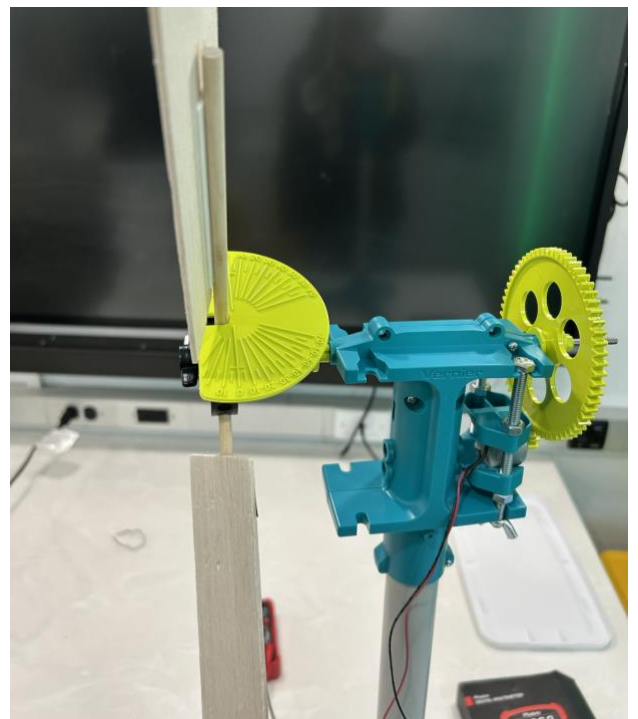
While not critical for participation in this lesson, it is helpful if students understand what electricity is, how it is generated, and how it travels to our homes and school. There are several pre-lab activities that can be used for review.

- Simple Circuits (with wires and bulbs)
- [PhET simulations](#)
- [Schedule a visit to “Electric Town” with Versant](#)

### **Vocabulary**

- [Magnetic Poetry](#)

## LABORATORY SETUP



## MATERIALS

- For the class:
- 2 Vortex Fans (spread around the class)

- 2 KidWind Turbines
- To save time, assemble turbines ahead of time. Certain parts are already assembled.
- Video link: [KidWind Turbine setup](#)
- Chipboard sheets
- Balsa wood sheets
- Cardstock
- Chipboard
- Duct tape
- Electrical tape
- Masking tape
- Wooden dowels
- 2 Vernier LabQuests
- 2 Vernier energy sensors
- 2 Vernier variable loads

For each group:

- 5 wooden dowels
- 1 plastic turbine hub
- Play money

## LESSON PLAN

### Slide 1: Introduction (10 min):

- Welcome students to the lab and direct them where to sit.
- Explain to students that they will be acting as Wind Energy Engineers and designing wind turbine blades.

### Slide 2: The Earth is a closed system.

- Energy from the sun enters the atmosphere, hits the Earth's surface and is partially absorbed, and then re-radiates back into space.
- Matter does not enter or leave the planet. Resources are limited and matter is not created or destroyed. This is the law of conservation of matter.

### Slide 3: Greenhouse Effect

- Greenhouse gases act similarly to the glass in a greenhouse: they absorb the sun's heat that radiates from the Earth's surface, trap it in the atmosphere, and prevent it from escaping into space. The greenhouse effect keeps the Earth's temperature warmer than it would otherwise be, supporting life on Earth.
- Many greenhouse gases occur naturally in the atmosphere, but human activity contributes to their accumulation. As a result, the greenhouse effect in the atmosphere is boosted and it alters our planet's climate, leading to shifts in snow and rainfall patterns, a rise in average temperatures and more extreme climate events such as heatwaves and floods.
- Human enhanced greenhouse gases: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous

oxide (N<sub>2</sub>O AKA laughing gas).

**Slide 4: Fossil fuels and Climate Change**

- Illustrate the correlation between CO<sub>2</sub> production and global temperature. As CO<sub>2</sub> levels increase, so does the global average temperature. CO<sub>2</sub> levels directly contribute to global warming due to their greenhouse effect which traps heat in the atmosphere.
- **Weather vs climate:** Weather is the current state of the atmosphere while climate is the average weather over a long period of time.

**Slide 5: Renewable Energy Sources**

- A great deal of resources are needed to support the human population (~8 billion).
- The supply of **nonrenewable resources** is replenished extremely slowly, if at all.
  - Coal, oil, minerals.
  - These can be used up much faster than they can be replenished and they add more greenhouse gasses to the atmosphere than renewable energy sources.
- **Perpetual resources** are those that last forever
  - solar energy and wind energy
- **Renewable resources** can be replenished within a human lifetime.
  - Timber, water.

**Slide 6:** Introduce the **structure of a wind turbine** and how it turns mechanical energy into electrical energy:

- A wind turbine is a machine that turns the energy of the wind into electricity. It works kind of like a big fan, but in reverse.
- The main part you see are the blades, usually three of them, which catch the wind and spin. These blades are attached to a spinning part called the rotor.
- **Pitch** is the angle of the turbine blades relative to the wind.
- As the rotor turns, it transfers energy to a large box behind it called the nacelle. Inside the nacelle, there are important parts: the generator, which changes the spinning motion into electricity, and the gearbox, which makes the spinning faster so more electricity can be produced.
- All of this is supported by a tall tower that holds the blades and nacelle high in the air, where the wind is stronger.
- At the very bottom is the base, made of strong materials like concrete or steel, which keeps the turbine steady. When the wind blows, it sets everything in motion, and the turbine turns that motion into power we can use.

**Slide 7: Wind turbines are much larger than you may expect.**

**Slide 8: Yawing: Facing the Wind**

- **Active Yaw**
  - Medium and large turbines
  - Anemometer (a device that measures wind speed and air pressure) on nacelle tells controls which way to point the rotor
  - Yaw drive turns gears to move rotor

- Sensors on the turbine figure out which way the wind is blowing, and then the yaw motor turns the nacelle to face the wind. It's like how you might turn your head to feel the wind on your face—except the turbine does it automatically to make the most electricity!
- **Passive Yaw**
  - Small turbines
  - Wind force naturally rotates the nacelle
    - Tail fin pushes turbine to face the right direction

**Slide 9: Why Are Wind Turbines So Tall? (Slide hidden - too advanced for middle school)**

- The power a wind turbine generates increases exponentially with wind speed because the energy in the wind is proportional to the **cube** of its speed. This means that doubling the wind speed results in eight times the power output. This relationship comes from the physics of wind energy capture. Wind power is calculated using the formula:

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$$P = 0.5 * \rho * A * C_p * v^3$$

- **P:** is the power in watts
- **ρ:** (rho) is the air density in kg/m<sup>3</sup>
- **A:** is the swept area of the turbine blades in m<sup>2</sup>
- **C<sub>p</sub>:** is the power coefficient (efficiency of the turbine)
- **v:** is the wind speed in m/s

**Slide 10: The Engineering Design Process**

- **Identify:** identify the problem, and the criteria and constraints
- **Imagine:** Explore materials and brainstorm ideas
- **Plan:** Create a plan individually, then collaborate and share ideas before making a group plan and gathering materials.
- **Create:** Build the product/prototype and test it.
- **Improve:** Analyze results, modify the process or design to make it better, and then repeat.

**Slide 11: The Challenge**

- Each student group will build a wind turbine blade system. Their goal is to have the blades transform wind energy into electrical energy and produce the highest number of volts possible.
- Explain and show the various materials that will be available for purchase.
- Student groups will design and build one system, test it, and then make changes and test again.
- Explain that a teacher will come take their order and deliver their materials.
- Pass out their money and have them begin planning.

**Closing (5 minutes):**

- Ask students what their highest voltage was and what their design was. What worked and what didn't work?