Wind Turbine Technology

Since the earliest times, humans have used the power in the wind. Maori and other early settlers used wind power, harnessed by sails, to reach New Zealand. Over the years wind has been used to pump water, grind grain, power sawmills, provide transport and, most recently, generate electricity. Wind turbines are now one of the fastest growing forms of new electricity generation worldwide.

The first wind turbine built in New Zealand, Wellington's Brooklyn wind turbine, was a 225 kilowatt (kW) turbine. Today, new wind turbines installed in New Zealand wind farms typically range from 500 kW to 3 megawatts (MW) (or 3000kW). New Zealand's wind farms have a combined capacity of 615 MW and supply about 5% of our electricity.

From the outside, wind turbines look much the same as they did 10 years ago. But like other forms of technology, such as cellphones and computers, wind turbine technology has improved rapidly in recent years, especially in the area of power control electronics and maintaining power system frequency. Modern turbines can provide ancillary services such as reactive power and frequency keeping services. These functions help to maintain the stability of the grid or local network a wind farm is connected into.

WHAT IS A WIND TURBINE?

There are four key parts to a modern wind turbine:

- the blades
- the nacelle
- the tower
- the foundation.

Most turbines have three or two blades, which rotate around a central hub to drive a generator housed in the nacelle. Blades are made from a variety of materials, such as fibreglass, carbon fibre or wood laminates. They are designed to withstand the force of strong winds.

The nacelle is the large housing at the top of the tower. It contains the generator and other important components such as the gearbox and control equipment.

Towers are usually tubular steel, although some turbines have lattice towers (like an electricity transmission pylon). Steel towers are usually painted a light colour, with non-reflective paint, to help them blend into the background.

The tower sits in a steel reinforced concrete foundation – the dimensions of which depend on the size of the turbine. The foundation is a substantial structure as it is designed to ensure the turbine can withstand very strong winds. It is always below ground level and not visible once construction is complete.

In most situations, a number of identical wind turbines are installed in one location where the wind conditions are favourable. A collection of wind turbines in one location is referred to as a wind farm.

WHY ARE TURBINES SO TALL?

Tall towers are used to elevate the blades into faster and less turbulent wind and also to allow for proportionally larger blades. Wind speeds increase with height above ground level. In addition, electricity output rises dramatically with blade length.

For example, at Tararua Wind Farm, the original 660 kW turbines have 23.5 metre blades, while the newer 3 MW turbines have a blade length of 45 metres. The larger turbines have a generating capacity almost five times greater than the smaller turbines.

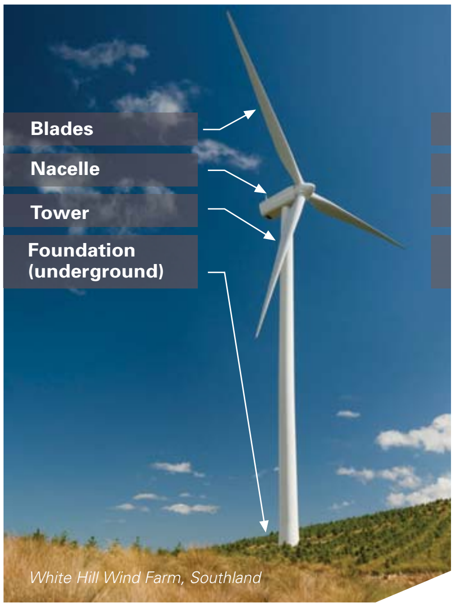
Large turbines are not necessarily suitable for all wind farm sites. Recently constructed wind farms in New Zealand have turbines ranging in size from 225kW to 3 MW. Developers will consider a range of factors, such as topography, access, ease of construction, wind conditions and generation requirements, when choosing a turbine for a proposed wind farm.

HOW DOES A MODERN WIND TURBINE WORK?

Wind turbines generate electricity by using the natural power in the wind. A wind turbine's blade is like an aeroplane wing: as the air flows past the blade it causes lift, which creates a turning force. The rotating blades turn a shaft inside the nacelle, which goes into the gearbox. The gearbox increases that rotation speed for the generator, which uses magnetic fields to convert the rotational energy into electrical energy. Some turbines like those at Hau Nui wind farm in the Wairarapa do not have gearboxes. In these 'direct drive' turbines the shaft connects directly to the generator.

The electricity from the generator goes via cables to a transformer, and then to the wind farm's substation, where it is converted to the right voltage for the grid or local network. The grid or local network transmits the electricity into homes and businesses.

Wind turbines have instruments on top of the nacelle, an anemometer and a wind vane, which respectively measure wind speed and direction. When the wind changes direction, motors turn the nacelle, and the blades along with it, around to face into the wind (this movement is called yaw). The blades also 'pitch' or angle to ensure that the optimum amount of power is extracted from the wind.

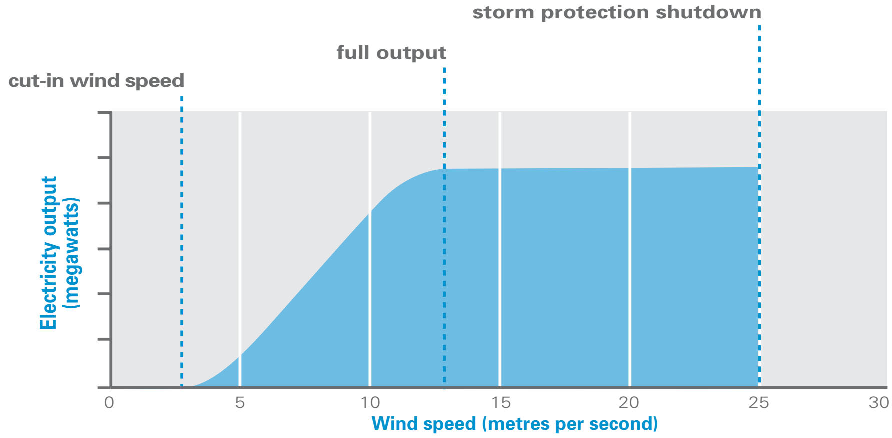


White Hill Wind Farm, Southland

Integrated lightning protection systems ensure that blades can withstand a direct strike without serious damage to the turbines.

Most wind turbines operate automatically and do not require operating staff to be on site all the time. At larger wind farms, staff will be based on site permanently to cary out regular maintenance. A computer continuously monitors power output and the performance of each turbine component. If the computer detects any problems it sends an alarm to alert the operator that some maintenance is required. The computer may automatically shut the turbine down until the problem is fixed.

TYPICAL POWER CURVE OF A WIND TURBINE



HOW MUCH ELECTRICITY CAN A WIND TURBINE GENERATE?

The amount of electricity a turbine generates depends on four factors.

1) The generating capacity of the wind turbine: A single 1 MW turbine that operates at a 41% capacity factor will generate about 3.6 million kilowatt-hours (kWh) of electricity in a year (see What is Capacity Factor?). A 2 MW turbine, operating at the same capacity factor will produce twice as much electricity.

2) The speed of the wind: The energy in the wind increases with the wind speed; when the wind's speed doubles the energy it contains increases by eight. Modern wind turbines are designed to operate in a range of wind speeds. The amount of electricity they generate will increase with the wind speed until the turbine reaches its maximum output (see Typical Power Curve of a Wind Turbine).

   Typically, a turbine will begin to generate electricity – or cut in – when wind speeds reach between 3 and 5 metres per second (10-18 kilometres per hour or a light breeze). The turbine will reach its maximum output when wind speeds reach between 10 and 15 metres per second (a fresh breeze), and it will maintain maximum output until wind speeds reach about 25 metres per second (90 kilometres per hour or a strong gale). At this point the turbine will automatically shut down to prevent damage.

3) The amount of time the wind turbine is operating: Wind turbines can operate at all times when the wind is strong enough for electricity generation. This is typically 90% of the time for wind turbines in New Zealand. This percentage of time spent operating is similar to other forms of generation in New Zealand. Maintenance on turbines is usually undertaken when wind speeds are too low for generation.

4) The way wind turbines are arranged: Wind farms are laid out so that one turbine will not affect the wind near another turbine. However other factors such as environmental considerations, visibility and grid connection requirements can take precedence over the optimum wind capture layout.

HOW MUCH WIND ENERGY CAN BE INTEGRATED INTO THE GRID?

Technically an electricity system can be run with 100% wind energy, however this may not be the most cost effective solution. The amount of wind generation that can be integrated depends on the nature of the electricity network or grid as well as the other types of generation in an electricity system.

Given the scale and high quality of NZ's wind resource, wind is likely to be supplying 20 percent of our electricity by 2030.

New Zealand's existing hydro generation provides an advantage for integrating a significant proportion of wind generation at a low cost. Hydro generation from lakes is a particularly good match for wind generation because hydro output can be changed reasonably quickly and easily to balance output from the wind farms.

Internationally, the effects of large amounts of wind generation on a system are seen as challenging but manageable. Some countries are already managing 10 to 20% wind generation on an annual basis, and planning to integrate 40 to 50% in the future. Work that New Zealand's Electricity Authority has undertaken shows that, like overseas, the effects of greater amounts of wind generation are manageable and not costly.

What is a watt?

The capacity of wind turbines is expressed in watts, or units of electricity. A 2 megawatt (MW) generator, when operating at full capacity will generate 2 MW of electricity at any given point. A kilowatt (kW) is 1,000 watts, and a megawatt is a million watts.

A watt-hour is equivalent to one watt of power consumed or generated for a period of one hour. So a 2 megawatt generator operating at full capacity for an hour will generate 2 megawatt-hours (MWh) of electricity.

To put these numbers in perspective, the average New Zealand home uses 8,000 killowatt-hours (or 8 megawatt-hours) of electricity a year.

What is Capacity Factor?

Average generating capacity factors

NZ – wind farms:	**40%**
NZ – all forms of generation:	**54%**
Australian wind farms:	**37%**
Global wind farm average:	**22%**

Capacity factor is a measure of the amount of electricity actually generated relative to the amount that would have been produced if the generator had been running at its full output over the same period. Capacity factor is not a measure of efficiency, nor a measure of the time spent operating.

www.windenergy.org.nz

Find out more about wind energy and wind farms in New Zealand at www.windenergy.org.nz.

NZ Wind Energy Association

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The New Zealand Wind Energy Association (NZWEA) is an industry association that works towards the development of wind as a reliable, sustainable, clean and commercially viable energy source. We aim to fairly represent wind energy to the public, government and the energy sector. Our members include 80 companies involved in New Zealand's wind energy sector, including electricity generators, wind farm developers, lines companies, turbine manufacturers, consulting firms, researchers and law firms.

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February 2011