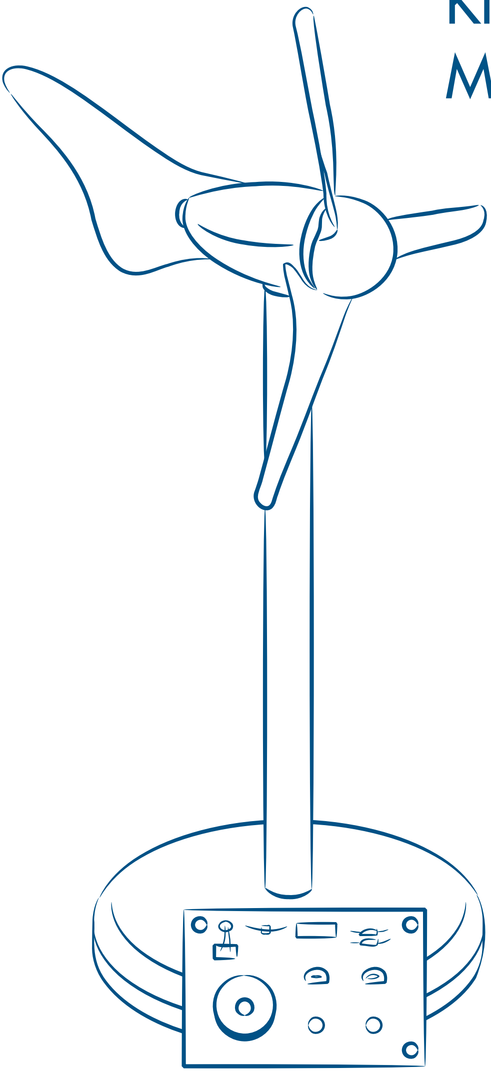
KidWind
MINI Turbine 2.0



instructions

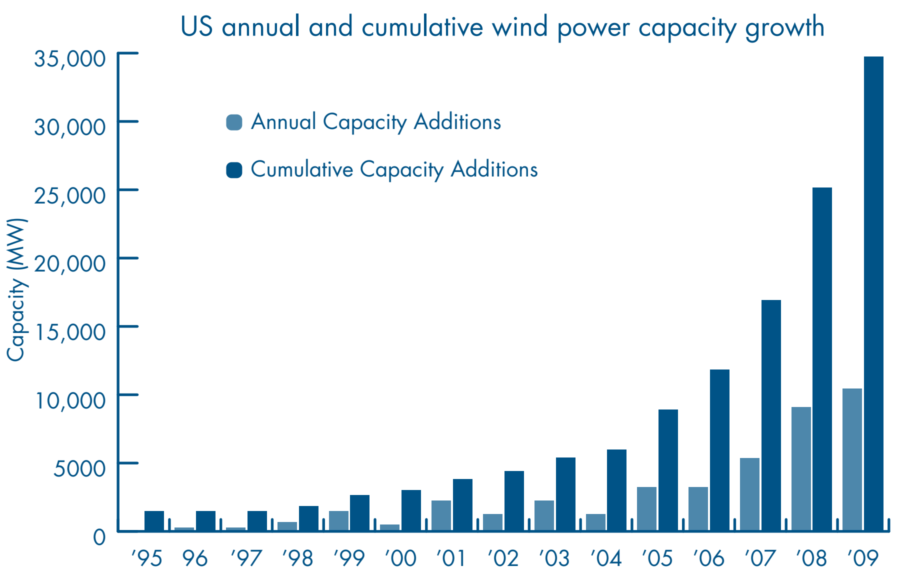
Why Study Wind Energy?

In 2009, wind power comprised 39% of all new energy installations in the US. As investors and power producers look to build new power infrastructure, they are choosing to build wind farms at an increasing rate.

Of our current electrical generation mix, about 2% of our energy is produced by wind turbines. That is double what we had three years ago: approximately 20,000 wind towers.

The current US wind power capacity of 36,700 MW is capable of generating enough power for over 10 million US homes! Some industry leaders believe that by the year 2030 we will get 15–20% of our energy from the wind. Reaching this goal will take great effort and lots of scientists, engineers, and technicians.

The KidWind MINI, and other KidWind kits, will help you explore some of the science and engineering behind the growing field of wind power so you can one day help move the US towards a sustainable energy future.



Source: American Wind Energy Association
US Wind Industry Annual Market Report—Year Ending 2009

The KidWind MINI

The KidWind MINI wind turbine kits are perfect for demonstrating how wind turbines function. They also allow you to perform experiemnts with wind power. Check out all the kits at: **www.KidWind.org/shop**

The KidWind MINI

The KidWind MINI is an easy-to-build turbine that produces enough electricity to power LED bulbs, a sound & light panel, and other load devices.

The KidWind MINI—Blade Design kit

Be a blade engineer! With the KidWind MINI—Blade Design kit you will also be able to use your turbine to make and test blades that you construct yourself. See what happens to wind turbine power output when you change the number, pitch, and shape of the blades.

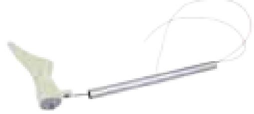
The KidWind MINI 2.0

1	MINI nacelle assembly	1	Sound & light panel
1	10″ aluminum tower	2	Alligator clip cords
1	Round wood base	5	Plastic bumpers
1	Red MINI blade set	1	Yellow plug

The KidWind MINI—Blade Design kit

1	MINI nacelle assembly	1	Yellow plug
1	10″ aluminum tower	2	Resistor (50 & 100 ohm)
1	Round wood base	1	12 hole crimping hub
1	Red MINI blade set	8	Corrogated plastic sheets
1	Sound & light panel	12	Dowels
2	Alligator clip cords	1	Multimeter
5	Plastic bumpers	1	KidWind protracter

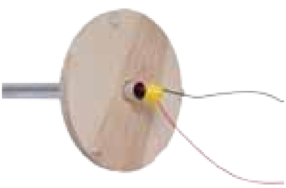
Building the MINI Turbine



Unwrap wires and pass them through the tower.

1. Unwrap the wires of your MINI nacelle.
2. Feed the wires down the aluminum tower.
3. Feed the wires through the wooden base.
4. Insert the nacelle post into the end of the tower.
5. Slide the tower through the wooden base.
6. Feed the wires through the hole in the yellow cap.
7. Insert the cap into the end of the tower.
8. Stand up your MINI Turbine.
9. Push the red blade set onto the shaft of the generator.

Feed the wires through the hole in the wooden base.



Feed the wires through the plastic plug and insert it into the tower.

Converting to blade testing turbine

The KidWind MINI–Blade Design kit includes a 12 Hole Crimping Hub and blade materials. This hub makes it easy to change blades and try your own designs.

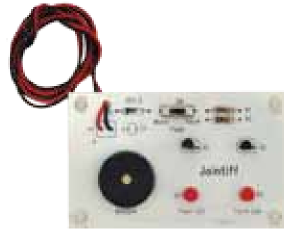
Pull off the red plastic blade set. The best way to do this is to pry it off slowly using a screwdriver or something similar. Replace it with the 12 hole crimping hub and you are ready to make and test your own blades. See page 12 for tips on how to make and test blades.

Stand up the tower and attach the red blades or 12 hole crimping hub.

Connecting Your MINI to Devices and Loads

KidWind MINI

The KidWind MINI comes with a sound & light panel that you can connect to your turbine to demonstrate power output. Be sure to connect red wires to red and black wires to black.



The sound & light panel uses the power your KidWind MINI generates to light an LED or play a song.

The KidWind MINI can power a variety of electrical devices beyond the included sound & light panel (especially if you build a mini wind farm)!

For more fun experiments, try pumping water with the KidWind water pump, electrolyzing water in a hydrogen fuel cell, or storing energy in a super capacitor. You can also connect it to another DC motor, which can spin a small propeller. All of these items can be found at www.KidWind.org/shop

The KidWind MINI Blade Design Kit

The MINI—Blade Design Kit comes with a simple multimeter so you can quantify how much power your turbine generates. The following directions will help you connect your MINI to the meter and record voltage and amperage.

Carefully remove blades, using a screwdriver to pry against the motor.

RESISTORS

Resistors are electrical components with a known resistance. There is a standard system of colored bands to show what the resistance of a resistor is.

The MINI Blade Design kit includes a 50 ohm resistor

and a 100 ohm resistor.

Measuring voltage

Attach the wires from the generator to the multimeter. Polarity is not relevant at this point.

To check the voltage, select DC volt (V) and set the number to 20.

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 because of the inconsistent nature of the wind or unbalanced blades.

Voltage is related to how fast the DC generator is spinning. The faster it spins, the higher the voltage. With no load on the generator, it has little resistance and can spin very fast.

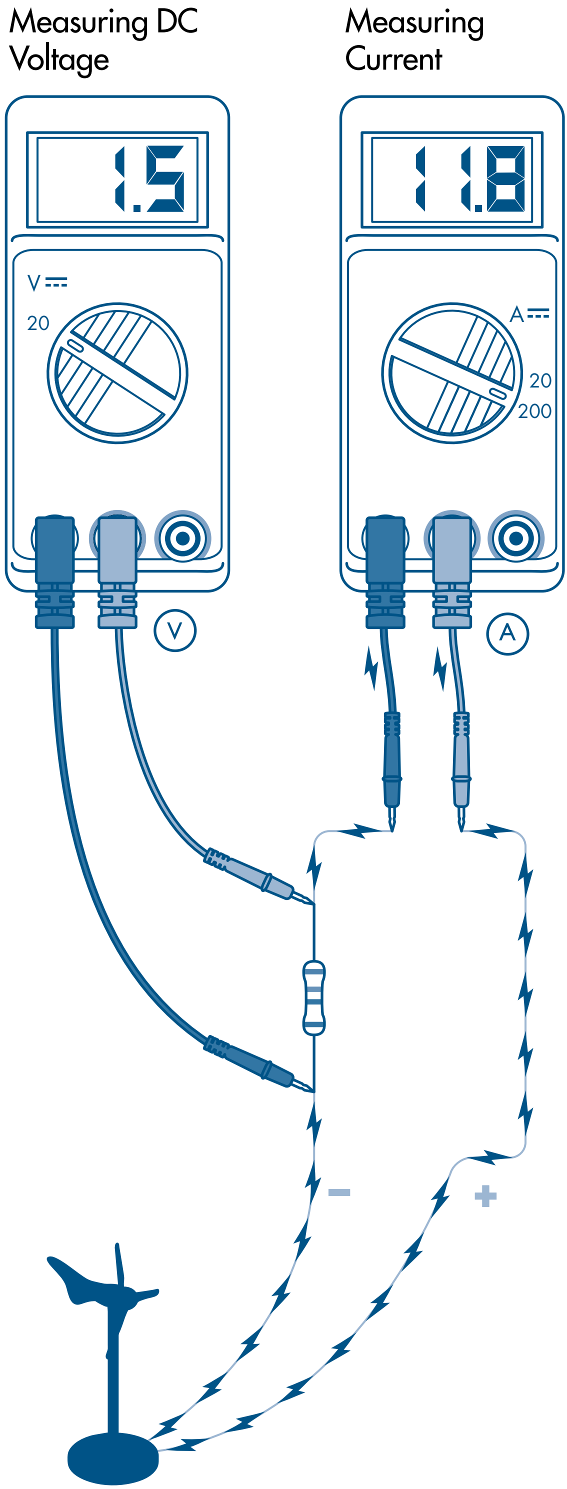
You can measure voltage with no load, but it is more realistic to place a resistor in the circuit and measure the voltage across the resistor. We commonly use 10, 30, 51 or 100 ohm resistors.

Measuring amperage

To calculate your turbine's power output, you will need to measure current as well. When measuring current you are monitoring how many electrons are being pushed through the wire by the turbine. We measure current from our turbine in milliAmperes.1A =1000 mA.

To measure current, place a load in series with the multimeter so the generator is forced to do some work. Set the meter to 200 or 20 mA, which is a typical range for our devices.

The current that your turbine produces depends on the load placed in the circuit and the torque your blades are generating.



VOLTAGE, CURRENT & RESISTANCE

Voltage (measured in volts), is also called "potential difference" or "electromotive force" (EMF). It is a measure of the amount of "potential energy" available to make electricity flow in a circuit. It is the electric "pressure" causing the current to flow.

Electric current is a measure of the rate at which electric charge (electrons) are flowing through a circuit. It is given in the unit of amperes ("amps"). Smaller amounts of current are often stated in milliAmps (mA). A mA is 1/1000 of an amp.

Electrical resistance is the opposition to the flow of electricity. Measured in ohms, it reflects how much electric "pressure" (voltage) is required to push a given amount of current through part of an electric circuit.

To measure the power your turbine is producing, you need to do some math with these values (see page 16).

Experiments for your KidWind MINI

The KidWind MINI was designed to demonstrate wind power technology while helping you do some simple experiments!

Experiment 1: changing wind speed

This experiment can be done with the red blade set or your homemade blades using the crimping hub. Place the turbine about three feet in front of a fan, and turn it on high. What happens when you turn the fan to medium or low? Does the LED bulb light up at any wind speed?

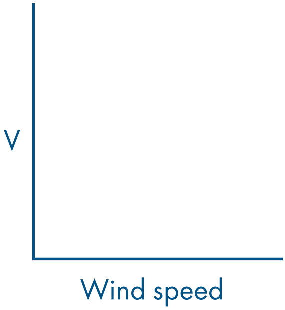
Now leave the fan on medium and move your turbine away from the fan by about a foot. Continue moving the turbine away from the fan, one foot at a time, until the LED bulb no longer works. How far away can you get? Why is the turbine unable to power the light bulb as you back away from the fan?

The KidWind MINI—Blade Design includes a multimeter. What happens to the voltage or current as you move your turbine further from the fan, or decrease the wind speed?

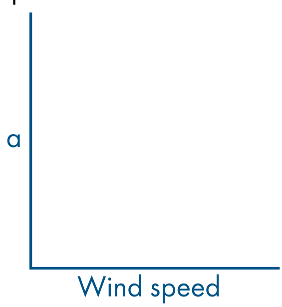
Experiment 2: blade design

The amount of power your turbine can produce depends on blade efficiency. To build efficient blades, you must capture the wind and reduce drag as they spin around. Blade design experiments are a fun and engaging way to explore how design affects power production. The blades on modern turbines "capture" the wind

Graph your Data



Try graphing the relationship between voltage and wind speed or amperage and wind speed.



CONNECTING WIRES

To make an electrical circuit, the conductive metal wires of each element must be in direct contact with those of the next. Make sure the ends of the wires are stripped, then connect them with clip cords or by twisting them together.

and use it to rotate the drive shaft of a generator. How well you design and orient your blades can greatly impact how fast the blades spin and how much power your turbine produces.

If you are doing this for a science fair or school project, you should focus on just one of these variables at a time, as your results can get confusing quite quickly.

You can do a lot of great experiments by isolating blade variables and examining how they affect the power output of your turbine. Try these variables to get started:

- blade pitch (angle)
- blade size
- blade shape
- number of blades
- blade materials

After attaching your new blades, try to light the LED bulb or measure your voltage, current, or power with a multimeter. How has the efficiency of your turbine changed? Try a few blade designs to learn what makes blades more efficient.

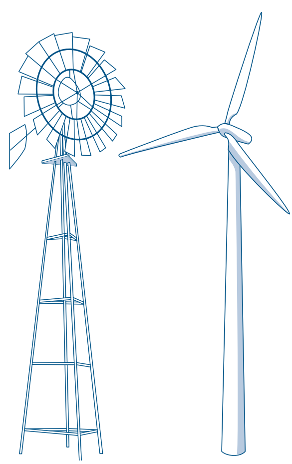
Experiment 3: building a MINI wind farm

A wind farm is a collection of wind turbines in the same location. This may also be called a "wind power plant," because many wind turbines working together can produce a lot of electricity—just like coal or nuclear power plants. Wind turbines are often grouped together in wind farms because this is the most economical way to generate electricity from the wind.

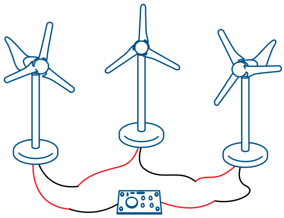
Two or more KidWind MINIs can be wired together to make a MINI Wind Farm!

CAN YOU BEAT THE ENGINEERS?

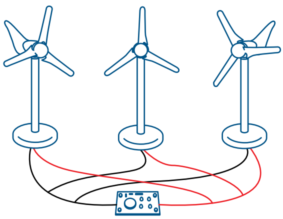
The red blade set is designed to be very efficient. If you are able to design a blade set that is better than our red blades, we want to hear about it! Send us a note at www.KidWind.org.



Examples of a water pumping turbine and a modern electricity generating turbine (*not* to scale)



MINI wind farm, wired in Series



MINI wind farm, wired in Parallel

Connecting turbines

When you connect your various components together (KidWind MINIs, load, meter, etc.), you can make more complicated electrical circuits. There are two ways of connecting components in a circuit: series and parallel.

A circuit wired in series has components connected end to end, like a chain. The electrons must travel a single path through all of the various parts of the circuit.

A circuit wired in parallel provides a different path for a current to travel through each of the components. In parallel, each component has a separate loop.

If you are connecting the KidWind MINIs in series, connect the wires of the turbines from positive (red wire) to negative (black wire), making one continuous loop through the circuit.

If you are connecting the turbines in parallel, connect each positive wind turbine wire (red) individually to the red lead from the multimeter or load device. Connect each negative wind turbine wire (black) individually to the black lead from the multimeter or load device.

The wires you use to connect your MINI Wind Farm to various loads act just like the high voltage transmission lines that bring the electricity of real wind farms to our homes and schools!

If you use a multimeter to record voltage and current as you add wind turbines to your wind farm, you will find some interesting results.

OUTPUT OF SERIES VS. PARALLEL

When you have multiple turbines wired in series, the voltage should increase with each additional turbine, but the current will stay the same.

If you wire the turbines in parallel, the current will increase with each additional turbine, but the voltage will not change.

Experiment 4: How does turbulence affect wind turbines?

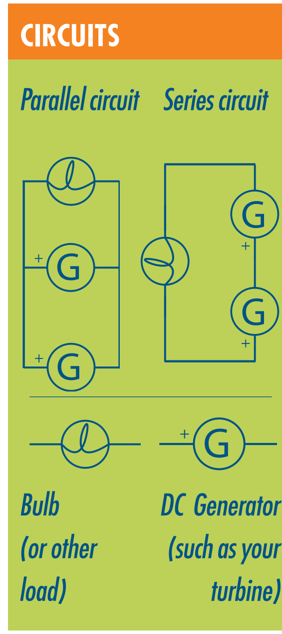
If multiple wind turbines are placed too close to one another or there are obstructions near a wind turbine, the efficiency of the turbines will be reduced.

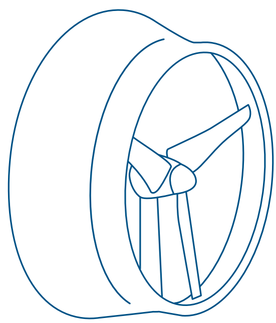
Place some objects to act as trees or houses in front of your MINI and see how the power output changes. How does this disturbance affect the turbine output or performance? Some people want to put wind turbines on the roofs of homes. Do an experiment and see if you think this is a good idea. Can you design a shroud around the turbine to collect more wind? Some inventors think this might be a good idea. What do you think?

Wind park effect

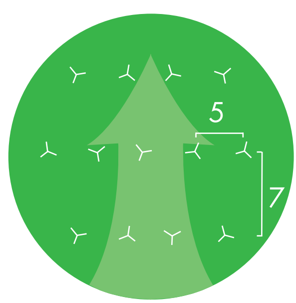
Each wind turbine extracts some energy from the wind, so winds directly downwind of a turbine are slower and more turbulent. For this reason, wind turbines in a wind farm are typically placed 3–5 rotor diameters apart perpendicular to the prevailing wind and 5–10 rotor diameters apart parallel to the prevailing wind. Energy loss due to the "wind park effect" may be 2–5%.

What effect do you find when you move the turbines around in your MINI wind farm? Place a few turbines very close together, or right behind each other. Do you notice a reduction in the efficiency of your wind farm?

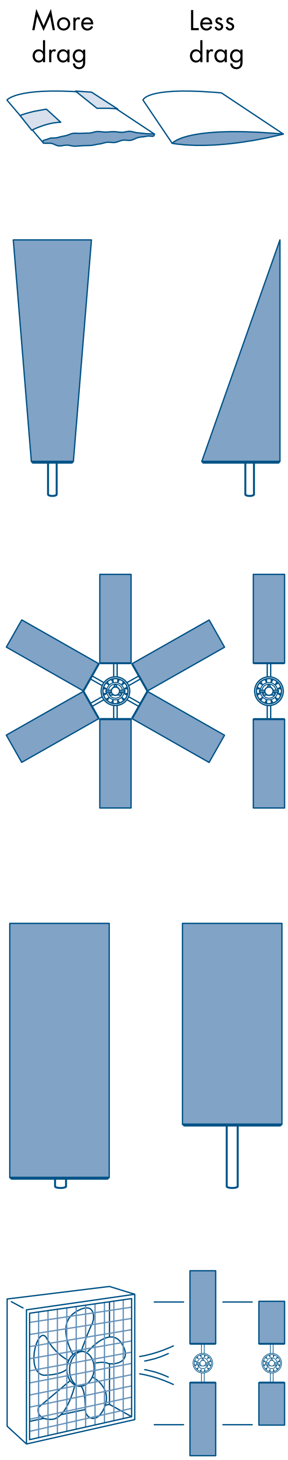




Here's an example of a shrouded wind turbine.



This wind farm was designed to minimize "wind park effect."



Tips on Making Blades

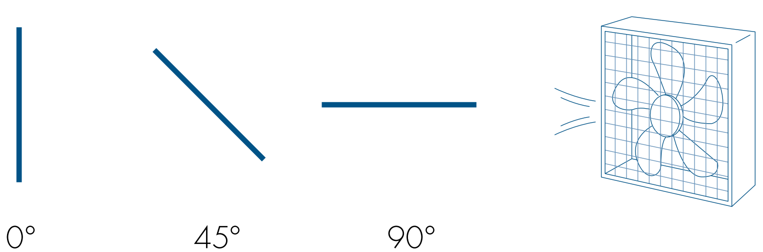
Efficient blades are key to maximizing power from a wind turbine. Sloppy or poorly-made blades will never produce enough energy to power anything. It takes time and thought to make good blades!

An important concept to keep in mind when making turbine blades is drag. Drag, or wind resistance, is the force that opposes the rotation of the blades. The amount of drag a blade experiences depends on how fast it is moving through the air and the surface area of the blade. Faster rotation means more wind resistance. More surface area means more wind resistance. Ask yourself, "are my blades creating too much *drag*?" If they are adding *drag* to your system it will slow down and—in most cases—low RPM means less power output.

Tips on improving blades

- Shorten the blades: Wind turbines with longer blades tend to generate more power. While this is also true on our small turbines, it is often difficult for students (and teachers) to make large, long blades that don't add lots of drag and inefficiency. Try shortening them a few inches.
- Change the pitch: Students commonly set the angle of the blades to around 45° the first time they try to use the turbine. Try making the blades flatter toward the fan (0°–5°). Pitch dramatically affects power output, so play with it a bit and see what happens. You can use a protractor to measure the pitch.

- Use fewer blades: To reduce drag, try using 2, 3, or 4 blades.
- Use lighter material: To reduce the weight of the blades, use less material or lighter material.
- Smooth surfaces: Smooth blade surfaces create less drag. Try removing excess tape or smoothing rough edges to reduce drag.
- Find more wind: Make sure you are using a decently sized box or room fan with a diameter of at least 14″–18″.
- Blades vs. fan: Are your blades bigger than your fan? If the tips of your blades are outside the fan wind, they are not catching any wind; they are just adding drag!
- Blade shape: The tips travel much faster than the root and can travel faster if they are light and small. If you have wide or heavy tips you may be adding lots of drag.



Finding a way to *twist* the blades (0° near the tip and around 10°–20° near the root) can really improve performance.

CAUTION

Do not touch the blades while they are spinning! They are moving very fast and will hurt your hand if they hit you.

Do not stand in the "plane of rotation" of the blades (to the side of the blades) in case something hits them and flies off. Stand in front of or behind the turbine.

Wear safety goggles when the turbine is spinning.

The Power in the Wind

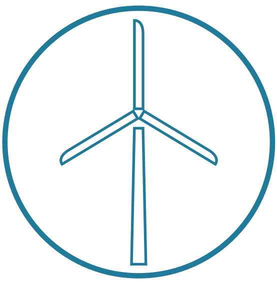
If a large truck or a 250lb linebacker was moving toward you at a high rate of speed, you would move out of the way, right?

Why do you move? You move because in your mind you know that this moving object has a great deal of energy as a result of its mass and its motion. And you do not want to be on the receiving end of that energy.

Just as those large moving objects have energy, so does the wind. Wind is the movement of air from one place to another. That's the motion part.

What is air though? Air is a mixture of gas molecules. It turns out that if you get lots of them (and I mean lots of them) together in a gang and they start moving pretty fast, they can definitely give you a serious push. Just think about hurricanes, tornadoes, or a very windy day!

Why aren't we scared of light winds while we stay inside during a hurricane or wind storm? The velocity of those gangs of gas molecules have a dramatic impact on whether or not we will be able to stay standing on our feet. In fact, in just a 20 mph gust you can feel those gas molecules pushing you around.



Humans have been taking advantage of the energy in the wind for ages. Sailboats, ancient windmills, and their newer cousins the electrical wind turbines, have all captured the energy in the wind with varying degrees of effectiveness. They all use a device such as a sail or blade to "catch" the wind. Sailboats use wind energy to propel them through the water. Windmills use this energy to turn a rod or shaft.

A simple equation for the power in the wind is described below. This equation describes the power found in a column of wind of a specific size moving at a particular velocity.

$P = \frac{1}{2} \rho (\pi r^2) V^3$

P = Power in the Wind (watts)
ρ = Density of the Air (kg/m^3)
1.2 kg/m^3 at sea level and 20°C
r = Radius of your swept area (m)
V = Wind Velocity (m/s)
π = 3.14

From this formula you can see that the size of your turbine and the velocity of the wind are very strong drivers when it comes to power production. If we increase the velocity of the wind or the area of our blades, we increase power output.

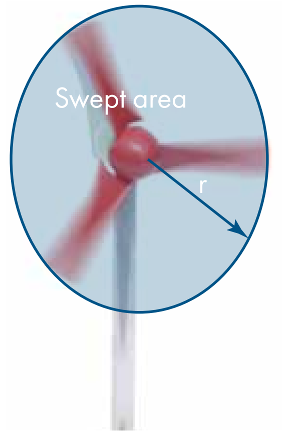
The density of the air has some impact as well. Cold air is more dense than warm air, so you can produce more energy in colder climates.

The power of wind farms

Recall the Power in the Wind equation:

$P = \frac{1}{2} \rho (\pi r^2) V^3$

What are we changing in this equation when we add wind turbines and create a wind farm? The density of the air will not change. Adding more turbines will not change the wind velocity, either. The part of the equation you are changing is the swept area (r).



Swept area is the area of the circle inscribed by the tips of a wind turbine's blades.

TYPICAL OUTPUT

Typical output for the MINI:

Voltage: 1–4 volts

Amperage: 20–100 milliamps (.020–.1 amps)

If your numbers have come out much higher than this, something is amiss. Check your units!

Advanced Calculations

Determining the power output of your KidWind MINI

These calculations are more advanced than just measuring voltage or current alone and require you to have learned how to use your multimeter properly. During these calculations, be mindful of the units to which your multimeter is set. Make sure it is set to volts or amps, rather than millivolts or milliamps. If you do not use the correct units, your calculations will come out wrong.

The equation for electrical power is shown below:

$P = V \times I$

P = Power in watts

V = Voltage in volts

I = Current in amps

Example:

Your KidWind MINI is producing 3v at 50mA. How much power is your turbine producing?

$P = V \times I$

$P = 3 \times .050\ A$

$P = .15$ watts

Ohm's law

Using Ohm's law, multimeter measurements, and resistors, we can do some simple calculations to determine current output. The foundation of these basic electrical computations is referred to as Ohm's law, after the German physicist George Ohm. In 1827, Ohm described measuring voltage and current through simple electrical circuits containing various lengths of wire.

Ohm's law:

$V = I \times R$

V = voltage in volts

I = current in amps

R = resistance in ohms

Using algebra we can rearrange this equation so we can determine the current from voltage and resistance:

$I = V/R$

Current = Voltage/Resistance (ohms)

Resistor = 50 ohms

Voltage = 1 volt

$I = V/R$

$I = 1/50 = 0.020$ amps = 20 milliamps

Computing power using voltage, current, and resistance

It can be difficult to calculate power by measuring current and voltage simultaneously. You need two multimeters and lots of clip cords. In certain situations, we can make this a bit easier using Ohm's law.

Remember: Power = Voltage × Current

Using substitution of Ohm's law, we can replace the current measurement I with V/R and derive the equation below.

$P = V \times I$

$P = V \times (V/R)$

$P = (V \times V)/R$

$P = V^2/R$

If we know the voltage that our turbine is producing and the resistance in the circuit, we can determine our power output.

Examples:

$V = 3$ volts

$R = 50$ ohms

$P = V^2/R$

Power $= (3^2)/50$

$= 9/50$

$= 0.18$ watt

$= 180$ milliwatts

Using these equations, you can now easily calculate how much power your turbine is producing in different experiments.

Wind Turbine Information

Windmills have been used for centuries to pump water or move heavy rocks to grind seeds into grain. A wind turbine is the modern advancement of the windmill, using the wind to turn an electrical generator instead.

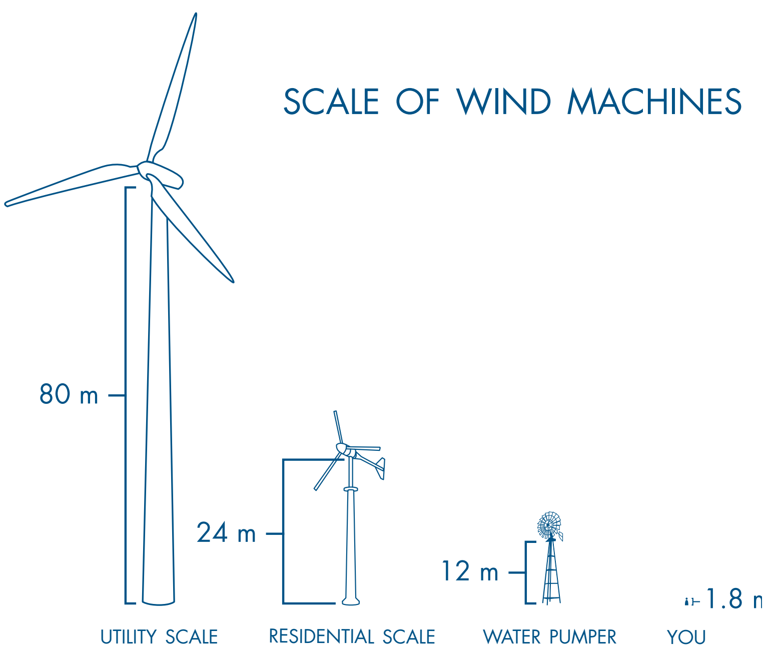
Wind turbine scale

The smallest production wind turbines have a rotor diameter of 1 m and only produce enough power to charge a few 12 volt batteries: about 100 watts.

A wind turbine that could power your whole house is still considered "small." This wind turbine might have a rotor diameter of 7 m and could produce 10 kW (10,000 watts) in a 25 mph wind.

A typical "large" or utility scale wind turbine has a rotor diameter of 80 m and stands on a tower 80–100 m tall. This wind turbine could produce 1.5 MW (1,500,000 watts)—enough electricity for about 400 American homes in a 30 mph wind.

Utility scale turbines are getting bigger and bigger. Some turbines today can produce over 5 MW and have a rotor diameter of 126 meters!



Energy transformations

Wind turbines transform the kinetic energy of the wind into electricity.

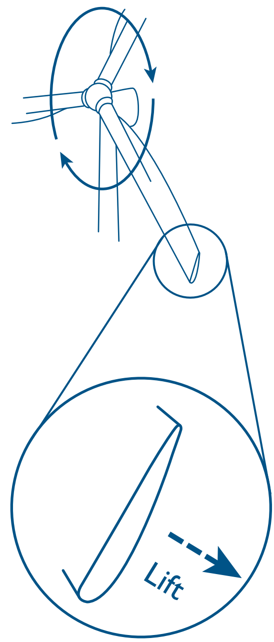
The force of the wind on the blades causes them to move. Blades are usually shaped like airfoils, using lift to spin the blades faster than the wind.

The blades and the hub together are called the rotor. The blades on large utility scale turbines change their pitch to react to wind speed. The red blades on your MINI have a fixed pitch, more similar to a residential scale turbine. With the crimping hub, you can manually change pitch.

As the rotor turns, it spins a drive shaft which is connected to a generator. The spinning generator converts mechanical (rotational) energy into the electrical energy we use every day. Many large wind turbines often have a gearbox between the rotor and the generator, so that the generator can spin much faster than the blades are spinning.

Generators on large grid-connected turbines spin at 1200 to 1800 revolutions per minute (RPM). On the smaller, residential turbines, the rotor and the generator spin at the same speed, anywhere from 0–500 RPM since there is no gearbox.

Your MINI does not have a gear box and is considered a "direct drive" device. That means you have to get the blades spinning very fast to create usable power. Large turbine manufacturers have started to make turbines without gearboxes, but to do this they need generators with lots of heavy magnets and wire. This makes the tower designers job much harder.



The airfoil shape of most wind turbine blades uses lift to increase rotor speed.

OTHER KIDWIND KITS

At KidWind we have other kits which let you experiment with gearboxes and winding your own generators. Check them out at www.KidWind.org/shop

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