

Basic PVC Wind Turbine

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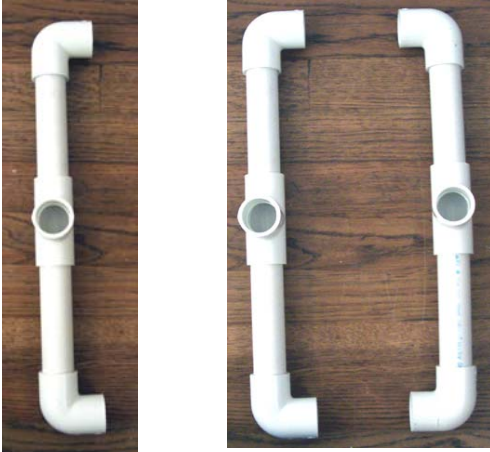
Basic PVC Wind Turbine

October 2005

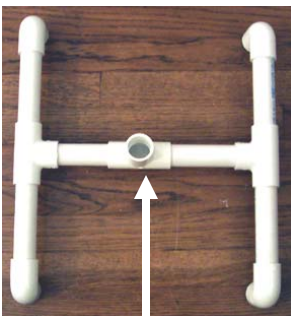
Kit Contents

- (6) 6" PVC pipe connectors
- (1) 2" PVC pipe connector
- (1) 24" PVC pipe tower
- (5) 90° pipe fittings
- (3) Ts pipe fittings (1 drilled)
- (1) Tinkertoy Hub w/adaptor
- (1) DC Motor

This is the first PVC Wind Turbine we developed at Kidwind. The idea was adapted from a design we found at the Otherpower.com website. While rugged and cheap to build the power output is only enough to power an LED. These instructions will show you how to build this PVC turbine and how to use a multimeter to record electrical data that your turbine generates.



(2) Identical Base Sides



PVC tee with hole

Sides joined together.

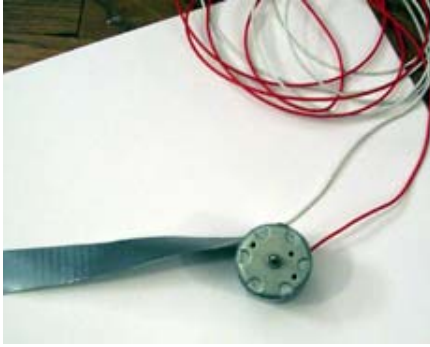
Make sure to use the PVC tee with the hole so you can get the wires out!

Building the PVC Tower Base

1. Using (4) 90° PVC fittings, (2) PVC tees and (4) 6" PVC pipe sections construct the two sides of the PVC turbine base. Make sure in this step to use the PVC tees that **DO NOT** have a hole drilled in them.
2. Fit the parts together without using glue (PVC glue is really nasty stuff). To make them fit snugly you can tap them together with a hammer, or bang them on the floor once assembled.
3. Next you need to connect the two sides. Use the PVC Tee with the hole to do this. You need the hole to snake the wires from the DC motor out.

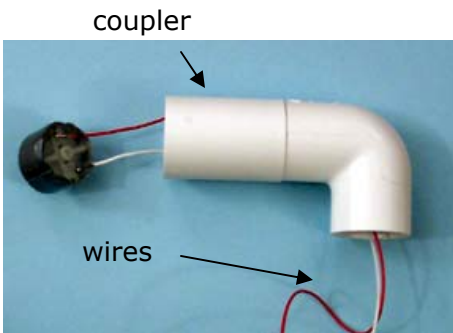
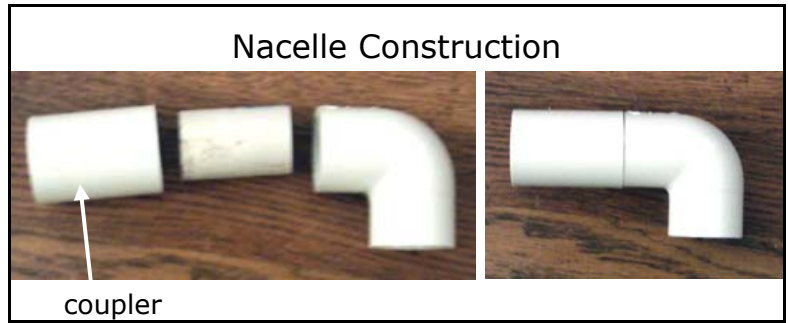


Building the Rotor & Hub



1. For this step you need (1) PVC 90 fitting, (1) PVC coupler, (1) 3" piece of PVC pipe and the DC motor.
2. Wrap a piece of duct tape around the outside of the motor. This piece of tape should be about 1" wide and 20" long. This will help the motor fit securely into the PVC coupler. To make it really solid you can epoxy it in.

3. Arrange the pieces like the image to the right. Then push them together to form a solid piece. This is called a **nacelle** it holds the DC motor, blades and other equipment.



Make sure the wires come out the bottom!

4. Insert the wires attached to the DC motor through the nacelle. They should come out of the 90° PVC fitting. Your motor will rest in the coupler.



Notice the motor is straight and not pushed all the way in!



Motor secured into the coupler. STRAIGHT!

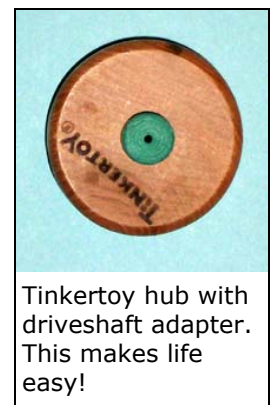
5. Insert the motor into the coupler. It should fit very snugly. If it is loose you should wrap some more duct tape around the outside. As you are frequently pushing on the motor you need to make sure this is tight!

6. When you insert the motor you also should make sure that it is straight and not too far in. If it looks cockeyed you should straighten it out as it will cause your hub and blades to wobble while spinning.



Nacelle complete with rotor hub.

7. After you have secured the motor attach the Tinkertoy hub. Press the hub onto drive shaft. It should fit very snug. Do not press it on so hard that the adapter rubs on the motor body. This would slow your drive shaft.



Tinkertoy hub with driveshaft adapter. This makes life easy!

Attaching the Tower to the Base

1. Snake the motor wires through down the tower and through the hole that is drilled in the PVC tee at the base of the wind turbine.
2. Attach the nacelle to the top of the tower.
3. Insert the bottom of the PVC tower into the tee at the center of the turbine base.
4. It should look just like the wind turbine to the right!
5. Make sure the PVC pipe has seated well into the fittings by tapping together with a hammer, or by banging on the floor.
6. Make sure that you didn't use any glue! Because once you are done you can take it apart and then store it away for next year.
7. To make your life easier you should attach alligator clips to the wires coming out of the turbine. This will make it easy for you to hook your turbine up to a multimeter!



SAFETY & BLADE TESTING AREA

- ◇ It is important to wear safety goggles when constructing blades with hot glue or sharp knives.
- ◇ You should always stand **in back of** or **in front of** the wind turbine during testing. If you stand in the PLANE of ROTATION you could be hit if your blade flies off during testing.
- ◇ Never make blades using metal or any sharp edged material as these could cause injury while spinning fast during testing.
- ◇ The voltage and current made by your turbine is not enough to cause injury. But it is always a good idea to treat electricity with care and caution.

SETUP FOR TESTING

Safely set up your testing area like the picture below. It is important to clear this area of debris and materials.

Stand In Front or Behind Turbine



Make sure the center of the fan matches up with the center of the wind turbine. You may need to raise your fan with some books or a container.



While you can use your wind turbine outside, you must make sure that you face it into the wind. This is because your wind turbine cannot YAW (or rotate) to face the wind. If the wind shifts, and the turbine cannot rotate, it may cause the driveshaft to be blown out of the hole.

For a wind turbine that can yaw check out the Kidwind Yawing PVC turbine on our website (<http://www.kidwind.org>)! There are also some plans that allow to make this turbine yaw as well.

How to use the Multimeter with your Wind Turbine

Small DC motors do not produce much power when we spin them slowly. As this turbine does not have any gearing our electrical output will be limited and a great set of blades in high winds might be able to light an LED. To accurately measure our production you should use a multimeter. If you are interested in lighting bulbs and creating more electricity you may want to check out the *Geared PVC Turbine* at the Kidwind Website (<http://www.kidwind.org>).

Power = Voltage (V) Current (A) <-- Watch Your Units
Make sure you are recording volts and amps (not milli or microvolts unless you want to!)

Voltage



1. Attach the wires from the generator to the multimeter.
2. To check the voltage select DC Volt (V) and choose a the whole number setting say up to at least 5 volts. Set at 20 DC Volts
3. Place your turbine out in the wind or in front of a fan and let it run up to speed. It is normal for the readings to fluctuate. Power output is not steady because the wind is not steady.



4. A set of very well designed blades may make around 1 volt Typical blades will be in the 0.2 - 0.5 volt range.
5. When you are measuring voltage you are measuring how fast the DC generator is spinning. The faster it spins the higher the voltage. As there is no load on the generator it has very little resistance so it can spin very fast. If you look closely when you add a load the RPM may drop as will your voltage.

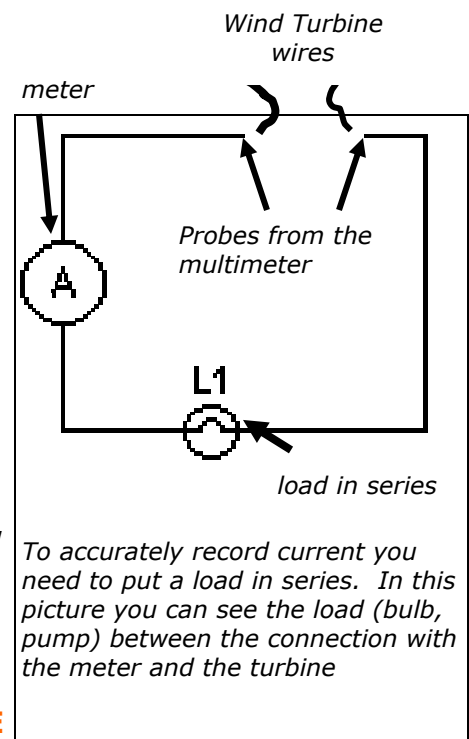
Amperage

1. To get a more accurate picture of the power output of your turbine you should measure amperage as well. To accurately measure the amperage you need to hook up your multimeter differently.
2. You need to place a load (or a resistive object - small bulb, resistor, pump etc.) in series with the meter so that the generator is "loaded" and has to do work.
3. A set of very well designed blades will make around 0.1 amps (100 milliamps) with this motor. Typical blades will be in the .02-.05 amp (20 -30 milliamp) range. This will vary based on your resistive load.

When you are measuring amperage you are measuring how many electrons your turbine can push. This relates to how much torque your blades are generating.

DON'T FORGET!

TURN OFF THE METER WHEN YOUR ARE DONE OR THE BATTERY WILL DIE!!



What can you do with your turbine?

Factors that Affect Power Output

Now that you have a wind turbine, it start exploring what factors affect how much power your turbine produces. Here are a few ideas for starters.

- *Wind Speed*
- *Generator Type*
- *Blades*

Wind speed is an easy one. Take your turbine and place it in front of a fan at three different distances. How does the power output change. Why does it change? Make a graph and discuss. Think about this in relation to the Power in the Wind equation.

Blade Design

An entertaining group of experiments involves blade design. The blades on modern turbines "capture" the wind and use it to rotate the shaft of a generator. The spinning shaft of the generator spins magnets near wires and generates electricity. How well you design and orient your blades can greatly impact how much power your turbine produces.

Experiments with blades can be simple or very complicated, it depends on how deep you want to explore. Some variables you can test about blades include:

- *Blade Length*
- *Blade Shape*
- *Blade Number*
- *Blade Materials*
- *Blade Pitch*
- *Blade Weight*

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

Lesson Zap! - Wind Turbine Blade Design



Background

Blade design and engineering is one of the most complicated and important aspects of current wind turbine technology. Today engineers strive to design blades that extract as much energy from the wind as possible throughout a range of wind speeds and gust yet be durable, quiet and cheap.



Objectives:

Students will be introduced to:

- The Design Process
- Scientific Method
- Science of Blade Design
- How to collect, evaluate and present data



Suggested Level

Middle & High School



Time Required

At least 5 class periods



Materials Required

- Some type of model turbine that can quickly interchange blades
- Multimeters or Voltage/Current Data Loggers or Multimeter Box
- Box fans
- Rulers
- Pictures of Wind Turbine Blades
- Scale Model Turbines (optional)
- PowerPoint of Wind Turbines Blades (optional)
- Wind Speed Meter (optional)
- Tachometer (optional)

Blade Construction Materials:

Cardboard, Balsa Wood, Tissue Paper, Plastic, Paper Cups, Index Cards, Exacto Knives, Scissors, Glue, Tape, String, Knex, Lego, Tinker Toys, Popsicle Sticks, Toothpicks, Hot Glue Guns

Lesson Plan in a Nutshell

This lesson has students go through the design process and the scientific method to test important blade variables. Students then use this data create an optimal set of wind turbine blades. You can do the basic lesson in 3-4 days or extend with a larger challenge that takes 5-7 days.

Part I (Days 1-2)

During the first day try to link wind energy to other topics you have covered (energy, generators, weather & wind, etc.) and help students understand blade basics and set up primary experiments.

- What are wind turbines?
- How do wind turbines transform the energy found in the wind?
- What are the major variables that impact energy production?
- How can we develop an experimental protocol to test these variables?

Part II (Days 2-3)

During the next two days students will build and test blades according to their experimental protocol. Once this is completed they will share their results with their peers in a formal setting.

- What variables have the most impact on power output?
- Do some variables matter more than others?
- What is the best way to share the results?

————— **If pressed for time you can stop at this point.** —————

Part III (Days 3-4-5)

Once students have heard from their peers about the most important variables we can now ask them to create an optimal set of blades incorporating these results.

- What did my peers say about blades?
- How can I incorporate this research into my final design?

Part IV (Day 5)

This is a testing and evaluation day. Today you will test the student made blades on a standard set up for how much power they generate. You can also have a competition to evaluate the creativity and engineering prowess of your students. It is fun to make this a day celebration!

Doing the Activity - A Wee Bit of Preparation

When to explore wind energy

You can explore blade design at a variety of points in a the Middle and HS curriculum. I have seen teachers use these materials in energy, weather and environmental science units. Physics teachers have used it to teach aerodynamics. Personally I use it to teach students how to properly set up and use the scientific method while exploring something new and different. Technology teachers have used this lesson to teach about the design process. Some teachers have used this lesson as a small segment in a month long exploration of wind energy. As you can see it is all over the place!

Classroom Wind Turbines

To run these experiments you will need some classroom wind turbines. **Kidwind** has developed a number of easy to construct PVC wind turbines. Plans and materials can be found at <http://www.kidwind.org/>. **Kelvin, Pitsco, Boreal Labs** and **Pico Turbine** also have wind turbine kits that will work with this lesson plan. There are some nice plans for building wind turbines from *Windpower.org* and from *Renewable Energy Canada*. Addresses to these plans can be found at the Kidwind website.

Some of the wind turbines above are designed to make electricity others are designed to lift weights. You can use either one in these experiments as this lesson is exploring blade design. For this lesson we assume you are using electrical generating turbines.

For a class of 25 students it is recommended you have 3-4 wind turbine testing stations around the room. You can get away with two but things will slow down at the turbines. You can also have each student use their own turbine but that can get expensive.

Fans

You will need 2-3 box fans to produce wind. The bigger the better. You can change wind speed by moving the turbine away from the fan or turning the fan lower. Please note that wind coming off of a fan is ugly, turbulent stuff that is not really like the wind your turbine would find outside. Modern wind tunnels pull air through to get a more realistic affect. You can build one of these but it will add significantly to the prep time.

Blade Construction Materials

Place all of the construction materials in one central location on a table or desk. Put all the working tools in a location where you can monitor their use and make sure that students are using them safely. It is useful to have some blades, turbines and hubs ready so you can demonstrate how to safely use the tools and turbines.

Pictures, Slides and Websites

You'll want to have some large pictures, a PowerPoint slide show with some images of large turbines and some close ups of their blades. Many great resources can also be found on the web check the resources section for these.

A Small Prize

At the end of the blade design challenge it is fun to give small prizes to the top sets of blades and the kids really get into it. We have given away T-shirts with funny wind logos, but treats and other things work as well.

Part I

Setting up the Experiments

Your first job will be to link the topic you are currently covering to the wind turbine model that is sitting on your desk. Students will be curious about the model turbine as they enter class. Let them examine it until you want to start. Once they are settled you can start asking questions to gauge their knowledge of wind energy and wind turbines.

Some possible questions...I am sure that you can think of many more.

- What do they think these devices are and what do they do?
- Have they ever seen a wind turbine in real life? How big was it?
- Where do we get our electricity from that powers our homes?
- Why would we want to build wind turbines?
- Where are the major wind projects occurring in the US?
- How much energy do we get from wind?
- How much could we get?
- How much do they get in other countries?

You can let this go for 5-10 minutes. There will be lots of questions. Answer the ones you can, challenge them to “look up the answers” to ones that you are not sure about. **(If you are looking for an intro lesson to electricity use in the US look at KidWind Lesson - Energy Notions.)**

Now we want to narrow down our discussion to the blades.

Show them the wind turbine. Spin the hub and show them how it makes electricity or moves a weight. This is a good time to show them a picture of a real wind turbine and how the one you are using is similar and different.



Ask the students’ what they think will affect the power output from the wind turbine. You will get many answers; wind speed, generators, designs, size etc. Hopefully someone will say blades. Push them on this idea. What if we had the same generator at the same wind speed what would **PRIMARYLY** determine the power we can get from this turbine? **THE BLADES.** That is what we are going to explore for the next couple of days.

Blade Variables

We now want to explore some of the variables that affect how much energy the blades can “capture”. Ask the students what some of these variables might be. The list below is a start.

Length	Number	Weight	Pitch/Angle
Shape	Material	Curvature	Twist
Wind Speed			

As you can see there are quite a few variables which makes it interesting and challenging. Students may have others that are not on this list. If the variable sounds testable and the students can present a solid argument and plan for testing I'd let them do it.

Test Plan

Break students into groups of 2-3 and give them a **Blade Experiment Sheet**. Make sure they fill out and understand this sheet completely before starting experiments. **This will make your life much easier.** In many cases I pick a group to torture and they must come up to the front of the class and explain what they are going to do in detail. While they are doing this I pepper them with *why* and *how* questions about their research.

While students are demonstrating how they will perform their experiments it is a good time to talk about safety.

Things to look out for:

- Students using tools improperly.
- Standing in the plane of rotation while testing blades.
- Goggles off while testing blades.
- These are all BAD!!!

For the next two class periods the students will perform these regulated experiments on one blade variable (length, shape, etc). Once they have collected their data they will need to produce a graph and make a short (3-5 min) presentation to the class about what they discovered.

Using the data discovered from all of the groups students will then have an additional 1-2 class periods to make and test an optimal set of blades for a design competition.

Problems & Issues:

- Make sure they understand how to analyze one variable — VERY IMPORTANT that you approve and they follow their work plan. Take your time with this!
- Groups of two or three are best.
- Blade pitch is very important make sure this group understands what this is and how they will measure it. Inadvertently changing blade pitch can also can mess up other experiments. Make sure that students keep pitch constant while testing other variables or the results can be problematic.

Blade Construction & Testing

Once students have an approved plan they can start to construct and test blades. As they are doing this make sure they sticking to their plan, are being safe and are collecting meaningful data. Remind them that they must be prepared to make a presentation to the class at the end of experimentation and that you will grade this presentation (they love that one).

Problems & Issues

- Students sometimes take too much time making blades. For this part of the lesson they do not need to be perfect. They need to work efficiently as they need to collect data from 3-4 different tests.
- Students need to know how to record voltage and amperage with a simple multimeter. Make sure you have done this yourself and can explain to the students. **Having the units correct is important!** You do not want to multiply volts times milliamps....you will get a very large incorrect number. It is OK to just record voltage which can make things easier.
- The hubs on many homemade wind turbines are not industrial scale. At high RPMs the blades may come off. If this continues to happen students need to find a solution (glue or tape). **SAFETY!! SAFETY!**
- Often there can be a wait at the testing stations. Student only need a few minutes to test and then change their blades. **More stations = less waiting.**
- Having the same fans at each station would be ideal but sometimes not possible. Make sure that students use the same fan and at the same speed. This is important during testing!

Presentations

Once you feel that your students have collected enough data they should answer the questions on the **Blade Experiment Sheet** and make a larger graph of their data to present to the class. Students can draw on the chalk board, but it is nice if it is on a large piece of paper so you can post it and the students can refer to it later. The data collection handout is a guide to giving their presentations . Tell them to discuss what they wrote down on their paper.

Remind students that it is a good idea to pay attention as the team that harnesses all of these variables most efficiently will probably win the competition step.

The questions below will help you examine the data more generally.

- What variable has the greatest impact on power output?
- What type of blades worked best at low speeds? High speeds? Were they the same types blades?
- What numbers of blades worked best?
- What shapes worked the best?
- What length worked the best?
- What problems did you encounter?
- What is the impact of quality of construction?
- Did the materials got really bendy when they got longer - was this a problem?
- What happened when the wind turbine blades were bigger than the fan?

Once the discussion is finished post the graphs and student "reports" where all students can read them. This data will be useful as they create their optimal blades.

Optional Discussion Idea

Write a simplified wind energy equation on the board. This equation was developed over years during experimentation.

Power in the Wind

$$P = 1/2 \rho A V^3$$

$$\text{Power} = 1/2 \times \text{AIR DENSITY} \times \text{BLADE AREA} \times \text{WIND VELOCITY}^3$$

There are a variety of questions that can be asked once they see this equation?

Ask them if they think the data the class collected reflects the basics of this equation. Based on this formula what is the most important variable? What is the next most important? What variable in this equation did we not test? What variables did we test that are not expressed in the formula? Why might their findings conflict with this equation. **HINT** - *It is common to find in a classroom that bigger blades do not make much power....this is typically due to the fact that large student made blades also have lots of drag! Something to look out for!*

Class Period 3 & 4

Setting Up the Challenge

Based on the data and the presentations give the students 1-2 class periods to create an optimal set of blades. Hopefully they learned something from their peers. Their final set of blades will be evaluated in three ways (you may pick one use all three)

- **Power output at low and high wind speeds**
- **Quality of Construction**
- **Level of Innovation**

Power output in this lesson will be measured by voltage and amperage or just voltage. If you are using other types of wind turbines you will compare weight lifted, or if you have a geared wind turbine that has more power output you can calculate the amount of water pumped etc. Quality of construction and innovation can be evaluated by the whole class using the voting sheets in the resources section. We recommend evaluating all three things as you give students with a variety of skills a chance to show mastery.

It is nice to have models of well constructed and innovative blades. That is tough the first time around, but as the years go by you will accumulate quite a few, I know that I have.

Working on the Optimal Blades

Same rules apply as students work on their second set of blades. One thing to watch out for is students taking lots of time to prep and not testing their blades. They need to get these things attached and tested so they can modify them. It can be a little depressing if a student spends two periods on a beautifully crafted blades and then they are total flop when they test them.

One way to make this more challenging is to limit supplies or attach costs to supplies. This cuts down on waste and makes students think a little more before junking materials.

Evaluating the Blades

If you plan on evaluating quality of construction and innovation I recommend having the students help out! Make all the students display their blades on a desk or table. They should label them with a card to identify them. Spend 10-15 min having the students walk around and evaluate the blades. In the appendix we have included voting sheets that you can use. It is also an opportune time for you as the teacher to do your own grading as well. You can even have students predict what blades will be the best and why.

Once the voting and evaluation is finished collect their sheets and get onto power output testing. Use students as recorders, timers and multimeter experts. Let each student mount and set their own blades.

Place the turbine at about one meter away and let it run for 30 seconds. Record data (voltage, amperage or both). We recommend picking the highest number you see in 30 seconds. Make sure that a student is recording this data. Do the same in low speed conditions, to simulate low speed you can turn the fan down or move the wind turbine back 2 meters. If after a few seconds students want to adjust let them do it once but that is it!

After all of the blades are tested, collect them in one place. Copy the data collected on the board so the students can transcribe the data to their **homework sheets**. Depending on their experience you may need to help them calculate power output in watts. (These numbers will be small and we will compare these values to other things they may be familiar with like light bulbs and refrigerators. Most of these model wind turbine make much less than 1 watt...small when compared to a light bulb at 60w!)

Conclusion/Discussion

It may take a day to tabulate all the data, but once you select the blades that make the most energy, are most innovative and well constructed (these can be the same or different). You can give small prizes to these student engineers. We often give t-shirts to denote champions.

Further Study (Optional)

Ask the students if they looked at “real” wind turbine blades while making their blades? How are they different or similar to your blades that you have created?

If you can find some model airplane propeller blades develop a way to attach them to the hub and test. Make sure to turn these propellers around as on a plane they are designed to push air not “catch” it. Record the data from the low and high speed tests on the board. These blades may be much more effective than the ones they built. They may not if you have really smart students!

Ask them why are these blades are so much more effective? The easy answer to this is that these blades produce and harness lift much like a plane wing does. Except in this case the “wing” is attached to a hub to produce rotational motion. This is where things can get interesting. Discussion about blade design can get as complicated as you would like about and you can use the supporting materials to go as deep as you would like

Wind Energy is Here & Now

If you have the time and money take your students to see a wind turbine or wind farm. The American Wind Energy Association has listing of wind farms on their website. Head to <http://www.awea.org> to see if there is a wind farm near your school. They often love to give tours to students.

One important thing to leave with students is that wind energy is a technology that is here and now. The large scale production of energy from the wind is not futuristic or far fetched, it is happening NOW.

Recent research from **Smart Power** shows that one of the major failures of the renewable energy movement is that people do not realize renewable energy technologies are viable and available right now. This is especially true of wind energy and needs to be emphasized.

It is also important to have some discussion about the limits of wind energy and some of the benefits/challenges it will pose to communities where it is sited. As we must go where the wind resources exist these challenges will occur in many locations. These challenges include view shed impacts, proper siting to avoid migration pathways, noise, and the intermittent nature of the resource. To examine these issue we recommend checking out **Kidwind Lessons on Wind Farm Siting or Scale Models**.

Wind Turbine FAQ

Why won't my dowels fit into the Tinkertoy hub?

Sand more! Or you can cut some slits in the end of the dowel. If sanding is a pain then you should head out and buy yourself some Tinkertoys. They work great but are a bit expensive!

Why are the dowels flying out of the hub?

You sanded too much!

Why won't the rotor spin when I put my turbine in front of the fan?

Check the orientation of the blades. Are your blades oriented in the same direction? Are they flat? Are they hitting the tower? Look at some pictures of old and new windmills to get some ideas about how to orient your blades.

Why does the turbine slow down when I attach it to load (pump, bulb, motor)?

Loading the generator forces it to do work. This makes it harder to push electrons through the circuit. The more load you add the harder it is for the generator to turn and the more torque you must generate from the blades. The only way to do this is to make bigger blades or relocate your wind turbine to a place with higher wind speeds.

Why are the readings on my multimeter all over the place?

Your readings are fluctuating because the wind coming out of your fan is fluctuating. It can also be caused because your blades are not spinning smoothly. This can be caused by blades that are not balanced, evenly distributed or are causing unequal amounts of drag.

What are the best blades?

That is for you to figure out! Lots of testing and playing will get you closer to your answer.

Is a fan a good wind source to test with?

Well, it is the best we have got, unless you want to build or have a wind tunnel handy. The wind that comes out of a fan has a great deal of rotation and turbulence. It isn't very smooth. While it will still make your turbine spin it is not exactly like the wind outside. To see this turbulence, hold a short piece of thread in front of a fan and move it from the center out. It should head out straight all the time...does it?

Can I take my turbine outside? Can I leave it there?

You can certainly take, use and test your wind turbine outside. But unless you have a yawing turbine it will not track the wind and may not perform optimally. To make it work well you will have to continually face it into the wind. I would not leave your turbine outside for too long. It is designed for basic lab tests and not to endure the rigors of the outdoor environment!

Based on the power in the wind equation it seems that longer blades should make more power. On my turbine this is not true!! WHY??

The blades on your turbine may be bigger than the diameter of the fan. If that is the case, the extra part is only adding drag so your blades will slow down. Additionally if you poorly design large blades they will have lots of drag near the tips and slow down. This will negate any positive effect of the added length. Also short blades spin faster than long ones, so if you are just recording voltage they will seem better. Try short blades with a load in series and see if they have enough torque to spin. Many cases they do not!

Basic PVC Wind Turbine Parts List

We sell all of the parts for the *Basic PVC Wind Turbine*. These are easy to build and for a classroom of 25 kids we recommend having at least three. Below is a parts list for this wind turbine.

PVC Pipe & Fittings

Head to your local hardware store or *Home Depot* the prices are not that bad and you don't need too many parts. All pipe is 1". This turbine has:

- ◇ (5) 1" PVC 90° Fittings
- ◇ (3) 1" PVC T Fittings
- ◇ (5 ft) 1" PVC Pipe
- ◇ (1) 1" PVC Coupler



DC Motor, Wires & Clips

A local electronics shop or *Radio Shack* will have wire, clips and multimeters. Kidwind also sells some of these materials. There are also a variety of online vendors. The DC Motor we use is the **Motor 500** by Pitsco. Other motors will work, but we have tested many of them and this is a very smooth spinning and has high output! This turbine has:

- ◇ (1) Motor 500 (Pitsco)
- ◇ (4 ft) 22 Gauge Hook Up Wire
- ◇ (2) Clips (Alligator or Banana)

Special Parts

The Tinkertoy hub, adapters and the Delrin 6 hole hub are specially made for our turbines. But for years we used to fashion your own using Tinkertoys. Head to your local toy shop or an online vendor to get yourself a barrel of Tinkertoys. A small junior barrel will run around \$20 and have plenty of materials for your turbines. When you want something rugged and tested though come to Kidwind.

- ◇ (1) Tinkertoy hub w/ Adapter sold by Kidwind

Tools & Materials

To build this turbine you'll need a drill, pliers, ruler, PVC cutter, hacksaw, wire strippers, soldering iron, solder, duct tape, epoxy and probably lots of other stuff that we can't recall! Most of all have fun and be safe!