Power from the people: a guide to micro-generation

EECA energywise™
THE POWER TO CHOOSE

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Introduction

New Zealand is blessed with abundant renewable energy resources compared to many other countries, and this has helped achieve a high percentage of renewable generated electricity in our electricity grid. Large-scale renewable energy development, such as wind farms, geothermal, and hydro energy, already provides cost-effective and 'clean' electricity.

Another way of harnessing the power of New Zealand's renewable energy resources is through small-scale generation, also known as 'micro-generation'. This is renewable energy generation on a domestic or household scale.

The motivation for homes or businesses to generate their own electricity using photovoltaic (PV) modules, small wind turbines, or micro-hydro schemes can come from the satisfaction of gaining independence from conventional electricity supply arrangements, or the desire to contribute to greater environmental goals. Improved security of supply and a favourable financial return can also be factors, especially for those whose home or workplace is located in isolated areas where generating their own electricity can be the only viable option. In many remote sites, off-grid power systems using renewable energy technologies are often more economic than relying on diesel generators, or financing the costs of connecting to the local electricity network.

Micro-generation is also an important component of what is emerging as the 'smart-grid'; a concept that replaces the existing model of one-way electricity supply from centralised generation plant to end users with an arrangement that allows for electricity to flow in optimal ways and directions, depending on the conditions at the time. Micro-generation may allow previously passive consumers of electricity to become more engaged and active participants in managing their energy needs.

Technology improvements and decreasing costs of some micro-generation, especially PV, along with rising energy prices and a growing popular interest in sustainability, mean that micro-generation is likely to become increasingly attractive and cost competitive, leading to greater uptake.

How to use this guide

This guide has been produced by the Energy Efficiency and Conservation Authority (EECA) in response to ongoing requests for information on micro-generation from the public. It is intended to provide guidance to both home and business owners who are interested in generating their own electricity, but need more information before going ahead. It is directed at the layperson who already has some basic knowledge of micro-generation. There is a glossary at the back which explains the technical terms used.

The section 'Different ways of using micro-generation' explains the difference (and implications) between being off-grid and grid-connected. The subsequent sections explore the characteristics, costs, and things to consider for each of the main micro-generation technologies – PV, wind, and hydro – plus the additional components needed to complete your generating system. The final sections outline a step-by-step process for determining the best system for your needs, and how to get in touch with the right people and resources to help you.

EECA has also produced 'Domestic-scale Distributed Generation: Guidance for Local Government', which is available at www.eeca.govt.nz or in hard copy from EECA. The document provides councils with information on micro-generation technologies and their potential effects, and how these can be mitigated or managed.

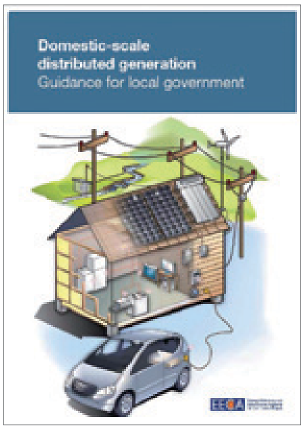


Figure 1. Guidance for local government on domestic-scale DG is available from EECA

What is micro-generation?

Micro-generation usually refers to electricity generation technologies that are a suitable size to provide partial or full power for your home or small business. Micro-generation technologies are a subset of distributed generation (DG), which is electricity generation designed primarily for local use, rather than being exported to the national electricity grid. DG is usually much smaller than industrial scale generation plants.

Definitions of micro-, mini-, and commercial-scale generation can vary, but here is a rough guide. This guide is aimed at those considering micro-generation, but those interested in mini-scale generation will also find it useful.

Micro-generation (up to 5kW)

A house with a 2kWp PV array or a 1.5kW micro wind turbine is an example of micro-generation. Such a system would offset a portion of a typical house's power bill, and may export a little back into the electricity network or form part of a 'stand alone power system' (SAPS).

Figure 2. A PV array in a micro-generation system

Mini-scale generation (5kW to 20kW)

Generation in this range could offset a portion of the power bill of a large household, business, or small farm, with some export back into the network. Examples include 10kW wind turbines on farms, or large PV arrays on businesses.

Figure 3. Part of the 10.5kW PV array installed on a Wellington supermarket. Photo credit: Joseph Mayhew

Commercial-scale distributed generation (20kW to 1,000kW)

Generation plant of this size is usually used to sell electricity to a retailer, another purchaser, or into the wholesale electricity market, although electricity can also be used on site. Examples include the Southbridge wind turbine (100kW) in Canterbury or the Mangapehi hydro scheme (1MW) in Taranaki. Generation of this scale is not included in this guide.

Figure 4. A 100kW wind turbine
Photo credit: Joseph Mayhew

Before you buy

An investment in micro-generation can be a very capital-intensive project, can have long payback times, and in many cases it will work out to be more expensive than purchasing electricity from a retailer. Before you buy a system you should ask yourself why you are interested in micro-generation. There may be other, cheaper ways of reducing your ongoing power bills or reducing your greenhouse gas emissions.

Energy efficiency and micro-generation

If your aim is to do your bit for the environment, it is important to remember that energy efficiency should come first. It is usually easier and cheaper to save a unit of energy than it is to generate a unit of electricity.

Ensuring your home or business is energy efficient will not only save you money in the first instance, it will also reduce the size (and therefore cost) of the generation system you will need. Energy efficiency improvements should always take place before investing in micro-generation.

Well-designed and energy efficient buildings, as shown in Figure 5, maximise passive solar heating, natural light, and ventilation, and have numerous other energy efficiency measures.

If you are designing a new house, you have the opportunity to build in energy savings for years to come. Tips include:

- Orient your house to make the most of the sun's heat, including solar heated water, and passive solar design that minimises your heating and cooling requirements.
- Design your roof so a PV array can be built in or mounted at a later date. A north-facing roof is best, although some variance from this can still be suitable.
- For an off-grid home, minimise use of electricity for cooking and water or space heating: other options such as gas, wood stoves, solar water heating, or a wetback will be more cost effective for these tasks.

Even if you are not building from scratch, there are ample opportunities available to reduce electricity use.

Further information

EECA provides information on energy efficiency and renewable energy to homes and businesses. The following EECA websites contain further information likely to be of use to you in pursuing your goal to be more energy efficient and environmentally responsible:

www.energywise.govt.nz
www.eecabusiness.govt.nz

Figure 5. This energy efficient house has a six star Home Energy Rating

Different ways of using micro-generation

Micro-generation can be used either in a SAPS or in a grid-connected system. These different applications are shown in the images below.

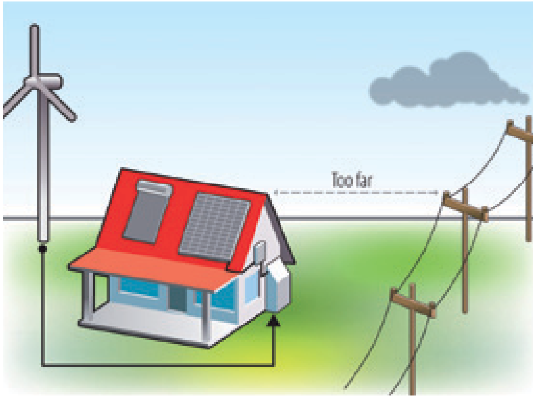


Figure 6. Illustration of a SAPS

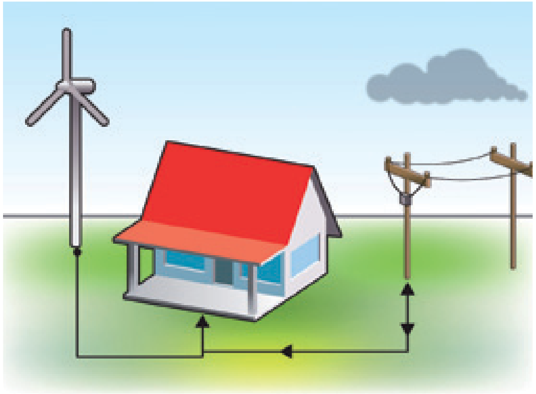


Figure 7. Illustration of a grid-connected system

Stand-alone power systems (SAPS)

A SAPS (also known as 'off-grid generation') is a system where all energy needs are provided on site.

SAPS are typically used in situations where it is more expensive to connect to the local electricity network than it is to build an electricity generation system.

At its most basic, a SAPS can simply mean a diesel generator; however, adding mini- or micro- scale renewable generation (PV, wind, or hydro) will reduce ongoing fuel costs, as well as the negative environmental impact of burning diesel. In addition, while the upfront costs of investing in micro-generation can be high, micro-generation usually tends to have much lower ongoing operation and maintenance costs than diesel generators.

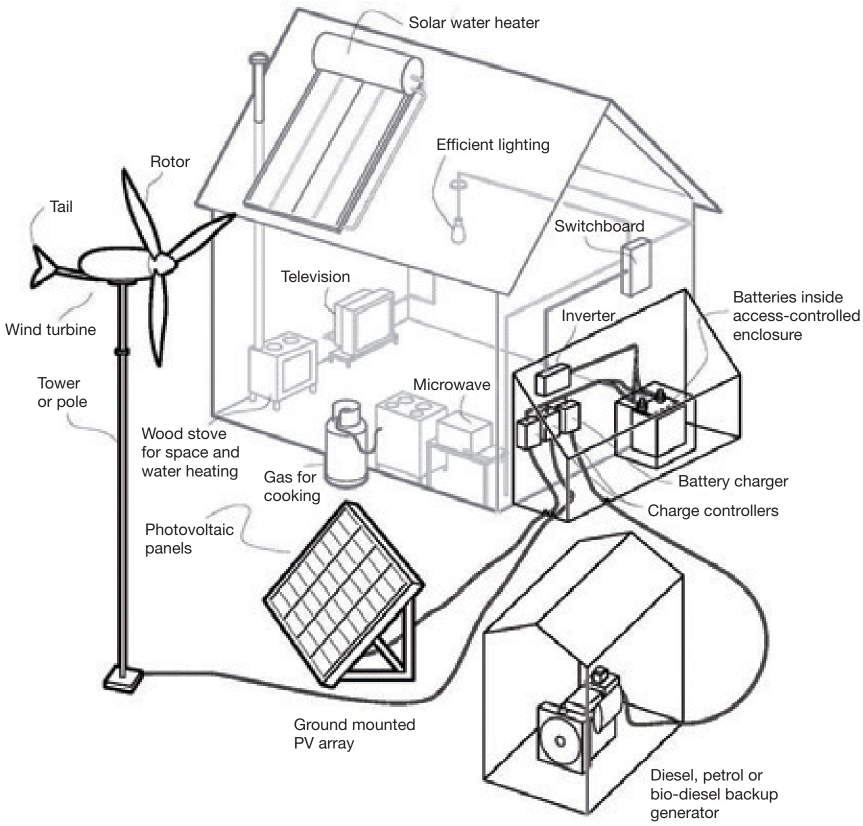


Figure 8. Main components of a SAPS

Weighing up SAPS against the cost of connection

The primary consideration when thinking about SAPS is usually the avoided cost of connection.

In some rural areas, connecting properties to the electricity network can cost between $30,000 and $50,000 per kilometre and in these situations a SAPS can prove to be a more cost-effective option.

The actual cost will depend on how far away in metres or kilometres your house or site is from the nearest network connection point, the terrain, whether new transformers or other equipment are required, and other factors. To get an accurate understanding of your potential connection cost, you should contact your local electricity network company.

The total capital cost of the SAPS, and its lifetime operating and running costs, should be compared to the total cost of connecting to the electricity network and the lifetime costs of purchasing electricity from a retailer.

It is recommended that you engage professional expertise to design and construct the system. However, the following sections will help you gather the information your supplier needs to design a well-performing system.

Information on finding a supplier is listed on page 50 of this guide.

Sizing your SAPS

SAPS are sized to meet two main criteria. The first is the average energy demand. The system must be able to generate, on average, as much electricity in a day as is used in the home. Alternative energy sources are commonly used to reduce electricity demand. Options for water heating include solar water heating, gas, or wood burners. These last two can also be used for space heating.

The second criterion is peak load. Peak load is the maximum amount of electricity that will be needed at any given moment, and which must be provided for by the system you install. As shown in Figure 9, electrical loads can vary a lot during a typical day, but with careful management the peaks can be smoothed, making a considerable difference to the cost of the system and/or the back up generation required.

Peak load can be reduced through the use of efficient lighting and appliances, or by the homeowner choosing not to run large appliances at the same time.

When selecting and designing a SAPS you will need to make trade-offs between capital costs and running costs, and how you want to use energy. Many owners of SAPS face the question: "Am I willing to pay more money for a large SAPS, or am I willing to use less energy and change my lifestyle a little?"

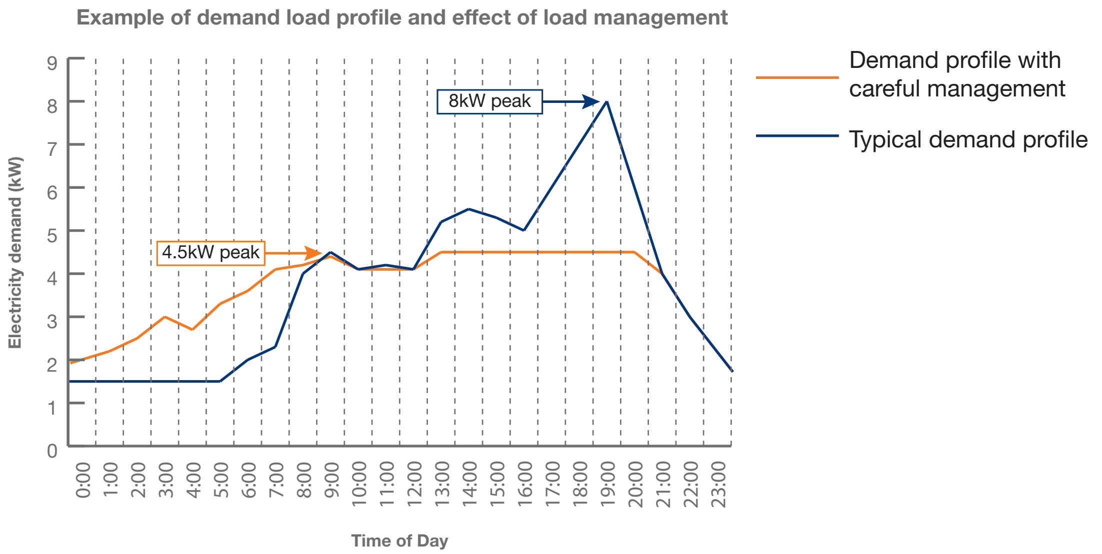


Figure 9. Load profile and example of load management

Designing your SAPS

A well-designed SAPS will make the best use of whatever renewable resource is available on your site in a way than minimises disruption to you, your neighbours, and to the environment. It will include enough battery storage to provide stored energy for when your renewable sources are not available, and to minimise the need for back up generation. Getting the balance right means the system is not oversized (which means a greater capital cost than is necessary), nor is it undersized (which requires back up generation, adding to fuel costs).

Some key questions your designer or installer may ask include:

- How far away is your nearest neighbour, or is likely to be? (This helps determine whether a micro wind turbine is a good option.)
- Do you have a good section of roof facing north? (This helps determine whether a PV array could be fixed to your roof.)
- How do you intend to heat your home and water? (They will usually advise you to use an alternative to electricity such as a wood burner and solar hot water heating.)
- Will you have a water pump? (A water pump can add considerable demand load.)

In addition, they will probably need to know what electric appliances you have in your house, how often you use them, and what their wattage rating is. An example form to record this is below:

Table 1. Simple energy audit spreadsheet for a SAPS

Appliance	Quantity	Wattage (W)	Hours used per day	Hours used per month	Monthly demand (kWh)	Annual demand (kWh)
Internal lights	*10*	*20 Watts*	*5*	*150*	*30kWh*	*360kWh*
External lights						
Water pump						
Fridge/Freezer						
Oven/Grill						
Microwave						
Washing machine						
Dryer						
Dishwasher						
Blender						
Fax/Telephone						
Electric blankets						
Hair dryer						
Bathroom exhaust fans						
Electric frypan						
Bread maker						
Kettle						
Toaster						
Iron						
Vacuum cleaner						
Stereo system						
Television						
VCR/DVD						
Sky decoder						
Computer						
Printer						
Phone charger						
Other						
Other						
Other						
TOTAL						

A table like the one shown above is used to calculate average energy demand. Your system must be able to generate, on average, as much electricity in an average day as is used in the home.
To estimate your peak load requirement, add together the wattage rating of all appliances that might be used simultaneously.

Back up for your SAPS

Because SAPS are not connected to the electricity network, batteries are usually required to store the output from micro-generation for later use. Banks of 12V to 48V lead-acid batteries are commonly used. The batteries typically need replacing in six to 12 years, depending on quality, sizing, and how they are used.

You will also need a controller and inverter, and probably also a back up generator, which could run on petrol, diesel, or biodiesel.

Bear in mind that batteries of different makes and ages should usually not be mixed together, which means it is important to get the size of the battery bank right to begin with, as it is difficult to add to it over time.

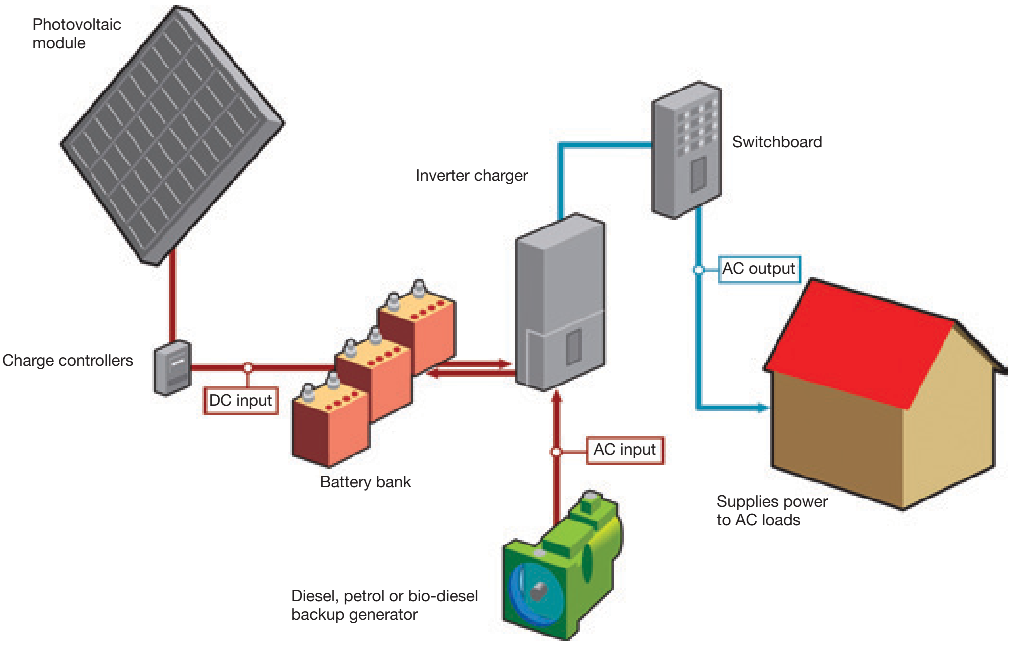


Figure 10. Example component diagram for a SAPS

Diesel generators and environmental effects

It is often assumed that there are environmental benefits of going ‘off-grid’ and generating your own electricity using micro-generation.

While this can be true, remember that SAPS almost always require a diesel generator to charge the batteries if they get too low. Combustion of diesel generates particulate emissions, nitrogen oxides (NOx), and greenhouse gas emissions.

Around 70% of grid-supplied electricity in New Zealand is generated from renewable energy sources, and by international standards is relatively ‘clean’. To match or better this, SAPS must be designed to minimise or even eliminate the need for diesel generators, although this may require greater investment in renewable energy technologies and battery storage.

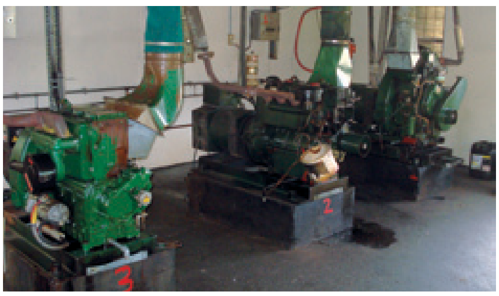


Figure 11. Diesel generators are commonly used with SAPS. Photo credit: Department of Conservation

Grid-connected systems

Micro-generation systems installed on properties connected to the electricity grid are called 'grid-connected', 'grid-tied', or 'grid-interactive' systems.

The most common form of grid-connected micro-generation is PV, although wind and hydro are also used. Grid-connected systems usually connect to the local electricity network through an inverter.

Owners of grid-connected systems might also be able to sell surplus electricity generated to an electricity retailer. When the system is generating more electricity than is needed on site – for example, during the day when no one is home – the owner could be paid for the surplus electricity produced. A special metering installation is required to separately measure electricity imported and electricity exported, and an inverter that converts DC into grid-compatible AC.

A grid-connected system is not suitable as a back up system that will provide electricity to your home if there is a power cut. If you want a back up power system you need to add batteries or standby generation, such as a diesel or petrol generator.

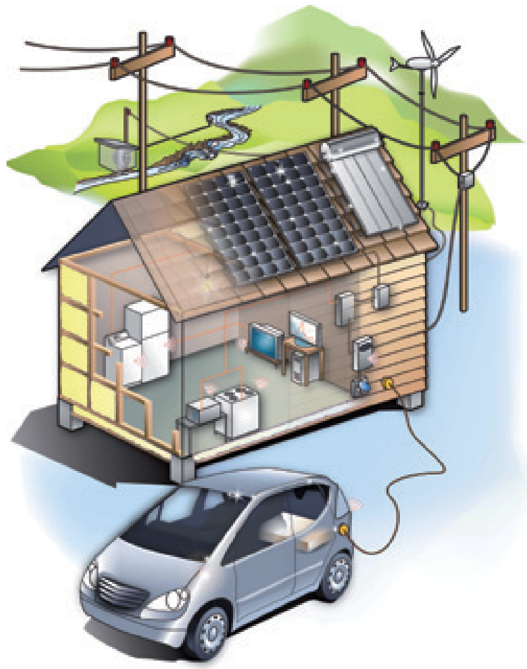


Figure 12. Illustration of a grid-connected PV array

Getting connected

One of the first things usually considered with grid-connected systems is whether you can sell back any excess electricity generated and what price you could be paid for this. Ask your supplier or installer for their advice or shop around the electricity retailers yourself. Be aware that the rates, terms, and conditions that an electricity retailer offers may change in the future; this is an important consideration for long-term assets such as micro-generation technologies. You may wish to seek legal advice before signing a contract. (See Selling electricity on page 15 for more information.)

In order to install a grid-connected system the owner of the system must apply to the electricity network company (sometimes called the 'distribution' or 'lines' company). This is the company that manages and maintains the local electricity wires that are used to convey electricity to and from homes, businesses, and companies. They need to check whether the system you intend to install is safe and complies with their connection and operation standards. There are 29 electricity network companies in New Zealand that maintain and operate the electricity distribution networks that interconnect the national grid and most residential, commercial, or industrial customers.

Electricity network companies are required to provide information on DG connection standards on their website.

Find out more about electricity network companies and the regions they cover on the Electricity Networks Association's website (www.electricity.org.nz). Figure 13 (see next page) shows the areas covered by the different electricity network companies.

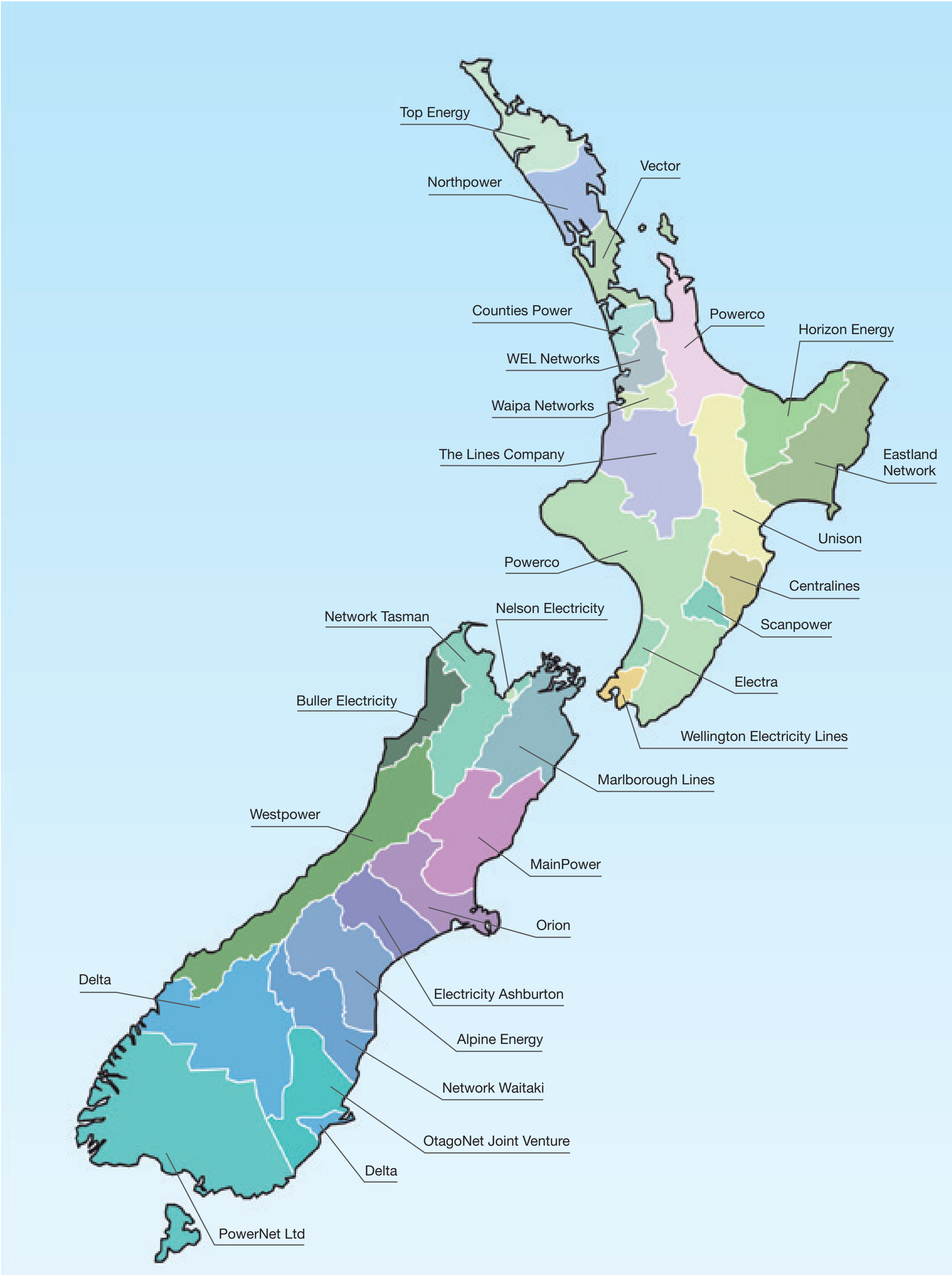


Figure 13. Electricity network companies in New Zealand
Source: Modified from the Electricity Networks Association

The electricity network company will have connection guidelines, and is likely to require the following information as part of your application:

- the type (e.g. PV, wind, hydro) and capacity (e.g. 500W, 1.5kW) of your generator
- details of the system configuration and components, to make sure the inverter meets the required safety standards. This includes whether the inverter has an automatic cut out to stop electricity being fed into the network if there is a fault or loss of power in the network. It will also be necessary to confirm that the rest of the system is safe and meets the relevant standards
- the location of the connection.

Note that your installer/supplier should be able to help you supply this information.

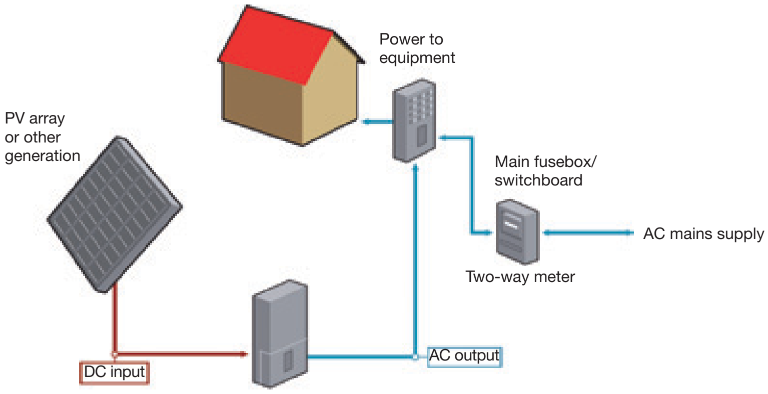


Figure 14. Example component diagram for a grid-connected system

DG connection regulations

The Electricity Governance (Connection of Distributed Generation) Regulations, released by the Government in August 2007, have introduced a process that governs the connection of DG into electricity network companies' lines. The regulations list the requirements for each party and are split into two categories:

- DG with a rated output of less than or equal to 10kW
- DG with a rated output of greater than 10kW.

Amongst other things, the regulations require that electricity network companies make available their connection and operating standards and if your connection is consistent with these standards the electricity network company should approve your connection. It is vital that all the safety and technical requirements of your electricity network company are adhered to. Never attempt to connect DG to an electricity network without the full approval of your local electricity network company.

The regulations also require that DG system owners wanting to be connected have a two-way metering installation. This meter measures both electricity imported and electricity exported from your property, and allows for a billing arrangement like 'net-billing'. Usually your electricity retailer will take care of providing a new electricity meter system for you, although you may be charged for this.

Under the regulations the network company is entitled to charge you for any costs that your generation plant causes the network owner to incur, net of any benefits that are provided by the connection of your generation plant. For micro-generation, which is likely to be less than 10kW in capacity, and installed behind pre-existing connections, it is uncommon for network companies to pass on connection charges as the impacts are usually minimal.

The network company may also charge you up to $200 for processing applications and up to $60 for inspecting installations. They are required to process your application within 30 working days.

For more information on the DG connection regulations, see the following websites:

http://www.ea.govt.nz (search for 'distributed generation guidelines')
http://www.seanz.org.nz/dg-metering-guide
http://www.legislation.govt.nz/ (search for 'distributed generation')

Selling electricity

If your micro-generation system generates more electricity than you use, you may be able to sell that surplus back into the network. The easiest way to sell electricity from a micro-generation system is to sell it directly to an electricity retailer. It should be noted that there is no regulation or law in New Zealand that obliges retailers to purchase electricity from distributed generators, or controls how much they will pay for the electricity. Therefore, the amount they choose to pay per kilowatt-hour (kWh) (often called the 'buy-back' rate), along with their terms and conditions, is determined by the retailer.

The buy-back rate that retailers offer is often less than their retail rate of electricity. This is because electricity retailers incur a number of costs such as transmission and distribution, billing and administration charges, and metering, which add to the initial wholesale cost of electricity. As rates vary from retailer to retailer, it is important to shop around to get the best deal.

Net-billing and net-metering

If you arrange for your electricity retailer to purchase your excess electricity, they will set up a special billing process. Your two-way metering installation will record both electricity exported and electricity imported. At the end of the month the retailer will calculate the cost of electricity you have purchased as normal by multiplying the import reading on the meter by the appropriate tariff and adding GST. From that amount, they will then subtract the value of electricity you have sold by multiplying the export reading on the meter by the appropriate tariff. The net of the value of imported electricity and exported electricity will be what you pay (or receive). All income earned from the sale of micro-generation electricity (regardless of whether the retailer 'nets' the transactions or requires separate transactions) is regarded by IRD as declarable income, and is therefore subject to income tax. You may need to discuss the implications of this with an accountant.

Note that 'running the meter backwards' (often called 'net-metering', which refers to when a single channel meter is used to record both imported and exported electricity), is prohibited in New Zealand. Using a two-way metering system approved by your electricity retailer is the only system permitted in New Zealand.

Figure 15. A typical two-way meter
Photo credit: Contact Energy

Standards and requirements

Do not attempt to install any micro-generation system yourself.

Any electrical work involving voltages above 120 Volts DC or 50 Volts AC is defined as 'prescribed electrical work' by the New Zealand Electricity (Safety) Regulations 2010, and you must be a licensed electrical inspector or electrician to undertake work of this nature.

There are a number of technical Standards relating to the design and installation of micro-generation systems which are mandated by the Electricity (Safety) Regulations 2010. An experienced and competent installer will always work to recognised Standards.

Below is a list of relevant Standards. (Source: SEANZ www.seanz.org.nz)

Table 2. Standards related to installation

AS/NZS 3000	The Australian and New Zealand Wiring Rules (including amendment No. 1)
AS/NZS 5033	Installation of photovoltaic (PV) arrays
AS/NZS 4509 series **AS/NZS 4509.1** **AS/NZS 4509.2**	Stand alone power systems Part 1: Safety requirements Part 2: System design guidelines
AS 4086.2	Secondary batteries for use with stand alone power systems Part 2: Installation and maintenance
AS 4777 series **AS 4777.1**	Grid connection of energy systems via inverters Part 1: Installation requirements
AS/NZS 3010	Electrical installations – Generating sets

Table 3. Standards related to products

IEC 61215	Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval
IEC 61646	Thin film terrestrial photovoltaic (PV) modules – Design qualification and type approval
IEC 61730 **IEC 61730.1** **IEC 61730.2**	Photovoltaic module safety Part 1: Requirements for construction Part 2: Requirements for testing
AS 4777 **AS 4777.2** **AS 4777.3**	Grid connection of energy systems via inverters Part 2: Inverter requirements Part 3: Grid protection requirements

Table 4. Additional Standards

AS/NZS 1768	Lightning protection
AS 3011	Electrical installations – secondary batteries installed in buildings
AS 2676	Installation and maintenance of batteries in buildings
AS/NZS 1170.2	Wind loads
NZS 4219	Specification for seismic resistance of engineering systems in buildings

Further information about Standards is available on the SEANZ website www.seanz.org.nz

Photovoltaics

Figure 16. A roof-mounted PV array in Wellington
Photo credit: Genesis Energy Schoolgen

Solar energy is the most abundant renewable energy source available. Photovoltaic modules (or 'PV') absorb the sun's energy and convert it into electricity, without emitting noise or producing greenhouse gas emissions. PV is a reliable and proven technology widely used internationally. Technological advances and new forms of PV that are being developed around the world are expected to continue to provide incremental increases in efficiency and reductions in cost.

Like wind turbines, PV is an intermittent generation source. It does not generate electricity at night, and is also affected by cloudy weather. New Zealand has a good solar resource with solar radiation levels equivalent to southern France in many locations. As shown in Figure 17, radiation levels in Dunedin are roughly as high as in Germany, where PV is used extensively.

Solar radiation in New Zealand cities, in the context of large international PV markets

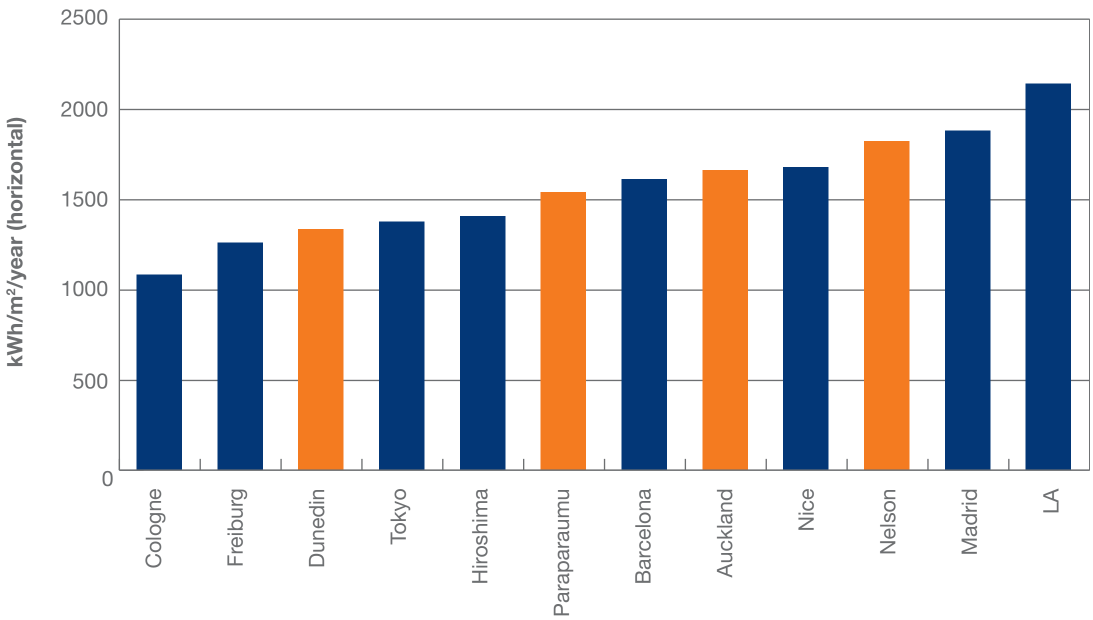


Figure 17. Solar resource in New Zealand compared to other locations
Source: Modified from IT Power Australia and Southern Perspectives Ltd 2009

PV modules are commonly used in communication systems, water pumps, lights on navigation buoys, and electric fences. While PV is often used in remote areas where connection to the electricity network is difficult or expensive, it is also becoming increasingly popular in urban environments in grid-connected applications.

How PV works

PV modules are generally either mounted on roofs or on the top of purpose-built frames for maximum sun exposure. The modules contain a number of electrically connected solar cells that are packaged together. These solar cells contain a semiconductor material, usually silicon.

Light contains particles called photons. When light hits the solar cells some of the photons are absorbed which frees some of the electrons in the silicon crystal, allowing them to flow through the cell layers to electrical wiring where they create an electrical current. In this regard, PV differs from solar water heating where solar energy directly heats the water.

Cross section of a Silicon-based PV cell

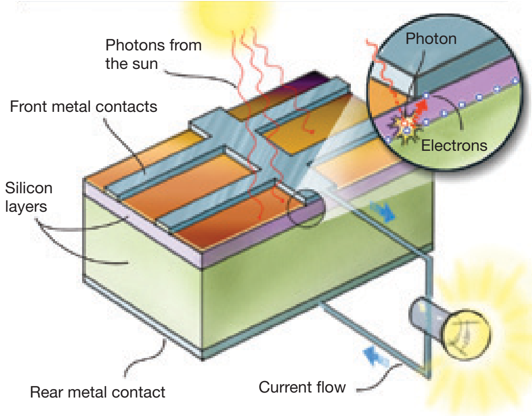


Figure 18. Cross section of a PV cell

Figure 19. PV modules being used as roof cladding
Photo credit: www.solarcentury.com

Characteristics of PV

Like other forms of micro-generation, PV has a relatively high upfront cost and, as such, is a long-term investment. However, as the technology evolves and manufacturing capacity increases, PV is becoming more affordable.

PV is modular, which means you can easily add more modules if you need more power or if your electricity demand grows. Another benefit is that the modules tend to be very robust and require little or no maintenance and are completely silent in operation. Most warranty periods are between 20 and 25 years, although the modules will probably continue to work for up to 30 years.

Environmental impact of PV arrays

Photovoltaics are not completely environmentally benign. Some manufacturing processes involve toxic substances, such as cadmium, though this is lessening as manufacturing technologies improve.

Modules at the end of their life should be disposed of carefully, and some manufacturers have waste minimisation and recycling procedures in place to reduce the environmental effects.

PV in stand-alone systems

PV arrays are commonly used in off-grid systems to provide the bulk of energy required, due to the robustness and reliability of the technology. In 'hybrid' systems other generating devices such as small wind turbine or micro-hydro can also be used. For some applications, such as solar powered water pumping, the PV array may run the application entirely without battery storage.

Figure 20. PV arrays installed in a SAPS
Photo credit: EcoInnovation

PV in grid-connected systems

At present grid-connected PV systems are capital intensive and struggle to be cost competitive with grid-supplied retail electricity. However, this situation is likely to improve as costs decrease and the market grows across New Zealand. PV can be used to provide both shade and electricity, such as on car park roofs, awnings over windows, or on patio courtyards, or even integrated into your building itself. Building integrated PV (BIPV) is where the PV modules act as an essential building material, such as roof or wall cladding. BIPV can replace traditional building materials and in so doing the project may be more cost effective.

Figure 21. PV integrated into a building façade
Photo credit: www.solarcentury.com

Table 5 below summarises some of the characteristics of PV arrays.

Table 5. Basic parameters of PV arrays

PV parameters	Comments
Size of typical residential application	Residential PV systems are often between 1kW and 5kW in capacity. A good rule of thumb is that between 6m^2 and 14m^2 is required per kW installed, depending on the type of PV modules used.
Size of typical commercial application	Commercial PV systems tend to range in size from 5kWp up, although many commercial applications are in the 10s or 100s of kW. The largest PV array in New Zealand is 52kWp, at Auckland International Airport, and it covers 416m^2.
Power	Each PV module has a rating specifying its peak electrical output under standard test conditions. Modules are available in sizes from 5Wp to 200Wp. A 1kW PV array could have 6 x 175Wp modules connected together.
Weight	A PV array usually weighs less than 20kg per m^2 of panel.
Construction	PV cells are made of several different materials, mainly silicon. PV modules are made up of cells sandwiched between glass laminate and tedlar, or polyvinyl fluoride. Some newer types of PV cell are created by depositing semiconductor layers as 'thin films' directly onto glass, metals, or even plastics of various types, including flexible sheets.

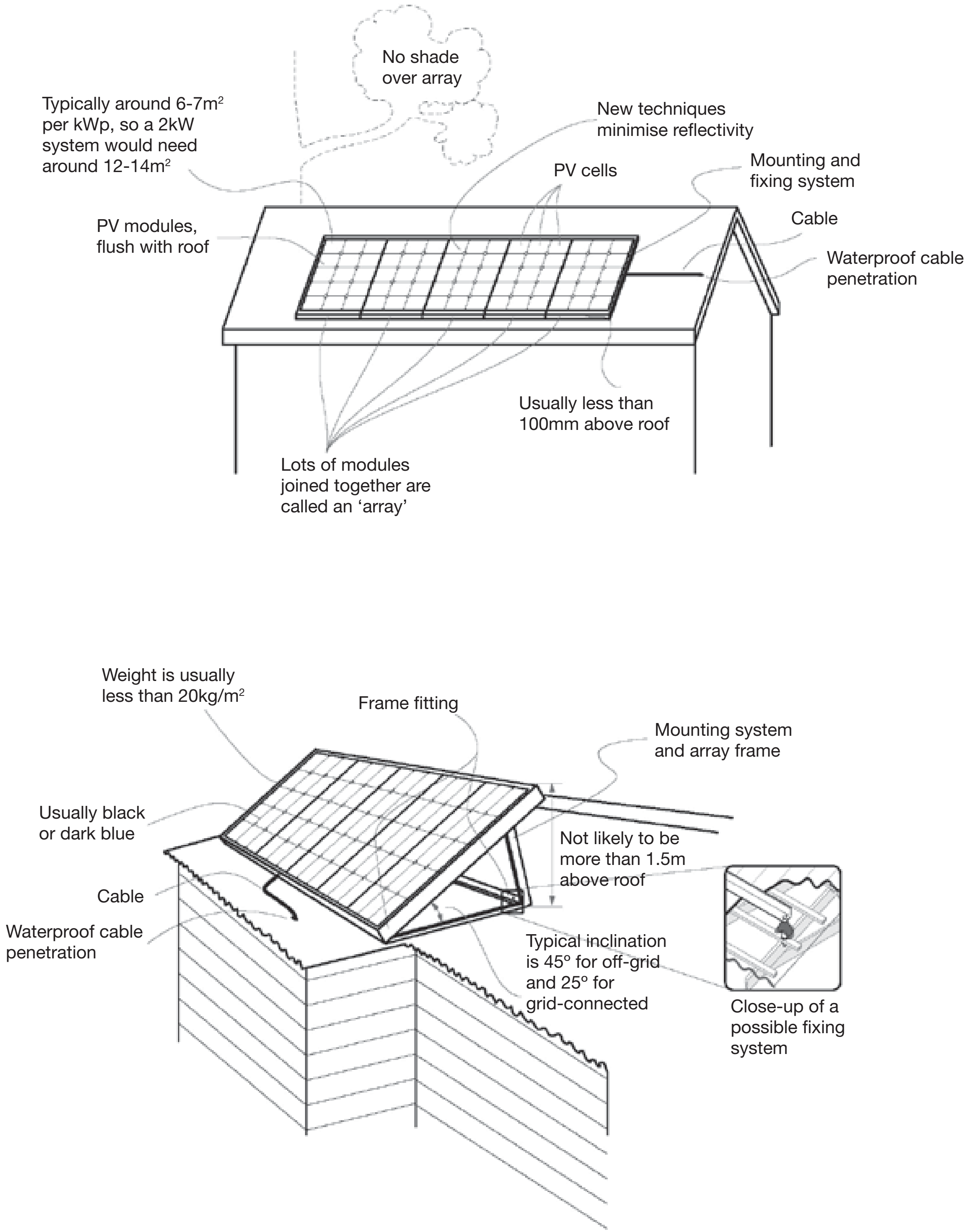


Figure 22. PV arrays, modules and cells

Assessing your site

PV can work in all parts of New Zealand; however, the best places to use PV are ones that get a lot of sunshine each year and where the sky is generally clear rather than cloudy. You should have clear and unobstructed access to the sun for as much of the year as possible, with little or no shading. Figure 23 shows average annual levels of solar energy in New Zealand.

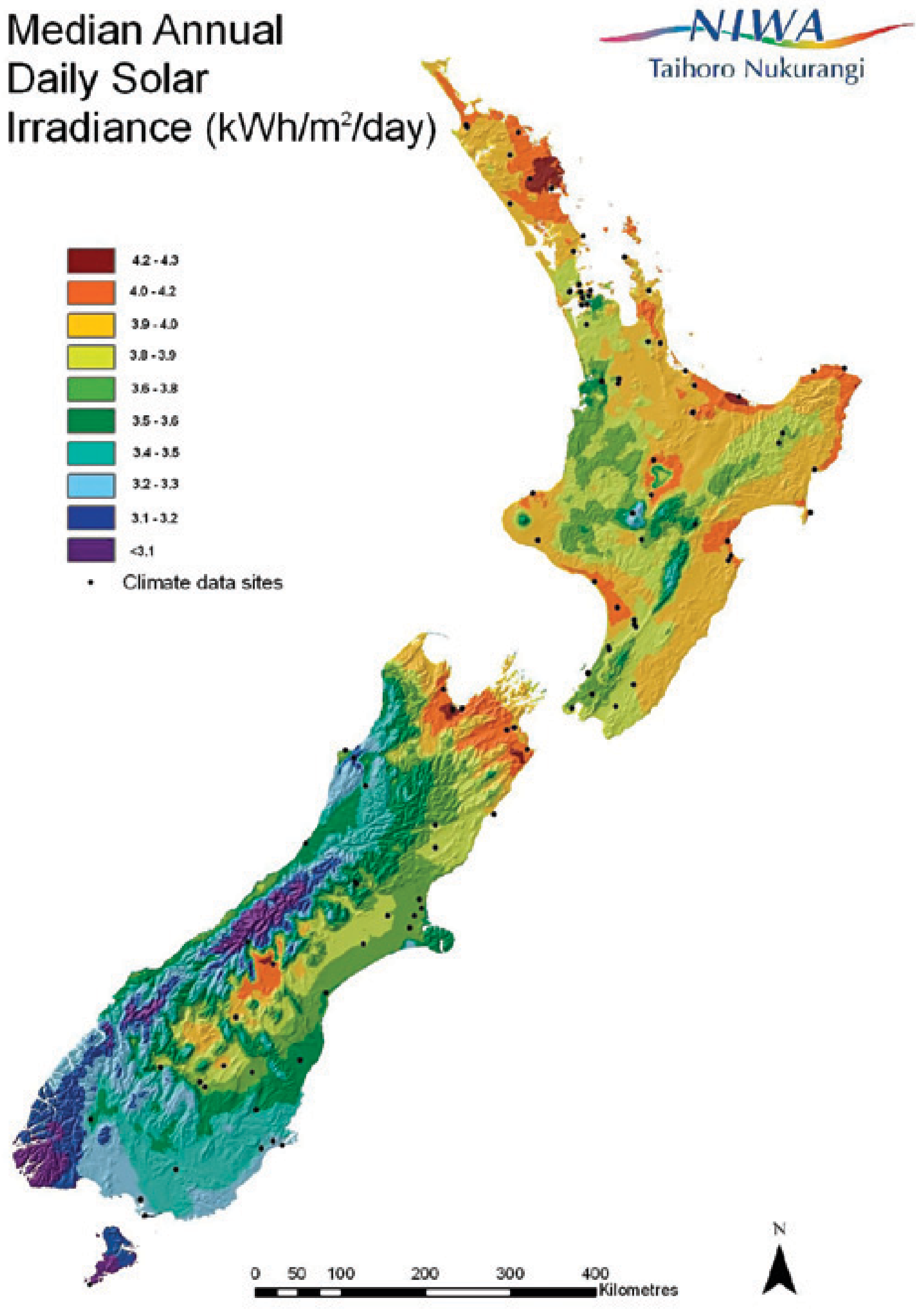


Figure 23. Map of the solar resource (kWh/m^2/day) in New Zealand
Source: NIWA (modified)

Choosing and installing PV

Making the most of the solar resource available on your site means getting the location, orientation, and inclination of your PV array right. In practice, issues relating to shading from existing buildings or other objects, the aesthetics of the installation, wiring, and cabling etc may necessitate a compromise.

Building consents

You may need to get building consent from your local council before you install a PV module or array. The council will probably want to be sure that the installation has been conducted in accordance with the New Zealand Building Code, that any roof penetrations are weathertight, and that all electrical work has been signed off as required.

Positioning your PV array

If you want to install the PV modules in plane with the roof you will often have to sacrifice some performance. An inclined array frame can be used to mount the array at the optimal inclination, and can even be modified to face due north if required. The additional cost of the array frame needs to be balanced against the value of the extra energy generated. Often it can be more cost effective to add another PV module.

If you have the land available, you may wish to consider installing your PV modules on inclined, ground-mounted frames. This can often be more cost effective and allows the array to be installed at the optimal orientation and inclination. This can also provide more flexibility in avoiding shading.

PV modules should not be shaded by trees, buildings, or other obstructions. Even minor shading can cause significant energy loss.

Figure 24. PV modules being installed on a roof
Photo credit: Genesis Energy Schoolgen

Figure 25. Ground-mounted arrays can allow more flexibility
Photo credit: Joseph Mayhew

Orientation

The best orientation for a PV array is usually due north; however, arrays facing northeast or northwest may also be acceptable, although usually with a slight reduction in performance.

Sun trackers

Sun trackers are systems that follow the sun as it moves throughout the day, enabling your PV module to have greater output. Trackers are used mainly with water pumping applications and in some stand-alone systems. When considering a tracker you should weigh up the value of the additional energy generated against the increased capital and maintenance costs of the tracker. As PV modules decrease in price, it may be more viable to increase the size of your system in order to increase output, rather than investing in a tracking array.

Inclination

The tilt, or inclination, of your PV modules is also important. Generally, the inclination of your module is determined by the latitude at your location. The minimum angle should be 10 degrees, to receive more light and to allow the rain to wash dust off.

The sun is always lower in the sky in winter and higher in summer, as shown in Figure 26. In an off-grid situation, where you are usually designing to maximise performance in the winter, a rule of thumb is to set the panel inclination to your latitude plus 10 degrees. This slightly reduces the summer output of the panels but increases the winter output.

For example, the optimum inclination angle for a module installed in an off-grid situation near Kerikeri, where the latitude is around 35 degrees south, would be around 45 degrees tilt.

If your property is connected to the grid and you want to maximise total energy output over the year, the optimum angle is about your latitude minus 10 degrees. This is the opposite of the off-grid example, and maximises summer output.

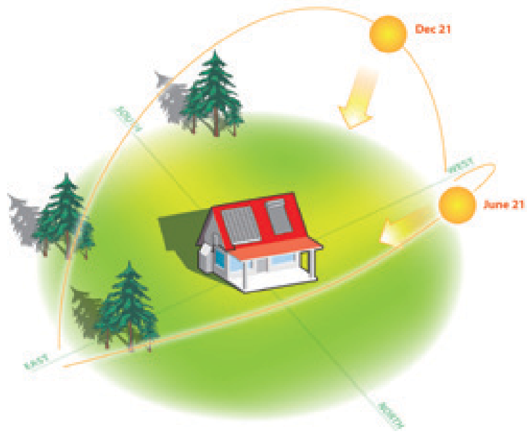


Figure 26. Illustration of array orientation and the sun's path

How much electricity will it generate?

Each PV module has a rating specifying its peak electrical output under standard test conditions. Modules are available in sizes from 5Wp to 200Wp. For example, a module with a 75W peak rating (75Wp) will have a power output of 75W under standard test conditions.

A typical domestic system is usually around 1,000Wp to 3,000Wp (1kWp to 3kWp). If you want a total combined capacity of 1kWp you will need to buy a number of smaller modules and put them together to form an 'array'.

Actual generation output

While the capacity rating tells you the peak electrical output of a module under test conditions, in the real world the PV modules will not be operating under such ideal situations and the output will be less.

You can use some rough calculations to get an approximation of what your PV array will actually generate over time. The amount of electricity that a PV array generates depends on the intensity of the sunlight it is exposed to. PV modules still produce power on cloudy days, but less than they would in direct sunlight. They also generate less in winter and more in summer.

Typically, PV arrays only generate 12% to 15% of their rated power output on average, over a year. This is called the 'capacity factor'. In very sunny sites the capacity factor is likely to be at the higher end of this scale, while in average or less sunny sites it will be towards the lower end. The capacity factor takes into account seasonal and daily variation and reflects the ratio of the actual output of the PV array over a year compared with its output if it had been operating at full rated power for the same period of time.

You can work out the approximate actual output by multiplying the rated output by 8,760 (the number of hours in a year), by a percentage figure between 12% (0.12) and 15% (0.15), which represents the capacity factor. Examples are shown in Table 6 (see next page).

Table 6. Approximate actual PV output (12% - 15% capacity factor)

Rated output (kWp)	Hours in a year	Amount generated in one year at rated output	Amount generated in one year (12% capacity factor - 15% capacity factor)	Amount generated in one day (12% capacity factor – 15% capacity factor)
2	8,760	17,520kWh	2,102kWh - 2,628kWh	5.8kWh - 7.2kWh
5	8,760	43,800kWh	5,256kWh - 6,570kWh	14.4kWh - 18kWh
7	8,760	61,320kWh	7,358kWh - 9,198kWh	20.2kWh - 25.2kWh

The cost of a PV system

Photovoltaics are usually a long-term investment. Nevertheless the cost of generating electricity from PV is likely to be greater than purchasing it from the grid, taking into account the capital costs, unless you are setting up a stand-alone system and can avoid the cost of connection.

Estimating the cost of a PV system can be difficult because costs depend on a number of factors including the PV modules, the peripheral equipment, the way the system is configured, labour costs, and consenting costs (if required). Use this information as a guide only.

At present (2010) PV modules alone usually cost around $4 to $8 per Watt peak, or $4,000 to $8,000 per kW. However, the modules alone are only one component of the total installed system cost. For a grid-connected PV array the balance of system costs include a grid-connect inverter, framing and cabling, and installation. For an off-grid system, the balance of system costs will likely include the battery bank, inverter/charger and charge controller, diesel generator, framing and cabling, and installation.

Table 7. Indicative costs of setting up a PV-based system

	Grid-connected system 2kWp	Off-grid system capable of generating between 5-7kWh/day
PV modules (2kW)	$8,000 - $16,000	$8,000 - $16,000
Inverter/charger	$2,500 - $5,500	$3,000 - $8,000
Framing	$1,000 - $2,000	$1,000 - $2,000
Batteries	Not required	$6,500 - $14,000
Diesel generator	Not required	$3,000 - $11,000
Balance of system	+-$1,000	+-$4000
Installation	$1,000 - $2,000	$3,000 - $6,000
TOTAL	$13,500 - $26,500	$28,500 - $61,000
$ per Wp installed (Incl. GST)	$7 - $13	$14 - $30

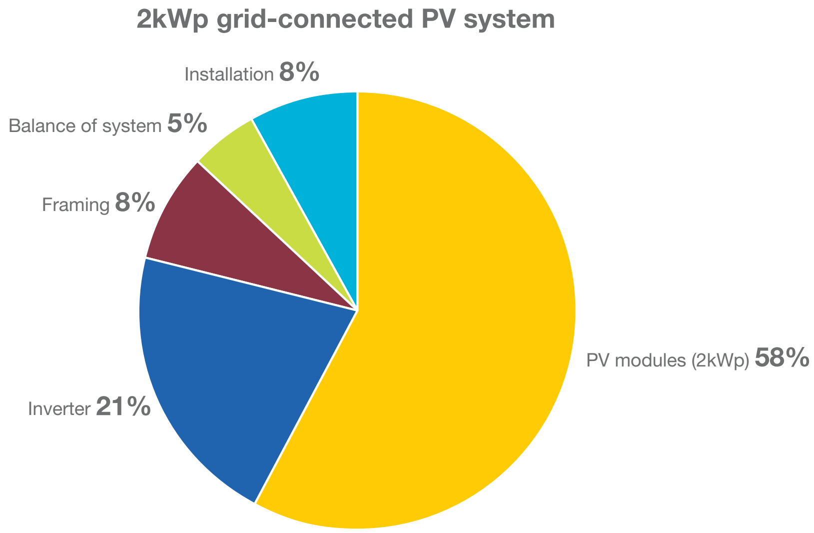


Figure 27. Indicative cost breakdown of a grid-connected system with 2kWp of PV

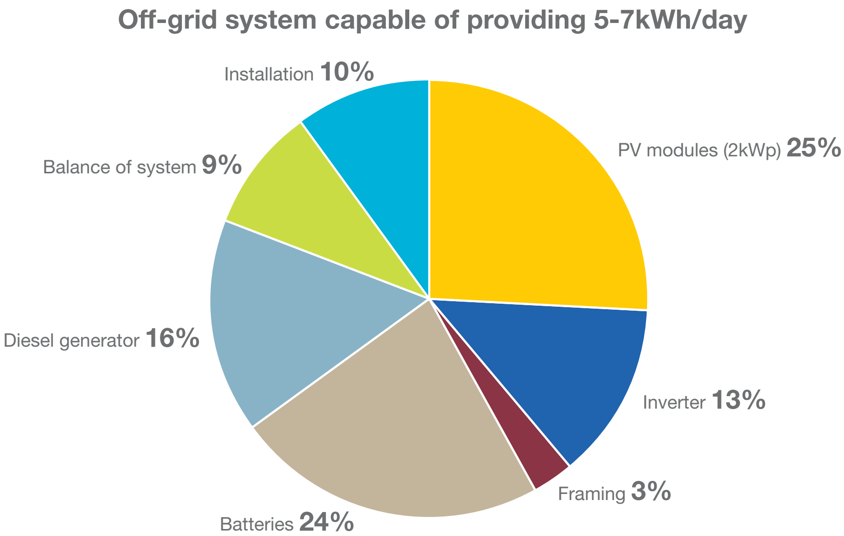


Figure 28. Indicative cost breakdown of a SAPS capable of generating between 5-7kWh/day

Maintaining your PV array

PV arrays usually require very little maintenance. You may need to clean the panels occasionally and may need to trim trees to prevent shading.

Figure 29. PV arrays need to be kept clear of shading from trees

Small wind turbines

New Zealand has one of the best wind resources in the world and power companies are investing in large wind farms in order to generate electricity from our wind resource. Similar opportunities exist at the small scale.

Small wind turbines are often used as part of a SAPS for single homes or farms but they can also be installed in grid-connected systems.

Wind energy can deliver many benefits: it does not release any greenhouse gas emissions, and the energy source is renewable and local. However, micro-scale wind turbines are costly and wind energy is extremely site specific. You will need to carefully assess the wind at your proposed site, the topography around the site, and the consenting requirements of your local council. While it may seem very windy at your site, it may still not be suitable for a micro wind turbine.

Wind turbines tend to be best suited to rural settings, but roof-top wind turbines in urban settings are also being trialled.

Small wind turbines generally have a capacity of 0.3kW - 20kW. Households usually use systems smaller than 5kW, while systems up to 20kW can be used on farms.

How wind turbines work

Wind turbines harness the energy in the wind to generate electricity. The wind turns the rotor blades of the turbine, which then spins a shaft connected to a generator. The generator uses magnetic fields to convert the rotational energy into electricity. Most turbines are horizontal-axis, with the rotor blades mounted upwind of the tower. Tail fins or an active yaw system ensure the blades are constantly facing the wind; however, other designs have the blades downwind of the tower.

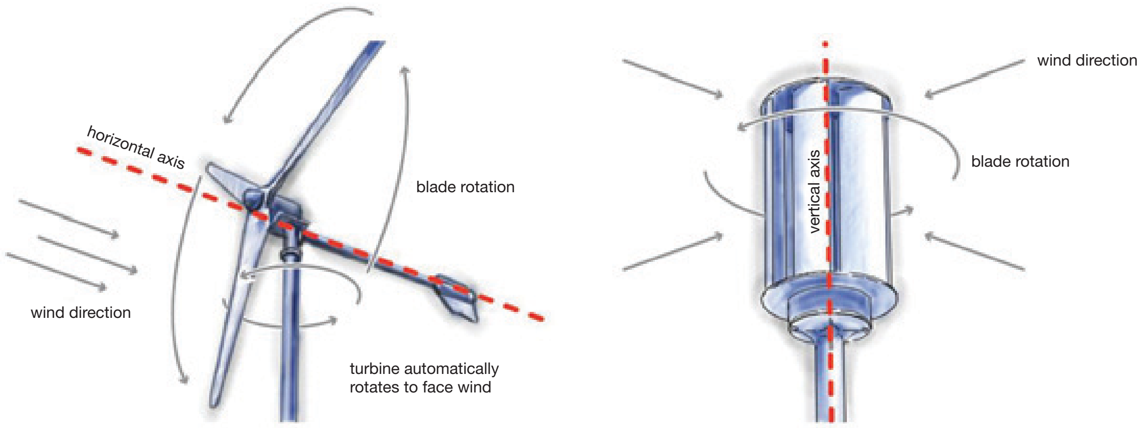


Figure 30. Illustration of horizontal (left) and vertical-axis wind turbines

Characteristics of small wind turbines

Wind turbines suitable for residential use are many times smaller than those used in commercial wind farms. There is a multitude of different wind turbines available. Table 8 explains some of the characteristics of small wind turbines.

Table 8. Basic parameters of small wind turbines

Some common micro- and mini-scale wind turbine parameters	Notes
Size	Micro- and mini-scale wind turbines range in size from those that have rotors of less than 1m in diameter to much larger devices that have rotors between 8m-10m in diameter. Most household-scale wind turbines have rotor diameters of less than around 5m.
Rotor blades and configuration	Wind turbines need only one blade to convert wind energy; however, most wind turbines these days use two or three blades. The blades are usually made from composites of fibreglass, carbon fibre, or wood.
Rated power output	The rated power output of micro turbines ranges from a few hundred watts up to around 20kW. Typical micro-scale turbines have a rated power output of 1kW-3kW.
Mounting locations	Micro wind turbines are most commonly mounted on top of towers or poles in rural areas with good wind resources. Some new designs can be mounted directly onto buildings or other structures. It is important that the wind turbine is sited away from obstructions in clear, uninterrupted wind flow.
Tower type and height	Towers are usually either free-standing tubular or lattice towers, or tubular masts supported by guy wires. The height is usually between 9m-20m above ground level. Performance improves dramatically with height so most towers are at least 10m high, and towers around 20m in height are preferable. Some towers can be 'tilted' up and down to make it easier to install and service the turbines.
Survival wind speed	All turbines need a mechanism to prevent damage in extremely high wind speeds. This is sometimes called 'overspeed control'. Some turbines are designed to continue operating in high winds, or have a feature that allows the blades to twist (or 'feather') out of the wind for protection (passive overspeed control). Other mechanisms are electrical breaking and pitch control (active overspeed control).
Wind speeds	Most micro wind turbines require at least 3m/s (11km/h) of wind before they generate electricity; however, at least 4.5m/s (16km/h) is usually required to start working effectively.

Rural vs. urban use

Micro- and mini-scale wind turbines can be used in both urban and rural environments, although they generally work better in rural environments.

Turbines should not be sheltered behind trees, buildings, or other obstructions. Disturbed wind flow can reduce the performance of wind turbines in some situations.

In urban areas average wind speeds are low and the wind erratic due to building and other obstructions. Turbines create noise, which can be unpopular with neighbours. With roof-mounted units, the building itself can often cause disruption to the wind flow, affecting turbine performance, and there may be issues with vibration.

These issues are generally less significant in rural areas.

Figure 31. Turbines need to be robust and able to withstand harsh conditions
Photo credit: Proven Energy New Zealand

Assessing your site

It is all about location when it comes to wind turbines. Good, strong wind resources are just as important to a wind turbine as sunlight is to PV cells. And yet while most people are aware that photovoltaics should not be put in the shade, wind turbines are often positioned poorly.

Wind turbines generally operate best on:

- areas with smooth, steady wind flows, as opposed to locations with irregular, turbulent flow
- gaps, passes, gorges, and valleys extending down from mountain ranges
- high, elevated plains and hilltops, ideally with gentle surrounding contours
- exposed ridges and mountain summits
- coastlines and inland strips with minimum wind barriers and vegetation.

The actual output will depend on capacity of the turbine and the wind speed distribution at the site it is installed. Most small wind turbines need an average wind speed of 4.5m/s (16kph) to operate effectively, although stronger than this would be preferable. Even in 'windy' Wellington, the annual average wind speed in Kelburn is only about 5.5m/s (20kph).

The importance of a good strong wind resource is due to the fact that the amount of energy in the wind increases as a cube of the proportional change in wind speed. This means that if the wind speed doubles, for example from 5m/s to 10m/s, the amount of available energy available in the wind is 8 times as strong (2 x 2 x 2 = 8). This relationship between power in the wind and wind speed is shown in Figure 33 below.

While it is therefore preferable to position a wind turbine in a site with the highest wind speed in order to extract the maximum amount of energy, it is important to remember that wind turbines require maintenance and this cost is likely to increase substantially if your turbine is continually exposed to very high or gusty winds.

Because there is significantly more energy available at high wind speeds, the wind speed distribution over the course of a year is also important. If the distribution of the wind includes incidences of higher wind speeds, even if the annual average wind speed across the year is lower, you will be able to extract proportionally more useful energy from these higher wind speeds. The example wind speed distribution in Figure 34 (see next page) shows that wind speed is skewed to the left, which indicates that lower wind speeds are most common.

Figure 32. Wind turbines need to be installed at exposed sites with a good wind resource
Photo credit: Genkit Nelson Ltd

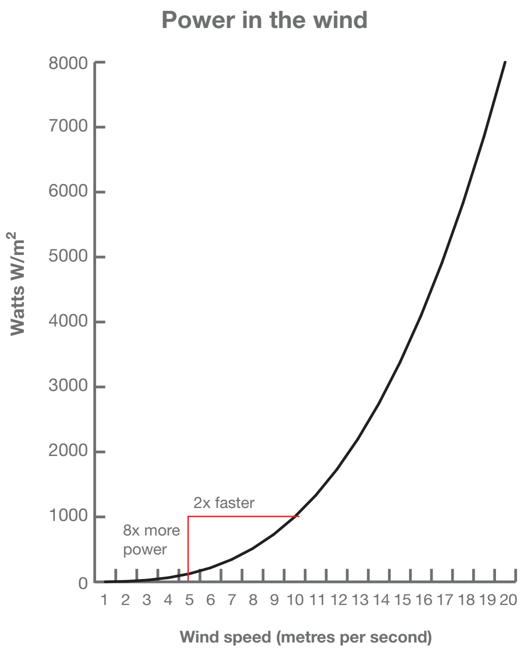


Figure 33. Power available in the wind

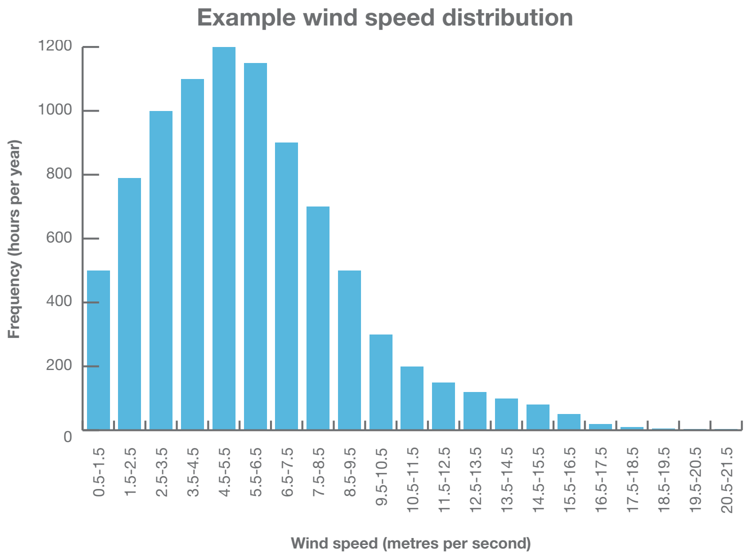


Figure 34. Example wind speed distribution

Measuring your wind resources

The most accurate way to assess the wind resource at your property is by installing an anemometer, which measures wind speed. However, this can be a costly process, and is rarely done for domestic-scale installations.

Instead, there are several other options for assessing the viability of a wind turbine. One approach is to use the Griggs-Putnam Index, which estimates the prevailing wind speed at a given site by observing the growth patterns of trees. This is based on the fact that in high wind areas trees 'flag', and lean away from the prevailing wind. To compare the vegetation on your property with the index, visit http://www.windenergy.com/aboutsmallwind/griggs-putnam.htm

Alternatively, if you live near a meteorological station or airport you can use their readings to estimate wind speeds at your property. You will need to check the height at which they take their measurements and compare the surrounding topography at the measuring site with that of your own property.

If someone in your area has a small wind turbine you could ask if they are recording their turbine's output. This can be used to give an indication of wind speeds in the area and the effectiveness of the turbine.

Choosing and installing your wind turbine

The wind turbine you choose must be appropriate for the wind resource available at your site and how much electricity you need to generate.

For example, a turbine designed to operate at lower speeds could be damaged if regularly exposed to strong winds. Similarly, a turbine designed to operate best in high winds may perform poorly in less exposed areas. Some turbine models will tolerate the constant re-orientation associated with disturbed, turbulent airflows, while other models might wear out sooner under the strain. Your supplier will be able to help you purchase an appropriate model.

Figure 35. Example of a micro wind turbine
Photo credit: EcoInnovation

Figure 36. Example of a 2.4kW wind turbine
Photo credit: Joseph Mayhew

Turbine performance

Wind turbine manufacturers should be able to provide a 'power curve' which provides an approximation of what the output of their turbine will be at different wind speeds. An example of a power curve for a micro wind turbine is shown below. Power curves can be useful to estimate how much electricity you may be able to generate at your site, assuming you know the characteristics of your wind resource.

Another good way of assessing the likely performance of a wind turbine is to ask your supplier for performance data for the turbine you are considering buying. They may have access to data which show, in a real situation, how much electricity the turbine generates over a given period, preferably a year.

You could also talk to other people who have already purchased the model you are considering. Ask them about performance, reliability, and repair requirements.

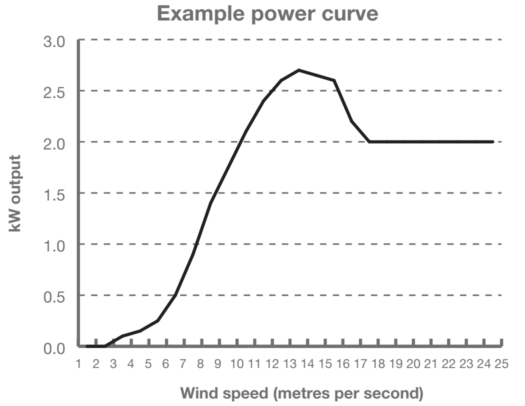


Figure 37. Example of a power curve for a small wind turbine

Figure 38. Two micro wind turbines in a grid-connected system near Christchurch
Photo credit: Joseph Mayhew

Quality standards

Small-scale wind turbines – either locally made or imported – do not need to meet any standards before they are sold in New Zealand, and as a result, some brands are more robust and reliable than others.

There are, however, some relevant international standards that some manufacturers are certifying to. Two of these standards are:

- AWEA 9.1 2009, American Wind Energy Association (AWEA)
- British Wind Energy Association (BWEA) Small Wind Turbine Performance and Safety Standard 29 February 2008.

Turbines that hold certification to these standards have been tested to withstand the structural loads the wind can impose and have verified performance information in a range of wind speeds.

Make sure you also carefully check the manufacturer's warranty period and conditions for their turbine and installation.

Some links with useful information about international standards are:

AWEA 9.1 standard: http://www.awea.org/smallwind/documents/AWEA_Small_Turbine_Standard_Adopted_Dec09.pdf

BWEA small wind standard: http://www.bwea.com/pdf/small/BWEA_SWT_Standard_Feb2008.pdf

BWEA small wind directory: http://www.bwea.com/small/equipment.html

Locating your wind turbine

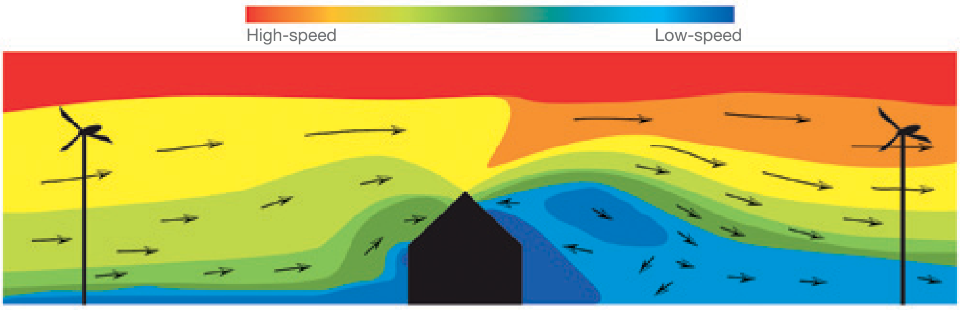
Wind turbines need to be located away from obstructions that may cause turbulence or interfere with the strong wind flow. When wind encounters obstacles and features on the ground the quality of airflow is disturbed, creating a zone of turbulence around the object. In general, the affected zone extends to about twice the height of the obstruction and can stretch downwind to a distance of about 20 times the object's height.

This is one of the main reasons why wind speed tends to be higher in rural areas where there tends to be more open and exposed space.

Wind speed also increases the higher you go because there is nothing to slow it down. Closer to the ground wind speed decreases as there is more 'drag' from the ground and obstructions, and right at ground level the wind speed is practically zero. This effect is called 'wind shear'. Therefore the higher you can mount the turbine the more energy you will be able to extract.

In practice you will also have to consider any potential height restrictions imposed under your district plan for wind turbine poles or masts. Your local council will have more information on this.

To reduce electricity loss and cabling costs (which can be prohibitive), you should try to keep your turbine within approximately 100m of where the power will be used.



Pole-mounted turbines should be located away from obstructions such as buildings or trees. Taller poles or tower are required to position turbines in stronger and more consistent winds.

Figure 39. Illustration of wind resources in a rural area

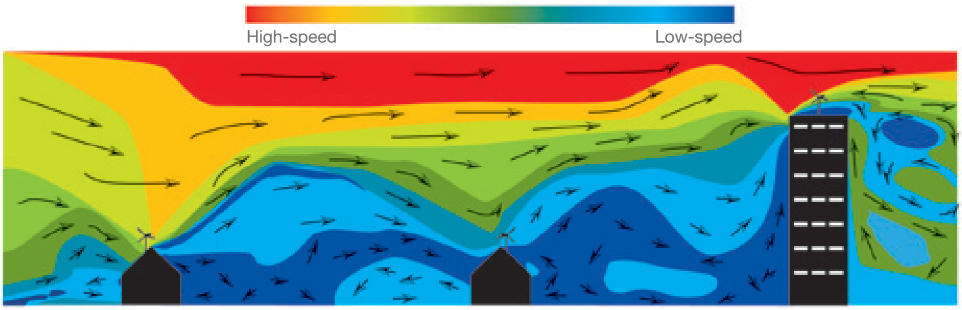
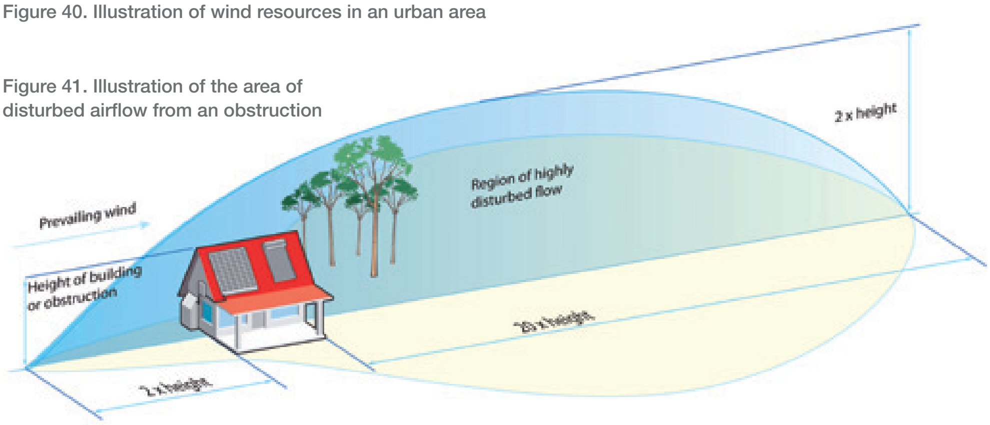


Illustration of wind-flow speeds in an urban environment. It can be more difficult to a site a turbine in consistent and strong winds.

Figure 40. Illustration of wind resources in an urban area

Figure 41. Illustration of the area of disturbed airflow from an obstruction



Environmental impact of wind turbines

The environmental impact of small wind turbines relates mainly to how they look and the sound they make. Your local council will look at potential visual and noise issues when it considers your application for building and/or resource consent.

Try to talk to your neighbours early on in the process. When planning a site for your turbine, think about their view, and try not to obstruct it. Be prepared to answer questions about noise, visual amenity, and safety. It may be useful for you or the installer to provide information about other similar wind energy installations nearby.

The level of noise generated by small wind turbines depends on the turbine size and type, and the extent to which you hear it varies with the level of background noise like the whistling of wind in trees, traffic, or farm machinery.

Bird collisions with small wind turbines are extremely rare; however, in sensitive areas this should be considered and taken into account when siting.

Towers and poles

Once you have found a possible site, you need to make sure you can install a tower or pole for the turbine to sit on. Wind speeds generally increase with height so in theory the higher the tower the better. In reality, however, the height needs to be balanced against the cost of a taller tower, visual issues, and council height restrictions. There is a variety of designs available and your supplier or installer should be able to talk to you about the most suitable options for your situation.

Figure 42 shows different types of poles and towers for micro wind turbines. Poles and towers are often made of steel, and may be guyed or can be self-supporting, either lattice or tubular in construction. Self-supporting poles are more compact and may be visually less intrusive, but tend to be more expensive.

The area of land required is generally between $4m^2$ and $9m^2$, depending on the particular model and on the foundations and/or guy wires etc. The electricity generated by the turbines is usually fed through wires down the pole or tower, through the foundations, and back to the building where it is connected to a distribution board, or into the battery bank.

When choosing the type of tower or pole and where it will be installed, consideration should be given to how the tower will be erected and lowered. Many turbines are required to be lowered so that they can be serviced.

Because there are many different designs of micro wind turbines available, manufacturers' guidelines and information should also be consulted for information on siting and installation.

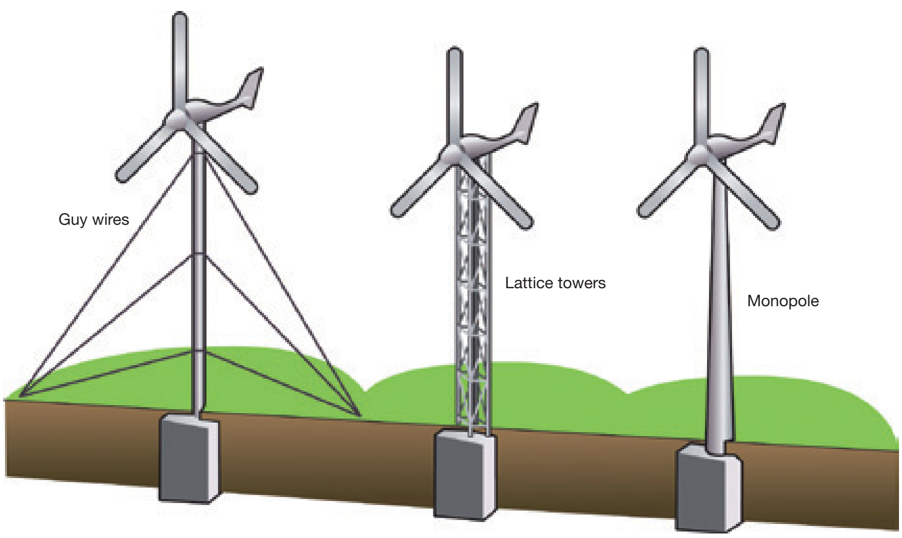


Figure 42. Examples of wind turbine towers and poles

Rooftop or building integrated turbines

Rooftop-mounted or wall-mounted micro wind turbines are a new and emerging type of wind turbine and there are many designs and types being designed and trialled, with some commercially available.

Figure 43. An urban micro wind turbine being trialled in Wellington
Photo credit: Joseph Mayhew

As shown in Figure 44, generally rooftop- or wall-mounted wind turbines require a solid section of building at the roof line to directly attach the turbine, providing a sufficient clearance above the apex of the building to take advantage of the wind resource around the building.

Due to the significant issues, including limited suitable wind resource in urban areas, noise, vibration, and other structural issues, these types of turbine are not common, often do not perform as expected, and tend to be much less effective than a well-sited wind turbine in a rural setting.

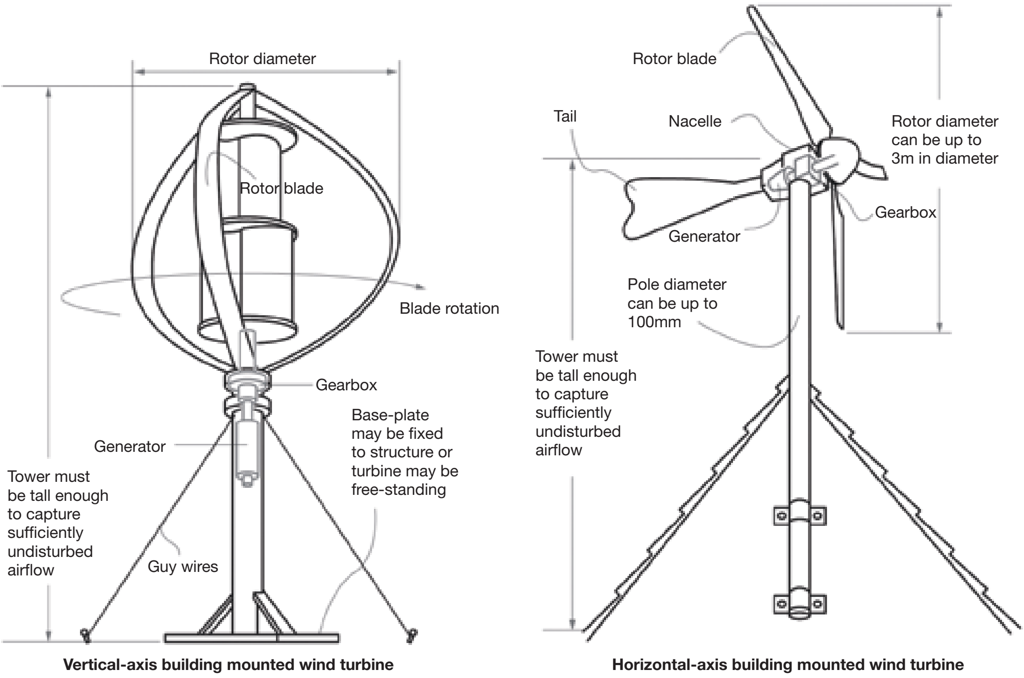


Figure 44. Examples of roof-mounted wind turbines

How much electricity will my small wind turbine generate?

The amount of electricity a wind turbine generates will depend on the wind speed at the site and the turbine's rated power output.

If a model has a rated power output of 1kW, it means it will produce 1kWh of electricity per hour when exposed to a specific rated wind speed.

This rated wind speed varies between different models and manufacturers, but is generally somewhere between 11m/s and 15m/s (about 40kph - 55kph). In the example power curve in Figure 37, if the turbine was rated at 12m/s, it would have a rated output of 2.6kW.

Actual generation output

The rated output is a useful guide but in the real world a turbine will not be exposed to ideal conditions, or the 'rated wind speed', at all times.

Instead, a micro and mini wind turbine will typically generate at only 10% to 30% of its rated power output on average over a year. This percentage is known as the 'capacity factor'.

It is difficult to accurately estimate the appropriate capacity factor for your site, unless you undertake resource assessments, which are costly. The table below assumes capacity factors between 10% and 30%, which is typical for a micro wind turbine in New Zealand. In very windy sites it is likely that the capacity factor will be higher, while in average or less windy sites it will be at the lower end of this range.

Work out the approximate output of your turbine by multiplying the rated output by 8,760 (the number of hours in a year), by a percentage figure between 10% (0.1) and 30% (0.3), which represents the capacity factor. Examples are shown in Table 9 below.

Table 9. Approximate wind turbine output (10% - 30% capacity factor)

Rated output (kW)	Hours in a year	Amount generated in one year at rated wind speed	Amount generated in one year (10% capacity factor - 30% capacity factor)	Amount generated in one day. (10% capacity factor –30% capacity factor)
0.5	8,760	4,380kWh	438kWh - 1,314kWh	1.2kWh - 3.6kWh
1	8,760	8,760kWh	876kWh - 2,628kWh	2.4kWh - 7.2kWh
3	8,760	26,280kWh	2,628kWh - 7,884kWh	7.2kWh - 21.6kWh

Retscreen

An alternative to assuming a rough capacity factor is Retscreen, a free tool that has been developed by the Canadian Government and is commonly used for pre-feasibility studies. You will need Microsoft Excel to use it.

Retscreen includes average wind data for a number of sites in New Zealand as well as power curves for a few turbines. Most of the turbines included, however, are much bigger than would usually be used for a domestic-sized installation so you may need to obtain the power curve from the turbine manufacturer and enter the data yourself.

Retscreen uses the power curve for the wind turbine and the wind speed distribution over the year to calculate what the wind turbine will produce. It requires some knowledge about the wind distribution, wind shear, and the effect of local wind conditions and obstructions at your site to get an accurate estimate. A manual is available to help you to learn more about how to use the tool. The Retscreen software and the manuals can be downloaded here:

Retscreen software: **http://www.retscreen.net/ang/home.php**
Retscreen manual: **http://www.retscreen.net/ang/d_t_guide.php**

The Canadian Wind Energy Association has some examples of small wind turbine calculations using Retscreen on its website. These can be downloaded here:

http://www.smallwindenergy.ca/en/SmallWindAndYou/UsingRETScreen.html

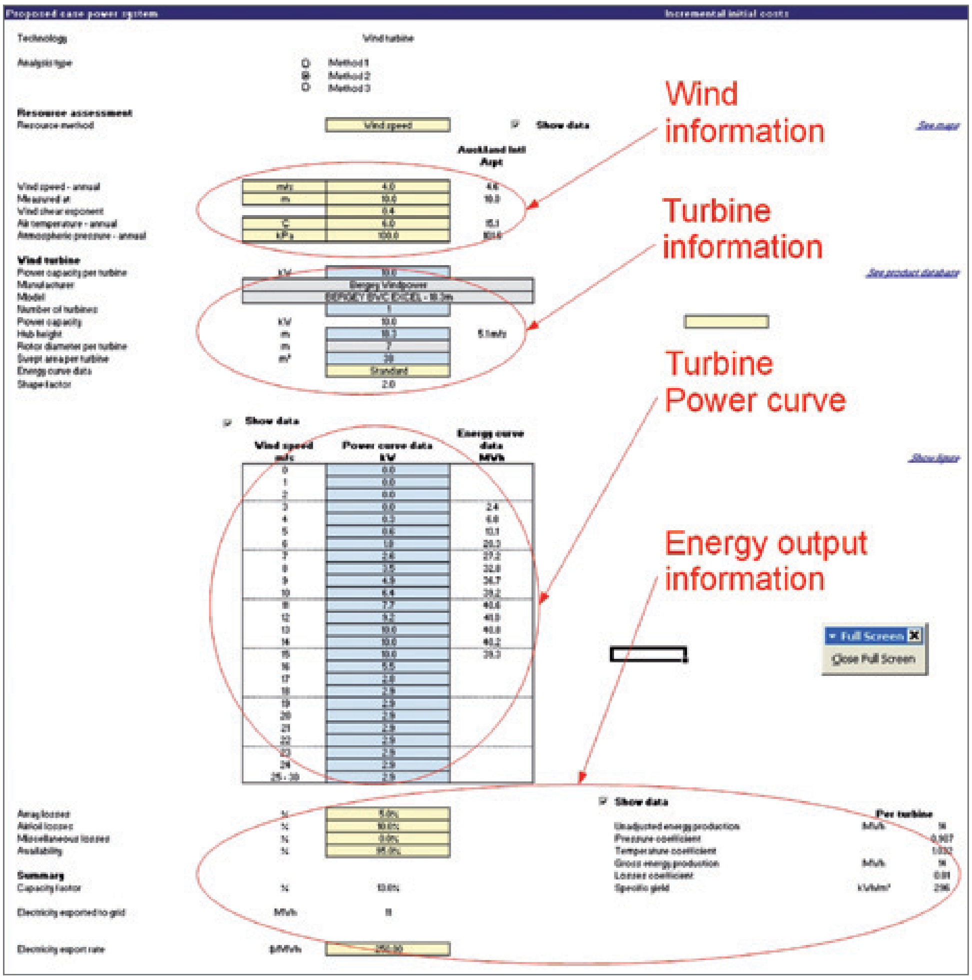


Figure 45. Screen-grab for Retscreen

Annual energy production (AEP) tool

Another useful tool is the AEP tool available from the European Wind Energy Association website. The software and manual can be downloaded from:

http://www.smallwindindustry.org/index.php?id=124

As with the Retscreen tool you will need to know information about the wind at the site and the power curve of the turbine you want to evaluate.

The cost of small wind turbines

Generally speaking, micro wind turbines cost between $3,000 and $8,000 per kW of rated power output. However, the turbine is only one component of a total installed system cost. For a grid-connected wind turbine, other costs can include a grid-connect inverter, the tower or pole and foundations, an engineer's assessment of the foundations, freight, consenting, and installation. For an off-grid system, other costs will likely include the battery bank, inverter/charger and charge controller, diesel generator, travel, cabling, freight, and installation.

Also take into account the ongoing maintenance costs, which can be considerable for small wind turbines.

The following table provides some indicative information on costs. Note that it is a guide only and should not be used as a substitute for a full (commercial) costing of your site and system needs.

Some micro wind turbines come with an in-built inverter, which may reduce overall system costs.

Table 10. Indicative costs of setting up wind systems using a 1kW-3kW turbine

	1kW-3kW grid-connected wind turbine	Off-grid system that is capable of producing between 5kWh and 14kWh/day
Wind turbine (2kW)	$6,000 - $18,000	$6,000 - $18,000
Inverter	$2,500 - $5,500	$3,000 - $8,000
Tower	$2,000 - $8,000	$2,000 - $8,000
Balance of system	$1,500 - $2,250	$4,500 - $6,700
Batteries	Not required	$6,500 - $14,000
Diesel generator	Not required	$3,000 - $11,000
Consenting	$500 - $1,000	$500 - $1,000
Installation	$2,000 - $10,000	$2,000 - $10,000
TOTAL	$14,500 - $44,750	$27,500 - $76,750
$ per Wp installed (Incl. GST)	$7 - $22	$14 - $38

Larger turbines usually cost more than small ones, but are generally cheaper on a per kW basis.

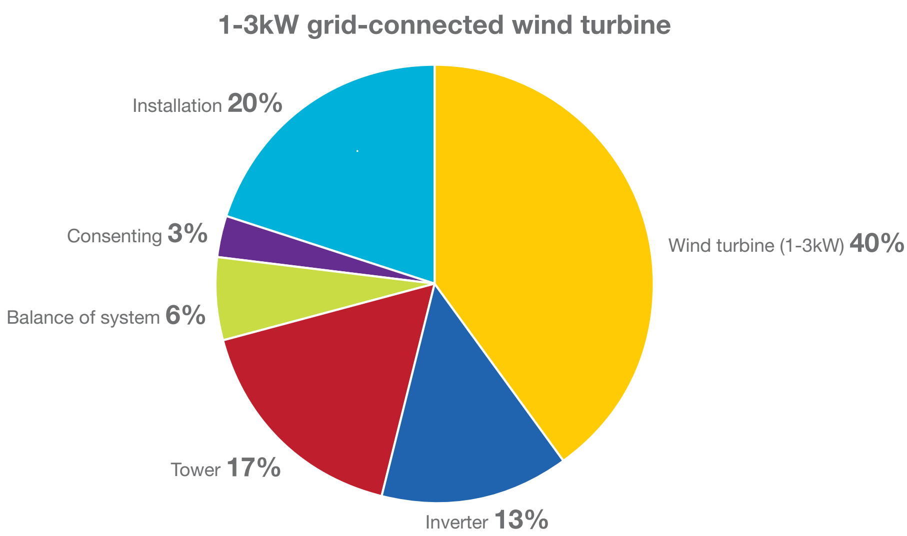


Figure 46. Indicative cost breakdown of a wind turbine in a grid-connected system

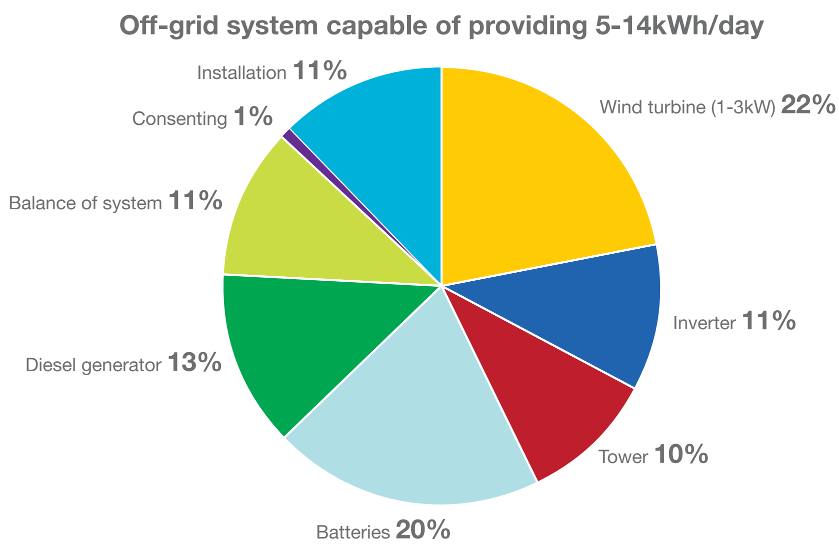


Figure 47. Indicative cost breakdown of a micro wind turbine in a stand-alone system

Maintaining your small wind turbine

Small wind turbines generally need more ongoing maintenance than PV arrays or even micro-hydro systems. This is especially true for turbines at exposed high wind sites, and in gusty areas such as cities.

Maintenance may include oiling and greasing parts and regular checking of bolts, electrical connections, brakes, and other features. Maintenance and operating costs may be significant and therefore should be built into your assessment of the economics of the project.

Ask your supplier about the best way to service your turbine, and find out what warranty and service they can provide.

Figure 48. Pole-mounted micro wind turbine with tilting mechanism
Photo credit: Gusto Energy Ltd

Keeping safe

Because small wind turbines involve many moving parts, electricity, and height, they pose a number of potential hazards. Always follow the manufacturer's instructions, and make sure the system is maintained by authorised and qualified people only.

Micro-hydro schemes

Micro-hydro systems work in a similar way to the large-scale hydro schemes that produce most of New Zealand's electricity: they convert the kinetic energy in moving water into mechanical energy to spin the turbine and generator, which produces electrical energy to be used directly, stored on site, or exported into the electricity network.

While large-scale hydro developments often require dams to store water behind them, micro-hydro is often run-of-river which means minimal or no storage is required, reducing the environmental impact. If storage is required, it is usually in the form of a small weir and/or a small storage tank.

Depending on the resource available, the output of a micro-hydro scheme is more consistent than that of wind or PV, although it sometimes varies with rainfall. It usually has a much higher capacity factor (usually greater than 50%) compared to other micro-generation technologies.

The output of micro-hydro is determined by the characteristics of the site and the resource availability, but most micro-hydro generators have outputs in the range of less than 100W to about 5kW. Systems are always designed according to the location and requirements of the user.

Hydro is usually the technology with the lowest cost of generation, so if you have a small stream or river on your property appropriate for a micro-hydro turbine, this will usually be your first consideration.

How micro-hydro schemes work

Micro-hydro systems use the force of running water to turn turbine blades, which spin a shaft connected to a generator. The generator uses magnetic fields to convert this rotational energy into electricity.

Most micro-hydro schemes temporarily direct water away from a stream and run it through a pipe to the turbine, before returning it to the stream. These types of schemes can have significantly less impact on flows and the volume of water within watercourses than larger schemes that require storage. If properly designed, they are unlikely to give rise to many adverse effects given the small volume of water diverted, except where watercourses have low flows.

In theory it is possible to capture hydraulic power whenever a stream of water flows from a higher level to a lower level; however, there are limits to what is practical and what can be effectively converted into electrical energy.

Figure 49. A micro-hydro turbine using a Pelton wheel
Photo credit: EcoInnovation

Figure 50. A 'Turgo' micro-hydro turbine
Photo credit: Alternative Power NZ Ltd

Vertical fall of water – the head

The 'head' is the vertical distance between where the water enters the system and where the generator is. Adequate head is essential for the micro-hydro system to work. Fast-flowing water by itself does not usually contain sufficient usable energy for electricity production.

A minimum vertical fall of 10m is recommended, but lower heights can work where there is enough flow and if the system is well designed with an appropriate turbine type.

The 'gross head' is the total vertical fall available in the scheme, while the 'net head' is a smaller amount which takes into account losses that are incurred while transferring water to the turbine (e.g. friction losses in the pipe). The gross head on your site will help determine the design of your scheme.

Water volume – the flow rate

The 'flow' is a measure of the volume of water that passes and which can be diverted into the micro-hydro stream. This is usually measured in m^3/second (also called 'cumecs'). In general it is more useful to have a high head with low flow, rather than the other way round.

Characteristics of a micro-hydro scheme

Table 11. Basic parameters of micro-hydro schemes

Micro-hydro parameters	Comments
Turbine types	The two main types of micro-hydro turbines are 'impulse turbines' (such as the Turgo or Pelton wheel) or 'reaction turbines'. In an impulse turbine, a high-speed water jet strikes and rotates the turbine buckets (runner), while a reaction turbine has the runner fully immersed in the water flow.
Diversion of water	The amount of flow able to be diverted will be limited by the resource consent requirements placed on the scheme. Generally, sufficient flow should be left in the waterway to minimise adverse impacts on aquatic life in the stream. Once the water is passed through the turbine it should be returned to the same body of water.
Required head and flow	Both the required head (the vertical drop between the intake and the turbine) and flow can vary considerably depending on the turbine used and its operating range. Generally, the higher the head, the more effective the hydro scheme will be. However, even a small head of less than 5m could be adequate, as long as there is sufficient flow in the stream and the correct type of turbine is selected.
Power	Micro-hydro turbines tend to be sized from a few hundred watts to around 5kW. The amount of electrical energy able to be generated depends on the flow of the river and the available head. Turbines less than 5kW in rated power output are often run-of-river schemes.

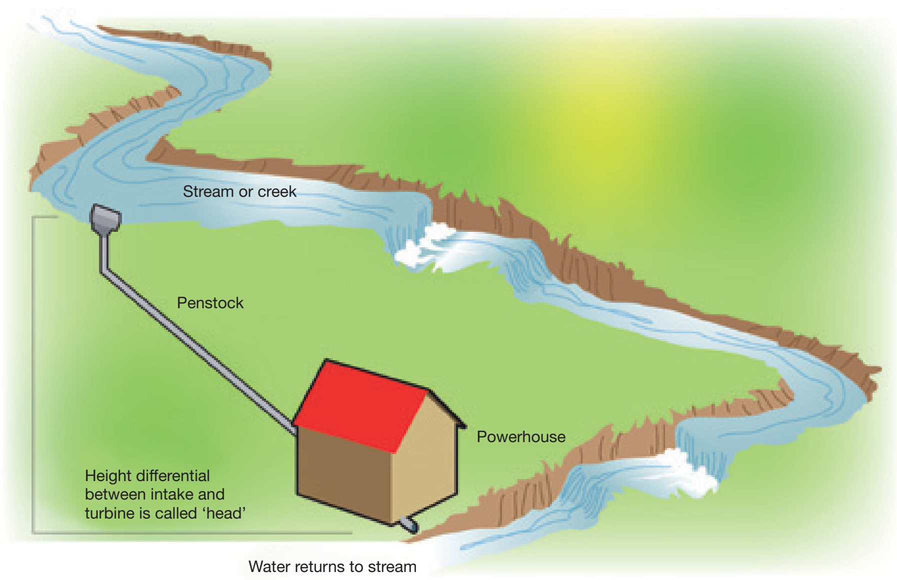


Figure 51. Overview of a run-of-river micro-hydro scheme

Assessing your site

There are thousands of small streams, creeks, or rivers in New Zealand that could be used to generate electricity on a small scale with minimal environmental impact. The best sites are likely to be on steep hills or ravines where water flows all year round, or at a waterfall, or where a reservoir discharges into a river.

Once you have found a site that may be suitable, you will have to undertake a pre-feasibility study. The pre-feasibility study will include assessing whether the head and flow of the stream are adequate and whether the stream runs year-round.

You may be able to undertake some of the pre-feasibility work yourself; however, an expert and knowledgeable installer or supplier of micro-hydro equipment may be required to help you with this. For more information on finding expert advice, see Finding a Supplier on page 50.

Measuring the head and flow

Measuring the head of your site can be a complicated process and is often left to experts to undertake. However, you may be able to undertake a preliminary assessment of the head by consulting topographic maps, or by using an altimeter, a GPS, or builder's level. Some of these methods should be undertaken by skilled operators who know how to calibrate the device and check for accuracy.

Figure 52. A photo simulation of a small weir on a micro-hydro scheme
Photo credit: Genkit Nelson Ltd

You will also need to measure the flow rate of the stream on your property. The flow of the stream will probably vary on a daily, monthly, and seasonal basis. For larger schemes, a study of the hydrology of the stream is required to know the minimum and maximum flows, so you can predict the output of your turbine in a range of conditions. You can contact the National Institute of Water and Atmospheric Research (NIWA), your regional council, or a local hydrologist to see if hydrology information on the waterway in question already exists. If flow information exists, note that your scheme will probably be limited to a percentage of that lowest flow.

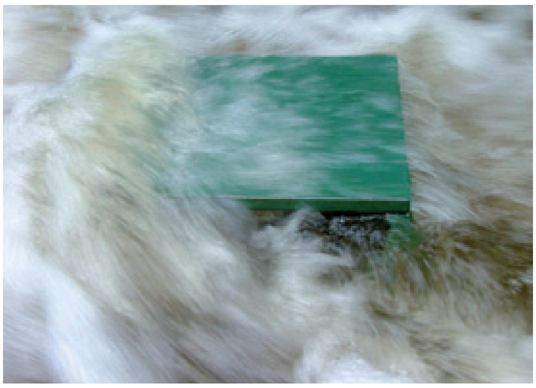


Figure 53. Micro-hydro schemes can be designed to withstand flood events
Photo credit: EcoInnovation

A simple way of assessing the flow rate in very small streams is to use the container method. This involves diverting the flow into a container or bucket and measuring how long it takes to fill the container. If a 10 litre container fills in 1 second, you have a flow of 10 litres per second (or $0.01m^3/s$).

Contact an expert for further information on assessing the head and flow of your stream.

Other important considerations are whether the stream dries up in summer months, or whether it is a consistent flow year-round. While a well-designed micro-hydro scheme will be able to withstand some flooding events, remember that equipment can be damaged in extreme conditions.

Environmental considerations and resource consents

Your local regional council may require that a resource consent is obtained to use the water in your micro-hydro scheme. The council should be consulted early in the process to understand its requirements and your supplier or installer should be able to help you with this process.

Your local regional council may ask you to provide information about the design of your scheme, and in particular it may have questions about how your proposed scheme could affect other users of the resource.

Like all forms of electricity generation, micro-hydro systems have an impact on the environment. Careful siting and design can minimise impacts on the flow of water, and on fish and other aquatic life. As a rule of thumb the maximum flow diverted from the stream should be no more than 50% of the minimum flow of the particular water source, although in some situations it may be appropriate to take less than this. It is important that the intake structure is appropriately designed to prevent any aquatic life from entering the system. It is also important to ensure that water is returned to the same water body as it was diverted from.

If the scheme is to be built on land managed by the Department of Conservation (DOC), you will need to obtain a concession. Contact DOC early in the process to understand its requirements.

What kind of turbine?

There are two types of turbine to choose from: impulse turbines and reaction turbines. Impulse turbines are usually used on high-head schemes, while reaction turbines are normally used on low-head schemes. However, there can be considerable overlap in the choice of turbine. For example, a well-designed system layout using an impulse turbine may be suitable for low heads.

Impulse turbines

With impulse turbines, water is carried to the turbine through a delivery pipe, known as a penstock. From there it is directed through one or more jets or nozzles onto the turbine wheel. Impulse turbines are generally better suited to high-head, low-flow applications. The most common form of turbine used in micro-hydro systems is the Pelton wheel.

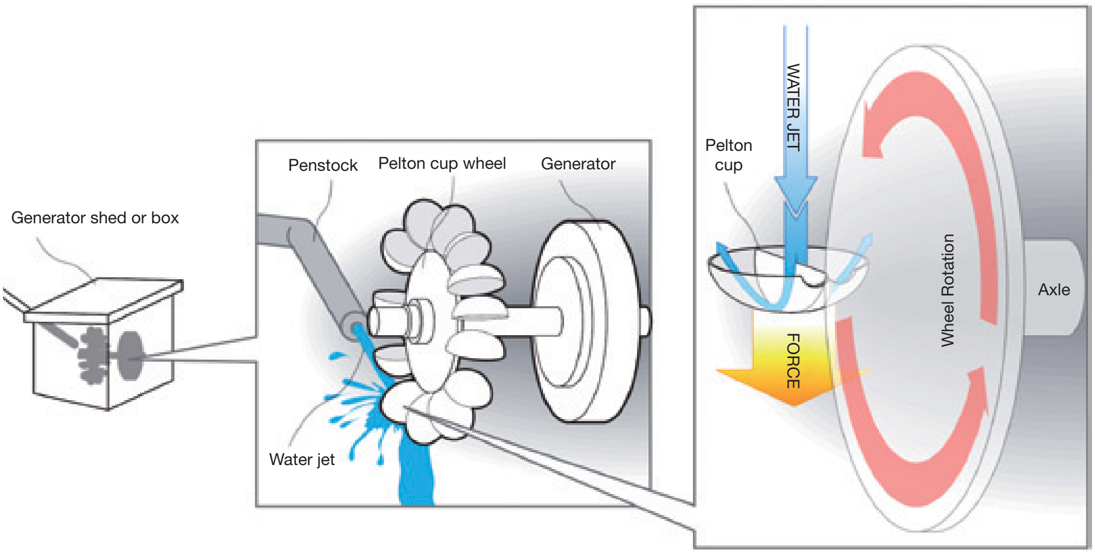


Figure 54. Example of a Pelton wheel, a form of impulse turbine

Reaction turbines

With reaction turbines, blades within an enclosed housing are fully submerged in the water. As the water flows over them, lift forces are created, causing the blades to rotate. Examples include the Kaplan and Propeller turbine, or a centrifugal pump running backwards. Reaction turbines are generally better suited to lower-head, high-flow applications.

How much electricity will my micro-hydro scheme generate?

If you have a good idea of the head and flow available on your site, it is possible to roughly calculate the potential output of your micro-hydro scheme. This is what the output would be assuming a constant flow of water, but allowing for system inefficiencies (e.g. energy losses due to the piping and in the design of the turbine etc).

Potential power output **P**(kW) = **Q** x **H** x **g** x **η**

Where **Q** = the flow of the stream in m^3/s, **H** = the gross head of the site, **g** = gravitational constant (9.8), and **η** = a system efficiency factor (usually between 0.5 and 0.7).

Example: A stream falling at 20 litres ($0.02m^3$) per second down a head of 40 metres would have a potential power output of about 3.9kW (0.02 x 40 x 9.8 x 0.5 = 3.9).

Actual generation output

The figure above is a theoretical figure based on optimal conditions. In reality, fluctuating water flow, seasonal variation, and down-time for maintenance and repairs will reduce the annual output. This is taken into account using the capacity factor (**CF**). A capacity factor of around 50% can be assumed for most micro-hydro plants.

Multiply the potential power output (kW), by the capacity factor of the scheme, by 8,760 (the number of hours in a year).

Energy generated (kWh) per year = **P** x **CF** x **8,760**

Example: A micro-hydro scheme with a theoretical power output of around 3.9kW could generate around 17,000kWh per year (3.9 x 0.5 x 8,760 = 17,082kWh).

The cost of micro-hydro

Each micro-hydro system is designed to suit the specific features of the property, and as such, costs can vary substantially. For example, a 1kW micro-hydro system could range in cost between $8,000 and $30,000, depending on the terrain. It is essential to talk to your supplier or installer to get a site-specific quote for your proposed scheme.

Many factors influence the cost of micro-hydro schemes. These include:

- the geography and geology of the land, and how easy it is to lay the pipes, penstock, and the turbine housing
- the lengths of penstock and cabling required to construct the scheme
- whether any earthworks are required
- building and resource consents
- obtaining approval from the DOC, if required
- the type of turbine you choose, and whether it is part of a grid-connected system or part of a stand-alone system.

For a grid-connected micro-hydro system, costs will include a grid-connect inverter, consenting, metering, and installation. For an off-grid system, other costs will include the battery bank, inverter/charger and charge controller, diesel generator, cabling, and installation.

Maintenance and other considerations

Maintenance costs for micro-hydro systems are usually not as great as for wind; however, you should check with your installer to get an idea of ongoing maintenance requirements.

Keeping safe

Because micro-hydro systems combine flowing water, electricity, and spinning parts, they pose a number of potential hazards. Always follow the manufacturer's instructions and make sure your system is maintained by authorised people only.

Figure 55. A SAPS with a micro-hydro turbine on the right
Photo credit: Genkit Nelson Ltd

Batteries, inverters, and other components

Whether you have a stand-alone or grid-connected application you will need a number of components and equipment to store electrical energy, monitor and measure power generation, control and regulate the system, and ensure that it is working efficiently and effectively at all times. These components are sometimes called the 'balance of system' (BOS).

SAPS components

Battery banks

In off-grid situations, batteries store the electricity generated so that power is available when the sun isn't shining, the wind isn't blowing, or the water isn't flowing. They also allow you to use more electricity at any given time than is being supplied by your sources of generation.

Making sure your battery bank is sized and designed properly is absolutely critical to the performance and life of your SAPS. If your battery bank is too small, it may be discharged at a low level too often, which shortens its life. If the bank is too large, it may not fully charge regularly, which can also shorten its life.

Your supplier should be able to design an appropriately sized battery bank for your system.

Deep-cycle lead-acid batteries are the most common form of battery used in SAPS. The construction of deep-cycle batteries is different from normal car and truck batteries, which are designed to deliver a short burst of current for engine starting. Normal engine-starting batteries would only have a short life if regularly discharged in the manner common in SAPS, and should not be used.

Figure 56. A battery bank in a SAPS
Photo credit: Genkit Nelson Ltd

Battery banks in SAPS usually have a nominal DC voltage of 12V, 24V, or 48V but the individual cells are usually only between 2 volts and 12 volts, and need to be arranged in series to provide the required voltage. Strings of cells in series can be connected in parallel to increase the battery capacity. It is preferable to have only one series string of cells, although lower-cost banks often have two or three parallel strings. Deep-cycle lead-acid batteries can either be:

- flooded, sometimes called 'wet' batteries, or
- value regulated lead acid (VRLA), sometimes called sealed. (There are two main types of VRLA batteries, gel and absorbent glass matt (AGM).)

Flooded batteries are often cheaper than sealed, and can also last longer. They will require occasional maintenance; mainly 'topping up' the cells with distilled water. Sealed batteries do not require any addition of distilled water, and can be oriented in any direction. If regular maintenance is not possible, sealed batteries may be a better option.

Period of autonomy

Battery banks are designed to store enough energy to provide power for a period of time without requiring additional charging from a generation source. The length of time that the batteries can run your system without input is called the period of autonomy. The longer the period of autonomy the larger (and therefore more expensive) your battery bank will have to be. Typically, battery banks for wind and solar systems will be sized for one to three days' autonomy, depending on your load demand and generating capacity. Hydro systems may require a shorter period of autonomy if the water supply is reliable.

Depth of discharge

The life of the battery bank will in part be determined by how it is maintained and used and how deeply the batteries are discharged each day or each 'cycle'. The daily depth of discharge depends on the type of battery but is usually no greater than 50%. If the battery bank is sufficiently large to allow a shallow depth of discharge, then the life will generally be longer.

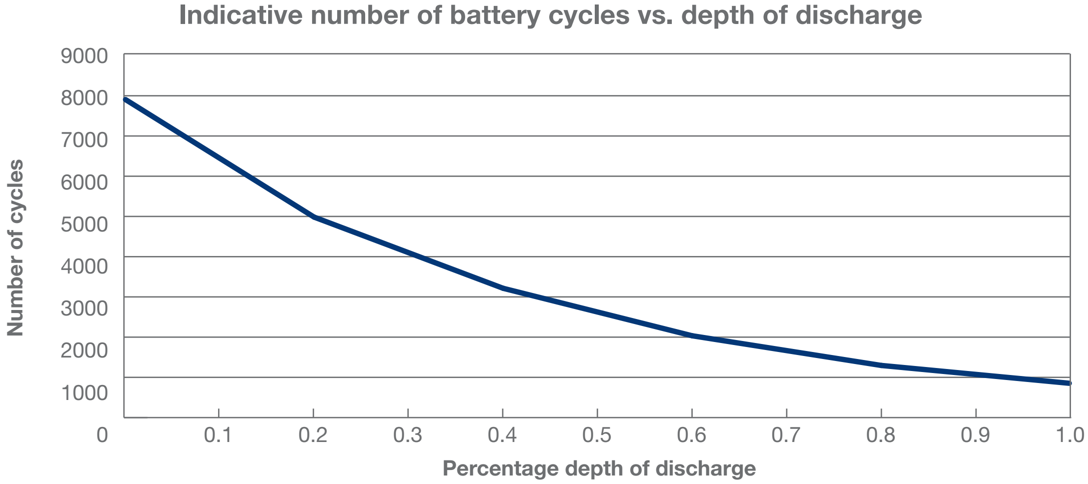


Figure 57. Battery cycle life vs. depth of discharge

Battery maintenance

Batteries usually require minimal but regular maintenance. This includes topping up batteries with distilled water (if they aren't sealed) and cleaning away corrosion, dust, and dirt. Another important part of maintenance is ensuring that the batteries are maintained above the maximum design depth of discharge, and for flooded batteries regularly performing an equalisation charge.

Your supplier/installer should provide an operation manual that will detail the required battery maintenance and when it should be performed. They should also provide a battery log that you will usually have to maintain to satisfy the battery warranty conditions.

Installing batteries

Batteries contain corrosive and toxic chemicals, and can emit dangerous and explosive gases. It is vital that your battery installation is designed and installed appropriately to minimise any risks.

When designing your house and/or SAPS, allow space for batteries. The area required for the batteries will vary significantly with size of system so it can be helpful to determine the likely required size of the battery bank early in the design process.

It is important that the batteries do not get too cold or hot as this will affect their performance and life. If you live in a cold area an insulated enclosure may be required. The batteries should never be installed next to a heat or a spark source (such as a generator) or be in direct sunlight.

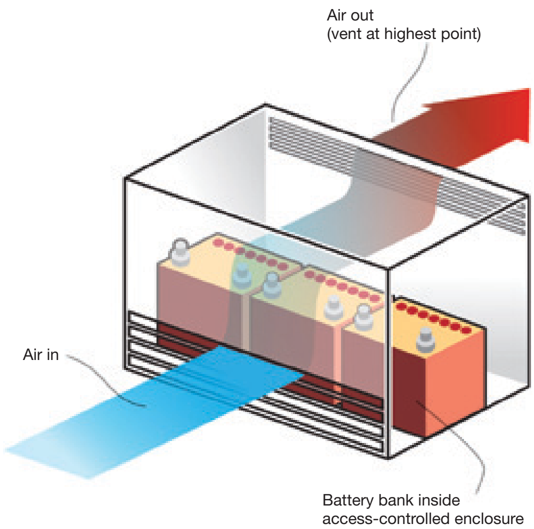
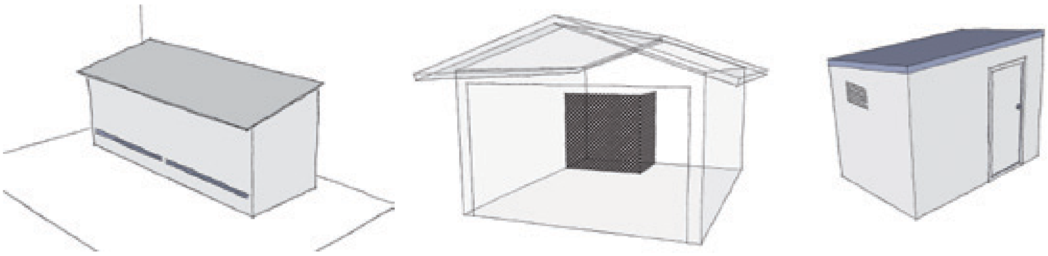


Figure 58. A typical ventilation arrangement

Because the gases from batteries rise, it is important that the battery bank housing is well ventilated. Figure 58 shows a typical ventilation arrangement, and Figure 59 shows some options for battery enclosures that prevent unauthorised access and meet the other requirements of the Standards.

Talk to your supplier and installer about the battery installation requirements and allow for these in your design. Your supplier will be able to design an appropriate enclosure in accordance with the requirements of recognised Standards. (See Standards and requirements on page 16).



Battery box — Dedicated (fenced off) area — Equipment room

Figure 59. Some options for battery enclosures
Credit: Southern Perspectives Ltd

Recycling old batteries

Batteries will typically need to be replaced within six to 12 years, depending on quality, size, and how they are maintained and charged.

Batteries contain hazardous substances such as acid and lead, and need to be disposed of correctly. Most materials used in batteries are suitable for recycling. Take old batteries to a recycling station, not a landfill. Your supplier or local council should be able to advise you on battery recycling options in your area.

Controllers

A controller, or ‘charge controller’, is used to maintain the charge voltage and current to ensure that the battery is optimally charged, preventing over-charging or excessive depth of discharge. A good charge controller is an essential part of a SAPS and will help to improve the life of your battery bank.

When the battery bank is fully charged, the controller either disconnects the charge source or, as is often the case with wind or hydro systems, sends energy away from the battery bank to a dump load, such as an element, air or water heater, or electric water pump.

Figure 60. Controllers used on a PV-based system
Photo credit: EcoInnovation

Some controllers can also prevent over-discharge of the battery by switching off appliances that use a lot of electricity but that don’t need to run continuously if the depth of discharge gets too low.

There are two main types of charge controller: ‘switched’, which are simple ‘on/off’ controllers, and ‘Maximum Power Point Tracking’ (MPPT). MPPT controllers can increase the yield from a micro-generation system by ensuring the system operates at its maximum output under the available weather conditions. They also allow greater flexibility with the input voltages from the system.

Inverters and inverter/chargers

An inverter is an essential device in your SAPS if you want to use AC appliances and lighting. The inverter in SAPS converts direct current (DC) electricity from the batteries to alternating current (AC), which most household appliances use. Some homes may be configured as DC only, therefore not requiring an inverter, but this is not common.

Many SAPS inverters now also include a charger, and these devices are known as inverter/chargers. The charger allows the batteries to be charged using a generator. Inverter/chargers are often configured to automatically start the generator when the batteries get to the maximum depth of discharge, preventing the batteries from being damaged and ensuring that there is always adequate energy for the needs of the building.

Inverter/chargers allow a lot of flexibility in the system operation, often allowing the generator and the inverter to supply the loads together for high-load appliances, or allowing the generator to charge the batteries at the same time as supplying the loads.

Systems can also be configured with a separate charger to charge the batteries from a generator.

A number of inverters are available on the market and your supplier can help you choose the right size and type. For a good inverter, you should expect to pay around $3,000 to $8,000. A typical off-grid household would require an inverter that can supply a continuous load of around 3kW to 5kW.

It is preferable that your inverter has a pure sine wave output as modified sine wave inverters may not be compatible with some appliances.

Figure 61. A Sunny-Boy inverter installation
Photo credit: SolarQuip Ltd

Monitoring

A monitoring system will allow you to effectively operate your SAPS. The most important meter in an off-grid power system is a battery monitor that accurately shows remaining charge in the battery bank.

Other meters may be used to help you keep an eye on your system including how much power you are producing and using, and the voltage levels on your system.

Back up generators

A back up generator is usually required for off-grid systems. It provides power during times when the other generation sources cannot meet all your energy needs, and is used to ‘top up’ the battery bank when its charge drops below a set level.

It is important to understand how to use your generator efficiently, to reduce fuel consumption and to prolong its life. Generally, it is more efficient to use your generator to charge your battery bank when it drops below a certain level, rather than using it to power your load directly. If you power your load directly, the generator can use much more diesel per kWh generated than if it operates at its optimum load.

For example, a generator with a rated output of 20kW will be most efficient if the demand load is as close to 20kW as possible. If demand drops, the generator does not have to ‘work hard’ and more diesel is required per kWh. This can also shorten the life of your generator and increase maintenance costs.

A battery bank can ‘smooth out’ your fluctuating demand load and allow your generator to only run under its optimum load.

It is important to consider the location of your generator if you are designing a house and/or a SAPS. Generators can be noisy, emit exhaust fumes, and can pose a hazard to small children or others who are not familiar with them. Generally a generator will need to be installed in a separate room or shed, or enclosure away from the house, and away from your battery bank. Your supplier will be able to advise you on the requirements for the location and housing of your generator.

Grid-connect system components

Grid-connect inverters

Inverters for grid-connected systems are sometimes called grid-interactive or grid-tie inverters. They convert the DC output of your micro-generation into AC so that it can be supplied into the electricity network. The device synchronises the AC output such that the frequency and voltage match the AC supply from the network.

It is essential to have a cut-off mechanism that disconnects the inverter output from the electricity network if there is a power cut, or for some other reason there is no electricity supply from the network. This prevents electricity from your micro-generation system entering the network or building distribution, potentially threatening any linesmen or electricians working on the network or building wiring. This disconnection device is usually built into the inverter.

Grid-connect inverters normally use MPPT to increase the yield from a micro-generation system and allow more flexibility with input voltages of the renewable energy generator.

A grid-tie inverter can often produce an electrical hum and as such should be installed in a location where this will not disturb people.

Meters and monitoring

You will need to use a meter if you want to export your surplus electricity to the electricity network. The meter separately measures electricity that is imported and electricity that is exported.
(See ‘Selling electricity’ on page 15.)

Like SAPS, grid-connect systems can also have monitoring systems. Monitoring can be on a device in the building or sometimes on the Internet. Monitoring will usually show the current power output of the renewable energy system and the energy it has produced that day and over previous days, weeks, or months.

Investing in micro-generation

The flow chart below outlines the high-level steps you may go through as you investigate micro-generation options. In practice, your supplier and installer will help you with many of these steps, and in some cases they may not be completed in this order.

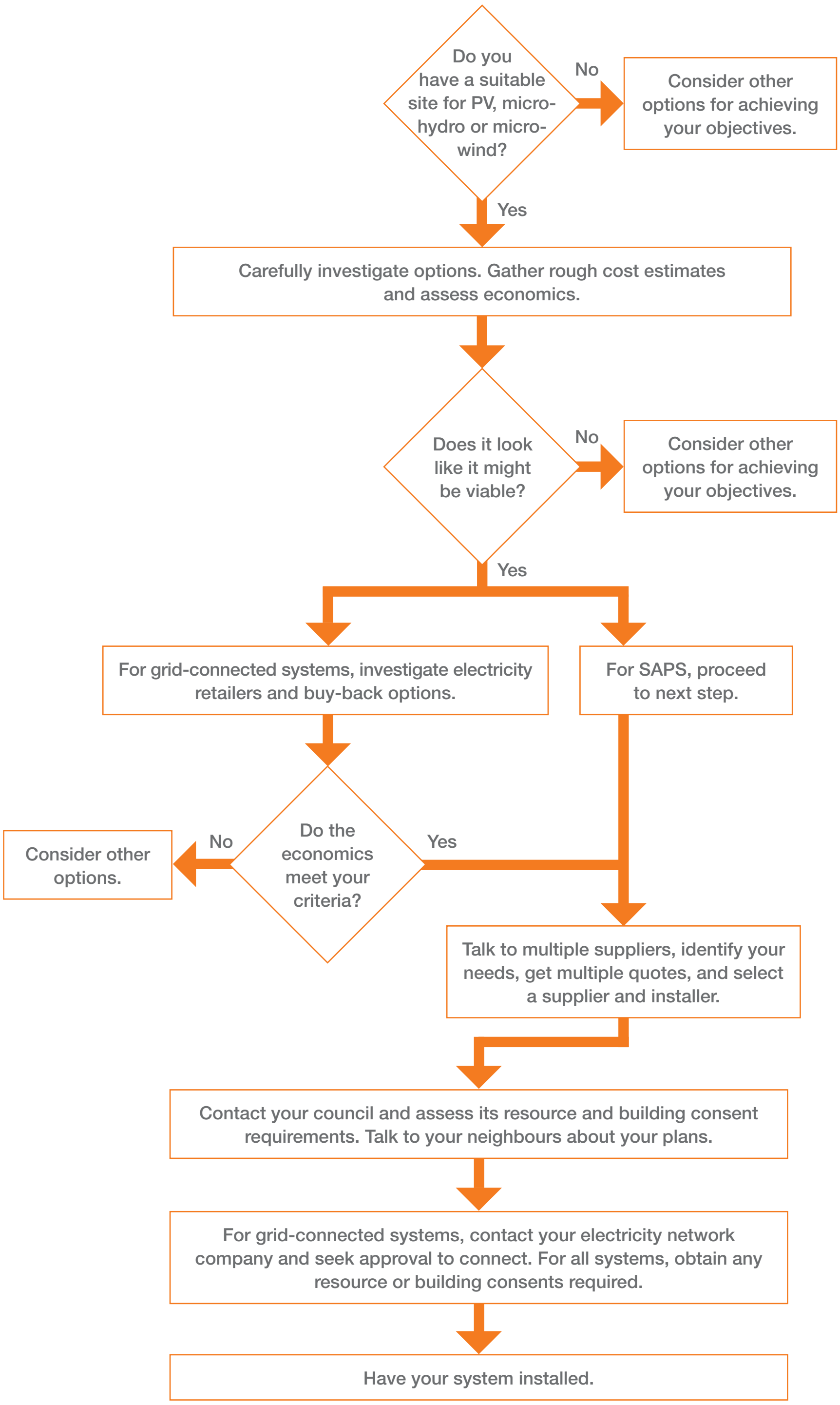


Figure 62. Indicative process flow chart

Finding a supplier

Selecting a qualified and experienced supplier and installer is one of the most important steps if you are interested in micro-generation. Finding a good supplier ensures your system is designed correctly, that you've got the right equipment, that it is safe and meets all appropriate standards and technical requirements, and that you are offered good after-sales support in case anything goes wrong.

Many suppliers and installers of micro-generation equipment in New Zealand are members of SEANZ, the Sustainable Electricity Association of New Zealand. SEANZ is working to improve the quality of installation in the New Zealand industry and is setting up an accreditation scheme.

In all cases you should make sure you get multiple quotes for the job, to ensure you are getting competitive prices. You should also ask your proposed supplier or installer about their experience installing similar systems, and see if you can get some references. Ask them about their experience installing to recognised standards, like those listed on page 16, and carefully scrutinise all warranty information and conditions.

Website directories

The SEANZ website **http://www.seanz.org.nz/business-directory** has a business directory of their membership. This is a good way of locating an installer or supplier near you.

In addition, EECA has published a directory of companies and businesses involved in DG, including micro-generation. This directory is available on the EECA and ENERGYWISE™ websites **www.eeca.govt.nz** and **www.energywise.govt.nz**

Contracts

All customers are encouraged to have a contract with their supplier or installer which outlines what the system will do, what equipment will be supplied and installed, the costs, and what is covered under warranty. The contract should also outline the responsibilities of various parties.

SEANZ has developed a draft contract that can be used for the purchase and supply of SAPS. It is available on their website at **http://www.seanz.org.nz/documents/doc_download/35-stand-alone-power-systems-contract-rev11**

Glossary

Alternating current (AC)

An electric current that periodically reverses direction. The frequency of the AC supply in New Zealand is 50Hertz (50 oscillations per second). Most household's electricity supply is AC, and the output of wind and hydro turbines is AC.

Ampere or Amp

A measure of the instantaneous electric current (the movement of electrons) flowing through a conductor or wire.

Amp-hour (Ah)

A measure of the electric current flowing in a conductor or wire past a certain point in one hour. For example, if you draw one amp of current from a battery for five hours you will have used five amp-hours.

Anemometer

An anemometer is a device used to measure wind speed. It is often mounted on a pole or tower at a site being investigated for a wind energy project. Usually it is used in conjunction with a wind-vane that measures the wind direction.

Back up generator

A generator running on diesel, petrol, or biofuel is often required to provide back up electricity supply in a stand-alone power system. When the charge in the batteries gets too low, or if you need extra power, the back up generator will start.

Balance of system (BOS)

All the components of micro-generation systems except for the generation technologies (PV, wind, or hydro). The balance of the system can include wiring, switches, metering, support racks and frames, inverters, controllers, batteries, and a back up generator.

Battery cycle

Every time a battery is charged and discharged counts as one cycle. The battery cycle life is a measure of how many times a battery can be charged and discharged.

Battery storage

Battery storage is used to store electrical energy. A battery contains a number of cells that store chemical energy and convert it into electrical energy as it is discharged.

Building integrated PV (BIPV)

PV materials that are used in place of conventional building cladding materials, such as roofing, skylights, or building facades.

Buy-back rate

The price (cents per kilowatt-hour, c/kWh) that an electricity retailer will pay you for electricity your generation equipment may export back into the electricity network.

Capacity factor

The ratio of the actual output of the plant over a period of time compared with the output of the plant if it had been generating at its full rated output, for the same period of time. For example, if a 1kW PV array could generate at that rate continuously for one year, the output would be 8,760kWh as there are 8,760 hours in the year. However, obviously PV cannot produce electricity at night, and less when it is cloudy or during winter, so the array will typically only generate between 1,051kWh (12% capacity factor, more common in southern regions of New Zealand) and 1,314kWh (15% capacity factor, more common in northern regions) per year. Capacity factor should not be confused with a measure of the efficiency of the PV cells or wind turbines.

Charge controller

A controller that regulates the rate at which a battery changes.

Depth of discharge (DOD)

The percentage of a battery's total capacity that has been discharged during use of the battery. For example, a 100 amp-hour battery that has been operating at one amp for 30 hours will have used 30 amp-hours of the battery's capacity, and so will have had a depth of discharge of 30%.

Direct Current (DC)

Electric current that moves in a steady state, in one direction only. DC current is produced by PV cells and batteries. DC current can be converted into AC current through an inverter.

Distributed generation (DG)

Electricity generation designed primarily for local use or embedded within a local electricity network, rather than being transmitted through the national electricity grid. DG often uses much smaller generation plant than industrial or utility-scale electricity generation.

Dump load

A device that accepts electricity from a generating source, such as a PV module or a wind turbine, when the batteries are too full to take further charge. An electric heating element is commonly used as a dump load.

Electrical energy

The capability of a flow of electric charge through a conductor to do work. It is also the potential for an electrical charge to do work and is often measured in kilowatt-hours (kWh) or megawatt-hours (MWh), but in standard SI units is measured in Joules (J) or Megajoules (MJ).

Electricity distribution networks

Local distribution networks that distribute electricity from the national grid to consumers such as homes and businesses. The networks include substations that convert electricity from the high voltages used to distribute electricity nationally to low voltages suitable for use in most commercial and domestic applications.

Electricity network company

Also known as a ‘distribution company’, or a ‘lines company’, an electricity network company manages the electricity distribution networks that bring electricity from the national grid to people’s homes and businesses. There are 29 electricity network companies in New Zealand.

Flooded or ‘wet-cell’ batteries

Also known as ‘vented’. A type of lead acid battery that uses a liquid electrolyte. The liquid electrolyte covers all internal parts of the battery cell, and occasionally requires topping up to replace water lost to evaporation or hydrolysis.

Flow rate

The amount of water that flows in a watercourse in a given amount of time.

Grid-connected or grid-tied

A generation system that is connected to the local electricity network and which can export excess electricity into the network.

Griggs-Putnam Index

A method of calculating wind speed at a particular site based on observations of growth patterns in local vegetation. Strong average wind speeds will deform trees and shrubs.

Head

The vertical distance between where the water enters a hydro system and where the turbine and generator are located.

Horizontal axis wind turbine (HAWT)

A ‘normal’ wind turbine where the nacelle and shaft are parallel to the ground and the rotor blades move in a plane perpendicular to the ground.

Hydraulic power

Power that can be derived from the force of moving water.

Impulse turbines

A hydro turbine that extracts energy from a high-speed water jet striking turbine buckets mounted on a rotor.

Inclination

The angle or ‘tilt’ of a PV module or array compared to the horizontal plane.

Intermittent generation

Some forms of renewable energy technologies, such as PV modules or wind turbines, are intermittent due to the fact that the output is uncontrollably variable; for example, because of the available wind or solar resources.

Inverter, or inverter/charger

An inverter is an electrical device that converts DC electricity from generation sources such as photovoltaics into AC electricity that can be used by modern appliances. An inverter/charger is an inverter and battery charger combined in the same unit, and can be used on SAPS.

Joule

A small unit of energy that is roughly equivalent to the amount of energy required to lift an apple one metre vertically.

Kilowatt

A unit of electric power that is equal to 1,000 Watts. As a measure it is used to rate the production capacity of generators, and also the electricity requirements (or demand) of appliances etc.

Kilowatt peak, or Watt peak (kWp, or Wp)

The peak power output of a PV module under certain standard conditions.

Kilowatt-hour (kWh)

The amount of energy used or produced equal to one kilowatt 'working' for one hour. A PV array that has a rated capacity of 1 kilowatt will produce 1 kilowatt-hour of electricity in 1 hour of operation (under standard conditions). The SI unit for energy is the Joule. 1kWh = 3600kJ

Kinetic energy

The energy available in an object or body due to its motion, such as a flowing stream of water.

Maximum power point tracking (MPPT)

A special controller that can increase the yield from a solar, wind, or hydro power system by ensuring the system operates at its maximum output under the available weather conditions.

Mechanical energy

Energy present in moving parts of a machine or body. This may be the rotation of a turbine or the movement of a piston in a cylinder.

Micro-generation

Domestic-scale electricity generation, usually with a total rated capacity of less than 5kW.

Micro-hydro

Domestic-scale hydro generation schemes, often run-of-river where a portion of the stream is temporarily diverted through the hydro turbine before being returned to the same waterway. The total rated output of a micro-hydro system is typically under 5kW.

National electricity grid

The New Zealand national electricity grid is owned and operated by Transpower and is made up of over 12,000km of transmission lines. Electricity is transmitted over the national grid at high voltages (up to 220,000 volts) from power stations to electricity network companies.

Net-billing

An accounting process whereby an electricity retailer bills a customer for the net value of their imported electricity after the value of exported electricity has been deducted. If the value of the exported electricity is greater than the value of the imported electricity, the consumer may receive a credit.

Net-metering

Where a single channel electricity meter is used to record both imported and exported electricity, by effectively 'winding the meter backwards' so it shows the net amount. Note: this is prohibited in New Zealand.

Off-grid generation

An electricity generation system or application that is not connected to the grid or local electricity network. Off-grid generation often includes energy storage devices such as batteries, a diesel or petrol generator, and renewable energy technologies.

Orientation

The position and alignment of, for example, a PV array relative to the points of the compass. In New Zealand, PV arrays should generally be oriented due north although some variation on this is acceptable.

Parallel (battery wiring)

Parallel wiring of batteries refers to connecting the positive terminal of one battery to the next battery's positive terminal, and doing the same for the negative terminals. Wiring in parallel means that the rated amp-hours are increased, but the output voltage remains the same as for a single battery. For example, two 6 volt batteries rated at 350 amp-hours wired in parallel would result in a 6 volt battery rated at 700 amp-hours.

Passive solar heating

Building design that takes advantage of the sun's ability to provide warmth. Typical features of a building using passive solar heating are: north-facing windows, good insulation, and thermal storage in materials such as concrete, ceramic tile, rock, or water.

Peak electrical output

The peak electrical output, shown as W peak (Wp) or kilowatt peak (kWp) of a PV array is a measure of output under standard test conditions. In the real world, actual output is likely to be less than the peak output.

Pelton turbine

A very efficient type of impulse hydro turbine design that converts the energy in a high velocity jet of water into mechanical energy through the jet of water impinging on a set of carefully shaped 'buckets' and turning the turbine runner or rotor which turns a shaft.

Penstock

A pipeline that carries water down from the intake of a hydro scheme and delivers it to the turbine and generator.

Photons

An elementary particle of light or electromagnetic radiation. The energy carried by a photon is related to its frequency or wavelength (essentially the 'colour' of the light).

Photovoltaics (PV)

A device that converts the energy in light (photons) into electricity, through the photovoltaic effect. A PV cell is the basic building block of a PV system, and numerous cells are usually connected together to create a single PV module (sometimes called a 'panel'). Numerous PV modules can also be connected together to form a larger PV array of the desired rated power output.

Power curve

A chart that shows the output of a particular model of wind turbine at different wind speeds.

Rated power output

Also sometimes referred to as 'rated capacity', or 'capacity rating'. The amount of power that a PV system, wind turbine, or hydro turbine can provide or produce, under certain standard conditions. For a PV module, the rated power output will be its electrical output under standard light conditions; for a wind turbine the rated power output will be its output at a rated wind speed; for a hydro turbine the rated capacity would be the output achieved with a certain head and flow.

Rated wind speed

The wind speed at which a wind turbine's rated power output will be produced.

Reaction turbine

A type of hydro turbine that extracts energy from a high volume of flowing water. The turbine is either encased, or fully immersed in the water flow. Most reaction turbines are used in low-head applications.

Run-of-river hydro

A type of hydro scheme where the natural flow and drop of a stream or river provide the hydraulic energy that spins the turbine. Although the scheme will often not utilise any water storage such as a reservoir or dam, sometimes a small weir is required.

Semiconductor

A substance with electrical conductivity properties between that of a good conductor and a good insulator. With silicon, a semiconductor used in the manufacture of PV cells, its properties can be changed by light. The interactions between photons in light and the semiconductor will liberate electrons that can be made to flow through a conductive path as an electrical current.

Series (battery wiring)

Series wiring of batteries refers to connecting the positive terminal of one battery to the next battery's negative terminal. Wiring in series means that the voltage output from the combined batteries is increased, but not the amp-hour rating. For example, two 6 volt batteries rated at 40 amp-hours wired in series would result in a 12 volt battery rated at 40 amp-hours.

Small wind turbines

There is no standardised definition of ‘small’, however small wind turbines are usually those below, approximately, 20kW in rated power output. Wind turbines of less than approximately 5kW are often called ‘micro wind turbines’.

Solar cells

See photovoltaics.

Solar power

Another term for photovoltaics, or solar generated electricity.

Solar water heating

Solar water heating refers to devices that heat water by capturing the sun’s energy as heat and transferring it directly to the water or indirectly using an intermediate heat transfer fluid. Solar water heaters generally have a solar thermal collector, a water storage tank or cylinder, pipes, and a transfer system to move the heat from the collector to the tank.

Stand-alone power systems (SAPS, or SPS)

A form of off-grid generation, usually sized for a home or small business. SAPS will usually include battery storage, a backup generator, an inverter and controllers etc., as well as generation technologies such as photovoltaics or a small wind turbine.

Turgo turbine

A type of impulse turbine that is designed for medium head hydro schemes.

Two-way metering

An electricity metering installation that records flows of electricity that is imported from the network, and electricity that is exported to the network. A metering system of this kind is required for grid-connected systems.

Value regulated lead acid (VRLA)

Also known as ‘sealed’ batteries, a type of lead acid battery that due to its construction will not spill electrolyte if inverted and does not require topping up. VRLA batteries can be gel based or use an absorbent glass mat.

Vertical axis wind turbine (VAWT)

A type of wind turbine where the shaft of the rotor runs vertically, and includes ‘drag’ and ‘lift’ variants. A drag type VAWT has cups that get pushed by the wind – like an anemometer. A lift type VAWT uses aerodynamic forces on the blades to rotate the shaft. One of the advantages of a VAWT is that the turbine does not need to point into the wind to operate. In general VAWTs have not performed well commercially, compared to HAWTs.

Voltage (V)

Voltage, or potential difference, is the electrical force that drives an electric current through a conductor. Voltage is measured using ‘volts’. The standard household supply voltage is 230V.

Watt (W)

A Watt is a standard measure of power or the rate at which work is done. One watt is equal to one joule per second.

Watt peak (Wp)

See kilowatt peak.

Wattage rating

Also known as ‘power rating’. A measure of the electrical power required to operate an appliance or electrical device. For example, a compact fluorescent bulb may have a wattage rating of 20W.

Weir

A low dam that is built across a stream or waterway to increase its level or divert its flow. A small weir is sometimes used in micro-hydro schemes to divert the water into the penstock.

Wind rose

A diagram that shows the frequency of wind speed and wind direction for a period of monitoring at a particular site. The wind direction is recorded in a series of discrete directions, giving the diagram a flower-like appearance.

Wind shear

The difference in the speed and direction of wind over a short distance. For example, at ground level the wind speed may be very low, but higher above the ground the average speed may be much higher.

Wind speed distribution

A chart that shows the frequency of different wind speeds, at a particular site. Certain distributions are commonly used – such as the Weibull distribution – to calculate the probability of particular wind speeds, and the number of hours per year where you can expect winds of particular speeds.

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NOVEMBER 2010/EEC1449

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