NEW ZEALAND WIND ENERGY ASSOCIATION	**Wind – New Zealand's Energy**

Wind Energy

Introduction to domestic/small wind systems

June 2004

The following document has been prepared by the New Zealand Wind Energy Association for those who are interested in installing a domestic wind energy system on their property.

Before proceeding, and if you are not already familiar with the basics of wind energy, we would encourage you to have a look at NZWEA's document

'Wind Energy – Introduction'

This document provides a brief introduction to some of the various issues which it may be useful for you to consider before you decide if and how, you would like to proceed further with any form of domestic development.

Small wind energy systems

A 10 kW wind turbine

Consumers with properties connected to the electricity grid network (the 'grid') can currently purchase power from the grid cheaply and conveniently. Consequently, and at the present time, the economics of small wind systems are such that they are most usually of greatest interest to properties which are remote and/or not connected to the grid.

Nonetheless most of the principles outlined in this document apply for grid connected properties. Major differences are outlined in Section 5.

There are a number of questions that it is useful to ask yourself if you are considering installing a small wind turbine on your property. These may include, but not necessarily be limited to, the following:

1 Development considerations

1.1 Power Requirements

What are my electrical power requirements?

Your instantaneous power demand depends entirely on the electrical appliances that you run. However, the average grid connected household uses about 20 kilowatt hours (kWh) of electricity per day. A 5 kilowatt (kW) wind turbine is often able to supply the power needs for such a home.

The electricity demand for remote properties (disconnected from the grid) is reduced as much as possible by selecting efficient appliances and using alternative energy sources for space heating, water heating and cooking. Remote properties may demand perhaps 5 kWh of electricity per day. In this case, wind turbines in the order of 1 kW may be used to supply the remaining electrical load.

For remote applications it is common to integrate the use of a small wind turbine with other power sources such as solar power or a backup generator. These alternate power sources will have an effect on the power requirements from your wind turbine.

Very small systems may operate at DC only to power essential low-power loads such as lighting and communications equipment.

Larger stand-alone systems may employ an inverter to convert the stored energy in batteries to fixed frequency AC, which allows the purchase of a wider range of 'standard' appliances.

1.2 Electrical Loads

How can I reduce electrical loads?

The electrical efficiency of houses varies greatly. Space heating and cooling is frequently an area where far more power than necessary is used. The addition of insulation, double glazing, curtains and blinds, and the removal of drafts is the first step. If heating is still required, the need for electricity is removed by using fuel fired space heating (eg wood, gas, LPG).

In locations with sufficient solar insolation, solar hot water heating with a gas booster should be used. Use of high efficiency fluorescent globes for lights in living rooms and sensor switches in rooms frequented less regularly can reduce the electricity demand of lighting. Electricity use can also be minimised by cooking with gas and the use of efficient appliances throughout the house.

1.3 Testing the wind speed

How do I know measure the wind speed?

Generally speaking extensive wind testing is not undertaken for domestic units since the cost of testing, using a standard test mast, is generally more than the cost of the domestic turbine itself.

Nonetheless there are various sources of data which will give you a pretty good idea of local wind speeds and directions. Please have a look at the NZWEA guide 'Wind Energy – Introduction' for more information.

1.4 Turbine Size

What size turbine do I need?

The 'capacity factor' of a wind turbine is the annual energy output divided by the theoretical maximum output (ie if the turbine were operating at maximum output all of the time). The capacity factor of a small wind turbine can vary enormously depending on location, but if in a good location it is usually 25-30 %. By dividing your average power requirement by an estimate of the capacity factor, you can work out the approximate size of turbine required.

Once you have used this information to narrow down your turbine choices, it is possible to do a more rigorous analysis of the power output based on the turbine power curve and the wind speed frequency distribution at the site.

1.5 Turbine Type

What type of turbine should I choose?

There are many manufacturers of small wind turbines with many variations on the theme.

Most wind turbines rotate about a horizontal axis, but vertical axis turbines are also available. Vertical axis turbines are simpler, as they don't need to change orientation to face into the wind, but they are usually less efficient.

Towers may be made of steel, concrete or wood, with the simplest being a telegraph pole. Steel towers may be guyed, and of tubular or triangular lattice construction. Self-supporting towers, either lattice or tubular in construction, take up less room and are more attractive but they are also more expensive. Towers, particularly guyed towers, may be hinged at their base to allow them to be tilted up or down using a winch or vehicle. This allows any maintenance work to be done at ground level, and the machine to be safely stowed away when not in use. Any fixed towers requiring climbing should be equipped with anti-fall devices for safety.

Blades may be made from plastic, wood/epoxy, glass fibre/epoxy or carbon fibre. Two bladed machines are available but three blades provide a very stable configuration and are more common. The shape of the blade will also vary slightly depending on the manufacturer.

Your wind turbine choices will depend on your budget, site and preferences.

1.6 Power Storage

How will I store the power generated?

If the site is grid connected, the grid acts as a storage and backup system.

For remote sites, battery banks are used to store the power that has been generated and not yet used. Batteries should have enough capacity so that the batteries maintain a charge of at least 50 %. For optimum battery life, deep cycle batteries should be used. Deep cycle batteries are rechargeable batteries that are designed to be discharged to 50 % or less without damage.

1.7 Other Equipment

What other equipment will I need?

You will need to mount your wind turbine on top of a tower to exploit the fact that wind speed increases with height above ground. The tower may or may not be included with the turbine. For example, if you are purchasing a turbine from overseas, it may not make sense to pay to ship the tower as well as the turbine.

For remote properties, a battery bank for power storage is needed. During long calm periods, the batteries may run flat and back up will be needed. For continuity of supply during these periods, a diesel or petrol generator will be required. As battery output is direct current and most household appliances are alternating current, an inverter will be needed to convert the battery output to alternating current. The other alternative is to use only direct current compatible appliances.

1.8 Turbine Placement

Where should I put the turbine?

The turbine should be located in a well exposed location, at least a distance of 20H from any obstacle of height H. The turbine will probably need to be installed within 100 metres of your house (or where you need the power) to minimise cable costs and electrical losses.

If there is a smooth hill nearby, placing the turbine at the top will generally capture higher wind speeds and allow for better exposure.

Ensure that the chosen location is not offensive to your neighbours.

1.9 Other Development Considerations

What other development considerations should I be aware of?

Each council has height restrictions and other specific requirement you should therefore be in contact with your local council to find out the applicable standards, restrictions and permitting requirements.

Although these are called ‘small’ wind turbines, the turbine rotor can be a significant diameter, so you will need plenty of space. Make sure the property is big enough (the council may stipulate the minimum size, otherwise at least half an acre is a good guide).

Let your neighbours know that you are planning to install a wind turbine, and ensure they agree with where you plan to put it. Although modern wind turbines are a lot quieter than their predecessors, they still make some noise and the effect on nearby buildings must be considered. The aesthetic effects of the wind turbine on your neighbour’s property should also be considered and discussed with them. Small turbines are mounted on towers anywhere from 10 m to 40 m in height, typically about 25 m.

If you live very close to an airport, it is advisable to make sure that airport regulations will not prevent you from having a wind turbine.

1.10 Return On Investment

Will it save me money?

The cost of energy from small wind turbine systems varies significantly. Set up costs can be substantial, particularly when the cost of additional equipment supply such as batteries and inverters is included. Such systems are typically only economic when the costs of connecting to the electricity grid are high. However, the running costs of a wind turbine are very low. There will be annual maintenance, which will be far outweighed by the power costs saved.

Once you have found a range of wind turbines that will meet your energy requirements, you should compare them on an economic basis. Some turbine suppliers include everything in their quote, including towers, delivery, installation etc. Some will only include the turbine. When comparing models, ensure that you are comparing prices for the same deliverables.

Payback periods will generally fall in the range of 8-16 years and some wind turbines are designed to last thirty years or more.

1.11 Maintenance

What maintenance will I need to do?

In most cases the only maintenance required is an annual service. Where parts have deteriorated, they will need to be replaced. If the turbine is damaged (eg by lightning) further unscheduled maintenance will be required. Some maintenance will be required of the batteries also as the levels of distilled water will need to be maintained and the performance of each individual cell should be monitored.

2 Small Wind Turbine Components

The following components are used in most small wind turbines:

2.1 Blades

Blades may be made from plastic, wood/epoxy, glass fibre/epoxy or carbon fibre. Two bladed machines are available but three blades provide a very stable configuration and are more common. Multiple blades, as seen in non-electrical wind pumps, are good for providing a high torque in low winds for starting and are common in very small machines to overcome generator “cogging” start-up torque.

2.2 Transmission

For small wind turbines, direct drive is standard to simplify manufacture, improve reliability and reduce losses.

2.3 Generator

Housed within the nacelle, copper windings are held between a sandwich of permanent magnets, either made from ferrite or neodymium. The AC output may vary in voltage and frequency as wind speed varies.

2.4 Yaw system

Small wind turbines are generally characterised by a passive yaw system, which is the simplest method. This is typically a tail vane fitted to the turbine, which keeps the machine in the correct orientation with respect to the wind direction.

2.5 Overspeed Protection

Small wind turbines are variable speed machines. A variety of techniques are employed to prevent them over-speeding in high winds. Most common is a "furling" mechanism where speed is controlled by turning the rotor out of the wind. This may be achieved by offsetting the rotor sideways on the mast with a hinged tail. In high winds the wind force on the rotor can then push it away from the wind by tilting to the side, or in some cases upwards.

2.6 Brake

Most small machines control speed only by "furling" and may have an additional mechanical brake to lock the machine after it is stopped.

2.7 Tower

Generally, wind speed increases with height above ground and the function of towers is to exploit this. Towers may be steel or wood, with the simplest being a telegraph pole. Steel towers may be guyed, and of tubular or triangular lattice construction. The tower supporting the turbine in Figure 1 above, is a guyed lattice tower.

Self-supporting towers, either lattice or tubular in construction, take up less room and are generally considered to be more attractive but they are also more expensive. Towers, particularly guyed towers, may be hinged at their base to allow them to be tilted up or down using a winch or vehicle. This allows any maintenance work to be done at ground level, and the machine to be safely stowed away when not in use. Any fixed towers requiring climbing should be equipped with anti-fall devices for safety.

2.8 Power controller

The power controller converts the output of the generator to DC electricity of a suitable voltage for battery charging. The controller can maintain electronic charge control of the battery and may also divert excess power to a 'dump' load.

3 Calculating Turbine Energy Output

Ideally, wind turbine annual production should be equal to net annual electricity consumption. If the frequency distribution (percentage of time the wind blows at each wind speed) of the local wind regime and the turbine power curve (the wind turbine power output for each wind speed) are known, the annual production for a given turbine can be estimated.

The specification sheet for most turbine models will include the turbine power curve. If the local wind speed frequency distribution is not known, it can be estimated using the Weibull frequency distribution.

$$f(x,\alpha,\beta) = \frac{\alpha}{\beta^{\alpha}} x^{\alpha-1} e^{-\left(\frac{x}{\beta}\right)^{\alpha}}$$

Where;

x = wind speed at which to evaluate the function [m/s]

α = parameter of distribution*

β = average wind speed at the turbine height [m/s]

*The value of α is estimated to be 2 for inland sites, 3 for coastal sites and 4 for island sites with trade winds.

Using this function it is possible to evaluate the expected frequency for each wind speed, multiply this by the turbine power output for that wind speed and sum these outputs over the operating range for the turbine. This will give the average expected power output for a given turbine on a given site.

To estimate the average annual energy output in kWh[1], the average power output should be multiplied by the turbine 'available' hours per year. The turbine is 'available' when it is able to produce power as long as the wind speed is within the turbine operating range. Maintenance, scheduled and unscheduled, will reduce the availability of the turbine. In most cases, the turbine is unavailable for only a very small percentage of the time, and for the accuracy of these calculations, can be ignored.

4 Power Storage and Backup

Since we have no control over when, how fast, or for how long the wind blows, wind energy systems for remote properties must incorporate a storage system. This energy store is usually in the form of rechargeable batteries. The battery store is topped up when the turbine is producing more power than is being used, and drawn from when the wind turbine is producing less power than is being used. It should have enough capacity so that the batteries maintain a charge of at least 50 %. For optimum battery life, deep cycle batteries should be used. Deep cycle batteries are rechargeable batteries that are designed to be discharged to 50 % or less without damage. Even so, the batteries will need replacing approximately every 7 years.

The cost of the batteries is significant – they can cost more than the wind turbine itself. And even for well designed systems, there may be times when the batteries are less than half charged or flat and back up will be needed. For continuity of supply during these periods, a diesel or petrol generator will be required.

As battery output is DC and most household appliances are AC, an inverter will be needed to convert the battery output to AC. The other alternative is to use only DC compatible appliances.

[1] 1 kWh (kilowatt hour) is the energy content of 1 kilowatt over a period of 1 hour

The cost of energy from small wind turbine systems varies significantly. Set up costs can be substantial, particularly when the cost of additional equipment supply such as batteries and inverters is included. Such systems are typically only economic when the costs of connecting to the electricity grid are high.

5 Grid Connected Properties

Some small wind turbines are available with additional electrical equipment allowing them to be connected to the grid so that any mismatch between output and load can be exchanged with the grid. The regulations for doing this may vary between power providers.

The advantage of a well-designed and implemented wind energy system for grid connected properties is that after the initial cost of purchase and installation of the system, there are very few costs. There will be annual maintenance costs, and much reduced (sometimes zero) electricity bills. So although the cost of the system is quite high, it can eventually pay itself off and end up saving you money.

For properties that are already connected to the grid, net metering is a way to avoid the expense of a backup system. This is where the wind turbine is connected to the electricity meter box and the grid acts as a back-up system. While there is no wind, the power company supplies all the power needed and the meter runs forward at the rate that electricity is being used. As the wind turbine begins to work the electricity drawn from the grid is reduced, causing the meter to slow down.

If the wind turbine output is the same as the electricity being consumed, the meter will stop turning. If the wind turbine produces more electricity than is being used, and the electricity company allows net metering, the meter will turn backwards, ‘refunding’ energy that has already been charged for, or ‘banking’ excess energy for use later in the billing period. If at the end of the billing period the same amount of power has been produced as used, the meter will read the same as at the start of that period and there will be no charge for electricity usage (although there probably will still be a lines charge).

It is a simple process to add these systems to an existing home. No changes in the household wiring are necessary. Apart from not needing power storage, the main difference between a grid-connected system and a remote system is in the power controller. Instead of converting the variable frequency AC turbine output to DC for charging batteries, it is converted to a voltage and frequency that is compatible with the local grid.

The best way to determine power requirements for grid connected properties is from historical electrical bills. If the implementation of small modifications to buildings or behaviour can reduce average power consumption, this is usually the most cost-effective first step.

There is currently no standard process for net metering in New Zealand. If you are going to connect your wind turbine to the grid, then you will have to meet the technical requirements of your network company (also known as your ‘lines’ or ‘distribution’ company. Your current electricity retailer will be able to give you the name of your network company.

You will need at least two meters, one for 'import' and one for 'export'. The rates paid and received for electricity imported and exported are likely to be different and you can get information on these rates by, in the first instance, contacting your existing electricity retailer.

Some protection equipment is likely to be required at your switchboard to ensure the outside electricity system can't be made live by your wind turbine (which would threaten the safety of workers if they thought the system was dead).