Materials for 15 Windmills or 15–45 Students

Grades
• 5–8, 9–12 (Extension Activity)

Concepts
• Energy and Transformations
• Forces and Motion
• Engineering, Art, and Design
• Using Basic Tools
• Collecting and Interpreting Data
• Math

Time Required
• Two class periods

Objectives
At the end of the lesson, students will:
• Know the fundamental parts of a windmill
• Be able to use the scientific method to isolate and adjust variables in a model windmill
• Understand energy conversions/transfer and how a windmill converts moving air into usable mechanical energy
• Have constructed a functional windmill that lifts weights
Your REcharge Labs Classroom Kit

The materials enclosed in this kit will help you bring engaging lessons about renewable energy into your classroom. Consider attending a REcharge Training, if you haven’t already done so, to enhance your experience using these materials.

About REcharge Labs

We believe that responsible and informed students of today will become our innovative renewable energy leaders of tomorrow. At REcharge Labs, our mission is to provide the resources to encourage this generation of informed thinkers, involved doers, and curious life-long learners.

REcharge Labs provide everything you need to teach renewable energy.

- **Professional development workshops** that prepare you to teach fun, hands-on project-based wind and solar activities.
- **Scalable activities** for different age groups and time frames.
- **Kits and resources** that fit educational standards and your budget.

We recommend attending a REcharge Lab training workshop to enhance your experience using these kits.

REcharge Labs was born out of programming from the KidWind Project, and relies upon KidWind’s resources and history to carry out its work. KidWind has been a leader in renewable energy education for over a decade. REcharge Labs, like KidWind, continues to be committed to bringing affordable, hands-on applications of our materials to teachers and students worldwide.

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Find kits and sign up for training workshops at

[www.rechargelabs.org](http://www.rechargelabs.org)
Materials

There are as many different ways to build your MacGyver Windmill as you can think of. Here we show you some suggested applications for the materials in this kit, but don’t let that limit you. Most of the materials are reusable, which means you can build and rebuild your MacGyver again and again. We strongly encourage you to provide additional blade-making material to introduce even more variables for your students to test.

Blades
- Index cards

Hubs
- Foam cylinder
- Cork

Driveshafts
- Skewers
- Straws
- Cardboard tube
- Dowels

Attachments
- T-pins
- T-pins

Weightlifting
- String
- Cup
- Washer
- Spool

You will need to supply the following materials:
- Box fan
- Ruler
- Tape
- Scissors
- 20” x 20” standard box fans
- Alternative blade material such as paper plates, scrap cardboard, lawn signs, pie pans, etc. Anything that catches the wind will work!
Topics for Discussion and Activity Integration

Forces and Motion
People use many kinds of forces to put objects into motion. Playing catch, swinging on a swing set, or riding a bike are ways that we use force to push and pull things to achieve motion. There are also forces constantly acting upon us that affect our movement, like wind, a hill, or something pushing or pulling us, like a dog on a leash. These forces cause us to slow down, speed up, or stop completely. Learning about forces and motion will help us understand how things work, and can help us understand how to make things work better in order to solve a problem. Students will gain a better understanding of forces and motion by testing a construction that moves with the wind.

Wind Power
Through experience, students are clearly very familiar with the wind and what it can do. They may not know where wind comes from, but they have seen how it can be helpful to society (kites, sailboats, windmills) and how it can be destructive (tornados, hurricanes). In this activity guide, we hope to show you some ways that we can harness the wind to do useful work in our daily lives (move objects, lift objects, etc.).

We understand that you may have a limited time to do these activities but when discussing wind power there are two important topics that may intersect with your exploration of this subject: energy and climate change. Below we offer some very brief guidance in talking with your students about these concepts.

Energy
When we are dealing with moving air molecules, gliding sail cars, rotating windmills, and turbines, we are exploring energy and the transformation of energy between different forms. While there are formal definitions of energy, such as the ability to do work, young (and older) students struggle with many of the basic concepts.

Young students understand energy from experience and not from textbooks and have a number of preconceptions about the topic. If you ask students to describe energy, you may hear the following concepts:

• Energy is a fuel that does work.
• Energy is linked to moving things.
• Energy is needed for living things to survive.
• Energy can move around in wires or be stored in a battery.
• Energy can be changed into different kinds of energy.

We are not worried about formal definitions of energy, understanding all the forms and sources, or technical aspects of energy transformations, although they can be easily incorporated into this lesson. It would be great if at the end of our activities students understand the following about energy:

• Energy is found in motion (and maybe light, heat, sound);
• Wind is the motion of air and has energy;
• The energy in the wind can be transferred to objects to make them move or rotate;
• We can use that movement or rotation to do useful work (make a car move, lift a weight or light a bulb)
Climate Change

When discussing wind power, one question that may come up is: why should we harness wind power to generate electricity? This is a very good question. It provides you an opportunity to discuss the delicate path we must walk between balancing our need for energy and the impact that generating electricity has on the climate.

Students of almost any age will be able to tell you something accurate about the weather. However, discussions about climate, and climate change, are more complex, and these conversations are probably more appropriate for students 3rd grade and above.

The first thing we can help students understand is that there is a big difference between weather and climate.

- Weather is the day-to-day state of atmospheric conditions like “Will it be hot tomorrow?”
- Climate is the weather of a place averaged over a period of time, often 30–40 years.

If young students can understand the difference between these two concepts, this will go a long way toward helping them understanding climate change as they become advanced students.

Discussing climate change can sometimes make students feel helpless. What can we do about such a big problem? While we do not want to scare students, we can tell them that scientists have discovered that our climate is changing in ways that may be different than in the past, and that on average, the planet is warming faster than it ever has throughout history.

Connecting climate change to electricity can be even more complicated. Most young students, and even older students and adults, do not know where or how their electricity is generated, but this can be a fun conversation! Currently, most of the electricity we consume in the US comes indirectly from burning fuel, such as coal or natural gas. These fuels are combusted to heat water, make steam, and drive a turbine which generates electricity that comes to our house over wires. The burning of these fuels generates CO₂ and pollution.

Most students understand that when we burn things, it creates smoke or pollution. We can ask students what they think could happen if there was a lot of pollution and tell students that the pollution created from electrical generation releases gases that are causing temperatures to increase over time. These temperature changes can impact all life on earth. More advanced students (4th grade and up) can explore mechanisms around how greenhouse gases heat up the earth.

This is a lot to digest for young elementary students, so here are a few major points when connecting energy and climate:

- All energy use has consequences.
- Current research informs us that the global climate is warming due human factors.
- As a society and individuals we can make choices that help reduce the climatic impact of electricity generation.
- Generating power with the wind is a choice we can make that reduces pollution and following climate impacts from electricity production.
Learning Goals

Students will use a limited amount of materials to design and build functioning windmill models. They will use these models to convert wind into mechanical energy in order to lift weights. Using the scientific method, they will conduct trials, change variables, and work to improve the performance of their windmills.

Getting Ready

- It is strongly suggested that teachers try to build their own windmills before the class begins. This is a valuable preview to the challenges and problems that students will face.
- Separate the materials to distribute to each group. Remember that materials for this activity are intentionally limited, as this inspires creative problem solving and discourages waste. Use common box fans (20” by 20”) to encourage the students to build efficient designs. Using the fan on a low speed is recommended.
- Have students do some background reading on windmills and wind power.
Activity

During the first class period, students focus on getting their prototypes to spin when placed in front of the fan. During the second class period, students participate in the Weight-Lifting Challenge to get their windmill to lift a cup of weights (washers).

**CLASS PERIOD 1**

**Step 1: Beginning questions for students**
- Who has seen a real windmill (mechanical or electrical)?
- What are the parts and features of a windmill?
- What is the purpose of a windmill?
- How does the wind cause the windmill to rotate?

**Step 2: What is the difference between a windmill and a wind Turbine?**
Ask a couple of students to draw a windmill on the blackboard. Ask the other students to describe how these windmills work and what they are used for. Generate a brief discussion about what differentiates the windmills from modern wind turbines.

**Step 3: Distribute materials**
Present the windmill design activity to the students and organize them into groups of 3 to 5. Give each group the required materials. Do not pass out the string, cups, or washers yet, as these will be distributed at the beginning of the second class period when the Weight-Lifting Challenge is presented. As you distribute the materials, be sure to mention some ground rules for safety.

**Safety Guidelines**
Always wear safety glasses when the rotor is spinning! You could be hit if your blade flies off during testing.

**Step 4: Spin in the wind**
Instruct the students to assemble a mechanism that will rotate when placed in the wind. Tell them not to worry about lifting weight yet. The first challenge is just to get the windmill to spin. Note: there are not enough materials to build a tower. These windmills should be held by hand or attached to the desktop.

Students can either hold their windmill by hand or tape it to the desktop.

**Step 5: Design and test**
Give the groups some time for initial designing and construction. Each group should have a chance to test their windmill with the fan at least once during this first class period. Three tests per group is ideal. There is no right answer here and many designs are possible. Students will feel confused. That is okay!

**Step 6: Discussion**
At the end of class, show students pictures of real windmills and wind turbines. Discuss how windmills work and the fundamental parts of a windmill. How do these real windmills differ from student designs? What new ideas do the pictures give them?
Other possible questions:
• What windmill designs worked best?
• What parts were most difficult to design and make functional?
• How did you attach your blades?
• Where is there friction in your design?
• How did you reduce friction in your windmill?
• How did you pitch or angle the blades?
• Were your blades changing pitch frequently?
• Did the fan work better from the front of the blades or the side?

CLASS PERIOD 2

Step 1: Weight-Lifting Challenge
By the beginning of this class period, most groups should have succeeded in getting their windmills to spin in the wind. Now introduce the Weight-Lifting Challenge. Give each group the string, cups, and washers. Their goal is to use the power of the wind to lift as many washers as possible. As students work toward this goal, they will have to isolate and improve certain variables in their designs.

Step 2: Test variables, improve designs
As students test their weight-lifting windmills, give them guidance and tips on how to improve their designs. Encourage them to focus on one variable at a time; conduct a trial, measure the results, make changes, and repeat the trial. The size, shape, pitch, and number of blades can be explored. The variables of fan setting (speed) and distance from the windmill should be kept constant. Remind students to use the scientific method as they design and test their prototypes.

Some groups may struggle to get the windmill to lift any weight. Urge them to look at other groups that have been successful. What techniques work well and what does not seem to work? Remind students that this activity is not a competitive contest, but rather a class effort. Students can learn from and support each other.

Step 3: Discussion
• How many blades worked well for lifting weight?
• Did more blades mean you could lift more weight?
• What blade pitch was best for lifting weight?
• Where did you attach the string? Why?
• How did your design change after the attempt to lift weight?
• How were you able to get more turning force from your blades?
• What ideas seemed to work well?
• What problems did you encounter?
• What parts of your windmill broke or failed?
For a quantitative analysis of your MacGyver windmill, you can ask students to calculate the energy required to lift the bucket of washers and determine the average power of their windmill as it lifts that mass.

Energy is measured in joules (J). Power is measured in watts (W). Power is a measurement of how fast energy is converted. In this case, power is a measurement of how fast the mass is lifted.

To calculate how much energy is required to lift the washers, students will first need to measure the mass (kilograms) of the washers they are lifting and how high they are lifting the washers (meters).

\[
\text{Energy (J)} = \text{Mass (kg)} \times \text{Acceleration of Gravity (9.8 m/s}^2\) \times \text{Height (m)}
\]

To measure power, they must also measure how long it takes to lift the mass to that height (seconds). Standardize the height so that every group must lift to the same height (0.5 meter or so).

\[
\text{Power (W)} = \frac{\text{Energy (J)}}{\text{Time (s)}}
\]

**Vocabulary**

- **blades**
  The aerodynamic surface of the turbine that catches the wind.

- **blade pitch**
  The angle of the blades with respect to the plane of rotation. For example: blades perpendicular to the oncoming wind would be zero degrees; blades parallel to the wind would be 90 degrees.

- **drag**
  For a wind turbine, this is also called wind resistance. The friction of the blades against air molecules as they rotate. Drag works against the rotation of the blades, causing them to slow down.

- **driveshaft**
  The rod or shaft connected to the hub; it rotates with the rotor.

- **force**
  A push or pull.

- **friction**
  A force that resists the relative motion of two bodies in contact.

- **hub**
  Central component connecting blades to driveshaft.

- **plane of rotation**
  The area directly in line with the rotor. It is dangerous to stand in this area because a blade that is not securely fastened to the hub and detaches could hit any person standing in this zone.

- **rotor**
  The rotating section comprised of blades projecting from a hub.

- **torque**
  A force times a distance that causes rotation. In a windmill, each blade acts like a lever arm rotating around an axis. The more surface area the blade has, the more torque the wind applies to the blade.
Did you like the MacGyver Windmill Class Pack? Then you might be interested in these REcharge Labs classroom kits.

**Sail Car Class Pack**
Build a Sail Car using inexpensive materials to demonstrate how wind can be used to propel an object. Gather measurements, record changes in variables, and use simple engineering design concepts to build sails that can push the car as far as possible.

**firefly™ Class Pack**
This activity explores basic wind turbine design. Understand how to make an efficient wind turbine by designing a pinwheel shape to catch wind and illuminate an LED bulb. Experiment with materials and get creative with design.

**Solar Town Class Pack**
Build a small solar powered house, then learn basic circuitry to wire it with lights, a motor, switches, power storage, and a solar panel. Use the model house to learn about energy consumption, efficiency, and conservation in an average household. A great activity to model real world applications. Connect with your neighbors to build a town!

**Solar Fountain Kit**
Learn how to use the power of the sun to build a creative electrical fountain. Discover how solar panels work, learn basic circuitry, and use this knowledge to build a custom solar powered fountain.

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