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An Introduction To Wind Power

Before I start talking about how to build your own wind turbines, I think it’s important to make sure you understand how wind power works and how the choices you make when planning your new wind power system affect your success.

I will also cover some of the basics of designing a comprehensive alternative energy system for your home, cabin, or RV. While this won’t be a comprehensive course on the complete system, it will get you where you need to be.

So What Exactly Is Wind Power?

Wind power is simply the conversion of wind energy into more useful energy. The term wind power is rather generic and covers everything from wind turbines that create electricity, sailboats, and wind mills that pump water in a pasture somewhere, and everything in between.

Wind power is called *non-dispatchable*. What that means is that when the wind is blowing, the power is there. When the wind stops, no more wind power. So for most applications you must design your wind power system to store the power generated in some way.

For example, if you are using a windmill to pump water, you’d want to have a storage tank that is filled when the wind blows, but has enough storage capacity to provide water when the wind isn’t blowing. Or if
you’re using a wind turbine to generate electricity, you’ll want to store that electricity in battery banks for later use.

Obviously this course is designed around creating wind turbines to generate electricity. But I think it’s important to realize that you can leverage the same concepts to accomplish other tasks as well.

As a practical example of modifying these concepts, on my father’s farm I have modified the design I teach in this course to use mechanical power to pump water from an artesian well up a hill to a holding tank.

The concepts that you will learn in this course are broad enough that your imagination is really the only limit!
How Do Wind Turbines Generate Electricity?

Using wind turbines to generate electricity is a fairly common thing. As I write this course, over 160 gigawatts of wind generation capacity is deployed worldwide. Eighty countries use wind power on a commercial basis. This is clearly a technology that is here to stay!

Wind turbines generate electricity by using a generator to convert the rotational forces created by the wind into electricity. It’s the same concept as the alternator in your car.

**Rudy’s Tip:** Generators are electric motors in reverse. Electric motors use electricity to provide rotational forces. Think about a fan running in the summer to cool off your house.

Generators are mostly the same, and do the opposite. They turn the rotational forces into electricity. You can actually use almost any electric motor as a generator; though purpose built generators will ALWAYS be more efficient!

The electricity that is generated by the turbine heads through wires into some sort of storage system, or sometimes directly into whatever is consuming the electricity.
We’ll focus primarily on systems that include battery storage as that’s the primary use for a wind turbine. Just know that if you want to modify the concepts to power something directly, you can!

**What Are The Main Turbine Designs Available?**

There are two main types of wind turbines available: Horizontal Axis and Vertical Axis turbines.

**Horizontal Axis Wind Turbines**

Horizontal axis wind turbines (HAWT) are what you see in your mind when you think about a wind mill.

They typically consist of a turbine sitting on top of a tower or pole with the turbine blades rotating like an airplane propeller.

They are called horizontal axis turbines because the axis of rotation when the wind blows is horizontal, or parallel to the ground.

HAWT are significantly more efficient than other designs for a variety of reasons. They can reach higher altitudes than other designs. This is significant because even a few feet of height can make a significant difference in the wind speed, and thus the power output of the turbine.
Vertical Axis Wind Turbines

Vertical axis wind turbines (VAWT) are a different model and are common in some parts of the world. They rotate around a vertical axis, hence the name.

Typically they have some sort of sail type blade that only catches the wind from one direction. When the wind blows, it causes the turbine to rotate. Picture a steamboat water wheel on its side and you get the concept.

VAWT can be placed closer together which improves the density of your wind farm. This is because they don’t slow the wind as much as a HAWT does.

They are quiet, don’t care which direction the wind is coming from, and allow you to place the actual generator and gearing closer to the ground.

We Will Focus On Horizontal Axis Turbines

In this course, we’ll focus almost exclusively on horizontal axis turbines. They’re more efficient, produce more energy, and are easier to build. They are also less sensitive to site issues, so you can usually find a good spot for them fairly easily.
What Are The Main Parts Of A Wind Turbine?

Wind turbines several common components. Occasionally you’ll find a different component, or additional components, but by and large these are the types of components you’ll find.

To make life easier for you, I’ve collected a variety of sources for turbine components and linked to them in Appendix A.

Generator

This is the heart of the turbine. Like I said before, this is basically an electric motor running in reverse. The generator will have a drive shaft coming out of one end. Coupled with a mechanical drive system, the rotation of the blade assembly will generate power.

You can buy new or used generators and electric motors from a variety of sources. Or you can always build your own if you’re feeling daring. It’s not really THAT hard!

Turbine Blade Assembly

The turbine assembly is like a large airplane propeller, and it has blades that rotate the assembly around its axis.
The number of blades varies by application. Generally speaking you will want to use three blades for most electrical generating turbines.

If you are modifying your turbine to provide mechanical wind power instead of generate electricity, you can add more blades.

The more blades you have the slower the assembly will rotate but the more torque it generates, which is great for mechanical advantage but not so good for power generation.

If you decide to add more blades, always shoot for an odd number of blades in the assembly. Even blade counts are harder to balance and are more prone to vibration damage. They also tend to be louder.

**Blade Hub**

The blade hub mates the blade assembly to the drive shaft of the generator. In its simplest form this could actually be part of the blade assembly.

Most hubs directly attach to the drive shaft, but you could consider a geared approach that offsets the drive shaft and the blade
assembly axis. This approach can be useful if you want to use different gear sizes to increase or reduce the speed of rotation. More on that later!

If you decide to do an offset mount, you’ll need to modify the turbine body to provide additional structural stability for the blade assembly. I don’t cover that in this course, but I’m sure you can figure it out!

**Turbine Body**
The turbine body houses the generator, has a wind vane at the back to rotate the turbine when the wind direction shifts, and provides a way to attach the turbine to the tower or mast while allowing it to rotate.

**Tower or Mast**
This is how you get the turbine up where it will actually do some good. It could be as easy as a 2” metal conduit with guy lines or a real welded steel tube tower.

Generally speaking, if you go higher than 20’ or so you need to be very careful structurally. The last thing you want is for your tower to fall over and destroy your turbine!

**How is energy stored?**
As you know, your turbine will only generate electricity when the wind blows. Unfortunately the wind won’t always be blowing when you need electricity. Therefore, you need to have a way to store that energy!
The easiest way to do that is with a bank of batteries that are charged when electricity is available and have sufficient capacity to power your expected load between charges. It’s pretty straightforward and we’ll cover it more in the design section.
Considerations When Designing Your Wind Power System

There are a number of design issues you need to consider before you build your wind turbines. This is planning ahead, and allows you to decide how many turbines you want to build, how much power to store, and so on.

You could blaze on without doing the planning, but I wouldn’t recommend that unless you’re just trying this as an experiment.

Site considerations

The first thing to deal with is the location you will install the turbine. Clearly a wide open area will work best, but you can make do with a forest around you if need be!

Height

You must decide what height you want your turbine to operate at. The higher you go the faster the wind speeds are, resulting in more power generation.

On the flip side, the higher you go the greater the force exerted on the mast or tower is. This can have disastrous results if you’re not careful. Generally speaking you’ll want to stay below 20’ without careful planning, but it’s certainly quite possible to go up far higher than that if you wish.
**Rudy’s Tip:** The forces acting on the mast are based on the length of the mast, not the actual height of the turbine. If you need extra height you could mount the mast on the roof of your home or a barn.

You get quite a bit of extra height that way, and as long as your mast length stays under 20’, you shouldn’t have too many issues with instability.

If you decide to try this, don’t install permanently at first. Some motors generate horrendous vibrations that could shake your entire house. You wouldn’t notice it if they’re mounted on a regular mast, but you’d sure notice it if it was on your roof!

**Wind Speed**
You need to determine what the average wind speed in your area is. There are a number of sites on the internet where you can get that data, but I’ve included a wind speed map as an extra bonus for this course.

You’ll need the wind speed later on to do rough estimates of the power output for your turbine!

**Obstructions**
You’ll want to place your new wind farm as far away from obstructions as possible. Trees, buildings, and so on will all cause wind turbulence and will lower the overall wind speed. Not good for your turbine!
You can usually get around most obstructions by adding height to the turbine. Definitely worth considering if need be!

**Power Storage System**
A power storage system is a critical part of your new wind power system. While designing a complete alternative energy system for your home is outside of the scope of this training, I'll give you an understanding of some of the basic concepts here.

This should be enough to get you going!

**Charge Controller**
A charge controller exists to regulate the flow of electricity from your turbine to your battery banks. It stops the flow when your batteries are fully charged, preventing overcharging.

Overcharging your batteries is dangerous, because they can explode! At a bare minimum it will significantly reduce the life of your battery.

For wind turbine use, your charge controller must have a dummy load. This provides a way to dump the electricity generated to somewhere else when the batteries are full. If you don’t do this, you’ll burn out your generator.

The reason why your generator will burn out is fairly straightforward. When it generates electricity, it self regulates its rotation speed. If there is no load (batteries, dummy load, etc) when electricity is generated, the
generator will spin progressively faster and faster which can burn out the generator or even destroy the blade assembly.

A dummy load is commonly used to heat water or to simply heat up a few coils that are exposed to the air, thus converting the electrical energy into heat energy.

**Inverter**

An inverter connects to your battery banks and converts the DC power stored in the batteries into AC power usable by your household appliances.

Inverters are rated by wattage, and you should calculate your desired load before buying an inverter. They are readily available and are not particularly expensive.

**Battery Banks**

Batteries are the heart of your storage system. You must have them to store the energy created by your turbine.

You must use deep cycle batteries for your battery banks. These batteries are designed to be charged and discharged many times, and will not lose capacity very quickly.

Do NOT use car batteries. They are not designed for frequent charging and discharging and will not last very long.
Batteries can be quite expensive. One alternative to buying new batteries is to procure used batteries and restore them. The process isn’t particularly complicated, but it involves handling battery acid and other potentially dangerous things.

**Generator: Build or Buy?**

One of the key decisions you will have to make is whether you want to build your own generator or buy a new one. Let’s discuss the various options for a moment.

**Fisher and Paykel**

The Fisher and Paykel generator is part of a motor from a washing machine. F&P motors are in quite a few domestic brands, though you’ll want to make sure you have one before taking the washer apart!

You can buy them used online or from various specialty retailers, or simply get one from the local junk yard.

The F&P generator is absolutely the best generator you can use for a wind turbine without building your own custom generator. The power capacity is truly second to none.

The downside is that it requires some modifications to the motor itself to function correctly. While those changes are worth doing if you want optimal output, they are outside of the scope of this course.
Rudy’s Tip: Use an Ametek or other permanent magnet motor for your first turbine. If you decide you want to build more, or go beyond the experimental stage, get yourself some F&Ps.

Ametek

Ametek motors are readily available on eBay or online, and are the easiest way to get started with a turbine. They don’t make them anymore, but there is an abundant supply available since they used to be used in a very wide variety of equipment.

I recommend starting with an Ametek generator for your first turbine. Absolutely the easiest way to go!

“Permanent Magnet Motor”

You can also buy a generic permanent magnet motor. These are simply motors that use real magnets instead of electromagnetic coils. You can find them in electric lawnmowers, edge trimmers, and anything else that uses an electric motor.

Rudy’s Tip: Old treadmills are a GREAT source of appropriate motors. They’re designed to operate at lower RPMs already, and you can get them all over town during garage sale season...

When shopping for a motor to use as your generator, you want to find a motor that runs at a relatively low RPM with a high voltage. For
example, a motor that runs at 350 RPM when powered by 35V will be well suited for use. One that runs at 6,500 RPM when powered by 15V will not.

**Building Your Own Generator**

You can definitely build your own generator. For optimal performance, this is often what you should do in the long term. I don’t recommend starting with this though!

I’m not going to tell you how to build your own generator in this course, though I’m considering creating a course that teaches you how to make them if there’s enough demand. Let me know if you’re interested!
Building your wind turbine

Ok, so let’s get started building your new turbine! This generator will produce a few hundred Watts of power and is a great starting point!

Parts List

Here’s a list of parts you’ll need. This list assumes that you’ll be using the recommended Ametek motor, a body made from ABS or PVC pipe, and a galvanized steel conduit for the mast.

Most of these items can be purchased online or from your local hardware store. Be sure to check Appendix A for some recommended places to buy some of the hard to find items.

Rudy’s Tip: Sometimes it can be hard to find longer lengths of galvanized pipe. This design uses a 12’ mast. If you can’t get a 12’ mast, you can modify and use a 10’ mast instead

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Item Description</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ametek Motor</td>
<td>Generator</td>
</tr>
<tr>
<td>1</td>
<td>2’ of 6” PVC or ABS Pipe</td>
<td>Blades</td>
</tr>
<tr>
<td>1</td>
<td>Blade Hub</td>
<td>Blade Assembly</td>
</tr>
<tr>
<td>1</td>
<td>Blade Hub Arbor</td>
<td>Blade Assembly</td>
</tr>
<tr>
<td>6</td>
<td>1” x ¼” Exterior Grade Bolt</td>
<td>Blade Assembly</td>
</tr>
<tr>
<td>6</td>
<td>¼” Exterior Grade Nut</td>
<td>Blade Assembly</td>
</tr>
<tr>
<td>12</td>
<td>¼” Exterior Grade Washer</td>
<td>Blade Assembly</td>
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<td>Quantity</td>
<td>Description</td>
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<tr>
<td>1</td>
<td>4” x 2’ ABS/PVC Pipe</td>
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<tr>
<td>1</td>
<td>2” x 2’ ABS/PVC Pipe</td>
<td></td>
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<tr>
<td>1</td>
<td>4” ABS/PVC Tee Joint (2” attachment)</td>
<td></td>
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<tr>
<td>1</td>
<td>4” -&gt; 2” ABS/PVC Reducer</td>
<td></td>
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<tr>
<td>1</td>
<td>2” -&gt; 1-1/2” ABS/PVC Threaded Reducer</td>
<td></td>
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<tr>
<td>1</td>
<td>2” ABS/PVC Pipe Cap</td>
<td></td>
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<tr>
<td>1</td>
<td>1” x 1-1/2” Galvanized Bushing</td>
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<tr>
<td>1</td>
<td>1’ x 1” Galvanized Threaded Pipe</td>
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<tr>
<td>2</td>
<td>1-1/4” Galvanized Conduit Washers</td>
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<tr>
<td>1</td>
<td>Can of ABS/PVC Cement</td>
<td></td>
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<tr>
<td>1</td>
<td>18”x18” Sheet of 1/8” Acrylic/Plexiglass</td>
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<tr>
<td>2</td>
<td>5” Stainless Worm Drive Pipe Clamps</td>
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<tr>
<td>1</td>
<td>12’ 1-14” Galvanized Conduit</td>
<td></td>
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<tr>
<td>3</td>
<td>14’ Length of 1/8” Steel Cable</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1/8” Cable Eye</td>
<td></td>
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<tr>
<td>12</td>
<td>1/8” Cable Clamp</td>
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<tr>
<td>3</td>
<td>¼” Exterior Grade Turnbuckle</td>
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<tr>
<td>3</td>
<td>¼” Anchor Shackle</td>
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<tr>
<td>3</td>
<td>3’ 1/2” Rebar</td>
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<tr>
<td>1</td>
<td>4” x 5/8” Exterior Grade Threaded Rod</td>
<td></td>
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<tr>
<td>2</td>
<td>5/8” Exterior Grade Nuts</td>
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</tr>
<tr>
<td>3</td>
<td>1-1/2” Chain Link Fence Clamps</td>
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<tr>
<td>3</td>
<td>5/16” Exterior Grade Carriage Bolts</td>
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<tr>
<td>3</td>
<td>5/16” Exterior Grade Nuts</td>
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<tr>
<td>6</td>
<td>5/16” Exterior Grade Washers</td>
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<tr>
<td>1</td>
<td>15’ Extension Cord</td>
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<tr>
<td>1</td>
<td>Gallon of Exterior Paint</td>
<td></td>
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<tr>
<td>1</td>
<td>Bearing Lubricant</td>
<td></td>
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<tr>
<td>1</td>
<td>Silicone Caulk</td>
<td></td>
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<tr>
<td></td>
<td>Charge Controller</td>
<td>Power Storage</td>
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<tr>
<td>1</td>
<td>Blocking Diode</td>
<td>Power Storage</td>
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<tr>
<td>1</td>
<td>Deep Cycle Golf Cart Battery</td>
<td>Power Storage</td>
</tr>
<tr>
<td>1</td>
<td>Power Inverter</td>
<td>Power Storage</td>
</tr>
</tbody>
</table>

**Create Your Turbine Blades**

There are three primary materials you can construct your blades from. I recommend using ABS/PVC for first time builds, but you can carve them out of wood or form them from fiberglass if you know how!

Creating wooden or fiberglass blades is beyond the focus of this course. If you’re interested in more information, let me know and I’ll point you in the right direction.

If you don’t want to make your own blades, you can also buy prefabricated blades off the Internet.

**Cutting ABS/PVC Pipe Into Blades**

This is the way to go, in my opinion. It’s quick, cheap, easy, and fairly sturdy. Best of all, it’s easy to replace if something happens!

Making blades is pretty straight forward. Here are the basic steps:

1. Take the 6” pipe and cut it lengthwise into four equal pieces. (The fourth piece is a spare if you mess up!)
2. Shape the blade using the diagram below. These steps are best for optimal results:

   a. Create a paper template for each cutout to be done

   b. Use tape to temporarily attach the template to one of the blade blanks

   c. Using a Sharpie or similar permanent marker, draw the edge you need to cut

   d. Rough cut your blade blank to shape

   e. Use the newly cut blank as a template for the other two blades.

3. Use sandpaper or a power sander to smooth the edges of your new blades. Try very hard to keep each blade roughly the same!
Attach The Blades To The Assembly Hub

You can buy a pre-made hub or make your own. It's up to you! This part is pretty easy. Take the hub and mark out the locations of the holes on your blade.

Start with one blade and drill the mounting holes. Use two 1” x ¼” bolts to attach the blade to the hub. Tweak as necessary! When you are happy with how it fits, repeat with the other two blades and your assembly is almost complete!

If your hub doesn’t come with an arbor to attach it to a motors drive shaft, then you’ll need to buy one. They will generally have a threaded bolt on one end which attaches to the blade while the other end clamps down on the drive shaft.

Don't attach the blade assembly to the generator yet!

Balancing The Blade Assembly

This step is important! If you have an unbalanced assembly your turbine could break apart if the wind speed picks up.

This is my preferred method, but it takes a bit longer. As you raise the bolt, the balancing process becomes more sensitive which allows you to accurately balance the propeller.
1. Get a 6”+ long machine threaded eye bolt. Choose one that fits the interior diameter of the center hole of your assembly hub.

2. Slide the bolt through the top of your assembly.

3. Put a washer onto the bolt and thread an appropriately sized nut onto the bolt until it’s barely on the bolt, yet still secure.

4. Suspend the assembly by the eyebolt with some clothes line, and hang it so it dangles freely.
5. Observe the way the assembly balances. Use sandpaper to remove weight from blades that are heavy.

6. When your assembly is balanced, raise the bolt up a few inches and repeat the balancing process. Do this until the bolt is as high as possible. This provides an optimally balanced propeller!

How To Build Your Turbine Housing

There are two easy options for building the main turbine body. You can use wood or go with the recommended ABS/PVC pipe model. For this course we’ll cover the pipe based housing. If you’re interested in using wood, let me know and I’ll see if I can hook you up.

Step By Step Instructions For An ABS/PVC Housing

1. Take the length of 4” pipe that you bought and cut off an 8” section.

2. Cut a lid out of the pipe per the diagram below. This forms the base for your generator and the main housing. Don’t throw out the lid, we’ll need it later.
3. Take the Tee joint and glue it to the generator housing you just cut out. See the diagram below for details. Make sure that the Tee part of the joint points straight down while the opening you cut is on the top.

4. Glue the 2” -> 1-1/2” Threaded Reducer to the 2” part of the Tee joint.

5. Glue the 4” -> 2” Reducer to the other 4” end of the Tee joint.

6. At this point, your assembly should resemble this:

7. Take the 2” pipe and cut a 14” long slot into it lengthwise, starting approximately 1” from one end. This will be the slot that holds the wind vane. Glue the 2” pipe cap onto the end that you cut the slot into.
8. Glue the 2” pipe into the reducer from step 5. Make sure the slot for the wind vane is facing up!

9. Thread the 1” – 1-1/2” galvanized bushing into the threaded reducer from step 4. Tighten with a pair of pliers, but don’t worry about glue or anything.

10. Take the sheet of acrylic or plexiglass and cut it out the wind vane. You can use the diagram below or design your own along these same lines.

11. Insert the wind vane into the slot in the tail pipe. Make sure it’s vertically aligned and resting on the bottom of the pipe. When you’re ready, use the silicone caulk to glue it in place with a water tight seal.
12. Once all caulk and glue has dried completely, paint the entire body and all of the blades with exterior paint. This is important for durability, but also helps with the looks of your new turbine!

13. Take the 1” threaded pipe and thread it into the galvanized bushing coming out the bottom of the main housing. You’ll use this to provide a pivot point for your turbine on top of the mast.

14. Congratulations, your housing is done!

How To Build Your Turbine Mast

And now, on to the mast! We’re almost done, hang in there! Get all the parts for the mast together. We’ll do some preliminary assembly and then put it all together onsite!

1. Drill a 5/8” hole about 80% of the way up your mast. For the recommended 12’ mast, a hole at 10’ up is about right.

2. Place your threaded rod through the hole and secure it with a nut on each side.

3. Slide the three chain link fence clamps onto the top of the mast so they rest on the rod you put in.

4. Take the steel cables and fasten cable eyes to each end with the cable clamps.
5. Attach each cable to a fence clamp that you attached to the mast in step 3. At this point you should have cables attached to each of the clamps.

**Base considerations**

**Using A Temporary Base**

For a temporary base, buy a 2’ precut plywood circle, a 1” galvanized screw-in pipe flange, and a 12” length of 1” threaded galvanized pipe.

Drill 4-6 holes around the perimeter of the plywood, about 2” from the edge. Attach the flange to the middle of the circle and thread the pipe onto the flange. Use heavy duty tent stakes to secure the base to the ground.

You’ll need a way to feed the power cable through the mast. An easy way to do this is to drill a hole large enough for your cable about 16” above the bottom of the mast, line the hole with a rubber gasket, and feed the cable through the mast.

To attach the mast to the base, simply slide the mast onto the threaded pipe and you’re set!

**Using A More Permanent Base**

This base is similar to the temporary base. Dig a 12” diameter hole about 2’ deep. Fill it up with QuickCrete and water it according to the
directions. Insert a 2’ length of 1” galvanized pipe halfway into the concrete so that you have 1’ sticking out. Make sure it’s vertically level!

Once the concrete sets up, feed the power cable similar to the way you did for the temporary base and slide the mast onto the stub pipe, and you’re good to go!

**Alternative Base Designs**

I personally prefer a base that allows you to tilt the turbine for maintenance purposes. It’s a more complicated plan and I’m not going to cover it here.

You can also use a galvanized Tee joint to run the power cable instead of drilling a hole in your mast. It’s definitely safer than drilling the hole.

**Final Installation Preparations**

1. Prepare the top end of the power cable and the wires coming off of the generator with matching spade terminals.

2. Bend a J type hook into each of the three rebar spikes.

**Mounting The Turbine And Raising The Tower**

1. Run the power cable through the turbine body. Make sure that you have the end with the spade terminals where the generator lives, and leave enough cable for ample slack when the generator is installed.
2. Install and connect the generator. Place the lid over the generator. Use the screw drive clamps to fasten the lid down.

3. Use silicone caulk to seal the gaps in the turbine body to prevent water from entering.

4. If you haven’t already, attach the blade assembly to the generator.

5. Slide the threaded pipe on the body onto the top of the mast.

6. Grab a helper and raise the mast reasonably vertical, and then slide the mast onto the base. Have the helper hang onto the mast and make sure it doesn’t tip over.
7. Hook a fully extended turnbuckle onto the end of a guy line, grab a rebar stake, and drive the stake into the ground at a reasonable distance from the mast. You’re looking for slightly tight, but not too much. Repeat this for the other two guy lines.

8. Tighten each turnbuckle until there’s no slack left. Using a level check for plumb in each direction. Adjust the turnbuckles until it’s perfectly plumb. There shouldn’t be any play in the tower at all.

Congratulations! Your turbine is ready to go!

Connecting Your Electrical System

1. You need to connect up the components of your electrical system per the diagram below.

![Diagram of electrical system]

Testing Your Turbine Output

When the wind blows, you’re ready to test. Take a multimeter and measure the voltage coming off the end of the power cable. Your
voltage will be variable based on the wind speed, but you’re looking for about 13-14 volts.

After the wind has blown for a while, your battery should be charged and you should be able to test the output in AC by plugging in a lamp or something to the inverter.

Success!
A Few Last Words

Stopping Your Turbine
You'll need to stop your turbine from rotating whenever you want to perform maintenance, or perhaps in the case of any high speed winds.

The easiest way to do this is to simply short out the power cable coming off the turbine. This will prevent the motor from rotating and you're good to go!

You could even add a panic / safety switch to your electrical system that allows you to turn the turbine on and off easily.

I Need More Power!
If you need to store more power, you can add more batteries to your array. This is particularly important if you want to use your new alternative energy system for more serious use.

If you need to generate more, you can add additional turbines or even make some solar panels and add them.

How Do I Know What My Turbines Have Done?
You can buy meters to monitor the battery state and the current that your turbine is generating. If you want to get high tech, you can even get meters that are computerized and you can graph all of the numbers you're interested in!
Appendix A: Where To Buy Stuff

Coming Soon…
Appendix B: Wire Gauge Tables

Common Wire Gauges and Resistance Chart (Copper)

<table>
<thead>
<tr>
<th>AWG</th>
<th>Maximum Current</th>
<th>Diameter in Inches</th>
<th>Resistance (Ohms) per 1000’</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>0.918</td>
<td>0.025</td>
<td>16.46</td>
</tr>
<tr>
<td>20</td>
<td>1.46</td>
<td>0.032</td>
<td>10.35</td>
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<tr>
<td>18</td>
<td>2.32</td>
<td>0.04</td>
<td>6.51</td>
</tr>
<tr>
<td>16</td>
<td>3.69</td>
<td>0.05</td>
<td>4.09</td>
</tr>
<tr>
<td>14</td>
<td>5.87</td>
<td>0.064</td>
<td>2.57</td>
</tr>
<tr>
<td>12</td>
<td>9.33</td>
<td>0.08</td>
<td>1.62</td>
</tr>
<tr>
<td>10</td>
<td>14.8</td>
<td>0.101</td>
<td>1.02</td>
</tr>
<tr>
<td>8</td>
<td>23.6</td>
<td>0.128</td>
<td>0.64</td>
</tr>
<tr>
<td>6</td>
<td>37.5</td>
<td>0.162</td>
<td>0.4</td>
</tr>
<tr>
<td>4</td>
<td>59.6</td>
<td>0.204</td>
<td>0.25</td>
</tr>
<tr>
<td>2</td>
<td>94.8</td>
<td>0.257</td>
<td>0.16</td>
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<tr>
<td>1</td>
<td>119</td>
<td>0.289</td>
<td>0.12</td>
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</table>

The Resistance Multipliers Of Other Materials Compared To Copper

<table>
<thead>
<tr>
<th>Material</th>
<th>Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>1.6</td>
</tr>
<tr>
<td>Gold</td>
<td>1.4</td>
</tr>
<tr>
<td>Iron</td>
<td>5.68</td>
</tr>
<tr>
<td>Steel</td>
<td>7.6 - 12.7</td>
</tr>
<tr>
<td>Zinc</td>
<td>3.4</td>
</tr>
<tr>
<td>Brass</td>
<td>3.7 - 4.9</td>
</tr>
<tr>
<td>Silver</td>
<td>0.94</td>
</tr>
<tr>
<td>Lead</td>
<td>12.8</td>
</tr>
<tr>
<td>Tin</td>
<td>6.7</td>
</tr>
<tr>
<td>Nickel</td>
<td>5.1</td>
</tr>
</tbody>
</table>
Voltage Drop Calculation Example

The length of our cable from the supply (wind turbine) to the load (batteries) can have a big impact on the power generated. All wire has a resistance, and any resistance is a loss, so we need to reduce this loss to a minimum. But just how much is lost?

Say our windmill is supplying 20 amps of power, and we have a 12 volt battery under charge. We have a power cable from our windmill to our battery of 100 meters, and the cable size is 6 AWG.

Using the cable cross reference here, we know that 6 AWG wire has a resistance of 1.3 ohms per 1km, or 0.13 ohm for our 100m length. Now there are two wires + and -, so we double that to get 0.26 ohms.

So if the windmill is supplying 20 amps, using ohms law we calculate 20 amps over our 0.26 ohm cable equals 5.2 volts lost in the cable. To work out how many watts is lost in the cable, we use watts = volts * amps, so 5.2 volts * 20 amps = 104 watts. As our battery is 12 volts, its using 12 volts * 20 amps = 240 watts. So our windmill is making 104 watts + 240 watts = 344 watts, 104 watts of which is wasted in the cable.
If we increase our wire size to 4 AWG, our total cable resistance drops to 0.16 ohms (0.83 ohms per 100m, times 2). This works out to 3.2 volts lost in the cable, or 64 watts wasted.
## Appendix C: Usable Ametek Motor Models

<table>
<thead>
<tr>
<th>Ametek Model</th>
<th>Nominal Voltage</th>
<th>Voltage Range</th>
<th>No Load Amps</th>
<th>Shaft Diameter</th>
<th>RPM</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ametek 20VDC</td>
<td>20 VDC</td>
<td>10/15 VDC</td>
<td>0.47</td>
<td>5/8” x 11/16”</td>
<td>550</td>
<td>13 lbs</td>
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<tr>
<td>Ametek 30VDC</td>
<td>30 VDC</td>
<td>12/24 VDC</td>
<td>0.15</td>
<td>5/8” x 1 7/8”</td>
<td>325</td>
<td>7 ¾ lbs</td>
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<tr>
<td>Ametek 40 VDC</td>
<td>40 VDC</td>
<td>12/24 VDC</td>
<td>0.50</td>
<td>5/8” x 1 1/4”</td>
<td>1050</td>
<td>11 lbs</td>
</tr>
<tr>
<td>Ametek 50 VDC</td>
<td>50 VDC</td>
<td>1/2” x 1 ¼” Shaft</td>
<td>0.40</td>
<td>4” x 4 7/8”</td>
<td>1200</td>
<td>11 lbs</td>
</tr>
<tr>
<td>Ametek 50 VDC</td>
<td>50 VDC</td>
<td>5/8” x 1 7/8” Shaft</td>
<td>0.60</td>
<td>4” x 7”</td>
<td>1700</td>
<td>12 lbs</td>
</tr>
<tr>
<td>Ametek 50 VDC</td>
<td>50 VDC</td>
<td>5/8” x 2” Shaft</td>
<td>1.00</td>
<td>4” x 7”</td>
<td>1800</td>
<td>12 lbs</td>
</tr>
<tr>
<td>Ametek 72 VDC</td>
<td>72 VDC</td>
<td></td>
<td>0.41</td>
<td>4” x 7”</td>
<td>1800</td>
<td>12 lbs</td>
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