The Poor Mans Guide to DIY Wind and Solar Systems

A step by step blueprint to build a Chispito Wind Generator, Solar hot water heater system or Solar window room warmer for under $150.00

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Table of Contents

DISCLAIMER

Please take care when working on any of the projects outlined within this manual. By reading this manual you agree to that you are responsible for your own actions. www.edgecuttingproducts.com will not be held accountable for any loss or injuries.

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Chapter 1: Before You Get Started!

Safety

Your Safety should be the very highest priority. Human life is more important than electricity. Wind generators, hydro systems, and even solar panels can be very dangerous, with fast moving parts, electrical sparks, and violent weather conditions. Some things to consider:

- Keep work area clean, as cluttered areas invite accidents.
- Always ground and fuse your electrical system, as well as each component within it.
- Use common sense. Be aware of what is around you. Keep work area well lit and avoid using electrical components near flammable gases or liquids.
- Always use proper wire sizes and types.
- Always wear goggles, gloves, and protective clothing.
- Always stand upwind when viewing the wind generator to avoid debris in case of failure.
- Always attach safety ropes and/or cables when erecting your tower and/or wind generator.
- Always wire connections securely with proper insulation, such as heat shrink tubing and/or electrical tape.
- Never touch the positive and negative wires at the same time while they are connected to the battery.
- Never leave your wind generator unconnected to anything, unless it is on the ground. It must be connected to a battery or other load. Or you can short it out by crossing the positive and negative wires FROM THE WIND GENERATOR together, to provide a closed circuit. If you do not do one of these, it can spin freely and attain dangerous speeds.
- Never expose batteries to heat, sparks or flames. Do not smoke near batteries. They can ignite and explode easily.
- Always protect wires and run them through conduit.

Safety is important, and the above listed warnings are just a few that can help you prevent an accident.

INTRODUCTION

I believe anyone can be in control of where his electricity comes from. There is nothing more rewarding and empowering than making a wind powered generator from scrap materials. Most of the tools and materials in this manual can be found in your local hardware shop or junk pile. Search your local dump and/or junkyards for the materials required. If you live in a city, do a search on freecycle.org for salvaged parts.

Wind power! It's been growing at an average rate of 30% per year, making wind the fastest growing source of energy in the world since 1990. This growth reflects the cost-competitive nature of wind power today. And wind power doesn't pollute!

Wind turbines draw upon the force of moving air to generate electricity by rotating propeller-like blades around a rotor. The motion of the rotor turns the drive shaft, which turns an electric generator.

Moderate to excellent wind resources are found in most regions of the United States, making wind power a feasible source of electricity in a variety of settings. Small wind turbines, those rated below 100 kilowatts, are used to power individual homes, farms, ranches, small businesses, and for telecommunications.

Small wind systems can be used independently of the electricity grid in what are called stand-alone, or off-grid applications. For example, off-grid wind/diesel hybrid systems in remote areas such as Alaska have enhanced system reliability and reduced fuel costs.

Large or utility-scale wind turbines range in size from 100 kilowatts to one or two megawatts. Tens to hundreds of these turbines can be connected to the electricity grid to form a wind farm that generates enough electricity for an entire community.

Power providers see wind farms as an environmentally attractive way to generate clean power for their customers, so the number of wind farms in the U.S. today is rapidly increasing.

Wind power contributes to a better environment by producing clean power, a stronger economy by creating wind power-related employment, and greater energy security by providing a domestic source of energy.

According to Wikipedia, **Renewable energy** is energy generated from natural resources—such as sunlight, wind, rain, tides and geothermal heat—which are renewable (naturally replenished). In 2006, about 18% of global final energy consumption came from renewables, with 13% coming from traditional biomass, such as wood-burning. Hydroelectricity was the next largest renewable source, providing 3% of global energy consumption and 15% of global electricity generation.

Wind power is growing at the rate of 30 percent annually, with a worldwide installed capacity of 121,000 megawatts (MW) in 2008, and is widely used in European countries and the United States. The annual manufacturing output of the photovoltaics industry reached 6,900 MW in 2008, and photovoltaic (PV) power stations are popular in Germany and Spain. Solar thermal power stations operate in the USA and Spain, and the largest of these is the 354 MW SEGS power plant in the Mojave Desert. The world's largest geothermal power installation is The Geysers in California, with a rated capacity of 750 MW. Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18 percent of the country's automotive fuel.

We can't depend on fossil fuels for our energy forever. Oil prices are skyrocketing around the world. Wars are being fought and people are dying over oil reserves. The damage to our planet and our climate is irreversible and is becoming more and more apparent by the day.

If we don't do something about our energy situation now, our kids and their kids are going to have to face some extremely difficult challenges in the future. What can we do? It seems that most alternative energy choices are too expensive to mass market. As an individual, is there really anything you can do to make a difference? If you plan on using renewable energy such as wind or solar power in your home then you MUST change the way you use energy. Remember, the definition of crazy: Doing the same thing while expecting a change. If you do the same thing you always have, you will get the same thing you always have gotten. There is no point going to all the effort of making a wind or solar generator if you are going to leave lights and power points on when the appliances are not being used etc.

We'll look at some of the things you can start doing right now, today, to do your part in solving the world's energy crisis. There are a multitude of things that you can do right now in order to cut down on your energy expenses.

STEP 1: Home Energy Audits - A home energy audit is the first step to assess how much energy your home consumes and to evaluate what measures you can take to make your home more energy efficient. An audit will show you problems that may, when corrected, save you significant amounts of money over time. During the audit, you can pinpoint where your house is losing energy. Audits also determine the efficiency of your home's heating and cooling systems. An audit may also show you ways to conserve hot water and electricity. You can perform a simple energy audit yourself, or have a professional energy auditor carry out a more thorough audit.

Do-It-Yourself Home Energy Audits

You can easily conduct a home energy audit yourself. With a simple but diligent walk-through, you can spot many problems in any type of house. When auditing your home, keep a checklist of areas you have inspected and problems you found. This list will help you prioritize your energy efficiency upgrades.

Locating Air Leaks

First, make a list of obvious air leaks (drafts). The potential energy savings from reducing drafts in a home may range from 5% to 30% per year, and the home is generally much more comfortable afterward. Check for indoor air leaks, such as gaps along the baseboard or edge of the flooring and at junctures of the walls and ceiling. Check to see if air can flow through these places:

- Electrical outlets
- Switch plates
- Window frames
- Baseboards
- Weather stripping around doors
- Fireplace dampers
- Attic hatches
- Wall- or window-mounted air conditioners.

Also look for gaps around pipes and wires, electrical outlets, foundation seals, and mail slots. Check to see if the caulking and weather stripping are applied properly, leaving no gaps or cracks, and are in good condition.

Inspect windows and doors for air leaks. See if you can rattle them, since movement means possible air leaks. If you can see daylight around a door or window frame, then the door or window leaks. You can usually seal these leaks by caulking or weather stripping them. Check the storm windows to see if they fit and are not broken. You may also wish to consider replacing your old windows and doors with newer, high-performance ones. If new factory-made doors or windows are too costly, you can install low-cost plastic sheets over the windows.

If you are having difficulty locating leaks, you may want to conduct a basic building pressurization test:

1. First, close all exterior doors, windows, and fireplace flues.
2. Turn off all combustion appliances such as gas burning furnaces and water heaters.
3. Then turn on all exhaust fans (generally located in the kitchen and bathrooms) or use a large window fan to suck the air out of the rooms.

This test increases infiltration through cracks and leaks, making them easier to detect. You can use incense sticks or your damp hand to locate these leaks. If you use incense sticks, moving air will cause the smoke to waver, and if you use your damp hand, any drafts will feel cool to your hand.

On the outside of your house, inspect all areas where two different building materials meet, including:

- All exterior corners
- Where siding and chimneys meet
- Areas where the foundation and the bottom of exterior brick or siding meet.

You should plug and caulk holes or penetrations for faucets, pipes, electric outlets, and wiring. Look for cracks and holes in the mortar, foundation, and siding, and seal them with the appropriate material. Check the exterior caulking around doors and windows, and see whether exterior storm doors and primary doors seal tightly.

When sealing any home, you must always be aware of the danger of indoor air pollution and combustion appliance "backdrafts." Backdrafting is when the various combustion appliances and exhaust fans in the home compete for air. An exhaust fan may pull the combustion gases back into the living space. This can obviously create a very dangerous and unhealthy situation in the home.

In homes where a fuel is burned (i.e., natural gas, fuel oil, propane, or wood) for heating, be certain the appliance has an adequate air supply. Generally, one square inch of vent opening is required for each 1,000 Btu of appliance input heat. When in doubt, contact your local utility company, energy professional, or ventilation contractor.

Insulation

Heat loss through the ceiling and walls in your home could be very large if the insulation levels are less than the recommended minimum. When your house was built, the builder likely installed the amount of insulation recommended at that time. Given today's energy prices (and future prices that will probably be higher), the level of insulation might be inadequate, especially if you have an older home.

If the attic hatch is located above a conditioned space, check to see if it is at least as heavily insulated as the attic, is weather stripped, and closes tightly. In the attic, determine whether openings for items such as pipes, ductwork, and chimneys are sealed. Seal any gaps with an expanding foam caulk or some other permanent sealant.

While you are inspecting the attic, check to see if there is a vapor barrier under the attic insulation. The vapor barrier might be tarpaper, Kraft paper attached to fiberglass batts, or a plastic sheet. If there does not appear to be a vapor barrier, you might consider painting the interior ceilings with vapor barrier paint. This reduces the amount of water vapor that can pass through the ceiling. Large amounts of moisture can reduce the effectiveness of insulation and promote structural damage.

Make sure that the attic vents are not blocked by insulation. You also should seal any electrical boxes in the ceiling with flexible caulk (from the living room side or attic side) and cover the entire attic floor with at least the current recommended amount of insulation.

Checking a wall's insulation level is more difficult. Select an exterior wall and turn off the circuit breaker or unscrew the fuse for any outlets in the wall. Be sure to test the outlets to make certain that they are not "hot." Check the outlet by plugging in a functioning lamp or portable radio. Once you are sure your outlets are not getting any electricity, remove the cover plate from one of the outlets and gently probe into the wall with a thin, long stick or screwdriver. If you encounter a slight resistance, you have some insulation there. You could also make a small hole in a closet, behind a couch, or in some other unobtrusive place to see what, if anything, the wall cavity is filled with. Ideally, the wall cavity should be totally filled with some form of insulation material. Unfortunately, this method cannot tell you if the entire wall is insulated, or if the insulation has settled. Only a thermographic inspection can do this.

If your basement is unheated, determine whether there is insulation under the living area flooring. In most areas of the country, an R-value of 25 is the recommended minimum level of insulation. The insulation at the top of the foundation wall and first floor perimeter should have an R-value of 19 or greater. If the basement is heated, the foundation walls should be insulated to at least R-19. Your water heater, hot water pipes, and furnace ducts should all be insulated.

Heating/Cooling Equipment

Inspect heating and cooling equipment annually, or as recommended by the manufacturer. If you have a forced-air furnace, check your filters and replace them as needed. Generally, you should change them about once every month or two, especially during periods of high usage. Have a professional check and clean your equipment once a year.

If the unit is more than 15 years old, you should consider replacing your system with one of the newer, energy-efficient units. A new unit would greatly reduce your energy consumption, especially if the existing equipment is in poor condition. Check your ductwork for dirt streaks, especially near seams. These indicate air leaks, and they should be sealed with a duct mastic. Insulate any ducts or pipes that travel through unheated spaces. An insulation R-Value of 6 is the recommended minimum.

Lighting

Energy for lighting accounts for about 10% of your electric bill. Examine the wattage size of the light bulbs in your house. You may have 100-watt (or larger) bulbs where 60 or 75 watts would do. You should also consider compact fluorescent lamps for areas where lights are on for hours at a time. Your electric utility may offer rebates or other incentives for purchasing energy-efficient lamps.

Energy Saving Tips:

1. Use energy efficient fluorescent light bulbs in all of your lights.
2. Turn off all appliances, such as TV's and computers when they are not in use. They still consume energy, even in standby mode.
3. Air dry clothes and dishes when at all possible, and only run the dishwasher or clothes washer with full loads.
4. Keep your thermostat at a comfortable but moderate temperature.
5. Avoid baths. Take short showers.
6. Purchase an energy-efficient electric water heater and operate it efficiently. Or select an energy-efficient water heater that doesn't use electricity.
7. Incorporate passive solar design concepts into your home, which include using energy-efficient windows. Properly insulate and air-seal your home. Select an energy-efficient heating system that doesn't use electricity.
8. During the heating season, keep the draperies and shades on your south facing windows open during the day to allow the sunlight to enter your

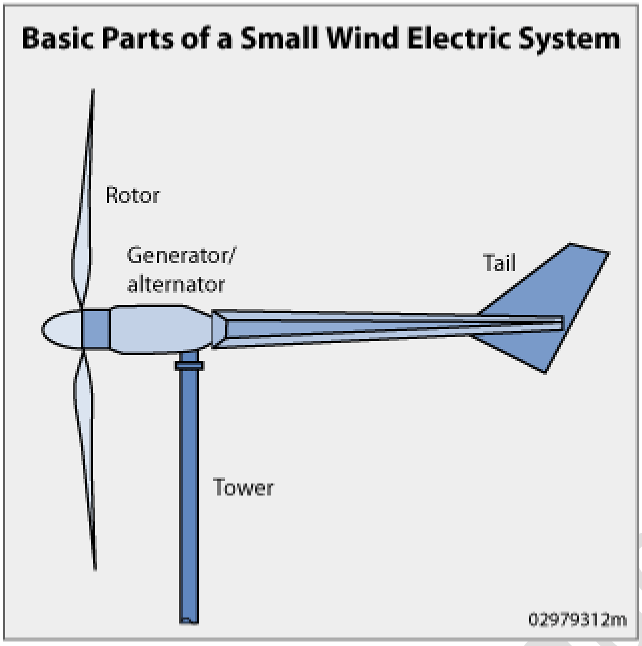
home and closed at night to reduce the chill you may feel from cold windows.

9. Use fans during the summer to create a wind chill effect that will make your home more comfortable. If you use air conditioning, a ceiling fan will allow you to raise the thermostat setting about 4°F with no reduction in comfort
10. Place heat-resistant radiator reflectors between exterior walls and the radiators.
11. Bleed trapped air from hot-water radiators once or twice a season; if in doubt about how to perform this task, call a professional.
12. Clean warm-air registers, baseboard heaters, and radiators as needed; make sure they're not blocked by furniture, carpeting, or drapes.
13. Clean or replace filters on furnaces once a month or as needed.
14. Insulate your hot water heater and hot water pipes to prevent heat loss.
15. Insulate heating ducts in unheated areas such as attics and crawlspaces and keep them in good repair to prevent heat loss of up to 60 percent at the registers

Chapter 2: How Wind Power Systems Work

In order for Wind power to work, you need is a driving force to create kinetic energy. In the case of wind turbines, that force is the wind. Wind is created by the unequal heating of the Earth's surface by the sun. Wind turbines convert the kinetic energy in wind into clean electricity.

When the wind spins the wind turbine's blades, a rotor captures the kinetic energy of the wind and converts it into rotary motion to drive the generator. A small wind system can be connected to an electric distribution system (grid-connected) or it can stand alone (off-grid).



Electricity is created by magnets rotating around an electrical coil and generating electricity. The wind power is used to rotate the magnetic field around the coil, causing atoms and electrons to be displaced, thus creating kinetic energy that is then translated into electricity.

Generating electricity using your own small renewable energy system fits the circumstances and values of many home and small-business owners. Although it takes time and money to research, buy, and maintain a system, many people enjoy the independence they gain and the knowledge that their actions are helping the environment.

A renewable energy system can be used to supply some or all of your electricity needs. Some people, especially those in remote areas, use the electricity from their systems in place of electricity supplied to them by power providers (i.e., electric utilities). These are called stand-alone (off-grid) systems.

Equipment Required for Stand-Alone Systems

In addition to building photovoltaic panels, a wind turbine, or a small hydropower system, you will need to invest either time or money in some additional equipment (called "balance-of-system") to condition and safely transmit the electricity to the load that will use it.

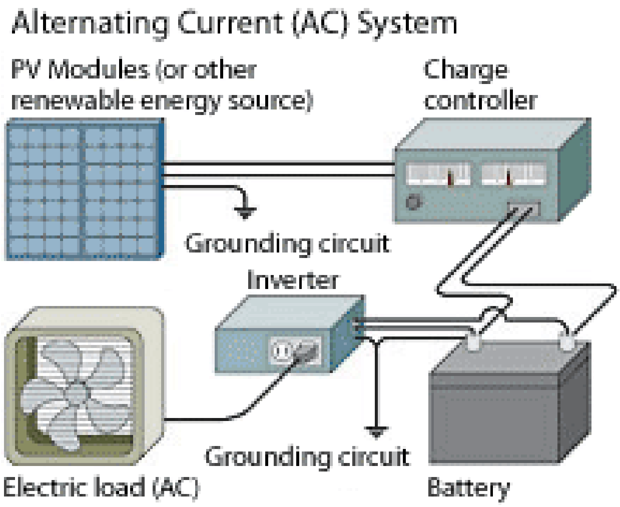


Diagram of a typical AC, battery-based system.

The amount of equipment you will need depends on what you want your system to do. In the simplest systems, the current generated by, for example, your wind turbine is connected directly to the load. However, if you want to store power for use when your turbine isn't producing electricity, you will want to use batteries and a charge controller. Depending on your needs, balance-of-system equipment could account for half of your total system costs.

Connecting Your System to the Electricity Grid

While renewable energy systems are capable of powering houses and small businesses without any connection to the electricity grid, many people prefer the advantages that grid-connection offers.

A grid-connected system allows you to power your home or small business with renewable energy during those periods (diurnal as well as seasonal) when the sun is shining, the water is running, or the wind is blowing. Any excess electricity you produce is fed back into the grid. When renewable resources are unavailable, electricity from the grid supplies your needs, thus eliminating the expense of electricity storage devices like batteries.

In addition, power providers (i.e., electric utilities) in most states allow net metering, an arrangement where the excess electricity generated by grid-connected renewable energy systems "turns back" your electricity meter as it is fed back into the grid. Thus, if you use more electricity than your system feeds into the grid during a given month, you pay your power provider only for the difference between what you used and what you produced.

Others connect their systems to the grid and use them to reduce the amount of *conventional power* supplied to them through the grid. A grid-connected system allows you to sell any excess power you produce back to your power provider.

Metering and Rate Arrangements for Grid-Connected Systems

The Public Utility Regulatory Policy Act of 1978 (PURPA) requires power providers to purchase excess power from grid-connected small renewable energy systems at a rate equal to what it costs the power provider to produce the power itself. Power providers generally implement this requirement through various metering arrangements. Here are the metering arrangements you are likely to encounter:

- **Net purchase and sale**
  Under this arrangement, two uni-directional meters are installed—one records electricity drawn from the grid, and the other records excess electricity generated and fed back into the grid. You pay retail rate for the electricity you use, and the power provider purchases your excess generation at its wholesale rate. There may be a significant difference between the retail rate you pay and the power provider's avoided cost.
- **Net metering**
  Net metering provides the greatest benefit to you as a consumer. Under this arrangement, a single, bi-directional meter is used to record both electricity you draw from the grid and the excess electricity your system feeds back into the grid. The meter spins forward as you draw electricity, and it spins backward as the excess is fed into the grid. If, at the end of the month, you've used more electricity than your system has produced, you pay retail price for that extra electricity. If you've produced more than you've used, the power provider generally pays you for the extra electricity at its avoided cost. The real benefit of net metering is that the power provider essentially pays you retail price for the electricity you feed back into the grid.

  Some power providers will now let you carry over the balance of any net extra electricity your system generates from month to month, which can be an advantage if the resource you are using to generate your electricity is seasonal. If, at the end of the year, you have produced more than you've used, you forfeit the excess generation to the power provider.

Equipment Required for Grid-Connected Systems

Aside from the major small renewable energy system components, you will need to purchase some additional equipment (called "balance-of-system") in order to safely transmit electricity to your loads and comply with your power provider's grid-connection requirements. You may need the following items:

- Power conditioning equipment
- Safety equipment

- Meters and instrumentation.

Because grid-connection requirements vary, you or your system supplier/installer should contact your power provider to learn about its specific grid-connection requirements before purchasing any part of your renewable energy system.

STEP 2: ANALYZE YOUR ELECTRICITY LOAD

Before you purchase and install a small renewable energy system you should analyze your electricity loads to see if one of the small renewable energy systems can meet all or enough of your electricity needs—is it economically feasible? You will also want to research your local codes and requirements for installing a system.

If you're designing a new home, you should work with the builder and your contractor to incorporate your small renewable energy system into your whole-house design—an approach for building an energy-efficient home.

Analyzing Your Electricity Loads

Calculating your electricity needs is the first step in the process of investigating renewable energy systems for your home or small business. A thorough examination of your electricity needs helps you determine the following:

- The size (and therefore, cost) of the system you'll need
- How your energy needs fluctuate throughout the day and over the year
- Measures you can take to reduce your electricity use.

Conducting a load analysis involves recording the wattage and average daily use of all of the electrical devices which are plugged into your central power source, such as refrigerators, lights, televisions, and power tools. Some loads, like your refrigerator, use electricity all the time, while others, like power tools, use electricity intermittently. Loads that use electricity intermittently are often referred to as selectable loads. If you are willing to use your selectable loads only when you have extra power available, you may be able to install a smaller renewable energy system.

To determine your total electricity consumption:

- Multiply the wattage of each appliance by the number of hours it is used each day (be sure to take seasonal variations into account). Some appliances do not give the wattage, so you may have to calculate the wattage by multiplying the amperes times the volts. Generally, power use data can be found on a sticker, metal plate, or cord attached to the appliance.
- Record the time(s) of day the load runs for all selectable loads.

A typical home uses approximately 9400 kilowatt-hours of electricity per year (about 780 kWh per month). Depending on the average wind speed in the area, a wind turbine rated in the range of 5–15 kilowatts would be required to make a significant contribution to this demand. A 1.5-kilowatt wind turbine will meet the needs of a home requiring 300 kilowatt-hours per month in a location with a 14 mile-per-hour (6.26 meters-per-second) annual average wind speed

STEP 3: Estimating Your Wind Resource

To help determine the suitability of your site for a small electric wind system, you need to estimate your site's wind resource. The wind resource can vary significantly over an area of just a few miles because of local terrain influences on the wind flow. You can use the following methods for estimating your wind resource.

Consult Wind Resource Maps

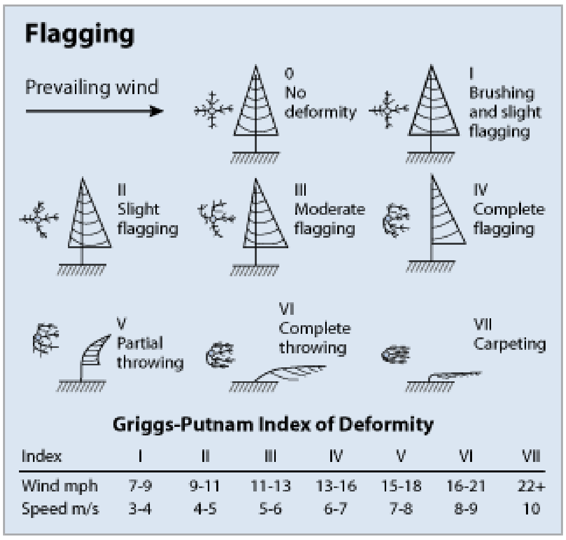
As a first step, you can consult a wind resource map, which is used to estimate the wind resource in your area. The U.S. Department of Energy's Wind Powering America Program has wind resource maps by state.

Obtain Airport Wind Speed Data

Another way to indirectly quantify the wind resource is to obtain average wind speed information from a nearby airport. However, local terrain influences and other factors may cause the wind speed recorded at an airport to be different from your particular location. Airport wind data are generally measured at heights about 20–33 feet (6–10 meters) aboveground. Average wind speeds increase with height and may be 15–25% greater at a typical wind turbine hub-height of 80 feet (24 meters) than those measured at airport anemometer heights.

Observe Vegetation Flagging

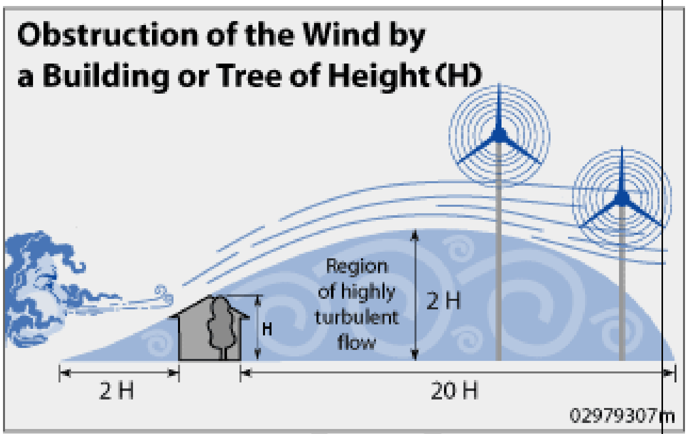
Flagging—the effect of strong winds on area vegetation—can help determine area wind speeds. Trees, especially conifers or evergreens, can be permanently deformed by strong winds. See flagging illustration on this page for more information.



Use a Measurement System

Direct monitoring by a wind resource measurement system at a site provides the clearest picture of the available resource. Wind measurement systems are available for costs as low as $600–$1,200.

The measurement equipment must be set high enough to avoid turbulence created by trees, buildings, and other obstructions. The most useful readings are those taken at hub-height, the elevation at the top of the tower where the wind turbine is going to be installed.

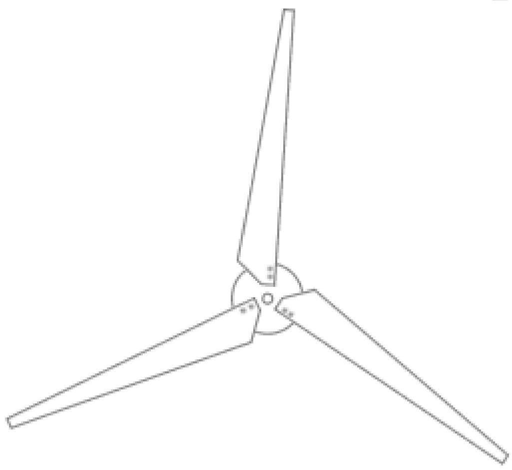


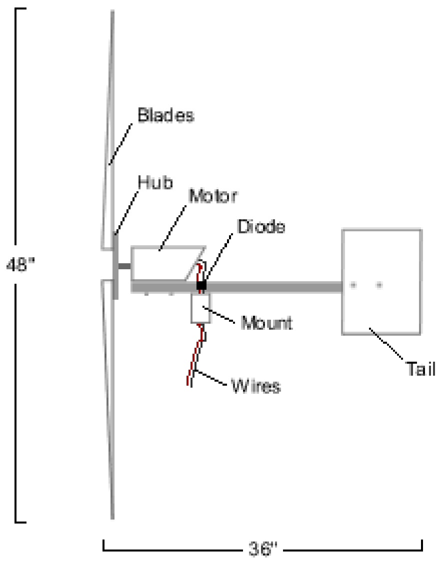
Obtain Data from a Local Small Wind System

Finally, If there is a small wind turbine system in your area, you may be able to obtain information on the annual output of the system and also wind speed data if available.

Chapter 3: Build Your Own Wind Generator

Step 4 DIY Build Your Own Wind Generator





The Chispito Wind Generator was designed to be simple and efficient with fast and easy construction. There are no limits to what you can do with wind power. There is a lot of energy in the wind. Power is the cube of speed, so a 40mh wind has 8 times the power of a 20mh wind. As an example a perfectly efficient windmill may produce 200 watts of power in a 20mh breeze, 800 watts in a 40mh wind, and 6400 watts in a 80mh storm gust.

What sort of windmills are we talking about? Lets begin with a few simple rules about windmills. Windmills behave in a way very similar to your average car engine. They have a power and torque curve, with different speeds for maximum power or torque. For electrical power generation ideally you need to operate your windmill in its peak power output.

1. More blades = less speed, less power but more torque, perfect for pumping water.
2. Less blades = more speed.
3. Larger propeller diameter = less speed but more power.

Two other factors to consider are turbulence and wind-shadow. Turbulence can be caused by the disrupted wind from one blade to the next or anything up-wind of the windmill and will have a big effect on efficiency. Wind shadow is the effect the windmill mast has on the propeller as each blade passes the mast. This shadow causes a sudden pressure change behind the propeller blade and results in vibration.

As a rule 3 blades is the best compromise between power, torque and speed. A 2 blade propeller will run faster, but there are dramatic vibration problems with 2 blade windmills during wind direction changes and therefore not recommended. A typical home made wind generator with a 3 blade propeller diameter of 2 meters will spin from 100 rpm to 600 rpm and is capable of supplying over 500watt.

The old farm style of windmills (Southern Cross, Comet) used for water pumping have lots of blades, giving them a lot of torque, however many blades means low RPM, and they are not suited to power generation. It is possible to use a gear box to speed up the output, but this creates its own problems and is best avoided.

Search the internet for information on home-built or Do it Yourself wind turbines or generators. They come in a multitude of designs and complexities. All wind generators consist of five basic parts.

1. **Generator:** Generators operate on the principle of electromagnetic induction. When magnets are rotated around a conductor, they generate electricity.
2. **Rotor blades:** Rotor blades are used to transfer energy from the wind into kinetic energy
3. **Mount or tail:** The tail keeps it turned into the wind
4. **Tower:** The tower helps to get it up into the wind
5. **Batteries and an electronic control system**

SUPPLIES

You can build your own wind generator for as little as $150. These windmills can be setup to power any household appliance.

You'll need this items to get started on your windmill:

- DC Power Motor (Ametek 30vdc)
- Body Assembly
- Tail Assembly
- Blades
- Hub To Connect The Propeller To The Motor
- Tower
- Battery Bank
- Nuts And Bolts
- Miscellaneous Hardware

The majority of the materials that you'll need can be found online and/or at your local hardware store. As for the tools, you'll need a socket set, several screwdrivers, a grinder, a jigsaw, and some sandpaper.

Now that you are ready to get started we need to source all of the parts you are going to need.

Step 5: find the right motor

Motor Finding A DC Motor

In order to find a DC motor you can check eBay, or look for inexpensive power tools. Drills, screwdrivers and other tools are a great way to find inexpensive DC motors although they do not generate much energy they are great for smaller projects.

The motor is the core of our Chispito system. You are looking for a permanent magnet motor. You may use any other simple permanent magnet DC motor that returns at least 1 V for every 25 rpm and can handle upwards of 10 amps Why permanent magnets? Because they work well as generators. Usually a DC motor will use power, but when we spin the motor in the opposite direction it will actually generate power. The power will go back out the same wires where the power usually comes in from. It's very simple, which is why DC motors are perfect for our DIY wind generator.

Also, they don't normally require high rpms to get some usable power out of them. To find out if your motor might work, look on the label and find the rpms. Then, find the working voltage. Divide rpms by voltage to get rpms per volt. For this sort of machine, you are looking for 25-35 rpms per volt. The more rpms per volt, the faster Chispito needs to turn to charge a battery, which means you will need more wind before it will start charging. So, go for low rpms per volt.

What DC motor should you use?

What you want to look for is a surplus permanent magnet DC motor and pay attention to the RPM, shaft size, amps and voltage. You need to look for a DC motor with a LOW RPM rating. The reason for this is because when we use a DC motor as a generator it must spin much faster than the rated RPM to produce the rated voltage. Your goal is to obtain a DC motor with HIGH voltage (over 12v), HIGH current and LOW RPM rating.
An ideal motor would be one rated under 400 RPM at 30 volts. When this is used
as a wind generator you could expect 12v at a low RPM.

The motor should also have a hub attached. If it doesn't, you'll have to find something that works. Saw blades, pulleys, and hubs from something else might work, but remember, this thing can get up to 1500 rpms, so get that hub on there tight!

The motor should be easy to turn by hand, and it should produce a bit of voltage with a hand turn. Something in the range of 1-2 volts with a hand turn will be great. If in doubt, hook the motor to a lathe or drill press to get a good representation of what it will output at set speeds. If the machine can't get power out of it, neither will the wind.

A lot of people like to use old computer tape drive motors (surplus relics from the days when computers had big reel to reel tape drives). The best apparently are a couple of models of motor made by Ametek. The best motor made by Ametek is a 99-volt DC motor that works great as a generator. Unfortunately, they are almost impossible to locate these days. There are a lot of other Ametek motors around though. A couple of their other models make decent generators and can still be found on places like eBay.

For instance, These are new surplus Ametek 38 volt motors. Great for making low power turbines in the 100 watt range. They start charging 12 volt at around 330 rpm and work well with blades of 4ft diameter or less. Maximum rating of 12 amps. They work great for other projects as well!

It has a 5/8 inch shaft, measures 4" diameter x 4.5" long. Has 4 tapped 10-32 mounting holes in the front plate. There are 3 wires from the motor, the brown wire isn't used, the black and white are the DC output wires. The positive lead would be determined by its rotation

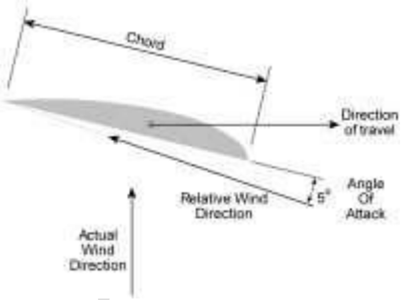
There are a ton of good DC motors, one of our favorites that you can find quite easily from eBay is the 1150 RPM 38 VDC Ametek motor. These motors will produce about 13 volts at about 390 RPM. This is Perfect for a homemade wind generator. If you have lower winds then you should go for the Ametek 30 VDC, as they do not need to spin as fast to produce 12 volts. These motors cost about $50

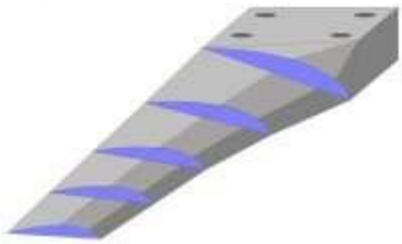
Step 6: Make the Blades

Blades

Windmill blades can be made from just about anything. Wood, steel, fiberglass, carbon fibre, etc. I've even seen a windmill using 8 wheelbarrows! Wood is the most common material for the DIY handyman, its cheap, easily formed, strong and flexible, remember trees are very good at bending in the wind without breaking

The profile of a well designed windmill blade resembles a aircraft wind, giving lift on the trailing edge. The blade has a angle of attack to the wind to give its best lift, and this lift drives the blade forward. There also needs to be a slight twist along the length of the blade, the blade tip is traveling much faster than the part of the blade closest to the center of the propeller, so the blade needs to be tilted to give the same angle of attack.





You also need to consider tip speed, or TSR (Tip Speed Ratio). The tips of the windmill blade travel much faster than the wind speed, so a TSR of 7 means the tips travel at 7 times the wind speed. A typical 2 meter diameter turbine at 500rpm could have a tip speed of over 200kmh, and any airborne dust or unfortunate insects will be very abrasive at this speed. For windmill blades made from a soft material, such as timber, a layer of wear resistant aluminum tape or fiberglass is usually applied to the leading edge.

Having said all that, we have found that using 8” PVC pipe works great for the DIY’er

Material for the Blades

- 24" length of 8" PVC Pipe (if it is UV resistant, you will not need to paint it)
- 6 X ¼" X 20 Bolts
- 9 x ¼" washers
- 3 sheets A4 paper and tape

The most efficient wind generators have a blade diameter of roughly 6 ft. and a total of 3 blades. If you find that 6 ft. is simply too large for your backyard than you can cut it back as needed. Don’t go much smaller than 4 ft. diameter otherwise it will be too hard for it to start spinning. Just make sure the shape and weight of each blade is the same.

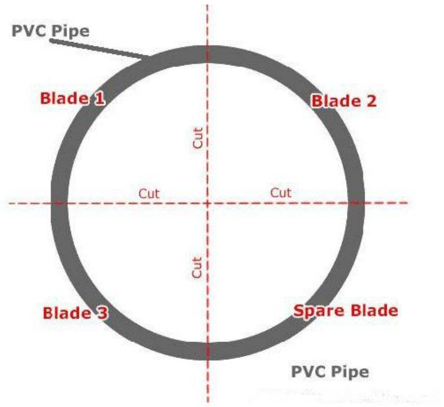
A backyard windmill will easily produce 300 watts of power and to do this output you will need to use a blade span of about 6 ft. with wind speeds of at least 20 miles per hour.

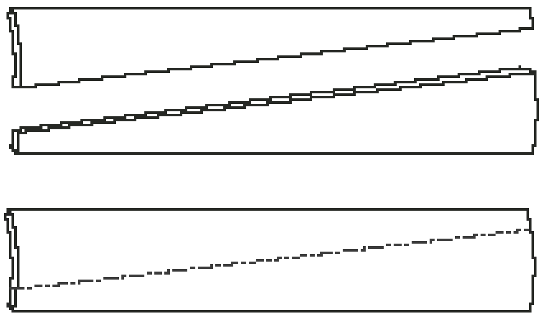
The best material to use to create your blade is ABS or PVC pipe. Pipe that is between 8 and 12” in diameter works the best.

Note: When using pipe, keep in mind these where intended to be used underground.

We recommend painting them with a UV inhibitor in order to prolong the life of your blades.

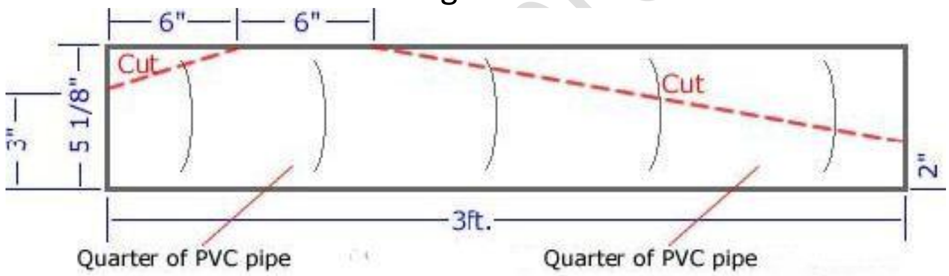
<u>Cutting the Blades</u>





You can use a jigsaw or angel grinder for this purpose. You'll want to cut the PVC pipe into a 3 ft length. Then cut the pipe into quarters as seen in the diagram: After you have cut the pipe into quarters you need to shape the blades.

Please see the below diagram for measurements.

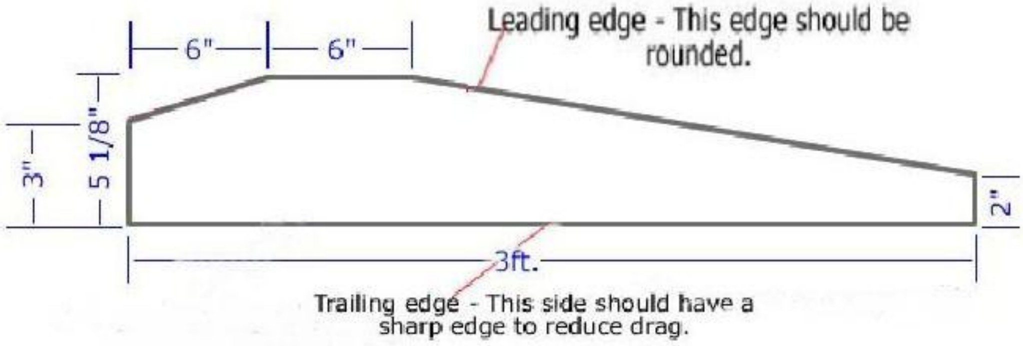


The wide part of the blade is what will help the windmill start spinning. The blade comes down to a narrow 2” tip as this will allow the windmill to spin at high speeds.

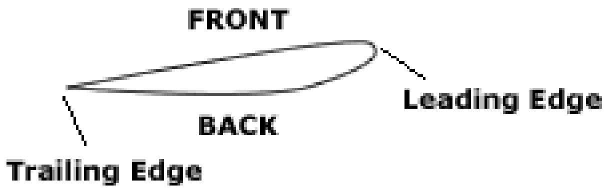
After the shape is cut you need to do some sanding/grinding. Make the leading edge rounded and smooth. This will allow the wind to flow over the top of it easier. Angel the trailing edge until it is sharp. This will reduce the drag from the blades as it spins around. Use an angel grinder to angle the edge you can then a sander to remove any rough parts.

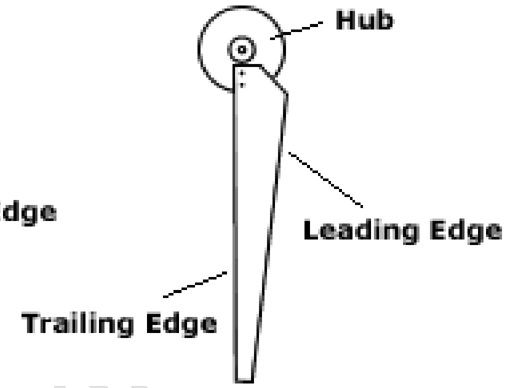
Sand the blades to achieve the desired airfoil. This will increase the efficiency of the blades, as well as making them quieter. The angled (leading) edge wants to be rounded, while the straight (tailing) edge wants to be pointed. Any sharp corners should be slightly rounded to cut down on noise

The below diagram shows what parts of the blade need to be shaped and grinded.



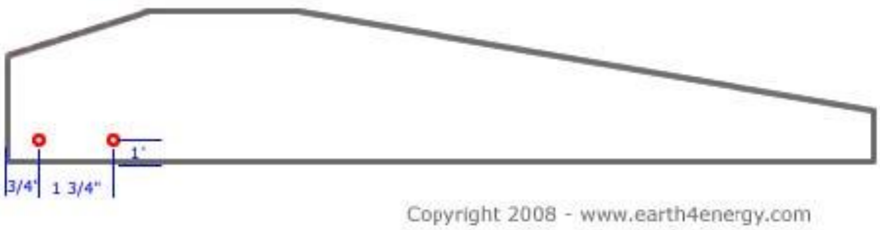
BLADE SHAPE





Now we need to drill a couple of holes. Bolts will go through the holes and attached the blade to the hub. The below diagram shows the placement of the holes when our hub design is used. If you plan to use your own hub from scrap metal than simply mark out the holes to suit your hub.

Note: It's a good idea to have the hub ready before drilling the holes in the blades. This way you can confirm the holes on the hub match the holes on the blade.

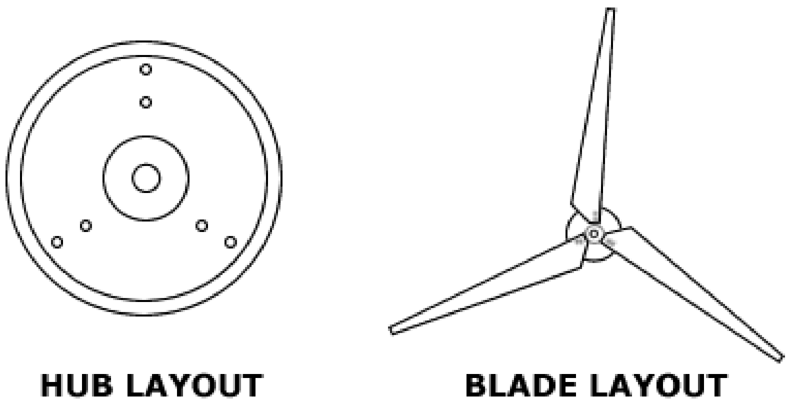


After you have finished one blade simply use the same above steps for the next 2 blades. You can use the extra piece of pipe and make a spare blade if you like too. When your blades are all shaped you should give them a sanding. This will help the paint stick to the pipe. Now that the blades are made its time to work on the hub.

Building the Hub

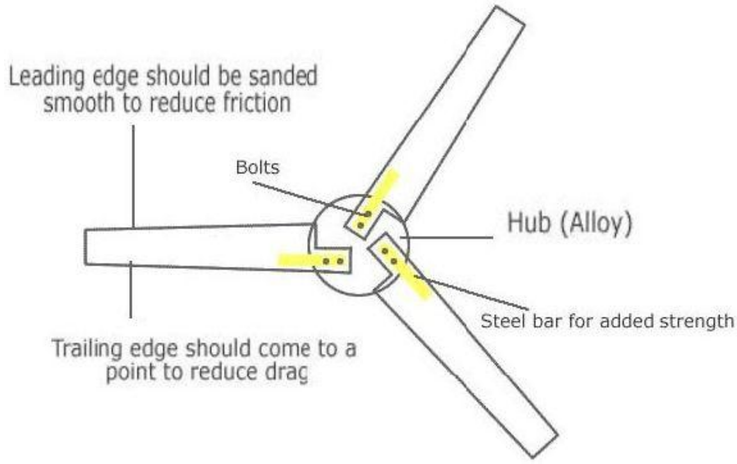
The hub connects your blades to the generator. These can easily be found at your local hardware store, on line, or even your local junk yard.

The hub must fit tightly on the DC motor shaft so that when the hub turns the motor will turn. Drill a hole in the very center of the hub that is the same size as the shaft on the motor. Attach the hub assembly to the motor later. The hub can be any old circular piece of metal or alloy and it should be quite strong. You can use old pulleys, cogs, saw blades (make sure to grind the edges smooth), etc. The part that connects the DC motor to the blades, the Hub's diameter must match the diameter of your motor exactly or it won't work properly. To make a hub, take a pulley that measures 6 inches in diameter and has a shaft the size of your motor diameter, then gather short pieces of 1/8 inch- to 1/4 inch-thick steel that measure about 12 inches long and 2 inches wide. You will use these to connect the blades to the hub. If you want to make your own hub then below is a template you can use. Mark this template out onto a piece of steel that is about ¼ of an inch thick.



Weld or bolt a coupling to the center of the hub. This is what the motor shaft will slide into and the coupling will hold the hub in place.

Attach the blades to the hub, and then the hub to the motor shaft. Flat steel bars, approximately a foot long and 2" wide work well to attach the blades to the hub. These bars will also add a lot of strength to the blades which will be needed for high winds. See the below diagram to see how it should look so far:



Once you have the hub assembly put together securely, it's time to move on.

Balance the blades and hub

Making sure the whole thing is balanced is a very important part. If it's not balanced it will not produce the expected output and over time will also ruin the motors shaft and bearings. Getting it correct right now will save you many headaches in the future.

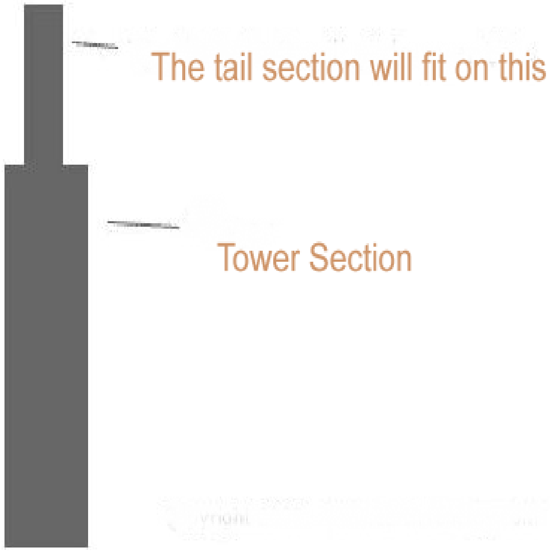
Here is an easy at home way to test if it is balanced. First, number each of the blades with a pen. Put the hub assembly on a pole and give the blades a good spin. Do this about 10 times and take note to what number blade is at the bottom each time. If you find that the same blade ends up at the bottom every time then you will know this blade is a little heavier than the others. To fix this you can shave a bit of the metal off the bars that hold the blades to the hub. Use a metal grinder to do this.

Mount the hub assembly to the DC motor

It's important that the hub assembly is tight and secure on the DC motor. Slide the shaft of the DC motor in the hole in the middle of the hub that we drilled before. To make sure the hub doesn't slide back out we can drill a hole through the end of the motor shaft and put a small bolt through it. Drill the hole in the shaft as far down as possible (when the hub is on) to insure the hub doesn't shake back and forth.

Building the Axis

You want the blades on your generator facing the wind at all times. For this reason, it's important to have it rotating on a horizontal axis when mounted to the tower. First let's take a look at what the top of your tower should look like.



If your tower does not have the smaller section on the top you will need to weld this piece of metal on. Make sure that the diameter of this piece is not wider than the diameter of the windmills tail shaft. The reason for this is because we will be drilling a hole in the tail shaft and it will slide over the top of the tower. Please see the diagram below:

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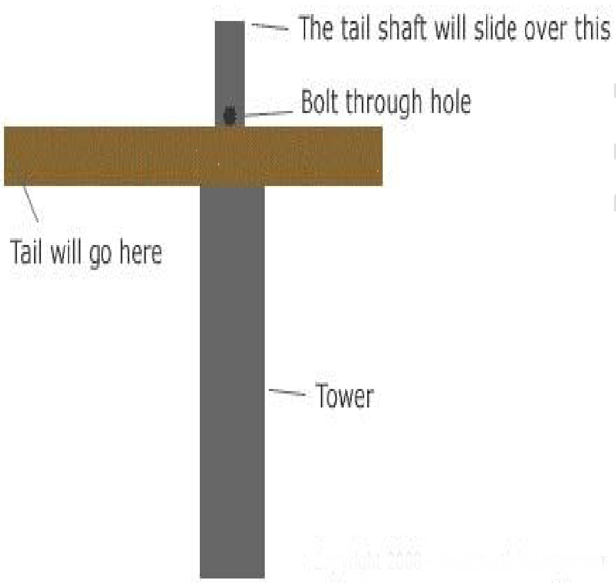
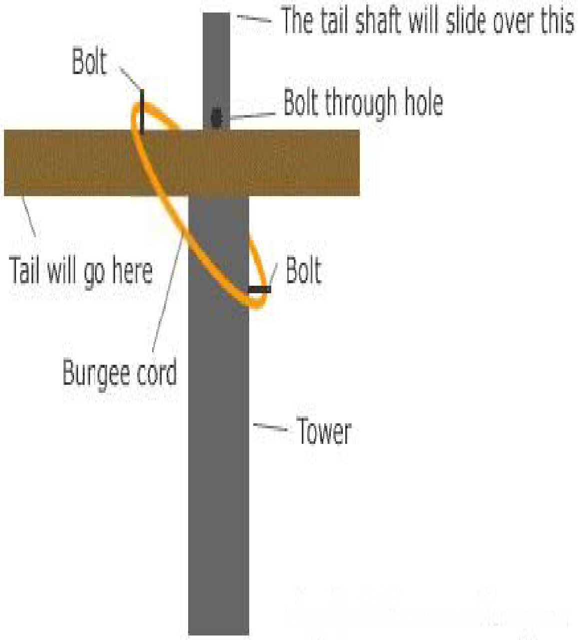


You will need to measure the height of your tail shaft and drill a hole through the top piece of the tower as show above. Make sure to drill the hole down far enough so that when we put a bolt through it, it will hold the windmills tail shaft in place. Now the shaft should be secure and it should be able to freely spin around the top of the tower. If it is tight you may want to grease up the top of the tower where the shaft spins around.

So this will allow the windmill to spin around so that the blades are always facing the wind, but how do we stop it from rotating wildly during high winds or severe storms? This is not something we want as it could tangle the wires and damage them. The easiest home fix for this is to use a bungee cord. You may think this sounds like a cheap little fix, and you are right! It is a cheap fix and that works very well.



up and tighten around the tower when it spins. The bungee cord is to be a loose fit so that the windmill can still spin 180 degrees without the bungee cord holding it back.

Another easy DIY rotating point is to use an old office chair (the ones that spin around). You can easily take apart these chairs and use the swivel section. This swivel can be welded to the top of your tower. Another way to mount your wind generator is listed below in the tower section.

You will need to use a couple of bolts to make sure the bungee cord doesn't slip

Step 7: Make the Mount and tail

Mount and Tail

The mount and tail should be sturdy. Weld the mount to the yaw pipe, if at all possible. Also, make sure your tail is on there good. If it vibrates, then add a bolt that goes all the way through the mount.

Tails are more effective if they are big, so don't skimp on the size. We like the metal casing of washers and dryers for our tails. Those cases will make a lot of tails, so make them as big as you can.

Balance of the mount and tail are extremely important. Without proper balance, the machine will vibrate and create stress everywhere. It will also be noisy. So, add weights, drill holes, and do whatever you can to get it as balanced as possible.

Tail

- 1 sqft (approx) lightweight material (metal)
- 2 X ¾" Self-tapping Screws

Building the Tail Section

The tailpiece is important for maintaining balance and ensuring that the blades maintain maximum efficiency. From our tests, a tail length of between 3' and 4' works the best. Simply cut out a tail shape from the metal and attach it to the back of the assembly. You can use any shape you like, just make sure it's large enough to catch the wind. You can fix it to the shaft simply by using a flat bracket.

The tail can also be made from plywood. Just make sure it is properly coated in UV paint to protect it from the sun.

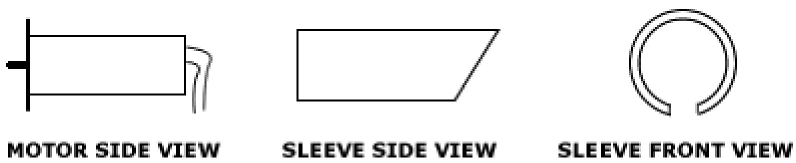
The exact dimensions of the tail are not important. You want about one square foot of lightweight material, preferably metal. You can make the tail any shape you want, so long as the end result is stiff rather than floppy.

The correct length of the wood is no too important. I used the best looking piece of scrap 2 X 4 off my scrap wood pile and going with however long it was. (step 8-Cut a protective shield for the motor) I also cut a piece of 4-inch diameter PVC pipe to make a shield to go over the motor and protect it from the weather. For a tail to keep it turned into the wind, I again just used a piece of heavy sheet Aluminum I happened to have laying around. I was worried that it wouldn't be a big enough tail, but it seems to work just fine. The turbine snaps right around into the wind every time it changes direction.

Here is another view of the completed head of the unit with the motor and tail attached.

Step 8: Make a Protective Sleeve for the Motor

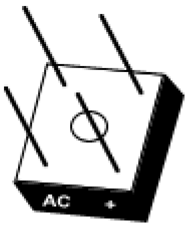
Making a Protective Sleeve for the Motor



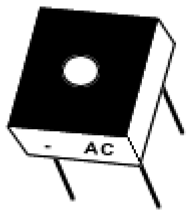
1. Draw two straight lines, about ¾" apart, along the length of the 3" x 11" PVC Pipe. Cut along these lines.

2. Make a 45º cut at the end of the pipe.
3. Place needle nose pliers inside the strip that has been cut out, and pry the pipe apart.
4. Making sure the bolt holes of the motor are centered in the middle of the missing strip of PVC pipe, push the motor into the pipe. An extra person will make this a lot easier.

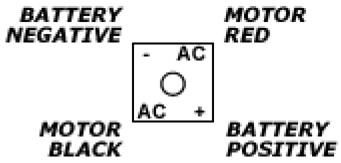
ASSEMBLY



DIODE TOP VIEW



DIODE BOTTOM VIEW



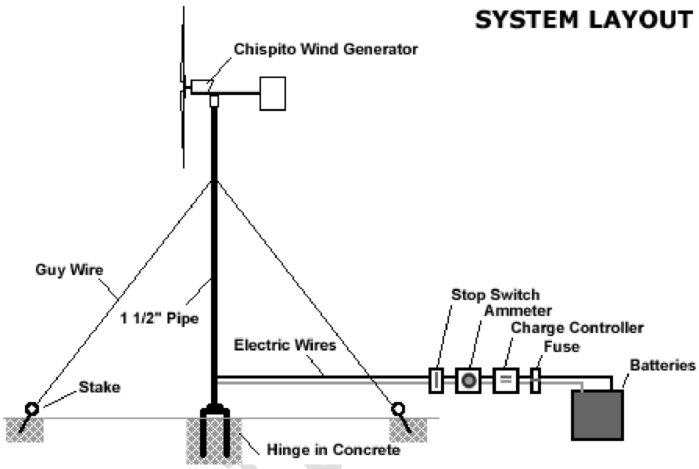
DIODE WIRING

1. Place the motor on top of the square tubing and bolt it in, using the two 5/16” x ¾” bolts.
2. Place the diode on the square tubing, about 2” behind the motor, and screw it into position using the self-tapping metal screw.
3. Connect the black wire coming out of the motor to the positive incoming terminal of the diode (Labeled AC on the positive side).
4. Connect the red wire coming out of the motor to the negative incoming terminal of the diode (Labeled AC on the negative side).
5. Center the tail over the square tubing, at the back end. Clamp your tail onto the side of the square tubing.
6. Using 2 self-tapping screws, screw the tail in place.
7. Place each blade on the hub so that all the holes line up. Using the ¼" bolts and washers, bolt the blades to the hub. For the inner three holes, use two washers per bolt, one on each side of the blade. For the outer three holes, just use one washer next to the head of the bolt. Tighten.

8. Hold the end of the shaft of the motor (which comes through the hub) firmly with pliers, and turn the hub counterclockwise until it tightens and stops.
9. Screw the nipple tightly into the floor flange using a pipe wrench.
10. Clamp the nipple in a vice so that the floor flange is facing up and level.
11. Place the square tubing (and everything that is on it) on top of the floor flange and move it so that it is perfectly balanced.

12. Through the holes of the floor flange, mark the square tubing at the point of balance.
13. Drill these two holes using a 5/32" drill bit. You will probably have to take off the hub and tail to do this).
14. Attach the square tubing to the floor flange with two sheet metal screws.

For a longer life span of your wind generator, you should paint the blades, motor sleeve, mount and tail.



You will need a tower, wire, ammeter, charge controller/regulator, and a battery bank for your Chispito Wind Generator.

Step 8: Make a Tower for your Wind Turbine

Tower Power

The tower is one of the most important components in your wind generator system. It must be strong, stable, easily raised and lowered, and well anchored. The higher your tower is, the more wind your generator will be exposed to. Guy wires must be placed at least every 18 feet of tower height. Guy wires must be anchored to the ground at least 50% of the height away from the base.

In general, wind plants should be installed on a tower at least 20 feet taller than the tallest object within 400 feet. A tall, lightweight, guyed tower topped with a small (1-

kilowatt to 10-kw) wind plant usually yields more bang for your buck than a larger wind plant positioned on a shorter tower.

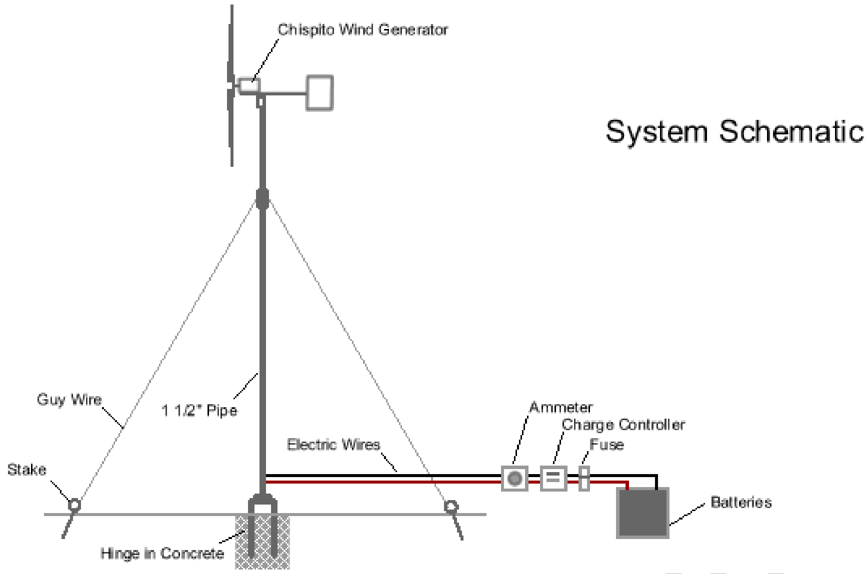
There are several reasons to mount a wind plant on a tall tower. One is to gain clearance above trees, houses and other obstacles that create turbulence and reduce the power of the wind reaching the wind plant. Wind acts like water in the way it flows across any topography. It is slowed by obstacles such as trees, ridges and rocks, and is channeled by the overall shape of the terrain.

The wind gets smoother at higher distances above the ground, it also increases in velocity. Most wind speed measurements are taken at a height of 6 feet because that's where wind affects us. But the wind speed is always greater higher above the ground. For example, a wind of 8 mph measured at 6 feet indicates a speed of 11.4 mph on a 36-foot tower and 13.9 mph for a 96-foot tower. *So what, you say, we've raised the tower 60 feet higher, only to increase the wind speed by a mere 2.5 mph?*

Remember the wind power formula: The power of the wind increases with the *cube* of the wind's velocity. So although the wind speed on top of a 96-foot tower increases just 25 percent compared to the 36-foot tower, the *power* of the wind reaching the taller wind plant increases 100 percent. The cost of an additional 60 feet of tower and rigging is generally less than the larger wind plant needed to give the same power increase

How to Build a Tower for a Chispito Wind Generator

A 1 inch diameter iron pipe is a good slip-fit inside 1 1/4 inch diameter steel EMT electrical conduit. I could use a long piece of 1 1/4 inch conduit as my tower and 1 inch pipe fittings at either end. For the head unit I attached a 1 inch iron floor flange centered 7 1/2 inches back from the generator end of the 2X4, and screwed a 10 inch long iron pipe nipple into it. The nipple would slip into the top of the piece of conduit I'd use as a tower and form a nice bearing. Wires from the generator would pass through a hole drilled in the 2X4 down the center of the pipe/conduit unit and exit at the base of the tower



SUPPLIES

Tools

- Pipe Wrench
- Vise
- Shovel
- Wheel Barrow (mix concrete)
- Wire Strippers
- Drill and Drill Bit

Materials

Base

- 2 X 2' X 1 ¼" Steel Pipe Nipple
- 6" X 1 ¼" Steel Pipe Nipple
- 2 X 1 ¼" 90 elbow
- 1 ½" Steel Pipe T

Pole

- 10 - 30 ft piece of 1 ½" Steel Pipe
- 2 pieces #8 Copper Stranded Wire (must be long enough to go through the pole to the batteries)

Guy System

- 1 ½" U-bolt
- 4 X Guy Wires, at least 25ft long (must be long enough to go from pole to stakes)
- 4 X Stakes
- 4 X Turnbuckles

ASSEMBLY

Base

1. Dig a hole about 1 ft in diameter and 2 ft deep.
2. Feed the 6" X 1 ¼" Steel Pipe Nipple through the horizontal part of the 1 ½" Steel Pipe T
3. Screw the elbows onto each end of the 6" X 1 ¼" Nipple.
4. Screw the 2 ft X 1 ¼" Steel Pipe Nipples into the elbows.
5. Set the hinge base in the hole, so that the T clears the ground. The horizontal part of the T should be level.
6. When the base is plumb and level in the hole, pour concrete into the hole.

Pole

1. Drill a large hole about one foot from the bottom of the 10 - 30 ft 1 ½" Steel Pipe for the wire to exit.
2. Screw the pipe into the vertical part of the T.
3. Make 4 loops of wire, each loop consisting of several turns of wire.
4. Place the 1 ½" U-Bolt round the pipe, 3 feet from the top of the pipe, threading it through the four loops you just made.
5. Move the loops so that they are equally spaced.
6. Tighten the nuts of the U-Bolt.
7. Secure a guy wire to each of the loops on the U-Bolt.

Guys

1. Put the four stakes (spaced evenly apart) about 12 feet from the base.
2. Drive each stake firmly into the ground, slightly angling them away from the base.
3. Wire a turnbuckle to each stake, using several strands of wire.
4. Raise the pole upright and level.
5. Attach the guys to the turnbuckles.
6. Hold the pole level and tighten all turnbuckles to ensure a secure fit.
7. Mark the front turnbuckle for future reference.

Wiring

1. Release the front guy and lower the pole to the ground.
2. Feed the #8 wires down through the pole an out through the hole in the bottom of the pipe.
3. Wrap the bottom ends of the wires together to provide a closed circuit.

Mounting the Chispito Wind Generator

1. Slide Chispito over the top of the pole.
2. Pull the wires up through Chispito.
3. Wrap the positive (red) wire from Chispito to the positive (red) wire going through the pole. Secure the connection, and use either wire nuts or heat-shrink connectors. Do the same for the negative wires.
4. Raise the pole by pulling the front guy into place. Tighten the front guy to the mark made earlier.
5. Unwrap the ends of the wires and connect them to the positive and negative terminals of your battery bank. If you have a charge controller and/or ammeter, please refer to manufactures instructions for system wiring.

Sizing Your System

Now That all the mechanical parts were sorted out, it was time to turn toward the electronic end of the project. A wind power system consists of the wind turbine, one or more batteries to store power produced by the turbine, a blocking diode to prevent power from the batteries being wasted spinning the motor/generator, a secondary load to dump power from the turbine into when the batteries are fully charged, and a charge controller to run everything.

There are lots of controllers for solar and wind power systems. Anyplace that sells alternative energy stuff will have them. There are also always lots of them for sale on ebay. I based my unit on the schematic of the one found on this web site:

Determining your system's size can help prevent overuse or damage to system components down the line. Start by evaluating your appliances in your home. Record how many hours a week you use the appliances and how much energy each consumes, in terms of watts. For instance, a lamp with a 40-watt bulb (an extremely inefficient light bulb these days!!) that is on for 5 hours a day will use 40 watts for 35 hours a week, or 1,400 watt-hours a week.

Once you get your typical energy consumption for a week, you can design your system to generate enough power in a week to keep your batteries fully charged. Your battery bank should be able to last you at least one week without any energy coming in. Say you want a battery to cover the above 1,400 watt-hours a week. At 12 volts (volts*amps=watts or watts/volts=amps), your battery bank will need a capacity of at least 117 amp-hours.

Your sources should be able to keep your batteries fully charged all the time. Lead-Acid Batteries should never go below 80% capacity for a longer life. In a general day, your sources should be able to completely recharge your bank. So, for the above example, we will need to produce 117 amp-hours at 12 volts in a week, or 16 amp-hours a day. Sources will be rated in watts, but their outputs can vary. A 120 watt solar panel is producing 15-18 volts and 6-8 amps. It will produce less in the morning and evening, but in our area, we can get 25-30 amp-hours average daily from our 120-watt solar panel.

So, now we are producing more than we are using. Is this a problem? Not really. This is actually good, and the system should be designed to use this extra energy for something useful. Water Heaters work great for this as a diversion load for your system. When your batteries get full, the diversion controller turns on the water heater and uses the energy coming in from the source. The controller and diversion load should be designed to handle the maximum output of all the sources. Diversion loads can be stacked to come on at different intervals, giving your system a sliding scale, depending on how much power is coming in at the time.

Once the usage, storage, and source capacity has been determined, you will need to decide how to use the energy. What appliance will be on 12 or 24 volt DC and which ones will be run through an inverter? Your inverter should be sized 25% larger than your biggest draw. Inverters are rated in watts and have a surge rating, but most users have found that surge ratings are useless. So, the above lamp is pulling 40 watts, so we would need at least a 50-watt inverter convert to 120 volts AC.

Wire size can play a big role in the efficiency of your system. For DC, wires should be copper stranded and as large as possible for lower line loss. The inverter should be as close to the batteries as possible and should use a big battery cable.

Chapter 4 Storage - Batteries

Storing the electrical energy that has been converted by your source is the hardest part of the home-energy process. Most systems use lead-acid batteries, which cannot be constructed very easily in your average home workshop. Still, they are efficient compared to the cost, and along with conservative energy use, deep cycle batteries can play a very important role. Lead-Acid battery systems can be any voltage, but most people use either 12 or 24 volts. Install a controller. Without a controller, your batteries could become overcharged, thus destroying them. To prevent this type of damage, install a controller between your windmill and your battery bank

So, what is a battery? A battery converts the electrical energy from your generator or solar panel into chemical energy by means of a specific chemical reaction. When you need to use electricity, the battery reverses the chemical reaction and releases electricity. Batteries come in all shapes and sizes, but for most small home systems, deep cycle lead acid batteries are used. These batteries can be found in most cities, and have many applications including golf-carts, forklifts, and telephone lines. Lead-Acid Batteries are rated in Amp-Hours, which means they contain a certain amount of time at a particular electrical draw. A 200 amp-hour battery with a 20-amp draw will be discharged in 10 hours of use. So, if you had a lamp that pulled 2 amps, you could light a room for 100 hours.

Most batteries in this class come in 6-volt sizes, but most appliances are at least 12 volt. To get around this, we use two 6-volt batteries, wired in series, to get one 12 volt battery. Then, our 12-volt batteries are wired in parallel to give us more amp hours. Our system voltage is always 12 volts.

Because batteries are expensive and are not the most environmentally friendly component, you will want to make them last as long as possible. Checking the water level regularly is vital, and should be part of your general maintenance schedule. Another key factor in the lifespan of your batteries is not leaving them drained too low for too long. We have learned the hard way, and it has cost us dearly. Now, we try not to drain our system below 12.0 volts (a battery is full at 12.6V), and so far we have been very pleased with the performance of our battery bank.

One thing to note when reading the level of your batteries is that you will only get a true voltage reading when there is no power coming in. For example, if there is no wind or sun, and hasn't been for a while, your voltage reading will tell you exactly what your batteries are sitting at, 12.6v being the maximum. However, when the wind is blowing, your voltmeter might read anywhere up to 14.6. This is because you are reading an average of what your batteries are sitting at and what is coming in. The closer the batteries are to full, the less the act as a voltage buffer, and the voltage rises faster.

Chapter 5 -Controls/Regulation

It is important to include electronic controls for your home energy system. Electricity coming from the source should be regulated against overcharging your batteries, and your appliances should be guarded from overuse.

Regulating your sources can be done in several ways, most commonly, using a charge controller. The charge controller can read when your batteries are full, and subsequently cuts out the source, so that no more power comes in. Then, when the level of the batteries drops a little, the charge controller will switch the source back on. Of course, if the charge controller cuts out the source, there is effectively a bunch of power that is being wasted (not being used). To counteract this, you can use a diversion, or dump, load, which uses up the excess energy when your batteries are full to power something like a hot water heater or air compressor.

Manual cut-off switches are essential for safety purposes. If you need to work on any part of the system, it helps to have a way to easily shut off any electricity coming in.
Your system should always be fused between the source and the battery, and also between the battery and the appliance. That way, if something should happen, the fuse will blow, interrupting the circuit, and your components will remain unharmed. Fuse your system as close to the batteries as possible.

You will also want a voltage meter to check the state of your batteries and an ammeter on each source to show how many amps your source is generating. Proper system health can be achieved with the proper controls, regulators, and metering.

240 Watt Direct Grid Tie Inverter - For Wind or Solar
The easiest most cost effective way to tie your small homebuilt wind generator directly to the utility grid is right through an existing 110 volt outlet. Hook this unit up to 200 watts of solar panels, and then plug it in to an existing 110 outlet.

OR
Wire up two small 12-volt riding lawn mower batteries in series for a 24-volt bank to act as a buffer between your small wind generator and the inverter, then plug the inverter into an existing 110 outlet. Stack as many units as you have input power for. Hooking up a Grid Tie system has never been easier! It's a Do It Yourself dream come true.

Grid-Intertied solar power system

This is the type of solar power system you should use if you a still using power from the grid. This is also known as ongrid, grid-tied or a utility interactive solar electric system. If more electricity is produced by the solar system then that is used by the household loads then this will actually turn the electric meter backwards. When this happens it will credit your account and you can use this for future month's power usage when less electricity may be produced (periods of cloudy weather). This arrangement is called net metering or net billing. Please consult your local electricity provider or stats regulatory agency for further information. A simple grid-intertied solar power system consist of:

1 Energy source – Solar panels
2 Array DC disconnect
3 Inverter
4 AC Breaker panel
5 Household loads
6 Kilowatt per hour meter
7 Grid

Grid-intertied solar power system with battery backup

A grid-intertied solar power system with a battery backup consist of:

1 Energy source – Solar panels
2 Array DC disconnect
3 Charge Controller
4 Deep cycle battery
5 System meter
6 Main DC disconnect
7 Inverter
8 AC Breaker panel
9 Kilowatt per hour meter
10 Grid
11 Household loads

The battery backup is used for times of cloudy weather or if maintenance is needed on the system.

Off-grid solar power setup

The off-grid solar power setup. In this setup a generator is needed to keep the battery charged when the sun doesn't shine

1 Energy source – Solar panels
2 Array DC disconnect

3 Charge Controller
4 Deep cycle battery
5 System meter
6 Main DC disconnect
7 Inverter
8 Generator
9 AC Breaker panel
10 Household loads

Chapter 6 The parts and what they do

Solar panels

Otherwise known as PV panels they a solar-electric system's defining component. PV panels capture the sunlight and create direct current (DC) electricity.

PV panels are rated in watts based on the maximum power then can produce when performing under ideal sun and temperature conditions. You will need to use the rated output of your PV panels to determine how many panels you will need to meet your electrical needs. You can then combine the PV panels in a series, which is called an array. We will talk about different wiring configurations later in this book.

DC disconnect

The DC disconnect is an important part of a system for maintenance. Using a DC disconnect makes shutting off the power much easier.

charge controller

A charge controller will drastically increase the life of your battery. This unit will protect the battery from being overcharged. When the battery bank is fully charged, the charge controller will interrupt the charging process. Some charge controllers also stop the battery from discharging at night time.

Deep cycle battery

This is the type of battery you should use in your system. This is what will store all of the energy produced by your PV panels. A great source for free deep cycle batteries from is old golf carts or forklifts.

System meter

A system meter is used to monitor how full your battery bank is. You can also see how much power is being used at any time. This is a great unit that can monitor your whole solar electric system.

Main DC disconnect

This unit is placed between the battery bank and the inverter. A main DC disconnect will allow you to disconnect the inverter for maintenance.

Inverter

The inverter is what turns the direct current (DC) into alternating current (AC). AC is what most of your household appliances use. Eg. Refrigerator, TV, VCR, Computer etc. etc. If you do not wish to use any appliances that need AC then you can simply use a DC input. A DC input costs around $10 from any car parts store.

You can also purchase inverters that plug into your homes power socket. These inverters will actually feed electricity back into your home through a normal power socket.

Generator

If you are setting up a solar electric system for off-grid living you will need to use a generator. A generator is used to produce electricity for times of cloudy weather or for when you are performing maintenance on the solar electric system.

Electrical panel Box

This is the point where all of the homes electrical wiring meets with the provider of the electricity, whether it is the grid, a solar electric system or a wind electric system. This unit is usually found in a utility room a garage of or mounted in a metal box on the outside of the building.

Each state/country has different standards for the way solar energy is connected to the AC breaker panel. For a grid inter-tied solar electric system you have to realize that in most countries it is illegal to hook up your solar energy system to the AC breaker panel unless you are a qualified electrician. At this point we recommend you call your local power company or an electrician.

If you do not wish to go as far as connecting your system to the breaker panel you can simply run your appliances straight from your AC inverter. Running your appliances straight from the inverter is easy and a very cheap option.

Electrical kilowatt per hour meter

If you home is grid-tied you will have a kilowatt per hour meter. This will monitor both the electricity coming from the grid and to the grid from your solar electricity system. If you are producing more electricity then you are using, you will notice you are actually turning this meter backwards!

Grid (utility grid)

The grid is the main power supply coming to your house (unless you are living off-grid of course)

Household loads

The household loads consist of anything in your home that uses power from your AC breaker panel. This includes anything that you plug into the wall.

Chapter 7

Obtaining free solar panels

To save even more money I'm going to give you a neat little tip that has literally saved me thousands. I will tell you exactly how I manage to get all of my solar panels for free. Now if you prefer to simply purchase your panels that's fine. I am just offering this information as you may be able to save some money.

Now you will often see signs around construction sites that are solar powered, (which is great) from time to time these signs will get damaged from drunk drivers or rubber-neckers passing through construction areas. Look closely at the signs and you will find a sticker with the phone number of the traffic sign rental contractor. Write down this phone number!

Ask for the shop maintenance manager or head mechanic and ask him for free damaged panels. Just about all traffic rental sign contractors have free solar panels that have some cracks or are slightly damaged. They replace them and throw away the damaged ones. We started asking for them and they let us have them for free. Most of the panels worked fine but didn't work at 100%. When they are free, who cares!

Test and repair the damaged panels as needed, cracks can be resealed with clear silicone. Wiring can be soldered back together. Also remember to leave your details with the company that gave you the free solar panels as they may have more in the future.

Another place to get free (or massively discounted) solar panels from is actual suppliers of the panels. Many home owners who have had solar panels for years will upgrade their panels. The old panels usually get thrown away because they are not the latest and they cannot be sold. This is where you swoop in and claim them.

All you need to do here is call some local solar power companies and ask if they have any old panels that will be thrown out!

If you cannot get any free panels from the above methods then do not give up hope. We have sourced MANY cheap solar panels from eBay. Buying these online are usually much cheaper than buying from large companies.

Chapter 8: Build Your Own Solar Panels

To build solar panels as cheaply as possible you will need the list of the parts below:

Solar cells: Obviously the most important part. The BEST place for old broken solar cells is again eBay. This time search eBay for “chipped solar cells” or “broken solar cells” etc. Below are a few listings that we have found and you can see that these are seriously cheap. All we need to do is fix them up! If you want to spend a little extra than just purchase solar cells that are not broken as it will make the project that much easier. You can also use complete/unbroken cells.
It is a good idea to get complete cells for your first project.

Strong plywood: This will be the backing to hold all of the cells. About 1/2 to 3/4 is enough. Don’t go out buy expensive hardwood as we are going to cover the wood in UV protector anyway.

Wood: We will make a wooden border around the cells. This is what we will fix the plexi-glass too. Picked this up from your local hardware store. Make sure it is not too thin because it will split when screwing it to the plywood backing and border.

Plexi-Glass: This is used to go over the solar cells to make the whole unit one piece. The flexi-glass should be about ½ an inch think. You can buy this from your local hardware store. Just give them the measurements you are after and they will cut it for you. It is a good idea to get this last so you will know the exact measurements.

Tin coated tabbing wire: Used to connect the cells together. This looks like a shiny silver flat wire. When the solder iron heats it the solder will melt and bond with the cell. Get 100 ft of .006 x.08 and 10ft of .008x .197. The thin wire is used to connect each cell together and the thicker wire is to join each string of cells together.

Silicone: This is what we use to hold the cells onto the plywood and the plexi-glass to the border.
Solder: We need the solder to hold the copper wire onto the back of the solar cells. The tin coated tabbing wire will usually hold itself down but if it doesn’t you will need extra solder to do the job.

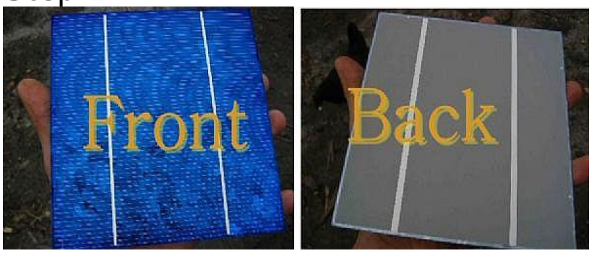
Rosin flux pen(or caulk): This is used to help the wire stick to the cells.

UV Protector: The Plywood needs to be coated in UV protector so that it will last longer out in the sun.

Volt meter: This is used to test the cells power output. You can get these from your hardware store for around $10. You can also buy them online for less. As you connect each cell together you can check the volts. They should increase with each new cell connected.

Let's get started

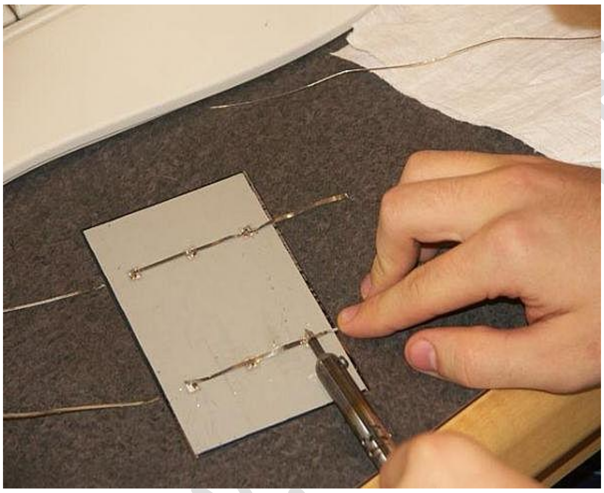
Step 1.



front and back view of a solar cell

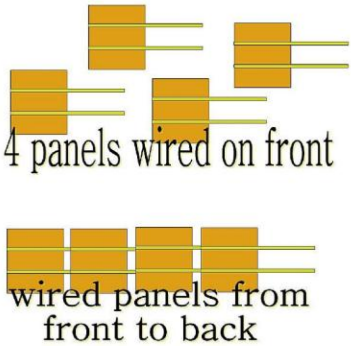
Join the solar cells together to form the circuitry. The first thing you will need to do is solder wire along the front of the cells. The wire should be twice as long as the cell and you will see why we do this soon. You should use the flat solder coated wire that is specifically made for joining solar cells.

Arrange all of the cells face down on the floor. On the back of the cells you will see little tabs. You will need to drop a small amount of solder onto each of these tabs. This will make it easier when it comes to soldering down the copper wire. Depending upon what type of solar cell you buy you will either have clear lines like the ones pictured or you will have tabbed cells. The tabbed cells look very similar except that the back will have metal squares instead of full lines. Both types of solar cells will work for building your own solar panel.



Forming the circuitry

Step 2



Series

Stay consistent in size of solar cells as well as energy output, this is to say that all your solar cells should be rated to produce the same amount of energy. Use enough copper wire to flow the length of your cell series so that you are essentially using the same piece of wire for every panel in that row

.

Step 3

Pen style Soldering Iron

When soldering your copper wire to your solar cells you will use an acid core solder. This material is cheap and easy to work with. Solder in a good solder gun will flow very freely so it is important to take care and get it only on the spot where it should go. Use a pen type soldering gun to join solar cells. This makes application very easy.

Step 4

The solar cells will be wired in a series starting and ending with the same polled solar cell. Series connection means the wires go from negative to positive to negative to positive etc. This type of connection will increase the total voltage of the solar panel. If each cell produces .5 volts and there are 32 connected in series, this complete circuit will produce 16 volts. So the above panel with 32 cells would produce about 64 watts of power at 16 volts and about 4 amps.

If you start with a positive solar cell you end with a positive cell, the same applies to a negative series. The front of a solar cell is the negative side, the back is the positive side. When you are attaching your copper wire with solder you determine the poll of your solar cell. If you solder copper wire to the front of your solar cell you will be starting the series with a negative cell. You would solder the next cell in the series on the back to produce a positive alternating until you end with a negative. The points on your solar cell where you attach solder and your copper wire should be slightly silver. If these points are white you can lightly scratch them with the blunt end of a pair of tweezers. This step is crucial to getting a solid contact on the solar cells.

Step 5

Wiring a Series

You will always have an odd number of cells in a series, and you will always have an even amount of series that make up your panel. A solar array can be made up of a number of panels to produce the amount of electricity you need.

Positive and Negative polls

Notice that the positive and negative wired series are on opposite sides of the panel this is because you do not want these wires to accidentally touch one another. All the solar cells are facing the same way, the diagram Is colored differently to show you the under over or over under wiring pattern.

Over and Under explained

I have included a diagram that more clearly identifies where your top soldered and bottom soldered wires should be in a solar cell. This is a very hard thing to teach in a 2d application. I hope that the inclusion of this diagram has clarified the soldering order of cells.

Step 6

Complete Homemade Panel

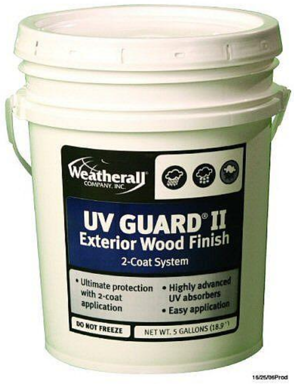
In the photo above you can see that an odd number of cells is used to achieve a series and that the series are ending on opposite sides. If you look closely 9 solar cells are used to produce a cell series and 8 series of solar cells are used to produce your panel. Now that you have the wiring figured out we can proceed to put the solar panel together

Putting it all together

Step 1.

Cut your plywood/plastic backing to size depending on how many solar cells you have. The individual solar cells will be glued to the plywood. The average cell produces about 2 watts so you should use 50 solar cells because this will produce a neat 100 watts of power. For more power wire multiple panels together. You can see in this picture that holes were drilled through the frame of the box to provide ventilation. As your solar panel is exposed to extreme temperatures this will keep your box from warping in the heat of the sun. This is an optional step that can save you money in the long run.

Step 2.



Apply 3 coats of UV protector to the plywood. Deck or fence sealers will work as well as paint however you will need to use many coats. The goal is to keep the damaging UV rays of the sun from damaging your wood.

Step 3.

Cut A layer of Masonite peg-board to fit loosely in the wells and after being coated with UV guard placed inside the solar panel box. The solar cells will be attached to it for easy maintenance if a problem should occur. You can also use cardboard, or any other non conductive material

Step 4.

Caulk on the cells.

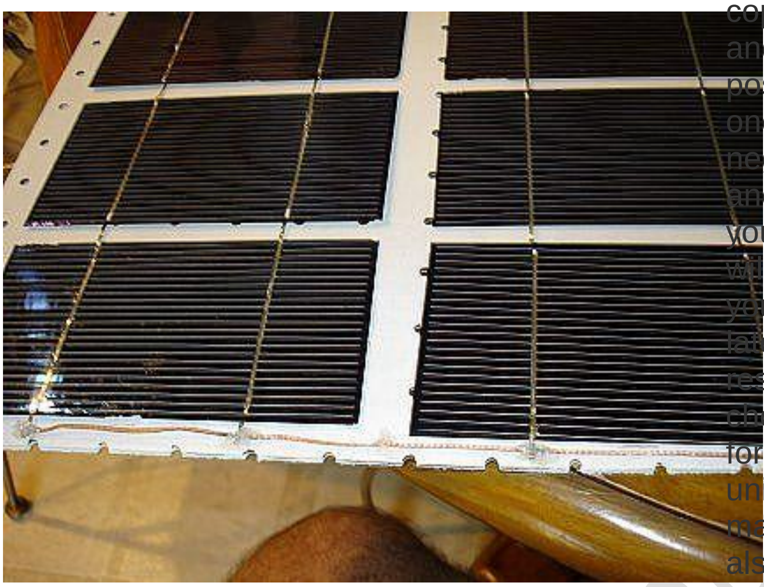
When attaching the solar panel to the substrate you want to be careful not to damage it. Add some caulk to the center of each cell, just a little is more than enough to hold it in place. You do not want to apply so much caulk that you glue them down completely as this will keep them from moving with the wind and break your cells. Using caulk in the middle of your solar cells is the easiest way to combat this problem and prolong the life of your solar array. You can use all purpose silicone caulking even the cheapest will work.

Step 5

Testing

Lay your substrate material on to the solar cells positioning carefully and allowing the caulk to dry. Once everything is dry you can flip your assembly over and fit it inside your homemade panel box.

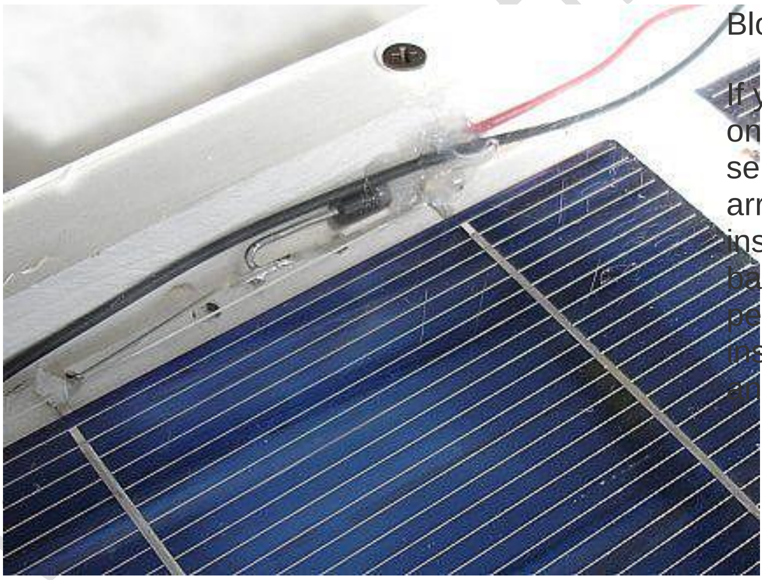
Step 6



Wired together

Using 2 pieces of properly gauged copper wire attach your positive leads and negative leads in series. Your positive leads should all be soldered to one piece of copper wire and your negative leads should be soldered to another piece of copper wire. This gives you a positive and negative terminal that will be leaving your box. Drill holes for your copper wires to leave the box and later be wired into your inverter. In the resources section is a guide for choosing the right type of copper wire for your application. Solar panels are unique to the homeowner and your materials for building it will be unique also.

Step 7



Blocking Diode

If you are using 2 different panels inside one box they need to be wired in a series as well. Each panel in a solar array needs to have a blocking diode installed to prevent damage to your batteries and inverter. Install this diode per the manufactures instructions. This insures that your solar power equipment and home will be safe.

Step 8

Plexiglas Top

Once you have everything wired up and working properly you can install your Plexiglas top. Drill pilot holes to keep your Plexiglass from breaking using an appropriate sized drill bit. Take caution as you do not want to apply too much pressure to your Plexiglas. Use a bead of caulk around the edge of your box, line up the Plexiglas and screw it down. You can add any edging that you wish remember the box can be as simple or elaborate as you wish.

1. Step 9

Installed your panel in a Window

Be creative in your choice of panel materials. I have seen old windows and new windows be used in homemade solar panel construction. This is a great way to ensure your panels stay out of the elements, especially if you have south facing glass or angled glass on your home.

Maintenance of your solar panels

You should clean your solar panels at least once per year to insure maximum performance.

- Confirm that the correct battery type has been selected.
- Confirm that the current levels of the PV (Photovoltaic) array and load do not exceed the ratings.

- Tighten all terminals, inspect for loose, broken, or burnt wire connections. Be certain no loose strands of wire are touching other terminals.
- Check that the charge controller is securely mounted in a clean environment. Inspect for dirt, insects, and corrosion.
- Check that the air flow around the charge controller is not blocked.
- Confirm that water is not collecting under the panel cover.
- Check that the charge controller functions and LED indicators are correct for the system conditions at that time.

To clean the panels use non-abrasive cleanser and paper towels. The surrounding environment and the amount of road dust encountered determine how frequently the panels should be cleaned. 4 times per year is preferred.

A critical part of maintaining the solar powered battery charging system is keeping the panel clean. The amount of power that a panel will produce is directly related to the intensity of sunlight that reaches the internal crystals. A dirty panel will allow less light to reach the crystals resulting in reduced power output. A layer of dust or road grime can reduce power output by 15 to 25%. Combining dust with leaves and debris that cover two or three of the individual cells can reduce output power by 50 to 75%.

Use of the basic maintenance tips, regular inspections and regular cleaning will assure maximum performance from the solar charging system.

Chapter 9

Solar hot water Systems

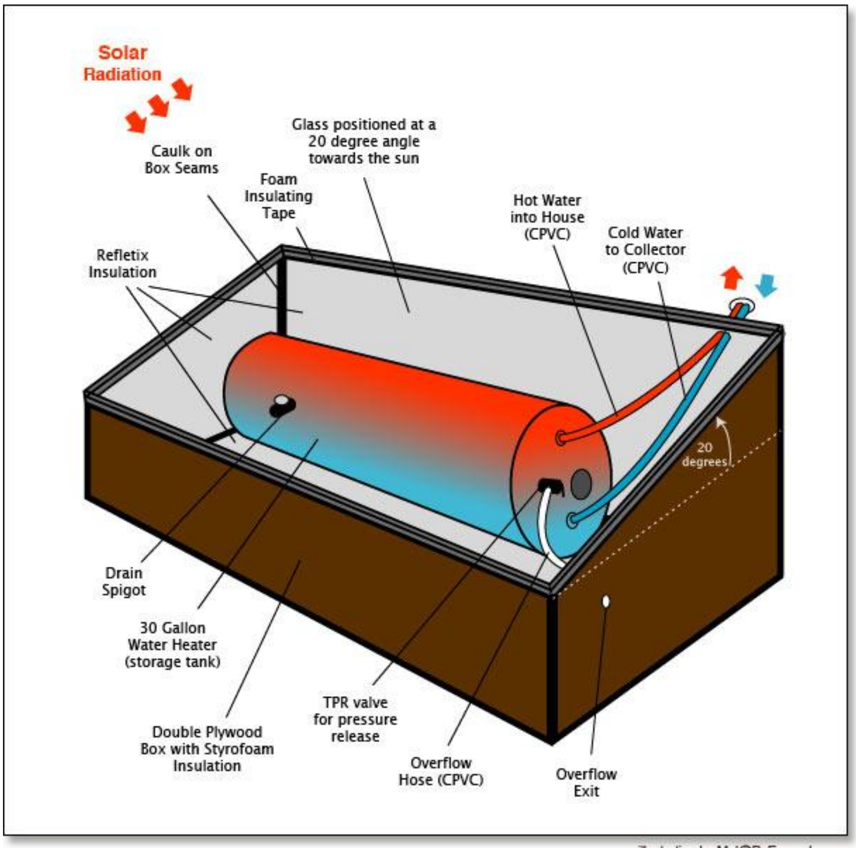


illustration by Mel@ByExample.com

How to build your own DIY SOLAR HOT WATER SYSTEM for under $150.00

Solar Hot Water Basics

While most people are captivated by the high-tech nature of solar-electric (photovoltaic; PV) systems, in most cases, a solar hot water system will harvest more energy at a substantially lower cost. In fact, compared to PVs, solar hot water (SHW) collectors are more than three times as efficient at producing energy from the sun.

Investing in an SHW system is a smart solar solution for most homeowners. This proven and reliable technology offers long-term performance with low maintenance. And with federal, state, and utility incentives available, these systems offer a quick payback—in some cases, only four to eight years.

A thoughtfully designed SHW system could provide all, or at least a significant amount, of your household hot water needs for some portion of the year. The California Energy Commission estimates that installing an SHW system in a typical household using electric water heating can shave 60 to 70 percent off water heating costs. To get the most for your money, you'll want a properly sized system that offers the best performance in your climate.

Solar Hot Water System Types

Five main types of solar water heating systems are sold today. These five are a distillation of dozens of types sold over the past 25 years. They are:

- Batch
- Thermosyphon
- Open-loop direct
- Pressurized glycol
- Closed-loop drain back

The proven winners are simple, reliable, and long lasting. Some systems are "open loop" (the domestic water itself is directly heated) and some are "closed loop" (a heat-transfer fluid is heated by the collector and the heat is passed on to the domestic hot water by means of a heat exchanger). Some systems are "active," using moving parts such as pumps and valves, and others are "passive," using no mechanical or moving parts.

There are many considerations in choosing the best system for a home, but the client and the situation will dictate the right system.

For instance, for a one- to two-person household in a temperate climate where hard freezes rarely occur, you might go with a batch heater, especially if the hot water will be used more at the end of the day rather than first thing in the morning. In a household with three or more people, where aesthetics and weight are not an issue, the Thermosyphon system might fit the bill, especially if there's no room for an additional tank near the existing water heater.

The drain back system, a personal favorite here in the Northwest, requires continuous drop between the solar collector and the solar storage tank. If continuous fall is not possible, there's always the pressurized glycol system where piping can go up, down, over, and around without concern. Usually more than one option can work for any situation.

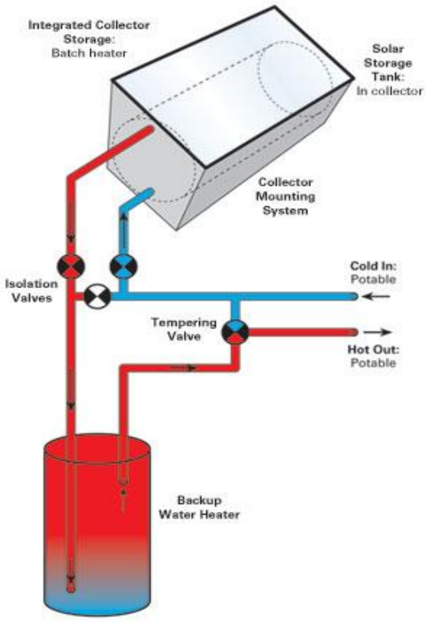
The number of people in the household will dictate how large the system will need to be, and which systems are even possible. Rebate and incentive programs may only qualify certain systems in a given area. Some systems are relatively easy to install for do-it-yourselfers, while others most laypeople shouldn't attempt. See the comparative chart showing features of the different system types. Make your choice, and enjoy using solar energy to heat your water!

Characteristic	Batch	Thermosyphon	Open-Loop Direct	Glycol	Drainback
Low profile—unobtrusive in appearance			✔	✔	✔
Lightweight			✔	✔	✔
Freeze tolerant				✔	✔
Easy installation & infrequent service	✔	✔	✔		
Passive operation—no pumps or controls	✔	✔			
Space saving—storage tank unnecessary	✔	✔			

Solar Batch Heaters

For a hundred years, simple solar batch heaters have been used in the United States. The term ICS (integrated collector storage) tells us that the collector and storage tank are combined into one unit. A tank of water, enclosed in an insulated box covered with glass, is placed in the sun facing south. Cold water is piped to the bottom of the tank; hot water is taken off the top. Whenever there's a call for hot water, water pressure from the home moves hot water from the top of the solar batch heater as cold water is pushed into the bottom.

Since the potable water is heated directly, this is an open-loop system. And since no pump is used to move the water from collector to end use, it is passive. The batch heater is a popular choice for homes in moderate climates where freezing is not much of an issue. Commercially manufactured batch heaters are relatively low cost. Crude batch heaters can even be homemade. If batch heaters are installed on the roof, weight has to be taken into account. Commercial batch heaters can weigh 200 pounds (90 kg) dry, and when filled with 40 gallons (150 l) of water, more than 320 pounds (145 kg) is added.



Because of their relatively low cost and simplicity, for those living in moderate climates with good sunshine available, the batch heater is probably the best value for heating domestic water.

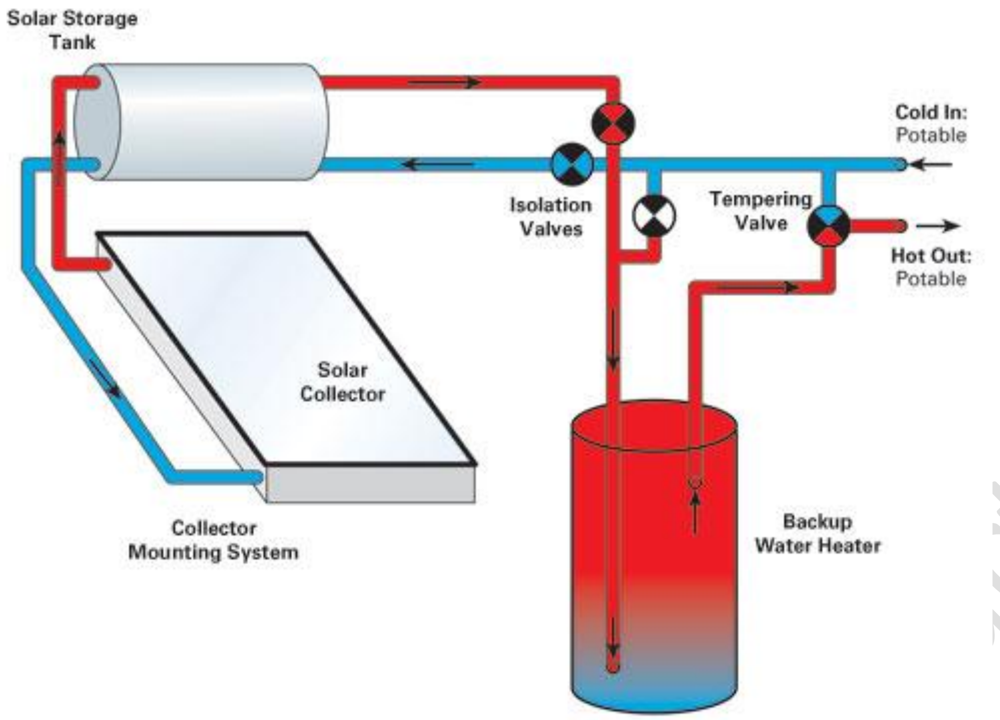
Thermosyphon Systems

Another relatively simple, passive system, and the most popular solar water heater worldwide is the Thermosyphon. Common in Japan, Australia, India, and Israel, they are easily recognizable because the tank must be located directly above the collector.

Thermosyphon systems work on the principal of heat rising. In an open-loop system (for nonfreezing climates only), potable water enters the bottom of the collector and rises to the tank as it warms. In colder climates, an antifreeze solution, such as propylene glycol, is used in the closed solar loop, and freeze-tolerant piping, such as cross-linked polyethylene (PEX), is used for the potable water lines in the attic and on the roof.

Several international manufacturers make Thermosyphon systems. The advantage of this system over the batch heater is that solar heat is stored in a well-insulated tank, so hot water can be used any time, without the penalty of overnight losses.

The following illustration includes the primary components of any Thermosyphon system. See our Solar Hot Water System Components section for an introduction to the function(s) of each component.

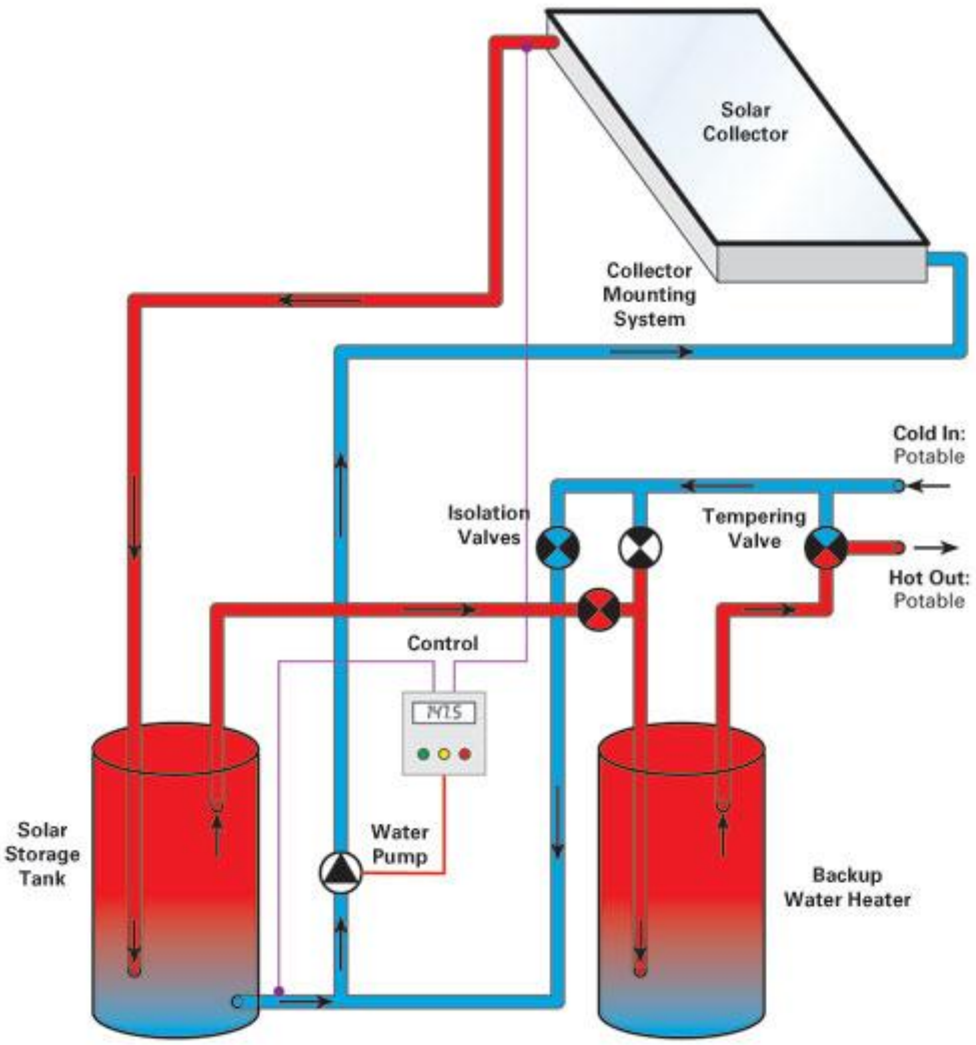


Open-Loop Direct Systems

Used in tropical settings where freezing never occurs, this is the simplest of the active systems. A standard, 52-gallon (200 l) electric tank can be used, teamed with a 40-square-foot (3.7 m2) solar thermal collector. Normally the electric element is not hooked up, so this tank becomes a storage tank only, for preheated water feeding an existing backup water heater.

An air vent, automatic or manual, is installed at the high point of the solar thermal collector to initially purge air. The pump, a small circulator pump using as little as 10 watts, can be powered directly by a 10-watt PV module, or a thermostatically controlled AC pump can be used. A snap-switch sensor can be installed to limit the temperature the solar tank reaches. Standard snap-switch sensors are available for 160°F or 180°F (71 or 82°C).

The following illustration includes the primary components of any open-loop direct system. See our Solar Hot Water System Components section for an introduction to the function(s) of each component.

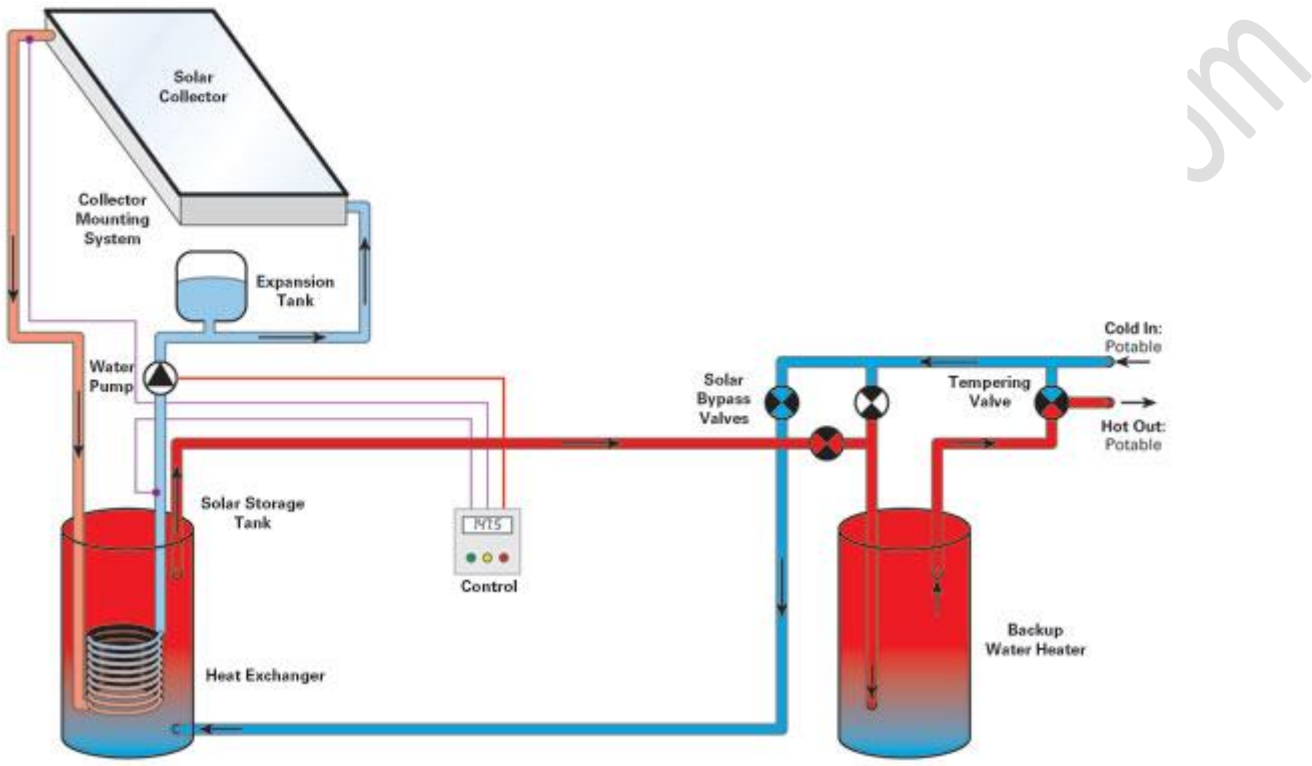


Pressurized Glycol Systems

In this active, closed-loop system, incoming potable water is routed to the solar storage tank, but never into the collectors. A water and antifreeze mixture circulates from the collectors through a coil of pipe in the solar tank, and then is pumped back through the collectors. (In most climates, a 50/50 propylene glycol and water mixture will keep collectors from freezing.) Heat transfer through contact with the pipe warms the potable water.

These systems require an expansion tank and a few other auxiliary components for filling, venting, and maintaining the system. A definite advantage to antifreeze systems is that the collectors can be mounted anywhere. These systems are pretty much the only choice in very cold climates.

The following illustration includes the primary components of any pressurized glycol system. See our Solar Hot Water System Components section for an introduction to the function(s) of each component.



Closed-Loop Drain back Systems

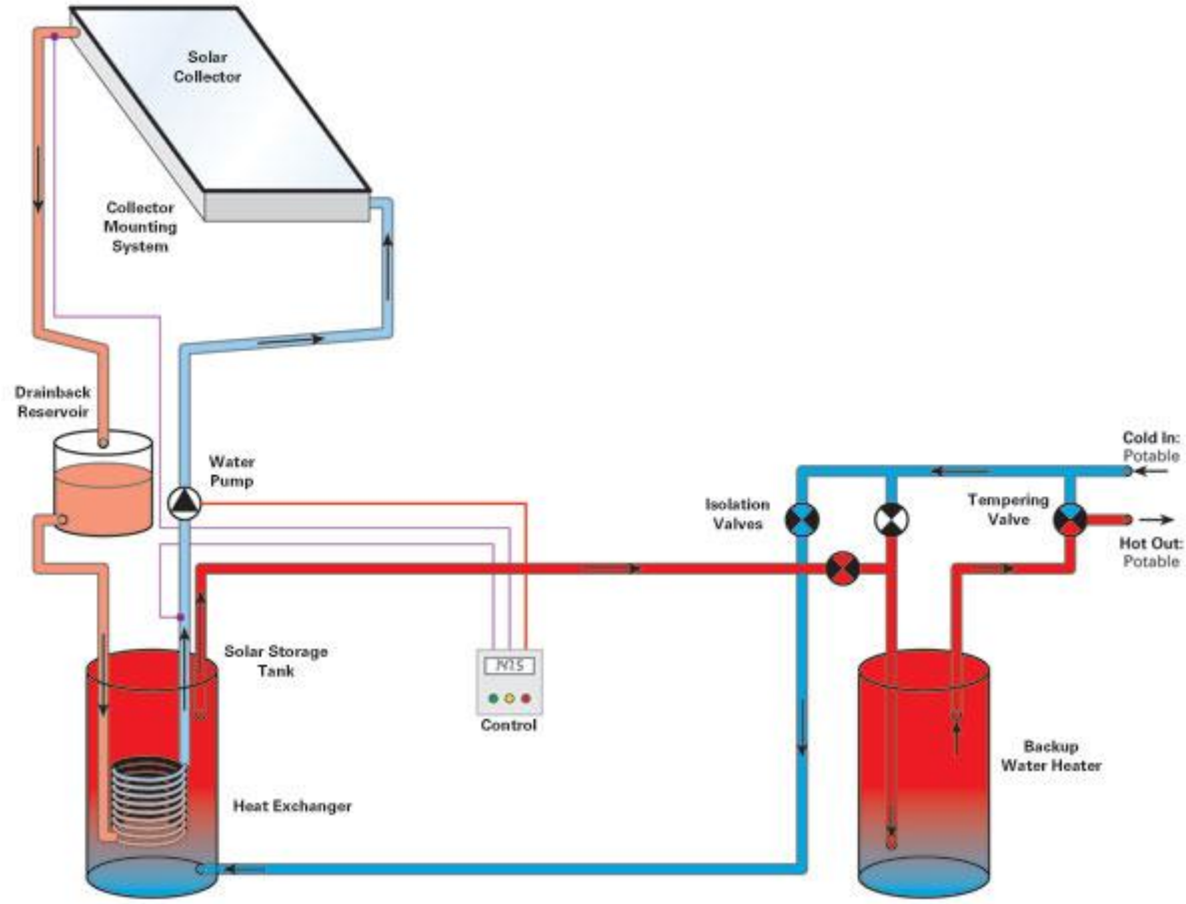
The closed-loop drain back system requires perhaps the least routine service of any active system. The heat-transfer fluid is distilled water, which seldom has to be changed. When the system is at rest (not pumping), the solar collector is empty and the distilled water is stored in a 10-gallon (38 l) reservoir tank, usually located just above the solar storage tank. Higher capacity reservoir tanks are typically required in large systems.

When the pump turns on, the distilled water is circulated from the reservoir back through the collector and heat exchanger, passing heat to the potable water in the solar tank. When the pump shuts off again, the distilled water drains back into the reservoir. The collector must therefore always be higher than the storage tank, and there must be sufficient continuous slope in the piping to ensure against freezing.

Drain back systems are effective and reliable. They work great, even on the hottest and coldest days of the year, and can operate twenty years without needing service. The only downside is that larger pumps usually have to be used, especially if you're pumping water two stories or more, since the drain back pump has to lift the distilled water to the height of the solar collectors.

One way around the height problem is to place the reservoir in the attic, reducing the height the pump has to lift. However, if it's located in a place where the pipes going to and from the reservoir could freeze, glycol must be added. This is also done when long, horizontal pipe runs do not allow drain back to occur quickly.

The following illustration includes the primary components of any closed-loop drain back system. See our Solar Hot Water System Components section for an introduction to the function(s) of each component.



Chapter 10 Solar Hot Water System Components

Understanding the basic components of an RE system and how they function is not an overwhelming task. Here are some brief descriptions of the common equipment used in solar hot water systems. Systems vary—not all equipment is necessary for every system type.

Solar Collectors
Collector Mounting System
Solar Storage Tank
Water Pump
Heat Exchanger
Expansion Tank
Controls
Isolation Valve
Backup Water Heater
Tempering Valve

Solar Collectors AKA: Solar thermal panels

A solar collector consists of a network of pipes through which water (or in colder climates, antifreeze) is heated. Collectors come in various sizes, with 4 by 8 feet (1.2 x 2.4 m) the most common.

On a typical summer day (sunny and warm), the fluid in the collectors reaches 140°F to 180°F (60°C-80°C). On a clear winter day (sunny and cold), it can reach 120°F to 150°F (50°C-65°C). When it's cloudy and warm, collectors can reach 70°F to 90°F (20°C-30°C), and when it's cloudy and cold, 50°F to 60°F (10°C-15°C). As long as the temperature in the collector is greater than that of your incoming cold water (usually about 50°F; 10°C), your solar hot water system is saving you energy.

Several types of solar collectors are on the market. Flat-plate are thin (3-4 in.; 7-10 cm), black, and covered with glass to hold in the sun's energy.

In evacuated tube collectors, a glass tube surrounds each individual pipe in a vacuum. This nearly eliminates the influence of ambient air temperature. Evacuated tubes perform better than flat-plate collectors in cloudy weather, and can achieve higher temperatures compared to other collector types, but are typically more expensive. All active systems and some Thermosyphon systems may use either flat plate collectors or evacuated tube collectors.

A third type, called integrated collector storage (ICS) or batch, combines the solar collector and storage tank into one unit. An ICS panel can resemble a flat-plate collector with greater depth (6 in.; 15 cm). A simple batch heater can be a tank within a glazed box.

Collector Mounting Systems

AKA: mounts, racks

The three most common mounting systems for solar collectors are the roof mount, ground mount, and awning mount. Brackets hold roof-mounted collectors, usually parallel to and a few inches above the roof. Ground-mount systems can be as simple as four or more posts in the ground, lengths adjusted to affect optimal tilt. An awning mount attaches the collectors to a vertical wall. Horizontal supports push the bottoms of the collectors out to achieve the desired tilt.

When choosing a mounting system, roof mounts are usually the cheapest option, provided tilt and orientation are within acceptable parameters. If weight is an issue, ground mounts can be a good choice. Wall mounts are another solution that can work well in some situations.

Find the sunniest spot for your collectors. Generally, you want no shading between 9 AM and 3 PM. Facing collectors up to 30 degrees east or west of true south and at your site’s latitude plus 15 degrees tilt, generally will still yield results within 15 percent of optimum. Any nominal losses from tilt, orientation, or even shading can usually be overcome by adding more collector area.

Solar Storage Tank

AKA: solar water tank, solar tank

A solar water tank is an insulated water storage tank. Cold water that used to go directly to your conventional water heater enters the solar tank and solar-heated water exits. In closed-loop systems, the water is heated by contact with a coil of pipe containing the water or antifreeze that circulates through the collectors. In open-loop systems, the potable water is directly circulated through the collectors.

The preheated solar water is then plumbed back to the cold side of your existing heater, which now functions as a backup. Whenever hot water is turned on in the house, preheated solar hot water is moved from the solar tank to the backup heater.

Water Pump

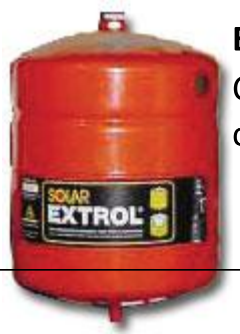
AKA: circulating pump, circulator

Pumps are used in active systems, but are not required in batch or Thermosyphon systems. They circulate water or antifreeze between the solar collector and the storage tank. The right pump for the job depends on the size of the system and the distance and height between the collector(s) and the storage tank. AC pumps plug into a wall outlet while DC pumps are powered from a DC source, such as a photovoltaic panel. Good pumps can last as long as 20 years with heavy use.

Heat Exchanger

Heat exchangers are used in closed-loop solar hot water systems. They enable the transfer of heat from one fluid to another without the two mixing. Internal heat exchangers are inside the tank and not visible. They can be as simple as a coil of pipe resting in the bottom of the tank, or wrapped around the outside beneath the insulation and cover. As the heated fluid from the solar collector travels through the coil, the heat is passed from the hotter fluid to the cooler potable water.

An external heat exchanger is usually a pipe within a pipe. The solar fluid and potable water flow counter to one another, and heat is transferred within the heat exchanger pipe. Fluid may be moved with pumps, thermos phoning, or a combination of the two.



Expansion Tank

Closed-loop systems require an expansion tank. An expansion tank has a chamber in which air is locked inside a bladder or diaphragm. It screws into standard 1/2-inch or 3/4-inch threaded plumbing fittings. When pipes are filled with heat-transfer fluid (water and glycol) and the operating pressure of the system is set, the fluid will occupy a given volume based on the temperature. As the sun heats the fluid, it expands. This is where the expansion tank is critical. Without it, something would blow!

The expansion tank allows the fluid to safely expand by compressing the air in the chamber. The size of the expansion tank needed depends on the total volume of fluid, which is determined by the number and size of collectors, and the length and diameter of the pipes in the solar loop.

In most cases, a total of 3 to 6 gallons (11-23 l) of fluid is in a solar loop. A #15 (2 gal; 7.6 l) expansion tank is usually adequate. It never hurts to go larger, especially for systems with more than 60 square feet (5.6 m2) of collectors. A #30 has twice the expansion capability. With the proper expansion tank in place, the fluid can go from 0 to 200°F (-18-93°C) with the pressure in the solar loop remaining the same.

Controls

AKA: differential controls, PV module

In active systems using pumps, whenever the collector is hotter than the storage tank, the pump should be on and the system circulating. When the tank is hotter than the collector, the pump should be off. This function is performed by either a differential thermostat control system or the use of a PV-powered pump. The differential thermostat controller compares heat sensor readings from the storage tank and collectors and switches the pump accordingly.

With a PV-powered pump, a solar-electric panel is connected directly to the pump. It's a simple setup—when the sun comes out, the pump comes on. The brighter the sun, the faster it pumps. Controls are not needed in batch heater systems, where energy is moved by simple water pressure, or in Thermosyphon systems, where energy is moved naturally by heat rising.

Isolation Valve

AKA: solar bypass

An isolation valve should be a part of every solar water heater to isolate the solar tank in case of a problem, while still allowing the backup water heater to remain in service. The isolation valve is a manual valve or valves placed in both the incoming and outgoing potable water lines to the solar tank. It can be a three-valve configuration, or a three-port and two-port valve. Manually turning the valve or valves will place the solar tank "on line" or "off line." It works by directing the flow either through or past the solar tank. These valves can also be plumbed to bypass the backup gas or electric water heater, allowing them to be turned off (eliminating standby heat loss) during the seasons when the SHW system can supply 100 percent of the household's hot water.

Backup Water Heater

AKA: natural gas, propane, electric, or wood water heater

The backup water heater ensures that hot water is at the tap whether the sun shines or not. On a sunny, hot day, if the sun has preheated the water to 140°F (60°C) or more, the backup water heater uses no energy at all because the solar preheat temperature is greater than the typical 120°F (49°C) thermostat setting. On a day when the solar preheat is 85°F (29°C); the backup heater boosts the temperature the remaining 35°F (19°C). Since incoming cold-water temperatures are at ground temperature (usually about 50°F; 10°C), 85°F represents 50 percent of the energy needed to bring the water from 50°F to 120°F.

Not all backup water heaters use a tank. Keeping a tank of water warm between uses can account for 15 percent or more of the total energy expended for hot water. Tankless water heaters eliminate this standby loss. Solar hot water systems and tankless water heaters are a winning combination. If you're in Seattle, for instance, and can reduce your water heating cost by 60 percent using solar energy, and save another 15 percent by going tankless, this results in a 75 percent total savings. The household that used to spend $300 per year to heat water now only spends $75. In sunnier climates, this number can approach zero. However, not all tankless heaters can be used as a backup heater for solar. Check with the manufacturer.

Tempering Valve

AKA: mixing valve

On a sunny day, the water in your collectors can reach scalding temperatures. A tempering valve can save you from a 160°F (70°C) shower. Ouch! The tempering valve goes at the very end of the chain, right after the backup water and before the faucet. If the water coming out of the backup heater is too hot, the tempering valve opens to mix cold water back in and prevent scalding. The temperature of the hot water can be set by the user on most valves. For instance, a popular valve allows a temperature setting between 120°F and 160°F (49°C-71°C).

Chapter 11
DIY Solar Hot Water Batch Collector for under $150

Water Heating

Water heating can account for 14%–25% of the energy consumed in your home. You can reduce your monthly water heating bills by selecting the appropriate water heater for your home or pool and by using some energy-efficient water heating strategies.
According to the Department of Energy, you and I now spend more than $1,100 a year on the energy it takes to run our homes. After the furnace, the single greatest energy-eater is the water heater. It costs hundreds of dollars a year to run. But you probably don't think about its operating costs because they are lumped in with other appliances that use the same fuel. As long as you get hot water when you turn the tap, everything seems to be fine.

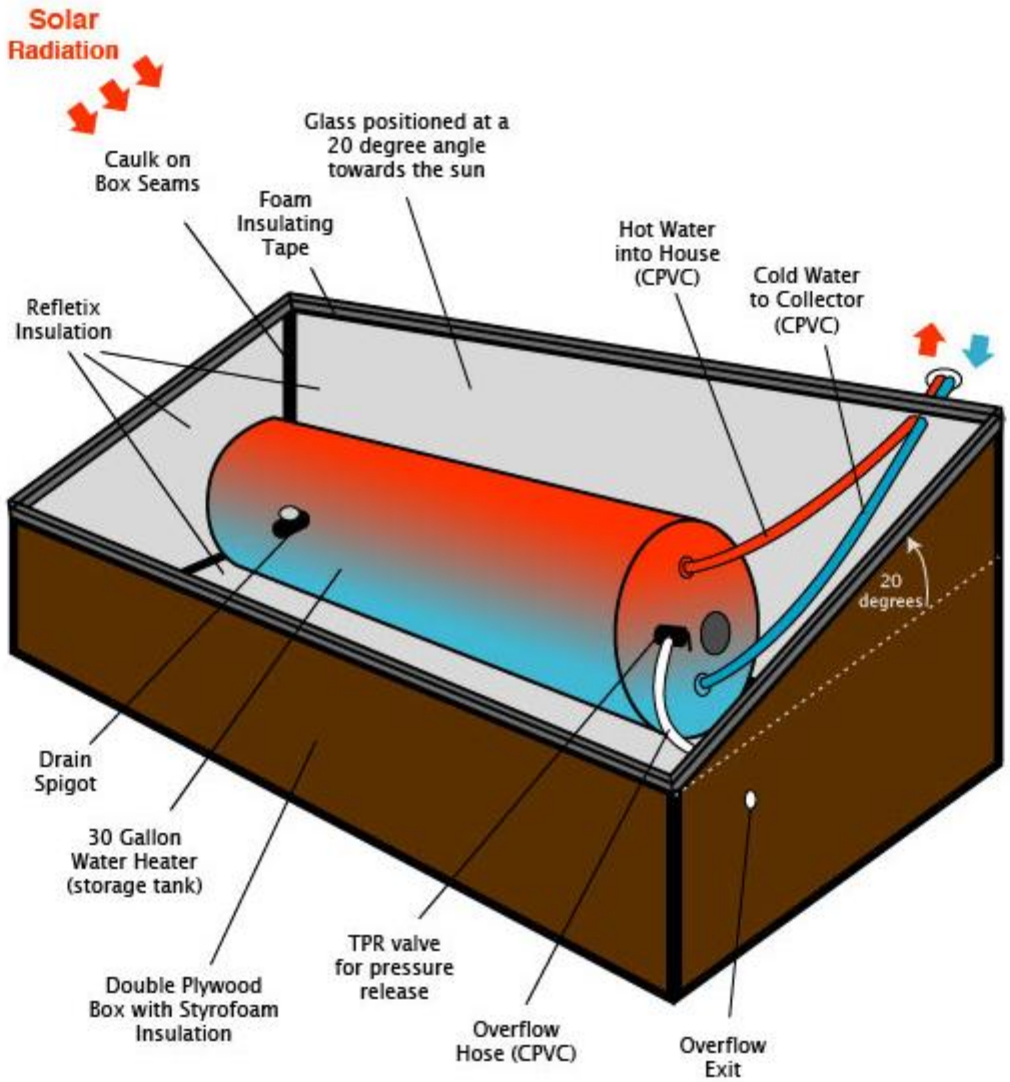
But everything isn't fine. Chances are, at least one out of every three dollars you now spend on water heating buys you absolutely nothing: It's simply wasted by the built-in inefficiencies of your system. To make matters worse, another third of your present water heating bill is a sort of hidden penalty for the "convenience" of using oil, gas, or electricity, because the sun easily could provide this much water heating energy for free. In other words, at least two-thirds of your present water heating expense is money down the drain.

The batch heater itself is a masterpiece of simplicity, with no moving parts or high-tech gadgetry. Likewise, our energy-efficiency upgrading is extremely simple and very, very effective. Both jobs require only ordinary hand tools and basic construction skills, yet the combined performance rivals that of some complex solar systems costing two or three times as much. How well does it work? If you live in the South or West, where there's plenty of sun and a generally mild climate, our retrofit can save you around 18.2 million Btus per year, equivalent to about 5,333 kwh of electricity, 200 gallons of fuel oil, or 24,300 cubic feet of natural gas (multiply by your present fuel costs for a ballpark estimate of monetary savings). In colder, cloudier climates, the performance is only a little lower. In Pennsylvania, for example, the batch heater must be drained during the below-freezing months of December, January, and February, yet the total annual savings are still almost 14 million Btus, equivalent to roughly 4,000 kwh of electricity, or 150 gallons of fuel oil, or 18,200 cubic feet of natural gas. Of course, your local climate and the care with which you do the job will determine exactly how many millions of Btus you can save each year, but you will save. And chances are, you'll save a bundle. Right now, one of our test families is saving almost $800 a year, based on local electric water heating rates of about 12 cents per kwh.

As for costs, the entire job -- everything from insulating the home's existing pipes to building and installing the solar water heater -- totals just $150, not including state, federal and local solar tax credits. To put this in perspective, our test retrofit will pay for itself in about 6 months, and then will go on to generate pure profits for the rest of its 10- to 20-year life. We don't know of any solar, do- it-yourself retrofit that will give you a better return on your investment. In fact, the job is so straightforward (taking only about five comfortably paced weekends), the cost is so reasonable, and the savings so spectacular, you can hardly afford not to do it.

The next few pages contain the information you need to perform your own batch heater/efficiency retrofit. We show you, step by step, how to build and install it. When you've finished, you'll have taken a giant step closer to energy independence.

This is a diagram of our most recent solar hot water experiment: the batch collector. The box is made from wood, insulated with styrophoam and lined with reflectix. The tank is recycled from an old hot water heater and is painted black.



Getting Started

The first step is to get a used hot water heater or any tank. Just to obtain the inner water tank. Just remember you will need to be able to connect to your water supply system. You can find them at yard sale and used appliance centers .

Preparing the Tank

Strip off the outer enclosure and insulation and revealed the metal tank. Next, remove all of the old pipe fittings. Another challenge using an old tank was the build up of sediment in the tank's bottom. The sediment dried and solidified in the bottom of the tank and was difficult to remove, though it was done successfully by rolling and rocking the tank back and forth. Then we filled the tank to rinse it.

Once stripped and cleaned, the tank was thoroughly sanded and then spray painted black. Put several coats of spray paint on to give it maximum coverage. The spray paint was necessary to protect the metal tank from exposure to moisture and to increase the tank's absorption of heat. The appropriate fittings were then secured and extra holes plugged. There are 2 hose fittings, a pressure release valve, and a drain spigot.

Constructing and Insulating the Collector Box

Your measurements should be calculated to accommodate the size of the glass, the size of our tank, and our desire for optimum solar exposure. Based on the sun's path we determined that the best angle for the glass to sit was 20˚. Once the frame is built, affix plywood paneling to the interior of the structure. Caulk all the interior seems and prime and paint the wood.

Preventing Heat Loss

If you used hot water only while the sun was shining, then you simply could insulate the walls of the batch heater's enclosure, and that would be that. But most families use large amounts of hot water twice a day: first around breakfast time, and again after supper. So a batch heater must be constructed to hold the day's solar heat through the evening and into the following morning.

At night (assuming the walls of the heater's enclosure are thoroughly insulated), the glazing will be the principal cause of heat loss. Because of this, a batch heater should be double-glazed to minimize this loss. In cool climates, it's also a good idea to add some form of movable insulation that can be opened in the morning and closed at night. Movable insulation is highly effective, but it has a drawback because the owner must schedule twice-daily trips to the heater in order to operate it. If you forget to open the insulation, you'll get no heat for the day. Also, though the work involved in opening or closing insulation doors is hardly major, it's not really in keeping with the purely passive concept of hatch heating. A more elegant solution is to use triple glazing on the enclosure to minimize convective heat loss, and a "selective surface" on the tank to minimize radiant heat losses. (A selective surface is a special product that absorbs large amounts of solar energy, but reradiates very little, keeping the heat inside where

photo by Caroline Shapcott

photo by Caroline Shapcott

Next, cut recycled Styrofoam pieces and wedge them into the frame structure to serve as insulation. We also added an additional layer of cardboard beyond the Styrofoam to increase insulation even more. **<u>Insulation is key to maintaining heat.</u>**

After insulating, paint the outer paneling and affix it to the outside of the frame. **<u>The collector box is essentially a plywood box within a larger plywood box with a layer of Styrofoam as insulation in between with an R rating of at least 19.</u>**

Tank Supports and Glazing

Before installing the tank we cut 2x4s to match the tank's curve and firmly fastened them into the collector box. These supports were designed to hold the tank and to bear a considerable amount of weight. We used a recycled sliding glass door for the collector's glazing. Our glazing is single pane, however double paned glass is preferred for its superior insulating properties.

Installing the Tank

After the box was built and painted, put the ready tank into place. Attach the water supply and return lines from the house into the collector's storage tank. Make sure the lines inside the collector are metal. PCV pipes can not withstand the heat during the hotter days and will burst. Cold water flows into the tank from the water system. Sun strikes the water storage tank and heats the water. The hot water floats to the top and the coldest water remains at the bottom of the tank. A hose leading from the top of the tank carries the hottest water into the house. Later an overflow hose was attached to the TPR valve to carry excess pressure out of the collector.

Line the interior with reflectix insulation to direct maximum light towards the tank, and to further insulate the box. Because reflectix is reflective the sun is directed to strike the bottom and back of the tank, which would normally be in shadow. Line the top edge of the box with foam insulating tape before putting the glass in place.

With the majority of the pipes inside the collector, we had no more frozen or burst pipes. In the spring you may encountered new and different challenges. With longer and more intense sun exposure the homemade hot water heater has become almost too efficient. Water is at scalding temperatures at the height of the day, and the CPVC hoses used for water intake and outlet may burst from heat and pressure!

Proper Sitting

In order to work properly, a batch heater needs a good location. First of all, it should be located as close as possible to your existing water heater to minimize heat losses from the connecting pipes. Second (and more obviously), it needs plenty of sunlight.
It's easy to find a good solar site. You start by determining where true or "solar" south is. (It's usually different from magnetic south as shown by a compass.) The fastest way to find true south is to drive a stake into the ground and observe its shadow at solar noon, when the shadow forms a precise north-south line. (South is toward the sun.) Solar noon is the time exactly halfway between sunrise and sunset, and may or may not coincide with 12 p.m. on the clock. You can find the times of sunrise and sunset in any almanac or daily newspaper.

Ideally, a solar heater should face due south. But if your home is off the mark, don't give up. Any location that lets you mount your batch heater so that it faces within about 20 degrees east or west of due south will provide upwards of 90 percent of the energy available at a due-south orientation, and that's still pretty decent performance.

Of course, shadows will ruin the performance of even a perfectly oriented solar system, so you need to be sure your south-facing location will remain essentially shade-free during the prime solar collection hours of 9 a.m. to 3 p.m. You can estimate sun and shadow at your site with an ingenious method developed by New York's Energy Task Force:

Stand where you want to place your collectors and face true south. Hold your left arm out straight, level with your eyes, and point at the horizon. Place your right hand, in a fist, on top of your left hand and "stack" your fists one on top of the other in succession, moving upward, the number of times listed in Table One. Do this three times, following the Table: Once for true south, next for 30 degrees east of south, and last for 30 degrees west of south. Any object you can see above your fists in these directions will cast a shadow on your collectors; any object below your fists in these directions is of no concern.

Energy Efficiency

A batch heater will work on almost any home, but will work best on a home with an efficient standard water heating system. To put it another way, it really makes no sense to invest in a solar water heater if the rest of your home's plumbing merely throws away most of the delivered energy.

"Most" isn't an exaggeration. The waste in standard systems is incredible. In one of our test homes, for example, we performed a simple, basic energy-efficiency retrofit of the existing standard water heating system. The entire retrofit took less than eight hours, and cost just $80. We turned down the water heater thermostat from 150 Degrees F. to 120 Degrees F., insulated the water heater tank and hot water pipes, installed an automatic timer on the tank's electric heating elements, and put on flow-restricting shower heads and faucet aerators throughout the house. When we were done, the energy used for water heating dropped by an incredible 50 per cent, saving the family over 3,600 kwh of electricity each year, worth $218 at local rates. Those energy savings are equivalent to about 136 gallons of fuel oil, or 165 therms of natural gas.

Chances are your present system is now wasting a similar amount of fuel. No batch heater -- or any other solar hot water system -- will work to its full capacity until this enormous waste has been dealt with. Good luck!

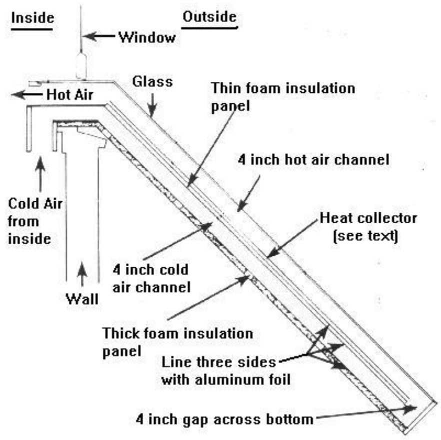
BONUS

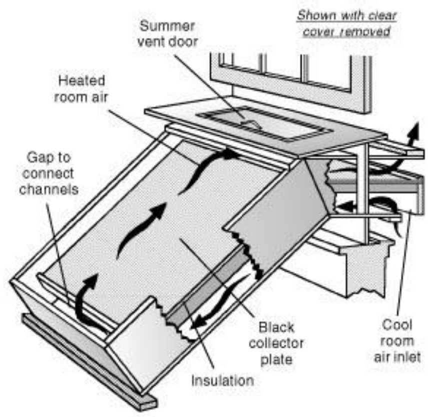
Chapter12 DIY Window Warmer*

A Passive Solar Space Heater for Home Use

Build this super-simple and super-effective solar collector in about one hour!

This simple and effective "window box" solar collector can be built in just under an hour by an experienced home craftsman (or in less than two hours by the more fumble-fingered among us) for the astonishingly low price. (see materials breakdown on next page). *As near as we can tell, seems to be an old Steve Baer design modified by William A. Shurcliff and further refined by some of *Mother Earth News'* research staff





How It Works

Sun shining through the solar panels heats the air inside the triangular shaped box. As the air inside is heated, it rises to the top of the box and passes into the house through the open window or opening on the first floor. As the heated air moves into the house, it is replaced by cool air moving into the box through the open window. There are no moving parts. Leaving the cellar door ajar may aid circulation. A small fan may aid air flow in the house. Some experimentation may be needed.

Once constructed, this sturdy unit should give years of dependable service.

The secret of the Window box Heat Grabber's quick assembly and low cost is a new rigid foam insulation board manufactured by Celotex. This board, trade-named "Thermax TF-610," is impregnated with glass fibers for strength, faced on both sides with heavy aluminum foil, and available in thicknesses ranging from 3/8" to 1-7/8".

Yes, the basic Thermax TF-610 sheet does have a slight disadvantage. Its aluminum foil surfaces can be punctured relatively easily by anyone intent on doing just that. There are, however, at least two remedies for this problem: [1] Substitute Thermax-610/.019 — which is the same foam, but faced on one side with a much heavier layer of aluminum—for the Thermax-610 specified here, or [2] use the Thermax-610 called for in our plans and protect the sides and bottom of the finished collector with a casing of scrap lumber. The second alternative will be less expensive than the first, but, really, neither course of action should be necessary unless you live in a high-vandalism area.

The ideal angle at which to position a south facing solar collector (in the Northern Hemisphere) or a north-facing collector (in the Southern Hemisphere) is your latitude plus 10°. Please take this into consideration when making the cuts called for in Steps 3 and 6 in the diagrams in the Image Gallery.

(Miami, for instance, is located about 25° north, which means that collectors there should be angled up at 35° to the horizon, which, in turn, means that the 67.5° cuts specified in the following plans should be 72.5° for Miami. Likewise, the cuts should be 65.75° for Washington, D.C; 61.5° for Seattle; and 54.5° for Anchorage. You can calculate the specific angle for your own location [subtract your latitude plus 10 from 180 and divide by two] or just average it out from the figures given here. The angle is critical, but not *that* critical.)

Remember that all the dimensions given in the plans are for a collector specifically tailored to fit the windows in one particular house. If your windows are wider or not as wide, feel free to build your Heat Grabber(s) accordingly. And don't get unnecessarily hung up on trying to keep the upper and lower air chambers in the collector exactly as deep as shown here either. A half-inch or more variation is fine. As a matter of fact, it's awfully hard to keep this little Btu-grabber from working, as long as its passages are deep enough for air to circulate through them at all.

One final caution: Although the single-strength glass used to cover the prototype Heat Grabber is no more nor less safe than the single-strength glass currently in use in millions of storm doors and windows throughout the continent. It can break and possibly cut you or a child if, for any reason, either of you falls into it. Take whatever measures you deem necessary so that such an accident never happens.

How It Works

The Heat Grabber is nothing but a weather tight box that's insulated on the bottom and sides and topped with glass. An insulated divider is positioned inside this box and brought out its top to form an open "lip" at the box's upper end. This lip is designed to hook over a windowsill so that the window itself can be pulled down snugly onto the glass which covers the top of the Heat Grabber, leaving the main body of the solar collector "leaning against" the south side of the house at a 45°-or-better angle. (See illustration in the Image Gallery — How it Works.)

The operation of the unit is just as simple. When the sun shines, its rays pass through the glass on top of the Heat Grabber, strike the upper surface of the divider (which is painted black), and warm the aluminum foil covering on that divider. As the foil heats up it, in turn, warms the air next to it. And that air, as might be expected, rises up the face of the divider and begins to pour out the opening at the Heat Grabber's top.

But, of course, that hot air can't move up the face of the divider unless it pulls cool air around the divider's foot to take its place. Which pulls even more cool air in through the lower opening at the collector's top (the only place that cool air can enter the otherwise airtight unit) and down under the central divider.

What we have, then, is a "convective loop" solar room heater that operates automatically on nothing but the sun's energy. Whenever the sun shines, this clever little unit (which, as near as we can tell, seems to be an old Steve Baer design modified by William A. Shurcliff and further refined by some of *Mother Earth News'* research staff) just sits there happily pumping thousands of Btu's of heat into the house. And when the sun quits shining? The air in the box cools and tries to sink to the collector's foot, which "shuts off" the whole convective loop. (The Heat Grabber, in other words, will spew heat into the room when the sun shines, but it won't pull heat from the room when the sun doesn't shine.)

Materials

Quantity	Material
1 sheet	1" x 4' x 8' Celeotex Thermax TF-610
1/2 sheet +	3/4" x 4' x 8' Celotex Thermax TF-610
1 tube	Liquid Nails panel adhesive
1/2 tube	silicone caulking compound
16	No. 8 finishing nails (scrounged)
3 pieces	single strength glass cut t fit
1/4 roll	all-metal aluminum foil duct tape
1 quart	Rustoleum flat black paint

Collector's size: 12.6 square feet

Tools

Thermax is so easy to work with that you won't need any saws, hammers or other "conventional" carpentry tools to build this solar collector. The Heat Grabber, in fact, was constructed with little more than a protractor, tape measure, paint brush and two little "we built 'em ourselves" knives. (See illustration in the Image Gallery — Tools.)

These knives are nothing but blocks of 1 " x 2-1/2" hardwood cut to fit the hand comfortably. The pieces of wood were then slotted and rigged with 10-32 bolts and wing nuts to grip Stanley 1992-5 utility knife blades at either a 45° (for "V" cuts) or a 90° (square cuts) angle to the blocks' faces.

All cuts on the Thermax used in the collector were made straight and accurate by sliding one or the other of the two knives along a board or other straightedge that had been clamped to the rigid sheets of foam. For "V" cuts, the blade in the 45° knife was set to slice only to within about 1/32" of the aluminum facing on the "far" side of the sheet (not all the way through either the facing or the foam). Since the foam varies slightly in thickness, this setting (for the most part) kept the blade from cutting too deeply. Two such cuts (with the straightedge reset between them), of course, were necessary for the completion of each "V".

And if you don't want to make "V" cuts and fold up the box of your solar collector? Then just build your "heat grabber" from separate pieces of Thermax, all made with right angle cuts; peel back the aluminum skin from the butted face of each joint; and glue the sections — foam to foam — together.