Wind power

Plan your own wind power system

- Understanding wind power systems
- System design and considerations
- Choosing a suitable site
- Water pumping

ATA

Booklet 3 ATA info series

Hybrid wind and solar power system

Location:	French Island, Victoria
House:	13 metre square cedar weatherboard
Wind generator:	Whisper 900 watt 3 blade machine, 19.5 metre tower
Blade diameter:	2.1 metres
PV panels:	8 x BP 75 watt panels, total 600 watts
Inverter:	Selectronic SE22 1600 watt sinewave inverter
Generator:	Honda petrol/gas with Bosch 55 amp 24 volt truck alternator and adjustable external regulator
Cost:	$21,000 (less $3300 rebate received through the Australian Greenhouse Office Photovoltaic Rebate Program)

Comments:

When Alison Pitt and Jane Unwin decided to pack up their city lives and move to French Island, one hour south of Melbourne, they were also moving away from dependency on mains power and water. They wanted their new home to be environmentally sustainable with minimal ongoing costs. A hybrid wind and solar power system has supplied all their power for over three years. A back-up generator is used for just 20 hours each year during Autumn when there may be a few still nights.

Jane and Alison are very happy with their hybrid system as it was designed for their needs and is user friendly. Converting to a remote area power system (RAPS) meant that they had to make some behavioural changes to reduce their energy use. Other sustainable features of their home include solar hot water, composting toilets and three water tanks.

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By Peter Freere and Trevor Robotham

The Alternative Technology Association (ATA) is a not-for-profit organisation that has been promoting renewable energy, water conservation and sustainable buildings since 1980. ATA provides expert, independent advice on sustainable solutions for the home to homeowners, government and industry.

With 6000 members across Australia and New Zealand walking the talk in their own homes, ATA's knowledge is based on our members practical experience.

ATA are the publishers of two leading magazines on sustainable living *ReNew: technology for a sustainable future* and *Sanctuary: modern green homes.*

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Introduction

The power of the wind has fascinated mankind for thousands of years and harnessing this power has challenged us for as equally long.

Men, women and children have tried to harness the wind to sail the oceans, to grind wheat into flour or just fly a kite.

In more recent times we have looked to the wind to provide low-cost electricity and to pump water. This sounds simple enough and there are lots of ways to do it successfully—but there are also many more ways to get it all horribly wrong.

This booklet has been written to help you better understand wind energy and how to select the right wind generator or windmill for your needs.

A brief history of wind technology

5000 BC – Middle East: First sail boats used on the Nile.

2000 BC – Ancient Babylon and China: First true windmills.

500-900 ADPersia: Vertical axis windmills used to grind grain and to pump water. Blades were made from bundles of reeds or wood.

1200-1400 – Holland: Dutch refinement of the windmilll for pumping water to reclaim land from the sea.

1750 – Scotland: Automatic direction change invented by Scottish engineer is added to Dutch windmill.

1807 – First automatic regulation of blades for high and low wind speeds

1850 – USA: Multi-vane farm windmill invented and is still used today.

1891 – Denmark: Paul La Cour develops the first electrical output wind machine using aerofoil blades.

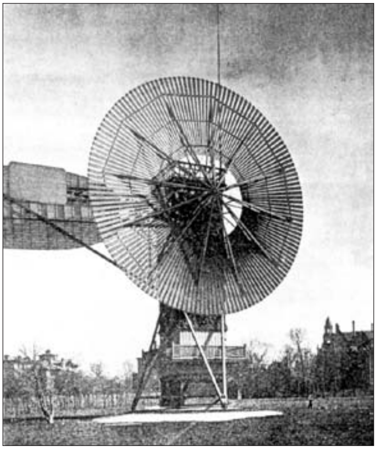
1920-1950 – USA and Australia: Domestic scale 1 to 3 kilowatt wind generators used extensively in rural areas.

1970 – Europe and USA: Oil crisis causes a growth in the development and use of modern wind generators.

1990 – First off-shore wind farms.

Now and into the future

Currently, wind energy is one of the fastest growing industries in the world. Global warming and fossil fuel supply limitations are the main reasons for this continued growth. Today's wind generators and windmills are the result of thousands of years of evolution. The use of modern materials and computer-aided design is making today's wind machines bigger, stronger, lighter, more powerful and more reliable. The future looks bright for both large and small wind generators. Windmills continue to be a good option for water pumping in many areas of the world. Wind energy is also playing a key role in assisting people in developing countries.



This huge 17m diameter wooden turbine was built in the late 1880s by Charles Brush. Despite its size, the limited technology of the day meant it could only produce around 12kW.

Where does the wind come from?

Wind is the result of the heating and cooling of land and water by the sun and the rotation of the Earth. The land warms up and cools down more than the water in the sea and lakes. Where the surface is warmer the air will also become warm, thus becoming less dense, causing it to rise and be replaced by air from the cooler region.

The larger the difference in temperature between the water and the land, the faster the air moves and so the stronger the wind. Generally the winds are strongest near the coast and deserts.

On a global scale the air over the north and south poles is drawn down from higher in the atmosphere and is replaced by the rising warm air coming from the tropics.

Local conditions like mountains and forests, buildings and rivers also effect the flow of the wind. These factors need to be understood and considered when siting a wind machine. We will look at this in more detail later.

Chapter 1: wind machine basics

1.1 Types of wind machines

Wind machines that produce electricity are generally called wind generators. Wind machines that pump water or grind grain are generally called windmills. The rotor or 'propellor' of the wind machine is often called the turbine. Wind machines come in two basic configurations.

1.1.1 Vertical axis

The blades spin around a vertical shaft helicopter fashion, although the blades are usually mounted parallel to the shaft at the end of supporting arms.

The main advantage of this style of machine is that they do not require any mechanism to point the blades into the wind—they catch the wind from any direction. The gearbox and alternator can also be mounted close to the ground so you don't need to climb a tower to service these parts. The advantage of having the alternator close to the ground is unfortunately outweighed by the fact that all the best wind is found some distance off the ground. The other down side is that generally only half the blade area is travelling with the wind while the other half has to move against it.

This family of machines includes the Savonius, Darrieus (or 'eggbeater'), the H-rotor giromill or cyclogenerator and Panemone. These machines were developed during the early stages of wind generator development but most are no longer in production. The only exception is the Savonius of which a spiral variation is made by a couple of manfacturers such as Windside in Finland. There is also a tiny savonius called the Dolphin, which is primarily designed for trickle charging batteries on boats.

Plans for making your own Savonius water pumper or electrical wind machine are available from several sources, including the publishers of this booklet, the ATA.

1.1.2 Horizontal axis

The blades spin around a horizontal shaft like the propeller on an aeroplane.

This type of wind machine can be made with the blades in front of the tower (upwind) or behind the tower (downwind). The only downwind machine currently in production is the Survivor range of machines made by Synergy in Hong Kong. The main problem with downwind machines is that the tower creates turbulence in the wind and puts extra stresses on the blades.

The upwind horizontal axis machine is by far the most popular design, with sizes from under 50 watts to 5 million watts (5 megawatts) in production today. Most of these machines have three blades, with only a few two, four, five or six blade machines made by smaller manufacturers.

1.2 Wind power system components

A wind power system consists of a few main components;

- the blades
- mechanical controls
- the generator or alternator
- electrical controls
- the tower.

For non-grid-connected wind generator systems, there will usually also be a battery bank to store the power for times when there is no energy input.

1.2.1 Blades

The job of the blades is to catch the wind in much the same way as the sails on a boat. The longer the blades, the more wind will pass through the turbine and the more energy will be produced by the wind machine.

Now for a short lesson on aerodynamics…

The most common form of modern wind machine – the horizontal axis type – is shown at left, while a vertical axis Savonius style machine (usually used for water pumping) can be seen at right.

There are two main aerodynamic forces: lift and drag. If you stick your hand out of the window while driving down the road (don't actually do this—it is dangerous!) the wind can make your hand rise up (lift) and also move back (drag). Changing the shape of your hand and angle of your hand to the wind changes the amount of lift and drag on your hand. This is the basic principle of aerodynamics, which makes planes fly and boats sail.

A boat sailing into the wind can actually travel faster than the wind—this is due to lift being created on the sails. A boat moving with the wind can only move as fast as the wind—this is drag.

A wind generator blade with a good aerofoil (the aerodynamic shape that allows the blade to do its job properly) can travel five to 10 times faster than the wind. In the case of wind generator blades, since they are attached to a hub and are pivoting around an axis, the lift effect causes the blades to rotate.

Most modern wind generators have two or three aerofoil shaped blades. Any more than three blades and you start to get turbulence from one blade affecting the next, which means that the turbine has to be designed to turn more slowly so that the following blade does not pass through the turbulence caused by the blade in front.

1.2.1 Blade materials

The main things to look for in good turbine blades are;

- Strength: there are a lot of 'bending' and centrifugal forces on a blade
- UV stability: so they don't become weak with exposure to sunlight
- Water resistance: water can penetrate wooden blades and make them heavier, thus unbalancing the turbine
- Cost: if a blade does break, how much will a replacement cost?

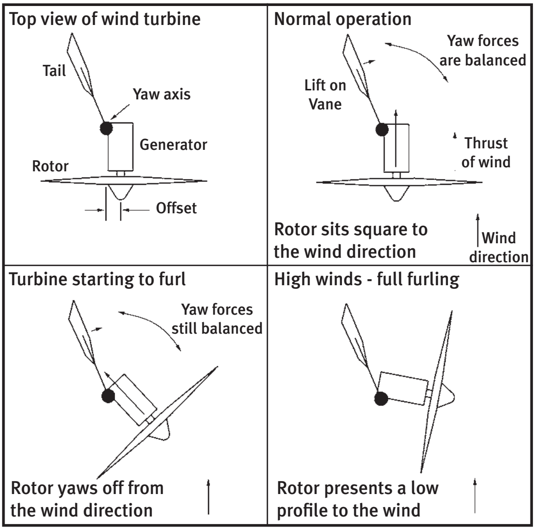
Common materials used to make blades include fibreglass, various plastics and wood. Aluminium and steel are very rarely used in blades now due to corrosion and fatigue of these materials.

1.2.2 Mechanical controls

The main reason for having mechanical control systems is to assist in starting the blades turning at the lowest possible wind speed, and to help protect the blades and the rest of the wind machine from damage when the winds get too strong.

A few machines have mechanisms to vary the blade angle or pitch as the speed of the wind changes, for example; Dunlite, Vergnet, Bergey and Westwind.

Dunlite and Vergnet use weights and springs while Bergey and Westwind use blades that can twist. By using weights on the front or leading edge of the blades, the blades will twist more or less as the wind speed changes.



Over-speed protection is achieved by reducing the area of the blades facing the wind. Sailing boats do this by raising or lowering the sails.

Small wind machines have tails to help point the turbine into and out of the wind. By balancing the weight and area of the tail against the wind force on the blades the machine can turn out of the wind automatically at a particular wind speed (often around 13m/s) and back into the wind as the wind speed drops again.

The machine can also be stopped manually, either with a cable attached to the tail furling system or by using a short-circuit switch—although the latter is usually an option only on machines with rotors less than 2.5 metres in diameter.

1.2.3 Alternators

Once the blades are turning, we need to convert this rotary motion into electrical energy, which is achieved using a device called an alternator, that produces AC electricity. To make electricity you need three ingredients;

1. A length of wire
2. A magnet
3. Movement

These three ingredients are the basic building blocks for all electromagnetic power generation. This applies to wind generators, coal-fired power stations, nuclear power stations, hydro-electric generators, car alternators, bicycle light generators et cetera.

Obviously, there is a large variation in the size and power output of wind generators and the alternators they use, but we can break this down to just a few variables:

• The amount of copper wire (aluminium can be used also)—simply change the number of coils of wire and/or the thickness of the wire used.

• The strength and number of the magnets. Magnets can be electromagnets (a coil of wire with electricity flowing through it) or permanent magnets.

• The speed of movement between magnet and wire and the distance between the two.

Most modern wind generators smaller than 20 kilowatts use permanent magnet (PM) alternators. These alternators differ from car alternators in that they are designed to operate at 300 to 1000rpm and use permanent magnets, whereas car alternators run best at 5000 to 6000rpm and use electromagnets (field windings).

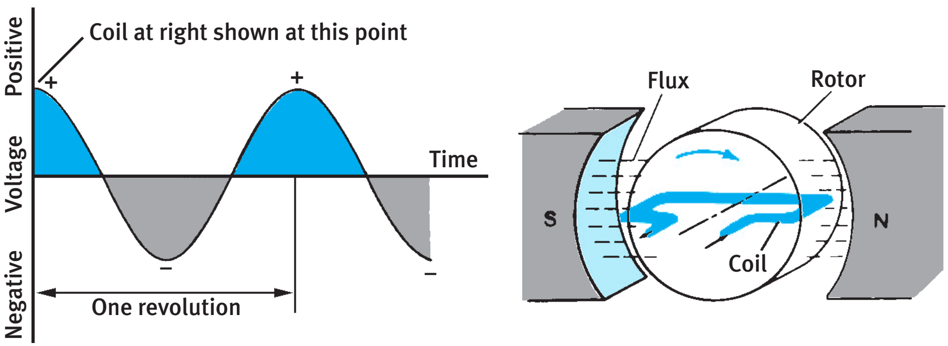
By using special low-speed alternators there is no need for a gearbox as was used on earlier models of turbines like Dunlite and Jacobs. Since 1985, manufacturers have been using new high-powered 'rare earth' magnets instead of the previous ferrite ceramic magnets.

However, rare earth magnets are very brittle, hard to machine, and sensitive to corrosion and high temperatures; but they can be expected to give four to five times the power output of ceramic magnets of the same size.

The next area to look at is how we control the flow of electricity from the alternator.

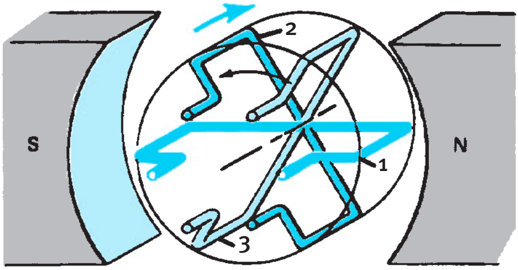
1.2.4 Electrical controls

The output from all permanent magnet alternators is AC (alternating current) electricity. This needs to be converted to DC (direct current) electricity to

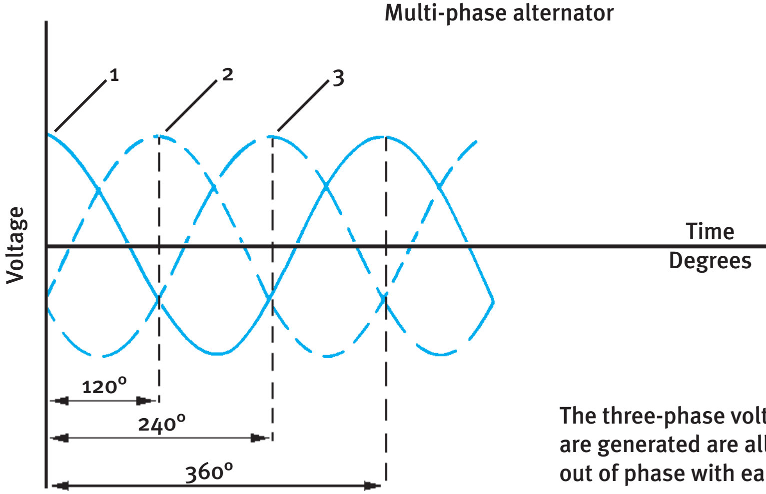


The basic concept of a single-phase, two-pole alternator. As the coil passes through the magnetic field, the sinewave voltage is induced in the coil. Note how the voltage first goes positive, then negative. This is why it is called AC, or alternating current.

A three-phase alternator is commonly used in wind generators. Some, like the one in this diagram, have fixed magnets and rotating coils, while others have fixed coils and rotating magnets. The latter layout eliminates the need for brushes in the alternator.



Multi-phase alternator



The three-phase voltages which are generated are all 120 degrees out of phase with each other.

charge batteries. To do this, a device called a bridge rectifier is used, which is located either inside the wind machine on top of the tower or in the control box on the ground. Some older wind machines used brush commutation of the output to provide internal rectification and hence a DC output. These units were basically a permanent magnet DC motor used in reverse.

Batteries don't like their voltage to rise too high or fall too low, so a device called a controller, or regulator, is used to keep the batteries happy and the wind generator under control.

The most popular (and simplest) controller is called a shunt regulator. The shunt regulator monitors the battery voltage and allows all the generator's power to go to the batteries until they are fully charged – usually 14 volts for a 12-volt system or 28 volts for a 24-volt system. Once the batteries are full the regulator diverts the power from the wind generator to a heater or similar load. This system keeps the wind generator under load at all times. Without a load the wind generator could overspeed and be damaged.

A solar panel has no moving parts to overspeed so it can simply be switched off. This type of regulator is called a series regulator—don't use one of these on your wind generator.

It is possible to connect a wind power system to the mains grid so that you can become an electricty generator (this is known as a grid-connected or grid-interactive system). With smaller wind generators this is done using a special device called a grid interactive inverter. Larger wind generators use induction alternators that can be connected to the grid without batteries or inverters—all they need is a voltage step-up transformer.

Domestic scale wind powered grid-interactive systems are rare, although the equipment to set up such a system is available in Australia. The advantage of a grid-interactive system is that it is a lot simpler than a battery-based system—with no battery bank to maintain and replace every 10 years or so.

However, there are a lot of rules, regulations and requirements to be dealt with when installing a grid interactive system. Depending on the energy company you wish to sell the electricity to, and the state you live in, installing a grid-interactive wind power system can be quite a difficult proposition.

1.2.5 Towers

All wind generators and windmills need to be installed on some type of tower, and the tower has to be positioned to catch the most wind. Read chapters 2 and 3 for more details on tower types and siting.

Chapter 2: Selecting a site

2.1 Where do I put my wind generator?

Selecting a good site for your wind generator requires a little information and application to get it right. Consult with your local wind power system installer to determine if your site is suitable.

If your site seems windy all the time, why does it matter where you put the turbine and tower? The reason is that there are two factors that will have a big impact on how effective your wind power system is. These are wind speed and turbulence.

2.1.1 Wind speed

Wind speed is what makes a wind turbine go—the greater the wind speed, the more power output from the turbine.

The energy contained in the wind increases with the cube of the wind speed. If you double the wind speed you get eight times the power (2^3 or $2 \times 2 \times 2 = 8$). This is known as the cube law, which is an important factor when figuring out how much energy you will get from your wind generator.

Even a small increase in wind speed will give a large increase in power. For example, an increase in speed of 14% from 3.5 to 4.0 metres per second will give a 48% increase in power.

This means that wind speed is critical in wind machine performance. An example of how power increases with wind speed can be seen when you look

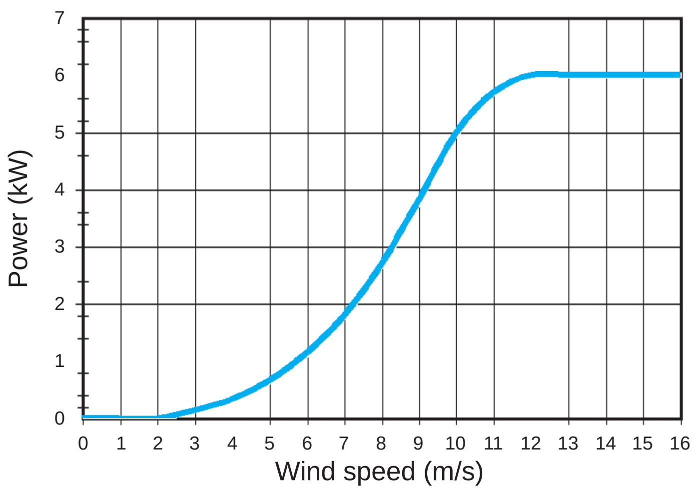


Figure 1. Typical wind turbine power curve. Here you can see the cubic relationship between wind speed and output power. Notice how the power output increase drops off after 5kW as the maximum output of the alternator is approached.

at a power output curve of a typical wind generator, such as that in Figure 1.

Since a small increase in wind speed makes a large difference to the amount of energy available, it is important to place the wind machine in the windiest place. Typically, the windiest places are at the highest point on the land – but not always. Sometimes, the funnelling effect of a valley can increase the wind speed quite significantly. However, many valleys also tend to be a place where vegetation grows well, and trees growing taller over the years can reduce the windiness considerably.

To properly do a wind survey is expensive as it requires both costly equipment and a full year of data to be collected. Even then, the year chosen for the measurement could turn out to be an abnormal year for wind. It is often cheaper to erect a small wind generator system and see how it goes. However, a common error when installing systems is the tendency to over-estimate the windiness of a site. So putting up even a small wind generator is still an act of faith and consideration must be given as to what to do if your site is not windy enough. For many sites, the addition of solar panels is a likely remedy, as hybrid energy systems are often thought to give the best of both worlds. This comes from the intuitive and observed behaviour that, if it is windy it is often not sunny, and vice versa.

If you have access to any wind data from a nearby airport or weather station this can be analysed to help predict your wind machine's output for your site. This will only be an indication of the wind available in your area, not an accurate assessment of your site, as there are many factors that affect wind availability – but it is a lot better than having no data.

Failing this, a handy reference to estimate wind speed is the Beaufort Wind Scale. Observe the wind speed at various times of the day and seasons and note these in a book for later analysis.

2.1.2 Turbulence

Turbulence is caused by the wind having to flow around obstructions like trees and buildings. This causes the wind to swirl and gust which is both damaging to wind machines and reduces their output power.

Fortunately, the best way to get access to faster and less turbulent wind is simple: put the turbine on a taller tower.

Wind moving over a hill or ridge will be faster at the top of the hill or ridge. Cliff tops cause turbulence so locate your turbine well back from the cliff edge.

The growth of trees can be a significant long-term problem for wind machines so a decision has to be made on what to do with trees which grow too high. However, if the tower is high enough, the trees will have little effect. Typically, a 20 metre tower is used for small machines and hence trees over 5 metres high and within 100 metres of the tower will begin to have an effect on the wind.

A simple test for turbulence is to fly a kite with some two-metre lengths of light ribbon attached to the string every five metres. If the ribbons flap around there is turbulence, but if the ribbons remain nice and straight this is a good area to locate your turbine.

2.1.3 Isolated barriers

Select a site that receives the least disturbance to prevailing winds. If sited upwind from an isolated barrier such as a building, a wind machine should be located at a distance from the barrier equal to at least twice the barrier height. If sited downwind from the barrier, the machine should be sited at a distance from the barrier equal to least 10 times the height of the barrier. If the machine is located immediately downwind of a barrier, then it should be mounted at a height of at least twice the barrier height.

2.1.4 Scattered barriers

Scattered barriers, such as groups of trees or buildings, will cause greater disturbance to air flow (turbulence) and so require the wind machine to be positioned at a greater height.

The Beaufort wind scale

Beaufort Number	Windspeed in knots (m/s)	Description
0	< 1	Calm: smoke rises vertically.
1	1-3 (0.5-1.4)	Light air: smoke drifts slowly downwind.
2	4-6 (1.8-3.2)	Light breeze: leaves rustle.
3	7-10 (3.6-5.5)	Gentle breeze: leaves are in motion.
4	11-16 (5.9-8.2)	Moderate breeze: small branches on trees move.
5	17-21 (8.6-10.9)	Fresh breeze: small trees sway.
6	22-27 (11.4-14.1)	Strong breeze: large branches sway.
7	28-33 (14.5-17.3)	Near gale: whole trees in motion.
8	34-40 (17.7-20.9)	Gale: twigs and small branches break off trees.
9	41-47 (21.4-24.5)	Strong gale: large branches break off trees; slight structural damage.
10	48-55 (25-28.6)	Storm: trees broken; minor structural damage.
11	56-63 (29.1-33.2)	Violent storm: widespread damage.
12	>=64 (33.6)	Hurricane: violent movement of trees and much destruction.

Locate the wind machine at a minimum height of three times the tallest upwind barrier in the direction of the most prevalent winds.

2.1.5 Valleys

The most suitable valleys will have the following characteristics: they will be oriented to within 35 degrees of prevailing winds, have a sloping floor, be surrounded by high mountains or ridges and will have narrower sections to cause a funnelling effect. Make sure you also check the wind speed and the likely growth of trees in the valley.

2.1.6 Passes and saddles

Passes and saddles should have the following characteristics: high hills, or mountains on either side and a smooth surface.

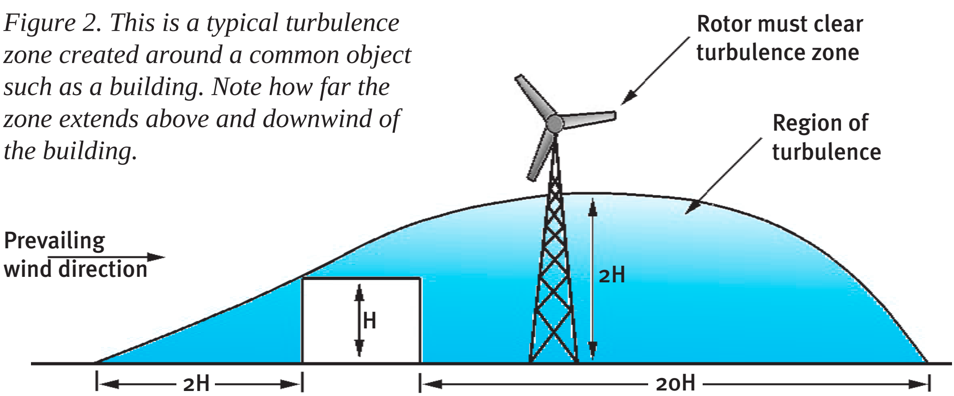
2.1.7 Temperature inversion effects

Temperature inversion layers typically occur as a result of the rapid re-radiation (cooling) to the atmosphere at night of heat energy stored in the earth's surface. Inversions are most likely to occur during winter when high pressure systems and light winds predominate. Inversion layers produce thermally stable atmospheric conditions—when the air temperature increases with height above the ground. A layer of denser, colder air forms above the ground and effectively dampens the transfer of wind energy from air at higher altitudes to air close to the ground. This effect is particularly strong at elevations of 0 to 20 metres.

To minimise the effects of temperature inversion layers, mount the wind machine at a height of not less than 20 metres above ground level.

2.1.8 Summary rules for siting

Figure 2. This is a typical turbulence zone created around a common object such as a building. Note how far the zone extends above and downwind of the building.



Correct siting of a wind machine tower is not overly difficult providing you follow a few simple guidelines:

1. Minimise turbulence at the turbine height (see Figure 2).

2. Choose a tower at least 10 metres higher than any object—such as trees or buildings—within 150 metres of the tower. A good rule is to position the wind machine at twice the height of the highest nearby obstacle.

3. Remember that obstacles can increase in height—trees grow!

4. Note the prevailing wind direction and locate the tower upwind of the highest obstacles.

5. Try to minimise compromises in tower location, tower height, and cable voltage losses (the longer a cable, the more power is wasted in the cable).

6. Consider using higher voltages to minimise voltage drop (higher voltages mean lower currents and lower power loss in the cable) and cable cost.

7. Rougher surfaces produce more turbulent winds. Open, smooth areas with few obstacles make the best sites for wind machines.

8. Never attach the tower to your house, regardless of what a manufacturer may claim.

Chapter 3: Selecting a tower

Once you have selected the best site for your wind machine you need to select the best tower for the optimum height.

3.1 Tower types

There are several types of towers, but avoid the following unless the tower has been checked by an engineer and deemed suitable: wooden poles, concrete poles and antenna masts.

The most common towers used for small wind machines are self-supporting tapered lattice towers (you need to like climbing or paying for cranes to install and service your wind turbine with this type of tower.) The other type is a tilt-down or tilting tower made from pipe or parallel lattice steel sections. These towers can be easily lowered for service and installation. This keeps your feet safely on the ground and eliminates crane costs. See Figure 4 for an example of how this system works.

3.2 Properties of a well designed tower

Cost: A tower can cost almost as much as the turbine itself—so don't cut any corners when selecting or installing it. The extra cost of a taller tower may add 10% to the cost of the total installation but yield 30% to 45% extra power for the next 20 years or more, making it a pretty good investment!

Quality: A good tower should be built to the relevant Australian standards and all the components should be rated as strong enough to do the job. Beware of cheap hardware-store grade parts with no load ratings. All parts should be galvanised steel or stainless steel to prevent corrosion.

Warranty: Ensure that the tower and the installation is guaranteed by the manufacturer and that the installer has public and product liability insurance.

Height: Ensure that the tower is the correct height for your site for now and in the future. The wind machine should be in turbulence-free air for all prevailing winds.

Service: The tower should be easy to raise and lower for any maintenance

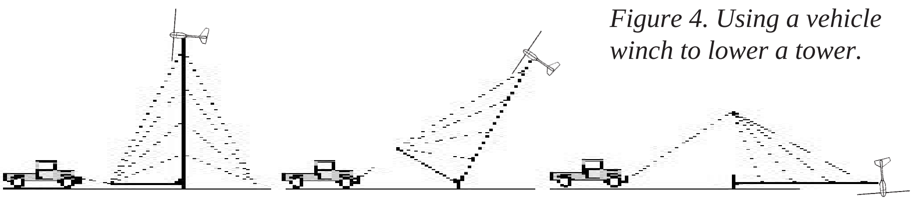


Figure 4. Using a vehicle winch to lower a tower.

inspections and repairs.

Rigidity: The tower should be vertical and rigid under all wind conditions for the machine to operate properly. Wobbly towers can cause metal fatigue and extra wear and tear on wind machines.

Resonance: Towers should not resonate in the operating speed range of the wind machine. Check with your supplier that resonance minimisation has been factored into the tower design.

Aesthetics: The finished tower should look good and be finished off in a tidy and safe manner. White plastic indicators covering the bottom two metres of the guy wires will help prevent tripping. Wire guy ropes or lifting ropes can corrode very quickly if left in contact with grass, so keep grass trimmed, or landscape around the tower base and guy anchor points.

Most towers for small wind machines in Australia are made using standard 6.5 metre lengths of pipe.

3.3 Suggested tower heights

6.5 metres (20 feet):	Never.
13 metres (40 feet):	Hill tops.
19.5 metres (60 feet):	Most installations.
26 metres (80 feet):	Buildings and trees nearby.
32.5 metres (100 feet):	Tall trees or obstacles nearby.

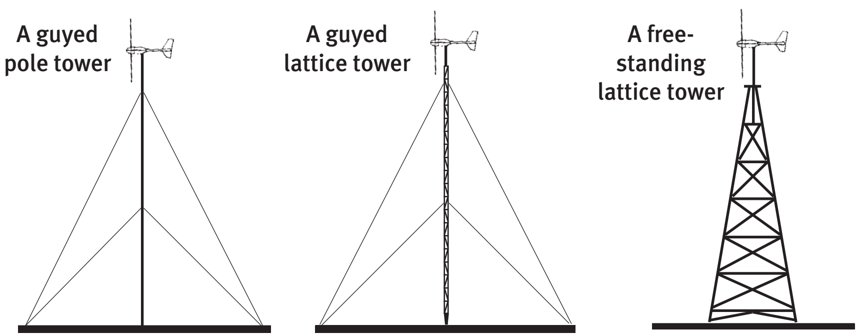


Figure 3. The three different types of towers available for small wind machines. Because of their wider base, guyed towers are stronger than free-standing types.

Wind power system planner

If you are planning an off-grid (stand-alone) renewable energy system you can use this simple planner to estimate how much electricity you use each day and what size renewable energy system you would need to meet your electricity requirements.
See the next page for the easy step-by-step guide to using this planner.

	Average power (watts)		Daily usage (hours)		Total (watt-hours)	
	Example	Your house	Example	Your house	Example	Your house
Kitchen						
Lights	20 watt CFL*		3.0		60	
Fridge	190		8		1520	
Microwave	1200		0.25		300	
Toaster	600		0.2		120	
Food processor	500		0.1		50	
Other						
Laundry						
Lights	15 watt CFL		1		15	
Washing machine	600		1		600	
Iron	1200		0.4		480	
Sewing machine	60		0.1		6	
Other						
Loungeroom						
Lights	2 x 20 watt CFL		4		160	
TV	120		2		240	
Video/DVD	110		1		110	
Stereo	60		2		120	
Vacuum cleaner	1000		0.2		200	
Other						
Bedroom 1						
Lights	15 watt CFL		1		15	
Other						
Bedroom 2						
Lights	15 watt CFL		0.5		8	
Other						
Workshop						
Power tools	300		0.5		150	
Pump	100		1		100	
Other						
Total Energy Consumption					4254	

* Compact fluorescent lamp.

Wind power system planner

Step 1. How much power do you use?

To find the total energy consumption in watt-hours, multiply the wattage of each appliance by the hours you use it per day. For appliances used only once per week, take the total time used per week and divide by seven to get the time used each day. You can find the wattage on the ratings plate at the back of most tools, motors and appliances. Our example system uses 4254 watt-hours (4.25 kWh) per day.

Step 2. Determining system voltage

If your total energy consumption is around 1kWh per day or less, then a 12 volt system voltage would be fine. You may also wish to use DC appliances directly from the battery bank, in which case a 12 volt system would be the most suitable, as most DC appliances are designed for this voltage. However, if you use more energy than this, or have several appliances that draw more than 1000 watts each, then a higher voltage should be used. You should also consider your future power requirements. In many cases, a 24 volt system will be fine, but for systems over 3kWh per day, a 48 volt system should be considered. For our example, with a power consumption of 4254 watt-hours per day, a 48 volt system would be recommended, as for a lower voltage the cables would have to be thicker and heavier (and more expensive).

Step 3. Size of the wind generator

Firstly, find the number of amp-hours you will require by dividing the watt-hours figure by the system voltage. For our example, this would be 4254/48, or 88.63 amp-hours per day.

Now you need to allow for the inefficiencies in the inverter and batteries as they charge. Assuming 85 per cent efficiency for the inverter, and 80 per cent for the batteries, we get 88.63/(0.85 x 0.8) = 130.3 amp-hours, rounded up to 131, which is the amount of energy we will actually need from the wind generator per day.

To calculate the size of wind generator needed, you need to look at manufacturers' power output charts and compare them in relation to the average wind speed for your site. The average wind speed will have to be measured based on site monitoring at the planned wind generator location and height. Normally, you would monitor for at least 6 months, preferably 12 months. If monitoring cannot be done over an extended period, basic wind speed measurements need to be done for at least a few weeks, or try the weather bureau to see if they have data for your area.

In a reasonable to good wind site, on average you can expect to get the equivalent of full output from the wind generator for four to six hours per day. So, assuming a five hour per day average, you would need a machine with a rated maximum output of 131/5, or 26 or so amps. This would be a 26 x 60 (the maximum voltage in a 48 volt system—you need to raise the batteries' voltage in order to push energy back into them while charging) or a 1.56kW machine, so you would install a 1.5 to 2kW machine.

Step 4. Sizing the battery bank

You need to have enough storage capacity so that you don't discharge your batteries by more than 15 per cent of their full capacity in an average day. This means that if you have a run of bad weather, you can keep going for five days before you have to start your backup generator. In practice you can size your battery bank by multiplying your daily consumption by five and dividing this by 0.7 (this gives you five days storage, plus 30 per cent reserve in the battery—remember that the battery must not be discharged by more than 70 per cent of its total capacity). In our example this would give (116 x 5)/0.7 = 829 amp-hours.

Step 5. What size inverter should I buy?

Most modern inverters have large surge and short-term output capacities. For instance, a 1200 watt inverter will be able to provide up to 3600 watts or so for short periods, and therefore should be able to run most 240 volt appliances. For the average house, an inverter in the range of 1200 to 2400 watts continuous output power would be appropriate. In most cases, a sinewave inverter is the most appropriate.

Chapter 4: System design

Designing a wind system is much like designing any power system—you start with a few basic questions: What job does the system have to do? What resources do I have? What is my budget? How will the wind system integrate with my existing equipment?

All the parts of the system need to work reliably and work well together. A good design will provide the power or water required when it is needed in a reliable, cost-effective manner.

4.1 Wind generator sizes

Small: Up to 10kW: Suitable for battery charging, grid connected systems and water pumping.

Medium: 10kW to 1MW: Large farm or industrial applications, and to supplement diesel generators in minigrids.

Large: 1MW to 10MW: Used in groups to make wind farms on land and off shore.

4.2 Wind system types

There are several common ways of using wind in a renewable energy system. All of these can be very successful if the components are selected carefully to complement each other. The common system types include:

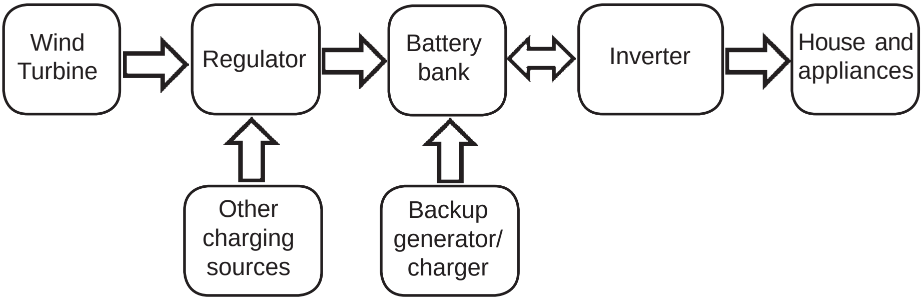
1. Wind generator only systems
2. Wind/solar/micro-hydro (hybrid) systems
3. Wind water-pumping systems

Although there are other wind turbine systems, for example, for milling or heating by driving a heat pump directly, these are rare applications and are unlikely to be the requirement for most prospective wind energy system purchasers.

4.2.1 Wind generator only systems

Unless they are grid connected, the variability of the wind requires such systems to have batteries for energy storage. Although other storage media such as ultra capacitors and flywheels are available, these are not yet commercially viable for most applications.

Grid interactive wind power systems, while fairly rare in domestic-scale installations, allow you to eliminate the battery bank—although a stable grid connection is required for this type of system.



The basic flowchart of a stand-alone wind energy system. Note how the battery bank is at the centre of the system—which makes it very important that the correct battery bank is selected!

4.2.2 Wind hybrid systems

Typically, wind hybrid systems include photovoltaic (solar) panels and may include a petrol or diesel driven generator set. The advantage of hybrid systems is that the multiple energy source availability reduces the risk of running out of energy. For example, often if it is not windy, then it is likely to be sunny. Failing both, a petrol or diesel generator can be used.

While multiple energy sources may allow you to reduce the size of the battery bank, this is usually not a good idea as even with more than one energy source it is easy to excessively discharge the battery bank. What's more, sufficient battery storage should be provided to allow for unscheduled maintenance and breakdowns, and to conserve generator use when only a small amount of energy is required.

4.3 Designing for your needs

When designing a wind energy system, you need to consider:

1. Your energy needs
2. Wind speed and site assessment
3. Wind machine performance
4. Position of wind machine
5. Tower type and height
6. Battery size and position
7. Inverter size
8. Controller
9. Noise
10. Cost effectiveness

11. Planning permission
12. Civil Aviation Safety Authority approval if near an airport.

The order in which you consider all the factors and make your plans is important. Until you have decided on the basic parameters of the wind machine you want to install, you cannot proceed to get planning permission.

4.3.1 Your energy requirements

You are looking to install a wind machine because you need electricity or water, but exactly how much do you need, both now and in the future? To determine this, either measure what you are using now, or calculate your energy usage using the pull-out work sheet in this booklet.

Start by determining how much energy you'll need in watt-hours. Look at the appliances that you already own and those you may wish to use and determine their power consumption in watts. Often, if the wattage is not listed on the appliance, the volts and amps often are. Multiply the two together and you will get a figure which approximates the power in watts. Be aware though that these figures are usually the maximum ratings so the appliance may not use this much power on a continuous basis.

You then need to estimate how many hours a day the appliances will operate. Add in appliances that you may not use every day, such as the vacuum cleaner and washing machine. If you use the vacuum for one hour per week, then you are using it for approximately 0.14 (1/7) hours per day.

Fridges are large consumers of energy, and for an average fridge, running times of up to 10 hours a day may occur. You may need to consider purchasing a new low-energy fridge—spending $2000 on a low-energy fridge may save $4000 to $5000 in other system costs.

When adding up your energy use, be honest – don't tell yourself you only watch TV for an hour a day when in fact you watch it for four!

Now, for each appliance, multiply the watts by the number of hours the appliance runs each day to get the watt-hours figure. Lastly, add up all the watt-hours figures from each appliance to get a total figure for the average energy you use per day.

4.3.2 Understanding your loads

It is important when designing a system that you know the types of appliances you want to use so that their energy requirements can be factored into the system design. Any appliances used should run on as little energy as possible to achieve the required result.

In a grid-interactive system, unless there is some form of battery backup, all appliances will need to be of the 240 volt AC type. In an independent (battery-based) system, all appliances may be 240 volt types, but there can be advantages in running some on DC directly from the battery bank. A good example of this is lighting. It is not very efficient running a 2000 watt inverter for a single fluorescent light, so running some DC lights directly from your batteries can eliminate this inefficiency. This setup has the added bonus that lighting will still be available even if the inverter fails for some reason.

In order to run large appliances (such as workshop machinery) you can configure the system to provide those loads from a circuit which has a demand start on the backup generator. This helps to reduce the overall size of the system which, if sized to cater for such large loads, would then have excess capacity for a large proportion of the time.

4.3.3 Running appliances from a battery bank

240 volt

Most homes will have the majority of their appliances as standard 240 volt AC type. However, there are a couple of things to be wary of when designing a system which uses AC appliances. Firstly, most AC appliances are not as efficient as they could be, being designed to run from power that is considered plentiful and cheap.

Another thing to bear in mind is that many appliances which have motors, such as fridges, vacuum cleaners and washing machines, will draw a start-up surge. That is, they will draw a much greater amount of power when the motor first starts than when it is running. See the inverter section 4.4.5 for more information about this.

Another problem is that many appliances—especially those with electronic circuits—may not run well on a modified-square-wave inverter. If you plan to use such devices, such as TVs or stereos, then you should consider purchasing a sinewave inverter. Even though the initial cost is greater for a sinewave inverter, the quality of the power provided is the same or better than mains power, so you can be sure all of your appliances will run as they should.

Extra-low-voltage DC appliances

There is a reasonable range of extra-low-voltage appliances available. You can buy 12 and 24 volt fridge units, and while they cost more than the 240 volt equivalents, are usually much more efficient.

Most cassette players and portable TV sets will operate from 12 volts (with appropriate adaptors where necessary).

Fluorescent lights provide the same light output as incandescent globes for a lot less energy. Extra-low-voltage fluorescent light fittings have a small inverter inside them which converts the extra-low voltage up to the few hundred volts necessary to operate the fluorescent tube. They come in sizes ranging from four to 40 watts and cost from $10 to $100.

Devices designed to run on extra-low-voltage DC directly from the battery bank can provide several advantages—including a degree of redundancy from the inverter and higher efficiency—but they will require the added expense of suitable wiring, so this has to be considered. Power is simply the system voltage multiplied by the current drawn, so, an extra-low voltage appliance rated equivalent to a 240 volt AC device will draw a lot more current, requiring thicker cables than would be needed for 240 volt systems.

There are many small appliances designed for the automotive market that can be used in 12 and 24 volt DC independent power systems. However, most of these appliances are fairly low powered.

4.3.4 The importance of energy efficiency

This is probably the most important part of system design, yet is often overlooked by the novice designer. There is no point spending large amounts of money on renewable energy generating equipment when the energy it generates is being wasted!

As an example, if you have a 100 watt incandescent light globe that is on for five hours per night, it will use 500 watt-hours of energy per night. To generate this much energy would take, on average, around 100 watts of wind generating capacity, worth around $500 or more. Yet, replacing this globe with a 20 watt fluorescent bulb will mean that only 20 watts worth of wind generation capacity would be adequate to power it—at a cost saving of hundreds of dollars! What's more, the required battery storage capacity and regulator size would also be less, providing further savings. Not bad for a $10 light bulb.

This example applies to *all* appliances to be used with an independent or grid-connected

Using energy efficient appliances, like this Waeco fridge, is doubly important when you are generating your own electricity.

system. Spending a few hundred or even a couple of thousands of dollars on more efficient appliances could save you a great deal more than this on generating equipment.

Probably the biggest culprit in power wastage is the AC fridge. Most fridges are very poorly designed, especially frost-free units which have heating elements in them to stop frost build-up. A good quality 12 or 24 volt DC fridge, or a more efficient AC unit, can save thousands in system costs.

For a full list of energy efficient 240 volt whitegoods see www.energyrating.gov.au

Phantom loads are also a great consumer of electricity. In the average Australian home more than 12% of daily electricity consumption is by electrical appliances which are not even being used. Examples of some phantom loads include VCRs, DVDs, televisions and stereos in stand-by mode and digital clocks on ovens and microwaves. Modern computers and peripherals also draw power when plugged in and turned off. Even plugpacks, such as mobile phone and cordless tool chargers, continue to use energy when they are switched on but not in use.

4.3.5 Energy auditing

Before a system is designed, it is important to reduce the energy consumption of the building itself. Most conventional appliances are hopelessly inefficient, so it's important to verify the consumption to ensure you will not be installing a renewable energy system that is smaller (or larger) than actually needed. For a home which uses gas or another fuel for water heating, cooking and space heating, electricity consumption should be well under 10 kilowatt-hours (kWh) per day, and preferably under five. If not, then you either have too many gadgets, or your appliances, lighting and house design are inefficient and require looking at.

An audit involves listing all appliances in the home including lights and

	Wind turbine rotor diameter			
Average windspeed	1m	2m	3m	5m
3m/s	70	350	860	2280
4m/s	210	860	2140	5710
5m/s	430	1710	3570	10,710
6m/s	570	2430	5710	15,710

Wind generator outputs (watt-hours per day) at various rotor diameters and windspeeds.

determining the energy consumption of each. This can be done by multiplying the power rating of each appliance (from its ratings plate) by the number of hours it is used per day. For appliances used occasionally such as vacuum cleaners, simply calculate the weekly consumption and divide that by seven for a daily rate.

4.4 Designing a wind power system

4.4.1 Wind speed and site assessment

This is a complex area which requires an experienced, trained site assessor or installer.

4.4.2 Wind generator performance and size

Wind generator size is difficult to accurately assess unless the wind regime is well known. If an expensive system is being contemplated, it would be helpful to install a small wind generator, say 100 watts in size, to assess the performance of the site. If the output proves satisfactory, then a suitable larger machine can be installed.

For medium and large wind power projects a temporary test tower with wind speed and direction instruments needs to be installed for 12 months. The wind data is recorded and processed to give an accurate prediction of potential wind generator performance for the site.

The diameter of the circle traced out by a wind machine's blades is the most important factor in determining how much energy it will generate. Use the table opposite to estimate the size of wind generator required for your site.

Note that if the average wind speed is used to calculate the wind generator output, then the result is likely to be an underestimate of the energy output of the machine.

4.4.3 Energy storage

It is generally not common to use the energy from a wind generator directly, so some form of energy storage is required. This is usually in the form of a large lead-acid or nicad battery bank. The size of the battery bank varies depending on each household's needs, and you must always allow for several days worth of storage for periods of no wind. Typically, five days energy storage is the minimum recommended, and many designers recommend seven or even 10 days storage.

The extra storage gives the system greater flexibility and allows it to provide energy more effectively. Storing the energy in a battery means typically up to 20% is lost from inefficiencies in battery charging. So, using the energy at the same time it is being generated—such as by running large loads like vacuum cleaners during windy periods—reduces these losses.

The type of battery used is very important. They need to be deep-cycle types designed for power supply systems—not car or truck batteries, which will degrade quickly with this sort of use.

Having worked out average energy usage per day in watt-hours, the size of the battery bank can be calculated. However, battery storage is usually expressed in amp-hours—which is misleading, as the energy stored depends on battery voltage. To convert between the two units, divide the daily watt-hour figure required by the nominal system voltage (12, 24, 48 volts or whatever). This gives the amp-hour capacity required of the battery bank each day. Then multiply this figure by five (or however many days energy storage is needed) to get the five days energy storage figure, and then divide by 0.7 to provide enough capacity so that the batteries are not discharged too deeply. This is then the total battery storage that you need.

One of the problems with a long wind lull is that the batteries can become flat and then cannot be recharged as there is insufficient energy coming from the turbine to supply the house with energy and also charge the batteries. Flattened batteries can be permanently damaged through sulphation, so if solar panels are also connected to the system, they will help to maintain the batteries as well as being able to supply some useful energy. This is known as a hybrid system and should be seriously considered when designing any wind power system.

These batteries are typical of those used for energy storage in wind power systems.

4.4.4 Inverters

The inverter you will need depends on your power requirements. If you only have low-power appliances—up to 500 watts per appliance—then you should be able to get by with a 1000 watt inverter with few problems. However, if you have a large washing machine, toaster or microwave, or you use a lot of power tools, then you will need a bigger unit, say with a 3000 watts continuous rating.

Selecting the right inverter is simply a matter of looking at the power ratings of your appliances, taking into account how many are likely to be running at one time, then choosing an inverter in that power range with the options and features you want. Another factor to consider when sizing an inverter is the surge requirement of some appliances. Appliances with motors—such as fridges, vacuum cleaners and washing machines— draw more than their rated running power when they first start up. This extra power is known as surge power. For example, a fridge with a motor rated at 150 watts may draw over 1000 watts when starting, so the inverter needs to have an adequate surge capacity to deal with this. What's more, an inverter running a 240 volt household must have enough spare capacity to start the 240 volt fridge, regardless of what other appliances are running.

4.4.5 Controls and regulators

It is possible to damage batteries by overcharging them. The maximum voltage that a lead-acid battery should be charged to is about 2.5 volts per cell or 15 volts for a 12 volt battery. To prevent batteries being overcharged, and to allow you to make use of excess energy produced by the wind generator, a device called a regulator is used. It automatically stops the wind generator charging the battery when the battery's voltage gets above a set value.

There are two main types of regulator used for wind generators; diversion or shunt. Diversion regulators are like an electronic switch which disconnects the panel from the battery when the battery is full. With most wind generators you must always keep a load on them to prevent them from overspeeding (there are a few exceptions to this—some very small wind generators don't require a load at all times). To maintain a load on the generator, the regulator connects the output of the wind generator to another load—often a water heating element, water pump or similar fairly consistent load.

Shunt regulators work in a similar manner, diverting excess energy to an alternative load. However, they do this gradually as the battery voltage rises, rather than switching on and off like a diversion regulator.

Regulators may include other features such as battery state of charge indicators or current flow indication, and many are now microprocessor controlled and can be programmed to suit different installations and battery types.

Many regulators have a feature known as temperature compensation. The voltage most batteries should be charged to varies with temperature, and because the batteries may be subject to wide temperature variations between seasons, it is important to make small corrections to the charging setpoints depending on temperature, otherwise overcharging or undercharging may result.

4.4.6 Noise

Most wind generators are not particularly noisy, but some can be, especially when there are high winds and the generator is yawing (turning out of the wind—also known as furling) or spinning with no load (some small turbines can do this safely). Mostly, noise is not a problem as the yawing tends to occur at higher wind speeds—when the wind itself is noisy enough to mask that from the wind generator.

Noise concerns certainly are an argument for not siting a wind generator too near the neighbours. Usually, the more blades the rotor has, the quieter it is. This is mainly because it will turn more slowly and as each blade produces less torque, when it passes in front of the tower it will have less effect on the torque being delivered by the rotor to the alternator, and so will make less noise. Another reason why slower blades make less noise is that the pressure that builds up between the blade and the tower as the blade passes is less. Generally, if the wind generator is noisy enough to disturb someone under normal wind conditions, then it is either faulty or is not well designed.

In most European countries, the noise limit in a residential area during the daytime is about 40 to 45dB(A) at the nearest house, which is the level of noise in a fairly quiet office.

In some countries, night-time noise limits are lower by 5dB(A). Typically, noise from a wind generator will be audible but not disturbing, much like having crickets in the garden.

4.4.7 Cost effectiveness

If the system that seems ideal is just too expensive, there are some things which can be done to reduce the cost—but it will mean that you need to adjust your lifestyle somewhat.

The basic requirement is to use less energy, or use energy only when it is available. This can be achieved by prioritising your energy usage so that some appliances are only used when energy is available.

Typically, lighting comes top of the list, followed by refrigeration and then by audio/video equipment or a washing machine. Efficient lighting does not consume much energy and audio/video equipment use can be postponed—but using less energy for refrigeration can be more difficult.

Fridges are often the largest single user of energy in a home. Whatever refrigerator is used (no matter how efficient), opening the door often wastes energy, as the cooled air literally falls out onto the floor (open a fridge door while you have bare feet to feel this for yourself). This can be improved by limiting the number of times the door is opened, by using a top-opening chest type refrigerator, by making your fridge full using empty ice-cream containers, or by having plastic curtains on all the shelves to limit the airflow out of the refrigerator.

Lastly, a switch (such as a timer switch) can be installed on the refrigerator so that it will operate only when energy is available.

Another way of reducing system costs is by the owner doing as much of the installation work as possible by themselves. This requires careful consideration of what must be done by a licensed and qualified person and what can be reasonably done by a handy person. The most likely restriction is that the low-voltage wiring (240 volt) must be installed by a licensed electrician. Low-voltage wiring can be lethal if installed incorrectly. Even extra-low-voltage wiring (12, 24 or 48 volts) must be installed to a professional standard, especially considering the higher currents involved. Put simply, if you are not sure about what you are doing, find someone who does. Don't be pig-headed about it—after all, it is your life and property at risk.

Usually, council permission must be obtained to erect anything permanent and/or of substantial size on a property. It may still be possible to get an owner-builder's license from the council, but the construction would then need to be approved by the council building inspectors as per regulations.

4.5 Other considerations

4.5.1 Siting for the neighbours

Most people are hesitant about new tall structures nearby, hence they may oppose a wind machine being erected in full sight. However, there are some simple precautions which can assist in attaining a suitable agreement with your neighbours.

Before erecting the machine, discuss the wind energy options with them. Seek their advice on siting. Perhaps drop some wind energy information off at their place for them to browse. However, once you have decided to go ahead, consider the following points.

Firstly, the machine should not be able to reach the neighbour's property if it should fall (or be lowered). Secondly, placing it in an inconspicuous position from the neighbour's point of view is likely to help. Finally, offering to sell or give away any excess power to your neighbour may be the clincher.

4.5.2 Planning permission

Your plan to install a wind machine may affect many people so consider the following when making your plans:

- National parks and some public lands may not permit them—check with the relevant authorities
- Neighbours need to be consulted and kept informed to prevent any conflicts
- Your local council will need to issue a planning and building permit so check to see if they have guidelines, or look for examples of other planning guidelines in your state or territory
- Possible negative environmental effects
- Native title and Indigenous groups
- Possible effects on native flora and fauna
- The geology of the site.

The bigger the project the more complex this process may be—so seek expert advice from an experienced installer or wind turbine manufacturer.

If you live near an airport, you may have to apply for approval from the Civil Aviation Safety Authority.

4.6 Conclusion

Designing a system is fraught with problems and unknowns. In the end, it is best to initially discuss the design with local experts to see if it tallies with their experience and work out where any differences may lie. There is considerable information available to assist you in designing an energy system, both in books and online, so take the time to do the research—it could save you a lot of time and money in the long run.

Chapter 5: Water pumping

Windmills have been a part of the Australian landscape for over 100 years. Their design hasn't changed much but the humble windmill may still be your best answer for cost-effective water pumping.

Water pumping using windmills is often viable in low wind speed areas, even with average speeds as low as 2.5 to 3m/s. Often in such areas the wind is a daily phenomenon at a particular time—hence the average is low—but when it is windy, the speed is usefully high. The energy required to raise water is not as high as one might expect, so even relatively inefficient turbines such as windmills do a useful job. In the end, the main requirement is a low-cost way of pumping water. However, traditional water pumping windmills have one major disadvantage in that they need to be placed above the water source. This can often be in the lowest patch of land, which will often have the least wind.

5.1 Pumping windmill types

5.1.1 Wind electric systems

The alternative to a traditional windmill is a wind-electric system, in which an electricity generating wind machine is placed in the windiest spot and an electric pump located near the water source. Such wind-electric systems have advantages over using remote area power systems for pumping in that they do not need batteries. On the other hand, a remote area power supply system can serve many needs simultaneously, including water pumping.

Sizing of wind-electric systems requires specialised calculations match the size of the electric water pump to the wind generator. A control interface between the wind generator and pump is required to allow the generator to start easily and then pump water once it is up to speed.

Wind-electric systems are quite rare,

with only one or two companies manufacturing them (US company Bergey being one of them), and off-the-shelf electrical water pumping wind systems do not seem to be readily available in Australia. They are also generally more expensive than mechanical water pumping windmills.

5.1.2 Pumping windmills

The windmill's most obvious feature is its many blades. These are necessary to provide enough torque to drive the piston pump which is usually found in these systems. The pump requires a lot of starting torque, but once pumping, the torque required is less and the blades will continue to drive the pump in very light winds. Direct drive windmills pump the most water in strong wind areas, but a geared-head windmill will deliver more water in lighter winds. In many dry areas the wind is not particularly good, so (if there is a choice), it is common to use a lower gearbox ratio or a larger rotor to obtain more frequent pumping—although less water is pumped in strong winds than when using a direct-drive windmill.

Windmills operate at windspeeds of up to about 12m/s, at which speed they will furl (that is, turn out of the wind) so they are protected from damage by very strong winds. Generally, they do not operate at more than 50 pump strokes per minute, to protect the pump and to guard against water hammer problems.

The most common pump type is the piston pump due to its relatively low cost. Since the piston is likely to travel the equivalent of several thousand kilometres per year, the seals will usually need replacing every year or two.

5.1.3 Compressed air windmill pumps

These are very rare, and we know of only two manufacturers, Bowjon (www.bowjon.net) and Airlift (www.airlift.com)—although Bowjon now seem to be unavailable. These use a windmill to drive an air compressor which pumps air down the bore via a small diameter supply pipe which is connected to the lift pipe via a T-junction below the bore water level. As the air rises back up the bore via the lift pipe, it lifts water along with it.

5.2 Calculation of windmill parameters

When calculating the size of pumping windmill required, you'll need to know;

1. The total pumped head; which includes head loss, drawdown (the depth well water drops due to pumping), tank height and static head.
2. Volume of water required
3. Wind speed at the site.

There are three windmill variables to combine to meet your pumping needs. Common ranges are:

	Metric size	Imperial size
Fan or blade diameter	1.8 to 9 metres	6 to 30 feet
Pump cylinder diameter	44 to 203mm	1¾ to 8 inches
Tower height	4.6 to 15 metres	15 to 50 feet

A common combination, made by Dean and McCabe in South Australia, is the Varco eight foot geared-head windmill with a 2½ inch pump on a six metre (20-foot) tower. This combination suits most situations and other manufacturers can supply similar combinations. The pump size can be easily changed if more or less water is required.

5.3 Pipe size

In general, the pipes should be designed for four times the average daily water flow in order to keep the head-loss low. The head-loss per 100 metres can be worked out using the table below. Your supplier can advise you on the best pipe size for your application.

5.4 Maintenance

Over 90% of all windmill failures can be traced back to lack of maintenance, so be sure to:

- Check the gearbox oil level every six months and change the oil every

	Pipe Diameter				
m^3/day	25mm	37mm	50mm	75mm	100mm
10	0.5	0.1	0.02	0.00	0.00
20		0.43	0.07	0.01	0.00
30		0.90	0.20	0.02	0.01
40		1.60	0.30	0.04	0.01
50			0.50	0.06	0.02
60			0.70	0.09	0.02
70			1.00	0.12	0.03
80			1.30	0.16	0.04
90			1.60	0.20	0.05
100			2.00	0.25	0.05
110				0.30	0.06
120				0.35	0.08
150				0.60	0.12
200				1.00	0.20
300					0.45

Head loss in metres per 100 metres of pipe length.

two years

- Grease turntables, furling and tail mechanisms every six months
- Check the tower, blades and head bolts every 12 months
- Check the pump shaft, washers and seals for wear every 12 months

In coastal areas or when pumping dirty water, more frequent checks may be required.

Often, water-pumping windmills are damaged by high winds. Although most will furl automatically, the mechanism is not always reliable—either because it is not correctly adjusted or it has seized up. Self-furling mechanisms are not often required to activate (in most cases) and hence do have a tendency to seize. Consequently, operating the furling system manually (at least monthly) is needed to keep it operational in the event of high winds.

5.5 Pump size

Suppliers are best-placed to advise on pump size. Size selection is a compromise between being able to pump sufficient water and being able to start pumping at a sufficiently low wind speed for the required head.

5.6 Storage tank or dam size

Since the wind does not blow continuously, lull periods may require the use of a storage tank or dam. Typically, data on wind lull periods may not be available, but a safety factor of two (making the tank twice as large) allows for long lulls or for when the pump is out of action for maintenance.

The cost of a tank per litre usually decreases as its size increases, so the cost of a safety factor of two is less than twice the cost of the smaller tank size. Dams are cheaper than tanks if you have a suitable property. A dam can hold enough water for several weeks or even months of use.

5.7 Conclusion

Standard water pumping windmills suffer from the disadvantage that they need to be placed directly above the water source, yet they are simple to operate and maintain with only a basic understanding of mechanics. Thus, such windmills appeal to many people and can be expected to provide many years of service—providing they are maintained and furled during storms.

Community wind farm system

Location: Leonard's Hill, Victoria

Wind generators: 2 X RE Power Systems MM82 2.05MW, total 4.1MW

Blade diameter: 82 metres

Tower height: 68 metres

Cost: $13,000,000

Comments:

The Hepburn Wind project is a co-operatively owned wind farm owned by around 1600 members, mostly in the local Daylesford area. The members have collectively invested more than $8.7 million in the project, with the balance coming from Bendigo Bank and the Victorian Government.

The project is expected to offset the energy use of around 2300 local homes, more than the number of homes in Daylesford. Hepburn Wind has chosen Australian-owned energy company Red Energy as their energy retailing partner.

Hepburn Wind co-operative members will share in the proceeds of electricity sold and a portion of profits will be returned to the local area via a community sustainability fund, with plans to provide more than $1 million to sustainability initiatives over the next 25 years.

Go to www.hepburnwind.com.au/register.htm for more information.

Useful references

Clean Energy Council (CEC): www.cleanenergycouncil.org.au

Civil Aviation Safety Authority: www.casa.gov.au

Australian wind turbine manufacturers

Electricity generating turbines

Soma Power: ph:(02) 4381 1531, www.somapower.com.au

Flowtrack turbines: ph:(02) 6689 0408, www.flowtrack.com.au

Wind Machine: ph:(08) 8554 7141, www.windmachine.net.au

Water pumping turbines

Oasis Windmills: ph:(03) 5828 6452.

Ropatec: Crest Australia, ph:(08) 8267 2366, www.ropatec.com

Tyco Pumping systems: ph:131 7867, www.tycopumpingsystems.com

WD Moore: ph:1800 654 766, www.wdmoore.com.au

Other Australian retailers of non-Australian made wind generators

Aerogenesis: www.aerogenesis.com.au

Advanced Wind Technology: ph:(07) 4093 8899, www.iig.com.au/wind

Conergy: ph:1300 551 303, www.conergy.com.au

EcoInnovation (New Zealand): www.ecoinnovation.co.nz

Jaycar Electronics: ph:1800 022 888, www.jaycar.com.au

Macfarlane Generators: ph:1300 622 436, www.macfarlanegenerators.com.au

Planetary Power: ph:(07) 4096 2420, www.planetarypower.com.au

Precision Wind Technology: ph:(02) 6679 1234, www.pwt.net.au

Rewind Energy: ph:1300 322 678, www.rewindenergy.com.au

Solar Charge: ph:(03) 9544 2001, www.solarcharge.com.au

Solar Online Australia: ph:(02) 4954 3310, www.solaronline.com.au

Todae: ph:1300 138 483, www.todae.com.au

Wind Turbines Australia: www.windturbinesaustralia.com.au

For more information on wind generator suppliers see the wind power buyers guide in issue 100 of *ReNew* magazine available at shop.ata.org.au

Interesting windmill related websites

All Small Wind Turbines: www.allsmallwindturbines.com

Build It Solar: www.builditsolar.com/Projects/Wind/wind.htm

Danish Wind Energy Association: www.windpower.org/en

Early History Through 1875: telosnet.com/wind/early.html

Morawa District Historical Society and Museum: www.members.westnet.com.au/caladenia/

Motorwave Group: www.motorwavegroup.com

Wind and Hydropower Technologies Program; History of Wind Energy: www1.eere.energy.gov/windandhydro/wind_history.html

Wondermagnet.com (amazing magnets): www.wondermagnet.com

Wind Stuff Now: www.windstuffnow.com

Windturbine Warehouse: www.windturbinewarehouse.com

Notes on using this book

Metric units of measurement are used in this booklet. Common conversions between metric and imperial units are given below.

- Wind Speed: metres per second (m/s): 1m/s=1.94 knots or 2.2mph or 3.6km/h.
- Distance: metres (m): 1 metre = 3.28 feet.
- Power: watts (W): 745 watts = 1 horsepower.
- Energy: watt-hours (Wh) or kilowatt-hours (kWh): 1kWh = 3.6MJ (particularly used in determining energy consumption of gas appliances).

Want to know more?

If you want to know more about renewable energy technology you can become a member of the Alternative Technology Association (ATA), Australia's leading environmental technology organisation. ATA is a non-profit, community-based organisation which supports householders to incorporate renewable energy, energy efficiency, water conservation and sustainable building practices in their homes. Known for its practical focus, ATA has Australia's largest network of people with these shared interests .

Membership includes access to ATA's advisory services, member discounts and a subscription to *ReNew* and/or *Sanctuary* magazine plus more.

For more information go to: www.ata.org.au

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