Wind systems

The amount of renewable electricity harnessed from the wind is growing rapidly. Australia has an abundant wind resource, which, if used to generate electricity, could save significant greenhouse gas emissions. To take advantage of this resource, turbines must be installed in open sites on sufficiently tall towers.

Appropriate wind system locations

Begin investigating wind technology by 'reality checking' your general location. Wind generators need 'clean' and sufficiently fast wind to produce electricity. Clean wind is strong and laminar, which means it flows in smooth streamlines and is not disrupted by nearby obstacles.

Coastal locations, and flat rural areas without significant vegetation or buildings, offer the most laminar wind flow. Small wind systems should generally be installed only in these areas. Significant turbulence is caused by terrain such as steep hills and cliffs as well as ground clutter such as trees and nearby buildings or structures.

Urban areas have a poor wind resource that is usually extremely turbulent. Productive wind power systems place the wind generator on tall towers in clean wind, well above areas of turbulence caused by obstructions — usually impossible in urban areas.

Urban areas have a poor wind resource that is usually extremely turbulent.

Wind systems installed on roofs typically do not produce much electricity, have short life spans and are thus never economically sound. Be wary of turbine installers or manufacturers claiming products are suitable for urban or turbulent locations, and always prioritise solar photovoltaics if investigating residential renewable electricity options in urban areas. Ensure your installer is certified by checking the Clean Energy Council list of Certified Small Wind Installers at www.solaraccreditation.com.au

Connecting wind systems

Small wind turbines can be connected as:

- grid connected, no battery storage
- off-grid or independent stand-alone power systems
- grid connected, with battery storage.

A grid connected system allows the wind system owner to send electricity back to the grid when excess electricity is produced, and draw electricity from the grid when more is needed.

Stand-alone power systems are most practicable in locations that are some distance from the electricity network. They typically use more than one technology to generate electricity, such as wind and solar photovoltaics combined, to take full advantage of seasonal and daily variations in wind and solar resources.


Photo: AUSWEA and University of Newcastle

A domestic wind turbine.

A grid connected wind power system with battery storage is currently uncommon; it is most practicable when an uninterruptible power supply is required.

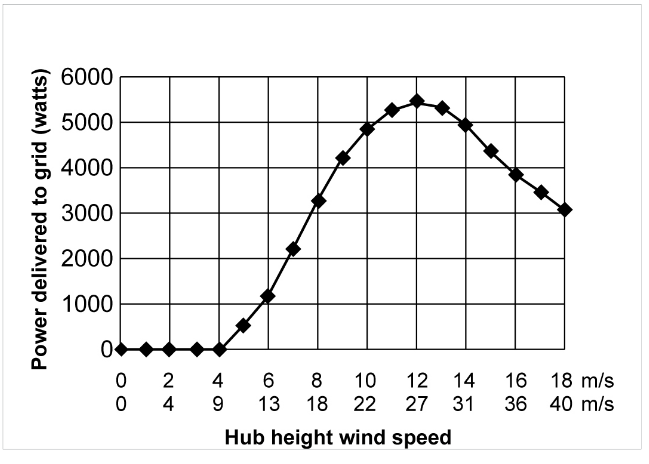
Determining your wind 'fuel' or resource

If your site seems suitable, quantify your wind resource, usually with the help of a wind site assessor or installer, to estimate how much energy a wind turbine will produce at your site.

In all areas of Australia the wind varies with the seasons, and many locations have stronger winds in winter. Many coastal regions often have sea breezes as their prevailing winds in summer.

Determining the average annual wind speed (typically measured in metres/second) at your site may be challenging, although several state government programs are developing tools to help estimate wind resources. When estimating the output of a wind system at your site, wind site assessors or installers should use:

- multiple wind speed data sources (e.g. wind maps or modelling, automatic weather stations, nearby monitoring sites) to generate a robust understanding of wind patterns at the site
- topography maps and a site visit to estimate wind shear (the rate at which the wind speed changes with increasing height from the ground)
- the proximity of trees, buildings and other obstacles to estimate turbulence intensity
- the power curve of the wind system, obtained from the manufacturer, which shows the expected power output of the turbine in any given wind speed.



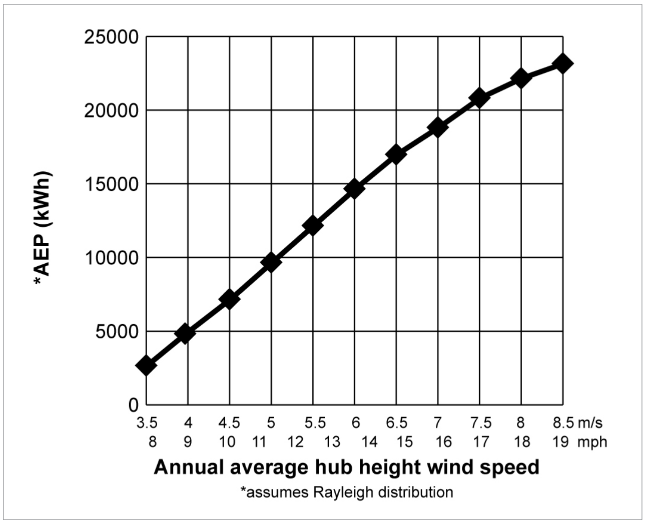
Source: www.endurancewindpower.com

The power curve for this particular turbine shows a power output of 500W at a wind speed of 5m/s and 4,900W (4.9kW) at 10m/s.

Off-grid small wind systems usually require a minimum average annual wind speed of at least 4–5m/s to be cost effective; for grid connected systems the annual average should be greater than 6m/s.

Automatic weather stations typically monitor wind speeds at 10m above ground level; wind models typically estimate wind speeds at heights of 50–80m. Note the height at which annual wind speed data is sourced, because if it is not exactly the same as the height of your tower, the wind site assessor must estimate the wind speed at your tower height.

For example, a site with 5m/s average annual wind speed at a height of 30m may only have 3m/s average wind speed at a height of 12m. In this case, a wind system placed on a 12m tower produces negligible electricity; the same system on a 30m tower produces at least ten times more electricity.



Source: www.endurancewindpower.com

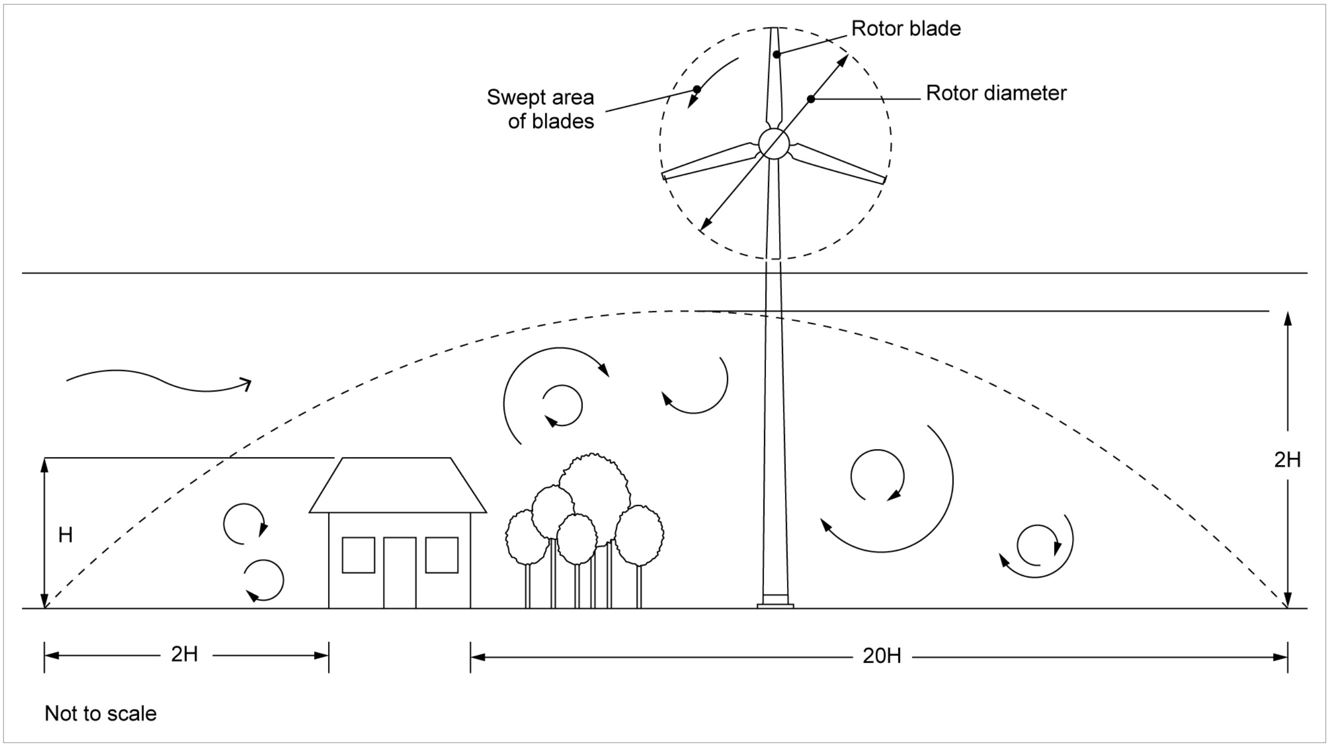
This turbine produces around 5,000kWh/year with an average annual wind speed of 4m/s or around 15,000kWh/year at 6m/s. Taller towers and good siting allow wind systems to access faster wind speeds.

Manufacturers should state the 'cut-in' wind speed of the turbine, the speed at which the wind generator begins to turn and generate power. In areas with frequent light winds, a low cut-in speed is important for maximum output.

Prioritise sites on elevated, open land where winds are unimpeded by trees and buildings. That's where wind turbines generate the most energy.

Sites on elevated, open land where winds are unimpeded by trees and buildings, should be prioritised, as this is where wind turbines generate the most energy.

Site turbines away from turbulent winds caused by any obstacles, if possible. In cases where wind systems cannot be sited away from obstacles, an appropriately tall tower is critical.



Turbulent winds extend up to two times the height of the obstacle and a distance downwind of 20 times the height of the obstacle.

Determining appropriate tower heights

The most common mistake for small wind systems is putting a wind generator on too short a tower. It's the equivalent of putting a solar collector in the shade.

Avoid making this common mistake by understanding output and site conditions, and asking the right questions of the installer.

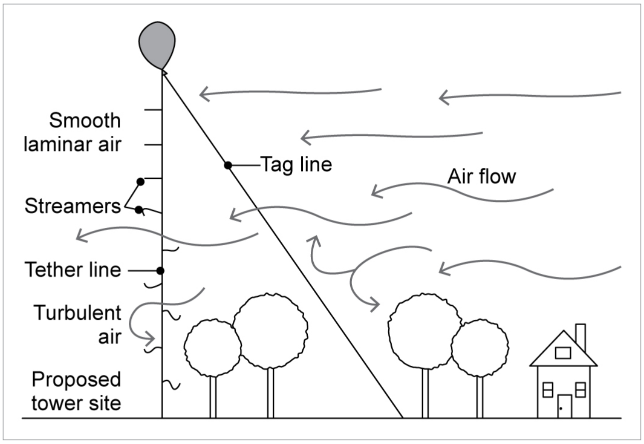
Output from a wind generator is tied to the speed of the wind in a cubic relationship — i.e. doubling the speed available to a wind system increases the power available by eight times. Tall towers that access faster wind speeds can reap larger rewards.

Wind speed increases, and turbulence decreases, with height. Below the height of 20m the friction between wind and earth slows the wind speed significantly. This zone is also often very turbulent.

Install your wind generator on the highest tower that is practicable and cost effective for your site. The majority of wind turbines installed in Australia are on towers that are too short, yet often the owners of these turbines are unaware. It can be hard to tell that a turbine is not performing properly just by watching it.

Towers of at least 24m height are appropriate in areas where the land is flat or elevated and there are no obstacles within 150m. The tower should also be at least 300m away from any steep bluffs or sharp changes in elevation. Place the turbine in the area of smooth laminar air. The diagram illustrates how to test for smooth laminar air using a balloon, tag lines and a tether line.

Install the highest possible tower for your site.



Test for smooth laminar air with a balloon, tag lines and a tether line.

If your site has ground clutter, the site assessor or installer must calculate the minimum tower height based on the proximity and height of the surrounding ground clutter.

A general rule for minimum tower height is that the bottom of the turbine rotor, or blades, should be at least 10m above the tallest obstruction within 150m or the nearby prevalent tree height. For trees, this means the mature tree height over the 20–30 year life of the turbine, not the current tree height. Consider also any future plans for buildings.

Effectively, this means the *minimum* tower height is:

(height of tallest obstacle within 150m) + (10m buffer) + (length of blade of selected wind system)

The site assessor should then round this number up to the next available tower height. The extra cost of installing a taller tower always pays for itself in the extra energy produced.

For small wind systems, towers of 24m, 30m or 36m are typically required. A height of 42m may be needed in areas with a few close taller obstacles, such as trees. Check the tower heights offered by manufacturers when selecting a small wind system.

Ask your installer or wind site assessor to provide expected wind turbine energy performance data for several different tower heights for your site, based on your site's average annual wind speed, wind shear and turbulence intensity.

Choosing a wind system design and manufacturer

Currently Australia does not have standards or certifications for small wind systems but the process is underway. Investigate the status of Australian small wind standards before selecting a manufacturer.
In the meantime, the USA's Small Wind Certification Council (www.smallwindcertification.org) based on the American Wind Energy Association's Small Wind Turbine Performance and Safety Standard is a useful reference. Turbines can be certified through the Microgeneration Certification Scheme which refers to the British Wind Energy Association Small Wind Turbine Performance and Safety Standard (www.renewableuk.com) and the International Electrotechnical Commission's Small Wind Standards.

Inverters used with grid connected small wind turbines in Australia typically need to comply with AS 4777-2005, Grid connection of energy systems via inverters, to be allowed to connect with the electricity grid.

The most cost effective, productive and reliable small wind systems are wind generators with a set of two or three blades that spin on a horizontal axis. Ask the installer, manufacturer or dealer these questions before purchasing a wind system:

- Does the wind turbine comply with any international safety and performance standards?
- What is the annual energy output (measured in kilowatt hours) for the turbine in annual average wind speeds of 4–7m/s? How was this information developed? Has this ever been verified by an independent testing or reviewing agency from real-life situations?
- How long is the warranty period for the turbine? What does the warranty cover? What is excluded?
- How many production models have been sold to ordinary customers? How many of the turbines sold are still running?
- Can you provide the energy performance data of three of these turbines in the field and refer me to these customers?
- Has the turbine ever gone through a reliability test? By whom? For how long? What were the results?

Choosing a wind system size

The first step in choosing the size of a wind system is to clarify your goals. For example, if you are installing a grid connected system and your goal is to be carbon neutral, then average the annual energy needs of the household or site over several years (or appropriately predict them for a new building) so you know how much energy you need your wind system to produce each year.

If you are installing a grid connected system and you would like to maximise its financial performance, consider any state grants available, any renewable energy certificates, and importantly the value of the energy produced by the wind system. For example, with current net feed-in tariffs, the energy generated by a wind system used instantaneously on site (or displaced import energy) is roughly $0.2855/kWh. This is a much higher value than generated energy sent back to the grid and not used instantaneously on site (exported energy), which is closer to $0.0800/kWh. Work with an independent small wind expert to analyse the expected displaced import and export values of the wind electricity for different wind system sizes, based on the daily load profile of the house and seasonal wind patterns, to determine the financial performance of the wind system.

Many Australian small wind systems are installed off-grid, and daily wind energy production to daily site energy needs must be considered. Typically, off-grid small wind system sizes are selected by considering the site's electricity loads (number of kWh used per day on site) and the system's estimated energy production at the tower height required, taking into account losses and seasonal variation. A guide for off-grid system sizing is that daily wind generation should be 150–200% of the site load, if the wind system provides all electricity for the site. This larger sizing is due mainly to dump load losses in off-grid systems.

In Australia, installed small wind generators are usually 'rated' in the range of 1–10kW but small systems also include turbines of up to 100kW. Micro-wind generators (systems < 1kW) are typically used for small battery charging, for example on boats.

Manufacturers provide a rated 'power capacity' of a wind generator at a specified wind speed. As not all manufacturers rate their systems at the same wind speed, the rated power capacity gives an indication only of a turbine's size relative to others.

Compare turbines by their predicted annual *energy* output for the average annual wind speed at your site. When you determine your minimum tower height, and average wind speeds at that height, obtain the manufacturer's performance data for certified turbines to see which meets your energy needs. Also compare the expected performance of the same wind system on a tower height 6m and 12m taller than the minimum tower height. Up to date wind turbine buyer guides can be very helpful for this comparison. Compare the numbers in the table to a household electricity usage of 5,000kWh/year.

Wind systems and their predicted annual energy performance in a range of wind speeds

	Predicted energy performance (kW/year) for manufacturer rated capacity of			
Average wind speed (m/s)	2.4kW at 13m/s	5kW at 17m/s	10kW at 12m/s	50kW at 9.5m/s
3.6	914	3,459	5,000	48,145
4.0	1,373	4,438	7,100	68,890
4.5	1,925	5,443	9,600	91,758
4.9	2,594	6,444	12,700	115,746
5.4	3,216	7,410	15,900	139,955
5.8	3,898	8,315	19,500	163,647
6.3	4,575	9,132	23,300	186,254

For a carbon neutral home, the energy needs of the actual household must be considered. For example, the 2.4kW wind system needs an unusually high wind resource (greater than 6.3m/s) to meet residential usage of 5,000kWh/year for a typical energy-efficient, grid connected household. The 5kW wind system would require a more typical wind speed of 4.5m/s to meet the home's energy needs. The 50kW wind system is more appropriate for grid connected rural farming applications with higher energy use.

Inverter and battery efficiency should be taken into account in accordance with design guidelines. A household electricity usage of 5,000kWh/year equates to about 13.5kWh/day.

Average daily output of a 1kW wind generator at various average wind speeds

Average wind speed (m/s)	Daily AC load (kWh) supplied by a 1kW wind system
4	2.1
5	3.0
6	5.5
7	7.6
8	9.1

In a typical wind regime of 5m/s, a 1kW wind system would produce a quarter of the daily energy needs of this household electricity use. However, turbine and battery sizing is complex for off-grid wind systems, especially for off-grid hybrid wind and solar systems. Off-grid wind and battery system sizing should be undertaken in consultation with an experienced installer.

Grid connected wind systems should be installed as close as possible to the connection point, typically less than 300m due to the cost of the connecting cable. For off-grid systems, the wind generator needs to be located as close as possible to the battery bank to overcome the power loss and voltage drop in the cables. If the preferred site is distant from the house, the batteries and inverter could be located near the wind generator and power transmitted as 240V AC to minimise cable losses. Alternatively, a turbine with a higher generation voltage can be chosen. Higher voltage transmission means lower losses.

Install grid connected wind systems as close as possible to the connection point.

Wind generators can produce some running sound in high winds, from the blades, gearbox or brush gear or from wind whistling past the tower, pole or guy wires. The sound may not be loud but may be noticeable to you or close neighbours. The background noise of the wind itself usually covers the sound of the blades. Always ensure that there are no objections to the low level noise produced, and that the turbine is located an appropriate distance from households.

Choosing a tower type

The three main types of towers: tilt-up, guyed lattice, and freestanding (freestanding towers could be a lattice or monopole tower) have a variety of considerations, shown in the table.

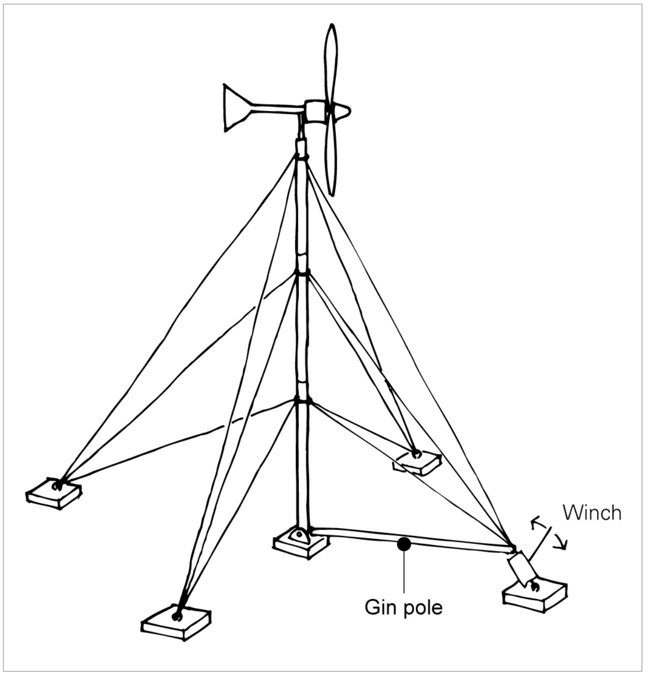
Tower types for wind systems

Tower type	Freestanding	Guyed lattice	Tilt-up
Installation	Crane	Installed on ground, lifted with crane	Installed on ground, lifted with crane
Base	7–10% of tower height for concrete foundation	Guy radius 50–80% of tower height; minimum cleared area required	Guy radius 25–60% of tower height
Maintenance	Climb	Climb	Lower turbine twice/year
Cost	Expensive	Least expensive	Mid-range cost

Tilt-up towers are designed so that they can be lowered and raised by tilting the tower with a gin pole and winch.

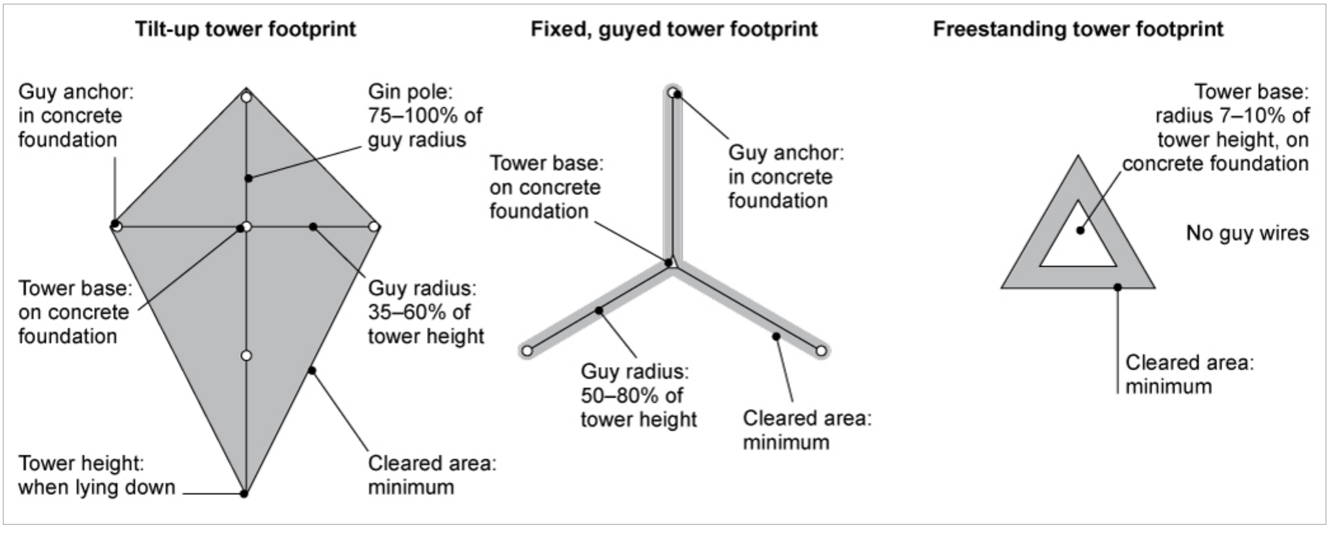
A tilt tower and gin pole must have sufficient area around the wind tower for the tower and the guy wires to be lowered. A 24m tall tower needs at least a 24m area for lowering. If a vehicle is used to raise and lower the tower it also needs room to safely access the site and manoeuvre.

The tower and the guy wires usually require concrete footings, although sometimes screw anchors or rock anchors may be used. These footings must be designed in accordance with the wind loadings for the particular site. Guy wire tensions need to be checked frequently.



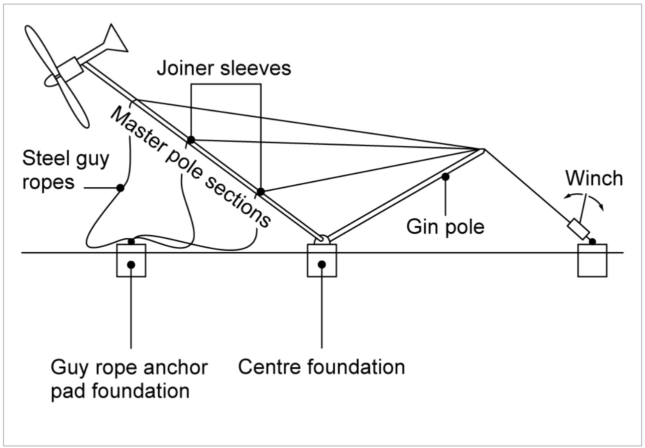
Source: Geoff Stapleton

Typical wind tower design.



Source: Ian Woofenden

Tilt-up, fixed and freestanding towers have different footprints on the ground.



Lowering the wind tower.

Turbine controls

As wind speed increases, the wind generator spins faster and generates more power at a higher voltage. If wind speed continues to increase past a certain point, the generator would ultimately be destroyed or wear out prematurely. Most wind generators therefore have a wind 'cut-out' speed at which the unit employs some form of overspeed control to either stop the unit generating power or govern the rotational speed to produce constant power.

The two most common forms of overspeed control are mechanical braking and feathering.

In mechanical braking, a brake, similar to those found in many cars, is applied as a result of the centrifugal forces developed when the unit approaches the cut-out speed. If the unit is operating in an area where average speed is close to the cut-out speed, braking might be frequent and the brakes will wear out rapidly.

In feathering, a turbine rotates the individual blades to reduce their angle into the wind, thereby reducing rotor speed. When the whole wind turbine turns out of the wind, the term used is furling.

Wind generators produce power when turning in winds above the cut-out point. If the batteries are fully charged the excess power is redirected into a dummy load, usually an electrical heating element. The dummy load can get very hot and should be positioned where it will not be touched accidentally, or create the risk of fire or explosion.

Maintenance

All wind turbines require regular maintenance, at least once but ideally twice a year. Compare your turbine with your car: a turbine is likely to spin about 7,000 hours a year; a typical car lifetime is 4,000 hours of driving. That's nearly two car lifetimes in a single year of turbine operation.

Well-designed wind turbines are projected to last 20–30 years. To ensure system performance, stick to a regular maintenance regime.

Most maintenance is centred on thorough inspections of the turbine and tower. The tower needs to be designed to allow access for servicing mechanical components, such as bearings.

References and additional reading

Contact your state, territory or local government for further information on renewable energy, including available rebates: www.gov.au

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