EECA

Energy Efficiency and Conservation Authority

RENEWABLE ENERGY

Guidelines for local authorities: Wind Power

IMPROVING ENERGY CHOICES

WIND POWER

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IMPROVING ENERGY CHOICES

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Wind Farm Developments

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1. Introduction

These guidelines have been prepared as part of the role of the Energy Efficiency and Conservation Authority (EECA) assisting the uptake of renewable energy in New Zealand. Wind energy is a significant renewable resource in New Zealand and its development is in its infancy; 36MW was installed prior to 2004. This will have increased 360% during 2004 and has the potential to exceed 2,500MW in the future.

The Resource Management (Energy and Climate Change) Amendment Bill passed in March 2004 requires planning and consent authorities to have, among other things, particular regard to energy efficiency and the benefits to be derived from the use and development of renewable energy.

The purpose of these guidelines is to assist local authorities in the resource consent assessment and decision-making process for wind energy developments.

The wind power guidelines include information to describe:

- The nature of the physical developments associated with wind energy developments.
- Generally, but with as much clarity and detail as possible, the likely effects of such developments and ways of avoiding, remedying and mitigating potential adverse effects.

As wind energy develops in New Zealand, these guidelines should help avoid the need for each local authority or other participant in the planning process to undertake their own research and investigation. However, because of the nature of wind energy development, there will always be some site-specific issues and effects to consider for each development.

Wind energy can be compared with other industries such as forestry, which over the years has addressed issues such as landscape change and roading infrastructure. Early recognition of similar issues in wind energy will help steer its development while achieving sustainable management in New Zealand.

1.1 New Zealand's electricity supply

Hydro currently provides around 60% of New Zealand's electricity, and fossil fuels, such as coal, gas and oil provide around 30%. By the end of 2004 wind power will provide less than 2% of our electricity. New Zealand's prime location in the 'roaring 40s' gives wind power the potential to become an important contributor to the renewable energy target set in the National Energy Efficiency and Conservation Strategy.

This target calls for a 22% (30 petajoule) boost in the amount of renewable energy produced in New Zealand by 2012. Renewables such as hydro, wind, bioenergy, geothermal, solar and biofuels will all play a role in meeting this target.

2. Advantages/disadvantages of wind power generation

While consenting authorities will have a focus on local issues, there are clear nationwide advantages and disadvantages of wind power generation which will be helpful in considering the requirements of the Resource Management (Energy and Climate Change) Amendment Bill.

2.1 Advantages of wind power generation

Wind power development is attractive at a national level for the following reasons:

- Unlike electricity from fossil fuels, the use of wind doesn't generate any greenhouse gases, such as carbon dioxide, which contribute to climate change. New Zealand's commitment under the Kyoto Protocol to reduce greenhouse gas emissions to 1990 levels makes renewable energy sources more attractive for electricity generation.
- The increased use of renewable energy sources, such as wind, contributes to the Renewable Energy Target set under the National Energy Efficiency and Conservation Strategy. Renewable energy also contributes to the Government's energy policy objectives. For example, wind power is consistent with the goals and outcomes identified for energy under the Government's Sustainable Development Programme of Action. More efficient and less wasteful energy use, the development and promotion of renewable energy sources, will enhance security of supply.
- New Zealand's extensive reliance on hydro electricity, combined with uncertainties surrounding our gas supply, reinforces the need for good diversity of supply. Wind and hydro are ideal complementary renewable power sources because when the wind does not blow, we effectively have electricity stored in our lakes.
- Wind power development contributes to investment and employment from local research and development relating through to the manufacturing and maintenance sectors.
- There are potential export opportunities for wind development expertise and technology.

A public opinion survey conducted in May 2004 [1], showed 82% approval of wind power, with wind the preferred source of new electricity generation for 41% of respondents. The survey showed that wind power development is attractive to New Zealanders for the following main reasons:

- 59% of respondents said wind power is an environmentally friendly method of electricity generation.
- 46% said it is low cost.
- 47% said it is a natural or a renewable resource.

In addition to the perceived benefits identified in the survey, wind power development is also attractive to electricity users for the following reasons:

- It allows for local independence in electricity generation.
- Developments have the potential for modular additions to match demand growth.
- As turbines and their towers can be readily removed, any adverse environmental effects are seen as temporary and reversible.
- In some regions wind farms are a tourist attraction.

Wind power development is attractive to developers for the following reasons:

- Climate change policies like the 'Projects to Reduce Emissions' and the planned carbon charge make fossil-fuelled forms of generation less attractive and more expensive, and alternatives such as wind farms increasingly cost effective.
- Wind farms have a relatively low capital cost and there is the opportunity to add or replace turbines progressively (i.e. all turbines do not need to be installed at once).
- Unlike fossil fuel fired generation, the operational costs of a wind farm are not subject to fuel resource pricing.
- Wind is a reliable resource with the annual wind energy variation typically 10% compared with rainfall variation which is 20%.
- Wind power adds diversity to the stock of generating opportunities.
- Wind farms may be installed relatively close to the source of demand, thereby minimising or avoiding line charges and transmission losses.
- The purchase of land for a wind farm is not always necessary and resource ownership is not an issue (usually wind farms co-exist with agricultural activities or conservation estate).
- Once consented, wind farms have one of the shortest construction phases of any form of electricity generation.

2.2 Disadvantages of wind power generation

However, as with all forms of electricity generation, wind power has some drawbacks:

- While reliable annually, wind is a resource which varies in its availability over short-term periods and therefore needs either an associated storage system or a complementary generating source (such as hydro which can be stored), in order to form a reliable primary source of energy.
- There can be complexities in feeding large supplies of electricity into local lines, although such difficulties can be overcome.
- There are some site-specific adverse environmental effects, such as noise and visual intrusion, which require careful consideration in certain localities, particularly in relation to the opportunities to develop exposed, high wind resource areas. These should be addressed through the consent process.

The main perceived disadvantages of wind power identified by New Zealanders in the public opinion survey were as follows:

- Wind power was seen as unreliable by 26% of respondents.
- 25% of respondents said wind farms were ugly or unsightly.
- 15% of respondents said the noise pollution from wind farms was a disadvantage.
- The cost involved in establishing a wind farm was identified as a disadvantage by 15% of respondents.

The more localised environmental effects of wind farms can however be addressed via the resource consent process and measures put in place to remedy and mitigate thier effects (refer to section 5 of these guidelines: Managing the environmental effects of wind power generation).

3. Wind power technologies

3.1 Background

Wind power is not new to New Zealand. Small windmills for raising water are still sometimes seen in rural New Zealand. In the past they were much more common. The wind power technology that is now emerging in New Zealand is considerably more sophisticated and is based on wind as a generator of electricity.

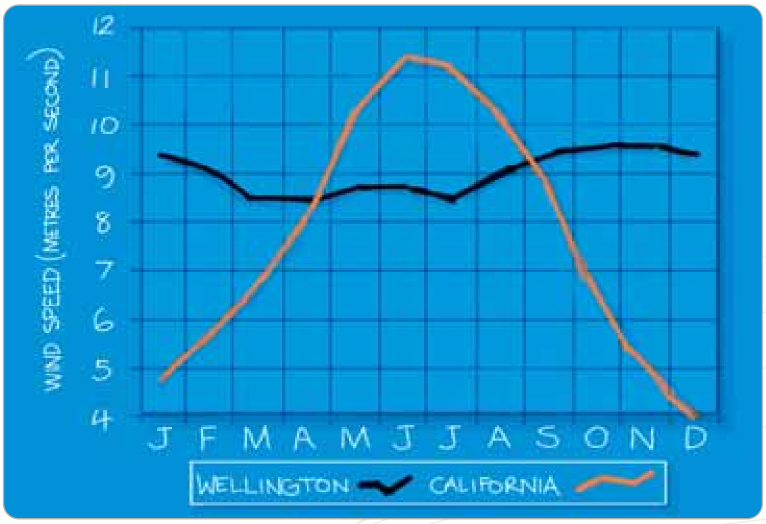
Electricity has become an essential service to modern-day life and in New Zealand its demand grew 20% during the past ten years. At its point of use it is a relatively benign form of energy. However there are always environmental effects associated with its generation, transmission and distribution. Any new generation developments, which are required to meet growth in demand, are likely to add to pressures on the environment.

In some countries wind energy developments are now main-stream forms of generation. Initially subsidised in several countries, the technological development which took place between the mid-1980s and the mid-1990s halved the cost of the generators. In the 1990s, installed generation capacity grew at 10% per year, worldwide.

Wind turbines can be located on land, or at sea with towers fixed to the seabed.

New Zealand is particularly well-endowed with wind resource. It was assessed in 2001 that New Zealand has 9,370GWh per year (approximately 25% of New Zealand electricity demand) wind farm potential at costs up to 10 cents/kWh. By the end of 2004 wind power will provide 1.7% of electricity supply in New Zealand.

Being in the 'westerly belt' of global wind circulation, our winds are not as seasonal as many countries. Wind resource in many areas can be harnessed at all times of the year, so many parts of the country experience higher average annual wind speeds than are common overseas.



Comparison of average monthly wind speeds, Wellington and California. The annual average wind speed for the Wellington site is approximately 9 metres per second (m/s), while that for the California site is approximately 7.5 m/s.

This leads to wind energy development being potentially more economic than in many other countries. It also means that wind energy can potentially make a more reliable contribution to New Zealand's total electricity supply than is possible in many other countries.

As power available from wind is proportional to the cube of the wind speed, regions with high average wind speed have significantly better wind energy resources than other regions. A site with an average wind speed of 9 metres per second (m/s), has the wind resource to generate more than twice as much electricity as a site with 6m/s average wind speed.

Although the characteristics of New Zealand's wind resource are continually being researched, there are many sites with an average wind speed greater than 8m/s. Some of these have already been identified as suitable for productive wind farms. As the economics become more favourable, both in terms of capital cost and increasing energy costs overall, wind power developments are beginning to 'take off' in New Zealand.

Good wind resource means that the following are likely to be the regions in New Zealand preferred by developers to establish first:

Northland
West Auckland
Eastland
Taranaki
Manawatu
Tararua
Wairarapa
Wellington
Marlborough
Banks Peninsula
Central Otago
Southland

The main industry related organisation associated with wind energy in New Zealand is the New Zealand Wind Energy Association (NZWEA). NZWEA has recently established a public information programme. For more information visit www.windenergy.org.nz.

Annual energy output (MWh/year) relative to mean annual wind speed (m/s) for a 1.65MW wind turbine.

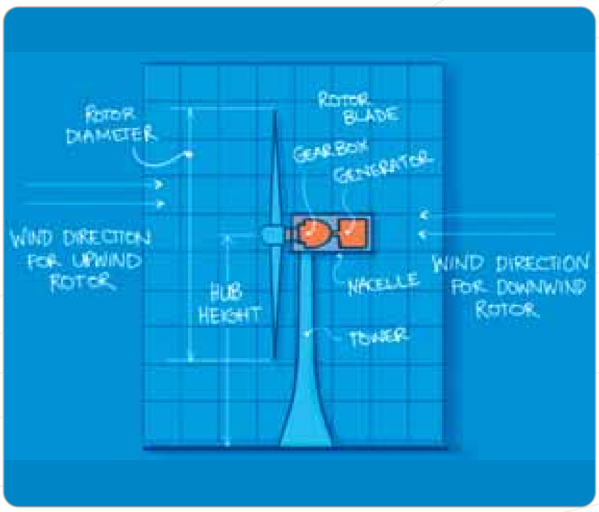
3.2 Wind turbines

There are two basic types of wind turbine design - horizontal and vertical axis. At present, the horizontal axis turbine, with blades rotating atop a tall tower, is the most common type worldwide. Vertical axis types are rarely used in commercial production. Each style has its own advantages in the production of electricity.

A typical horizontal axis wind turbine. This is a turbine at Te Apiti. It has a 1.65MW generator on a 70 metre high tubular steel tower with 36 metre long blades.

A conventional horizontal axis wind turbine consists of four main elements:

- Foundations, which are generally a concrete slab flush with the ground, normally 7-15 metres in diameter, or a slab with piled foundations or rock anchors. A few small models of wind turbines require guy wires for stability, as well as foundations.
- A tower of either steel lattice, steel tubular or concrete tubular construction. Towers are typically between 3 and 4.5 metres in diameter at the base and taper to about 2-3 metres at maximum height. The height of towers varies with the size of the generator and the length of the blades. Modern large generators may have towers as high as 100 metres, although 40-70 metres is most common. The height is necessary to give access to higher and less variable wind speeds than at ground level, and also to allow safe passage of blades.
- A ‘nacelle’, which houses the gearbox and the generator and sits on top of the tower. The hub supporting the blades is attached to the gearbox at one end of the nacelle. Some turbines are gearless and the hub is attached directly to the generator. Nacelles are of varying sizes, depending principally on the design and size of the generator. Most nacelles are the size of a van. The nacelle revolves horizontally on the tower to allow the blades to face the wind regardless of its direction.
- The rotor, consisting of hub and blades and the shaft connecting to the gearbox or generator. These are the main moving parts of the turbine and depending on their length typically rotate at between 15 and 40 RPM. Blades may be made of a number of materials, most commonly a plastic or epoxy, sometimes wood laminate, and occasionally with a metal core. They are aerodynamically designed to maximise the extraction of energy from the wind. They are either designed to adjust along their axis so that they can take advantage of different wind speeds and they ‘feather’ at high wind speeds; or alternatively they may be fixed, in which case they are designed to stall at higher wind speeds. In length, blades may exceed 35 metres but most are between 25 and 30 metres long, giving a rotor diameter of 50 to 60 metres. Most turbines have three blades, and some designs have two. Demonstration turbines have been trialled with one blade.



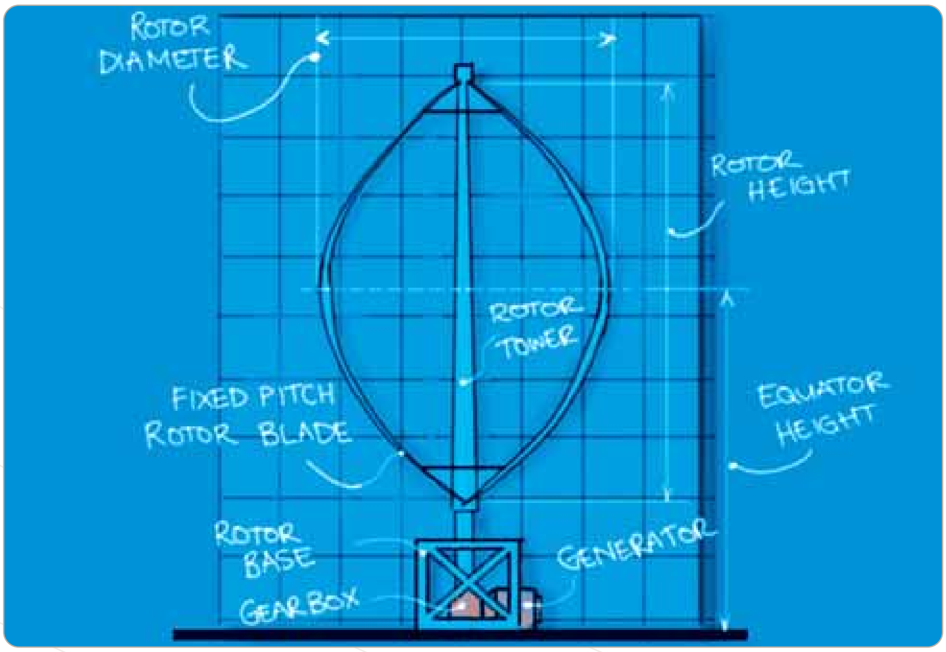
Components of a horizontal axis wind turbine.

The vertical axis machines often have a generator at or below ground level, and blades fixed at both ends of a support beam rotating centrally about a vertical axis. They may be lower in height overall, and may require slightly larger areas of land for each machine. Guy wires may be needed for vertical stability.

Turbines are computer controlled and are designed so the blades either operate at fixed or variable rotating speeds. Fixed speed turbines have either one or two speeds. Variable speed turbines increase and decrease with wind speed. At low and very high wind speeds the blades stall or feather (pitch edgewise) in the wind, the generator switches off, and a brake prevents rotation.

Commercially-built wind turbines have generating capacity ranging from 50kW to 4MW. Larger turbines are being developed. Off-shore turbines, which are becoming more widely used in parts of Western Europe, are typically in the 3-4MW range.

The average sized wind turbine installed has increased over time. Typically 2.5MW are being installed in Europe. In 2004 Meridian Energy is installing 1.65MW turbines at its Te Apiti wind farm, not far from TrustPower's Tararua Wind Farm, which consists of 660kW (0.66MW) turbines. Phase One was installed in 1998-99, with Phase Two commissioned in 2004. The larger turbines used at the Te Apiti site result in increased energy generation per hectare of land utilised.



Components of a vertical axis wind turbine.

3.3 Wind farms

Wind power developments may be a single or small number of turbines primarily serving smaller settlements, or they may be developed as larger 'wind farms' with connections to the national grid. There is no set size for a wind farm. This size usually depends on economics, available land and transmission capacity. Typically a wind farm in New Zealand will consist of 5-50 turbines, and occasionally larger wind farms will have approximately 100.

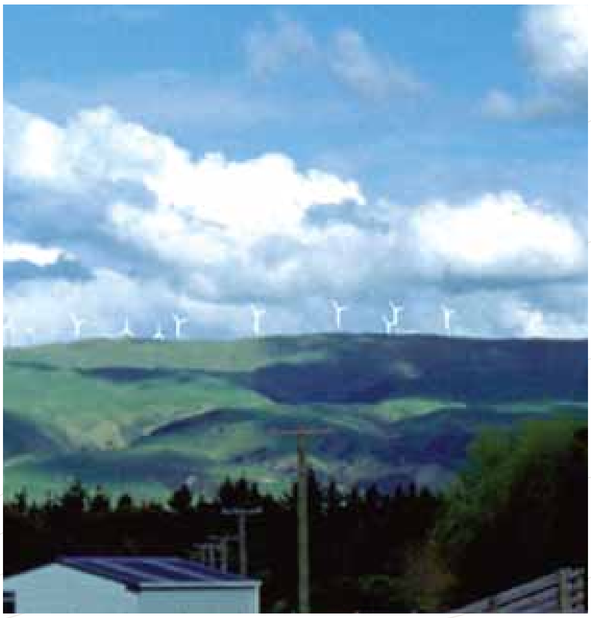
Wind turbines need careful layout to ensure they do not disturb significantly the wind flow to neighbouring turbines. On flat terrain, turbines are usually spaced 5-10 rotor diameters apart (300-600 metres). In hillier areas, individual sites need to be carefully evaluated to make best use of the wind resource, so the spacing may be quite variable. A wind farm consisting of several turbines clustered or spread out on a ridge is also a common form of wind farm.

Hau Nui, a small wind farm in rural Wairarapa. Note the small transformers.

Access routes to a wind farm are necessary, particularly for the construction phase, but may be downgraded to small vehicle access to the site and between the turbines after this phase. Initially, wind farms tend to draw crowds of sightseers, but as people become more accustomed to them, they are less of an attraction.

Most commercial wind turbines are expected to have an operating life of about 15-25 years. However, with New Zealand's particular wind resource characteristics, and as technology is still developing, it is likely that wind farm components will be replaced more frequently, as well as progressively over time. Replacement turbines may be different in size and design from those first installed.

With one or a small number of turbines, a small transformer linking into local 11kV or 33kV lines may be all that is needed for a grid connection. With larger farms, a small on-site substation is installed. Wind farms are generally computer controlled, and a small building may also be required. There may also be one or more anemometer masts located within a wind farm.



Tararua, a large wind farm designed to make the best use of the wind resource in complex terrain.

4. Initial research installations

Before a wind farm is proposed, there is normally one to three years' data-collection and wind monitoring at the site. This assists in determining the most efficient siting of turbines. As noted above, power available from wind is proportional to the cube of the wind speed. In regions of flat terrain, prediction models can be used to assess wind speeds with reasonable accuracy. However, in New Zealand this is more difficult as most potential sites are in or close to hills and broken country, so that more specific local data is needed.

Measurement of wind speed and direction at different heights is undertaken by installing a mast on suitable representative locations, to support several anemometers and other measurement devices, and a small photovoltaic panel (which generates electricity from solar energy) to provide power for data collection and transmission. To achieve accuracy for wind turbine heights of 40-80 metres, wind speeds are measured at around 50 metres above ground level.

The masts are of similar type to those associated with long-term monitoring of wind farm areas which have been described earlier in this guide. Because of their narrow width and usually dark colouring, they have minimal visual effect, except in the immediate vicinity of their location. Because of their height, a light or bright colour may be required if they are in the vicinity of an airport. No special access or maintenance provisions are required for research masts.

Research masts are installed to measure wind speed and direction.

5. Managing the environmental effects of wind power generation

5.1 Background

The nature of the environmental effects of wind power and the ability of the effects to be satisfactorily avoided, remedied and mitigated will depend on three factors:

- the technology involved,
- the proposed site and its specific characteristics, and
- the nature of surrounding activities/land uses.

This section addresses some actual and potential adverse effects of wind power developments. Although these will be discussed in general terms, councils should always consider site-specific and neighbourhood factors when examining consent applications. These are the primary matters to be considered in terms of the statutory planning requirements enacted by the Resource Management Act (RMA), whether a single turbine or a large wind farm is being proposed.

Wind development issues worldwide are very similar. As an example, the European Best Practice Guidelines [2] list the following matters as being potentially appropriate for explanation in an environmental assessment:

- Site selection (why the site was chosen)
- Visual and landscape assessment
- Noise assessment
- Ecological assessment
- Archaeological and historical assessment
- Hydrological assessment (potential effects on water courses)
- Interference with telecommunications systems
- Aircraft safety
- Safety assessment (including structural integrity, highway safety and shadow flicker)
- Traffic management and construction
- Electrical connection (the impacts of new infrastructure such as overhead lines and substations)
- Effects on the local economy
- Global environmental effects
- Tourism and recreational effects
- Decommissioning

The above issues and associated potential effects are typical of any major construction project. Actual and potential effects of wind energy generation that are likely to influence site selection and resource consent applications in New Zealand are described in the following sections.

Te Apiti wind farm

5.2 Construction phase

The net land area required for wind farm installations is comparatively small, and because of the wide spacing of individual turbines and relatively small area taken up with tower foundations and access roads, this generally amounts to about 2% of the total land area of the whole site. However, the construction phase will result in effects over a wider area.

As some wind farms may be developed progressively over time, the construction phase may be staged or intermittent. Resource consent applications should clarify proposed construction timing and duration intentions, to ensure that these aspects can be adequately evaluated, and any consents granted will have appropriate conditions attached.

Photographs of construction at Te Apiti.

5.2.1 Site access

Gaining access for construction is likely to involve enhancing an existing road or establishing a new one. Its construction may involve noise, dust, and interference with water courses and vegetation. As for any road, its design needs to manage drainage of water and to avoid slips and vegetation removal, so minimising scars on the landscape. Ultimate width of any access road may be narrower than required for construction. For example, the Te Apiti wind farm constructed during 2004 required a temporary road 10-metres wide but following tower erection it was later narrowed to a 5 metre wide permanent access route.

Features such as ecologically sensitive areas and archaeological sites should be avoided in design. Because of the temporary nature of construction and the probable remoteness of access roads, noise will normally not be a problem. In areas close to houses, the New Zealand construction noise standard (NZS 6803P, 1984) applies.

Dust from access construction processes can be addressed by seeding temporarily stock-piled material, or occasional water spraying.

The immediate community should be advised of the timing and duration of access construction.

5.2.2 Access to and between turbines

Cranes will need access to individual turbine locations for the erection of towers and for the installation of the nacelle and blades. Other vehicles will need access for foundation construction, laying underground cables, commissioning checks, maintenance and repair. Following installation, these activities involve small vehicles on an occasional basis only.

Depending on the nature of the ground in the vicinity, access between installed turbines can be minimalised, but the construction phase may involve vegetation clearance, some levelling, trenching for cables, and importation of roading materials to form tracks.

Any potentially adverse effects can be handled through design and through definition of practice in contract documents.

In some sensitive locations, reinstatement of vegetation cover may be very important, and accesses may be encouraged to become overgrown. This may particularly be the case in sensitive coastal or ridge top locations. In farming locations, pasture can be reinstated.

5.2.3 Dust

As wind farms are located in windy exposed sites, there is potential for temporary dust nuisance due to use of access roads, construction activities, and foundation excavation material left on site.

If loose material is not being removed from the site, it should be carefully spread in appropriate areas, and planted or appropriately seeded as soon as possible. Depending on the area, it may be desirable to import or collect water on site, to spray as a dust mitigation measure.

5.2.4 Ecology

If the construction phase is carefully addressed, major long-term effects on the ecology of an area are unlikely.

Construction should be timed to avoid nesting periods for birds in the area, and to minimise erosion of exposed surfaces by rain or wind. Reinstating local ecology may require temporary fencing, and an active planting programme.

5.2.5 Safety

Overseas, the construction period is found to have some risks for site workers. This is a matter of occupational health and safety, rather than a resource consent issue. However, public safety during the construction phase is a potential effect to be addressed. Because of the potential danger, particularly during erection of towers and blades, the public need to be excluded from the immediate area.

5.2.6 Noise

In general, construction noise from the erection of turbines will be minor and very temporary, and will have minimal impact, especially in rural areas. However, sites which are close to dwellings or urban areas may require some special consideration.

Noise of access formation, excavation and construction of foundations and construction of any assorted buildings or structures such as transformers or switchyards, is much the same as any construction noise. Where this is likely to be of concern, the relevant New Zealand Standards can be included in a consent condition.

5.2.7 Traffic

Construction traffic involves vehicles normally associated with any construction site. Earth moving equipment will include bulldozers, dump trucks and excavators. There will be one or two particularly long loads per turbine as the blade and tower components are brought to the site, as well as conventional trucks bringing in other materials and possibly removing soil, and workers' transport. Oversize loads should be timed to avoid peak traffic on local roads. Up to 400 tonne cranes may be used, which also need transporting to site.

5.2.8 Temporary buildings and parking

If a wind farm is being developed at one time (as apposed to in stages), it is likely that some temporary on-site facilities will be needed such as site sheds, portable toilets, storage buildings or containers and temporary car parking areas for workers' vehicles. Such temporary facilities will generally have minor visual and site disturbance effects.

5.3 Commissioning phase

Commissioning of turbines is a process which may take a few days or a week for an individual turbine. It is done immediately after installation, and usually involves manufacturers' and contractors' representatives undertaking a series of tests relating to tower, nacelle and blade stability, and performance. Environmental effects such as noise may be part of the commission tests.

If studies and tests in the consent process have been undertaken, the risk of any unexpected environmental effects arising at the commissioning stage will be reduced. However, at the commissioning stage, some effects such as communications interference or unexpected noise may be noticed. In this case, a turbine owner may need to do remedial work on or off-site.

5.4 Operational phase

5.4.1 Noise

Noise potentially arises from several aspects of a turbine: the generator, the gearbox, and contact between the nacelle and the supporting tower, which together give rise to mechanical noise. There is also aerodynamic noise from blade rotation. The combination of noises from a wind turbine can be described as a mechanical noise such as a milking shed pump, combined with an aerodynamic cyclical swishing sound from the blade movement.

Considerable design effort has gone into minimising noise from wind turbines. Aerodynamic noise from the blades of a wind turbine reduced dramatically in the 1990s. Multi-speed turbines and improved design of blade edges nearer the tip ends are important for reducing noise levels. At distances of more than 200 metres, the swishing sound of the blades is usually masked by background noise such as from wind blowing around trees, fence wires or neighbouring buildings. Mechanical noise has also reduced significantly in most modern wind turbines due to improved engineering and components.

However, such noise is generated only when the turbine is operating. For conventional horizontal axis turbines, this is at wind speeds of between 4m/s and 30m/s. Normal New Zealand noise standards require measurements to be based in the absence of wind and are therefore not relevant to the evaluation of wind turbine noise.

In 1998, Standards New Zealand produced a national Standard for the assessment and measurement of sound from wind turbines [3]. It incorporates the effects of background noise levels and allows comparisons between a ‘before’ and ‘after’ situation.

The Standard was specifically developed as an aid to planning consent procedures, and to provide guidance on the limits of acceptability for sound received at residential and noise sensitive locations. It also includes a precise method for post-installation compliance testing. The NZ Standard has been adopted as the State standard in Victoria, Australia.

It states that “Sound levels measured at the boundary of any residential site must not exceed the greater of 40dB or background noise plus 5dB.”

The noise of a wind turbine generator can be ascertained from a manufacturer's standard specification, and the noise generated should not vary over time if the machine is well maintained. Aerodynamic noise is also often estimated in a manufacturer's specification. This information can be compared with available measured information relating to the local environment.

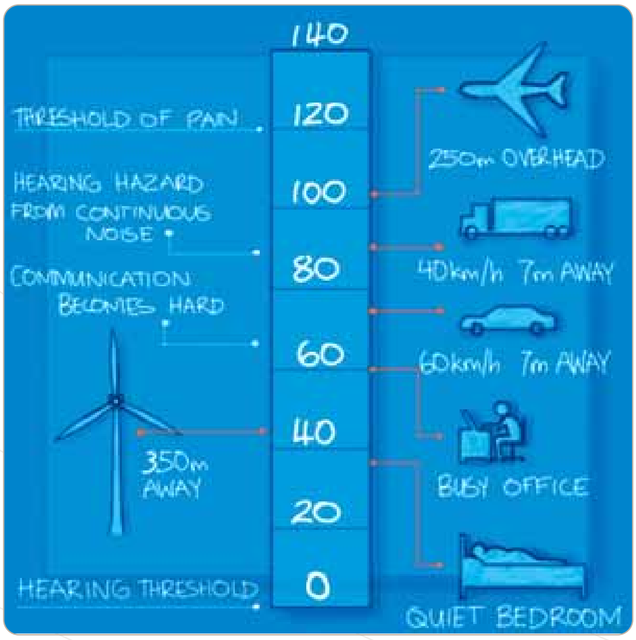
In general terms, noise decreases rapidly with increasing distance from its source. A turbine which typically emits 95-105dB(A) at source will be measured at 55-60dB(A) at one rotor diameter distance from the tower base, and will be virtually indistinguishable from background levels of 35-45dB(A) at 350 metres distance. In general, wind turbines sited more than 350 metres from housing on flat grassy terrain, for example, will not cause any noise nuisance to local residents.

This generalisation may not hold true if the wind turbine is particularly large, emits low frequency sound levels, is of an unusual design or located in peculiar topography. For example, some residents have raised concerns when living 2.5km away from the nearest wind turbine. Distance by itself is not always an indicator of the degree of effect. New homes have been built as close as 700 metres to the Brooklyn wind turbine in Wellington. In Denmark, the distance between turbines and populated areas is allowed to be as close as four times the total height of the turbines or approximately 440 metres for larger turbines, and in some areas of the United States the limit is approximately 300 metres.

Wind turbine developments which are located within 500 metres of dwellings, and which have special audible characteristics, should always be the subject of special evaluations.

There is some debate about the way sound levels from a wind farm are measured. The effect from low-frequency sound, which attenuates slower than higher frequencies, is often raised as a concern. However as long as these frequencies are assessed separately in any evaluation then a wind farm can be designed to meet New Zealand Standard or local authority requirements. Some local authorities may have zoned some areas as having higher or lower acceptable noise levels than the National Standard.

Similarly, the potential effects of infrasound from wind turbines are sometimes raised as a concern. Infrasound is very low frequency sound - often below the level of human



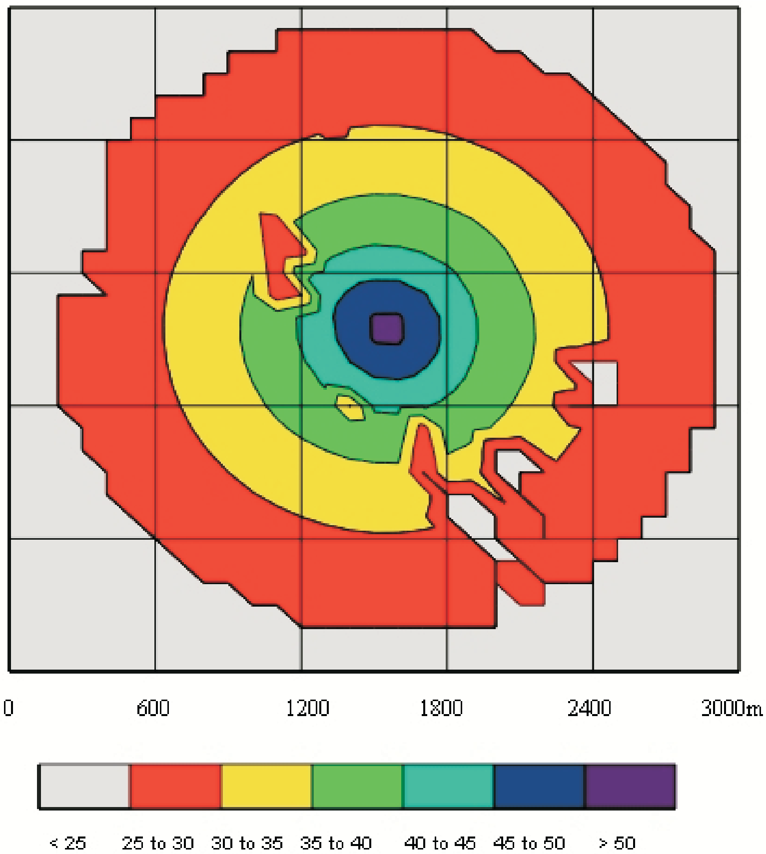
Wind turbine noise level comparisons.

hearing. If 'loud' enough, infrasound can be heard or felt as a vibration. While wind turbines have been listed as one of many potential sources of infrasound (along with household appliances and the wind itself), this was due to an old American down-wind turbine which is no longer used. The author of the report often quoted, Dr Geoff Leventhall, has stated there is no significant infrasound from wind turbines currently used. Dr Leventhall has categorically stated that there will not be any effects from infrasound from wind turbines.

The nature of the local terrain, its vegetation cover, and any specific characteristics of the local wind conditions (such as frequent occurrence of low wind speeds in a valley floor in combination with high wind speeds on top of a nearby hill) can modify the noise levels, and should similarly be carefully evaluated. Particular prevailing winds may result in the frequent occurrence of higher than normal noise levels being experienced by some neighbours, and this also needs to be taken into account.

If noise is likely to be an issue, sound predictions based on the type of turbine to be used, the local terrain, and detailed analysis of localised wind conditions should be provided in a resource consent application. These should be in the form of 'worst case' condition contours on a locality map showing sound levels at distances from the turbine itself.

If noise is an aspect which is required to be remedied or mitigated through a plan or in a consent condition, it is most appropriate to do this by setting a level not to be exceeded at a receiving point, rather than by determining turbine location, distance or type. This leaves a developer free to make choices in respect of the means of achieving the performance requirement.



Wind Turbine Sound Pressure Levels in dB(A)

Calculated at 100m grid points.
Layout: 1 Wind Turbine, 72 m hub height.

Source sound power level: 102 dB(A).
Air absorbtion: 0.005 dB(A)/m
Reduction with non-line of sight to hub: 10 dB(A).

Sound level predicition diagram (dB(A) at 1.5 metres above ground level). Sound levels are down to background levels within 350 metres of the site from a single wind turbine, 102dB (A) at source. Courtesy of PB Power NZ Limited.

5.4.2 Visual effects

Visual effect is one of the most common concerns associated with wind energy development, and most difficult to deal with. Generally, turbines can not be hidden; they are visible and individual human response to them varies widely. Turbines can be perceived as 'dynamic visual sculptures' or 'interesting' by some people, while at the same time being seen as an 'unacceptable visual intrusion' or 'ugly' by others.

In addition, responses may vary over time. For example, studies of public perception in the UK and Australia found that local residents were more receptive to wind turbines after the wind farm had been operating for some time.

The easiest way to address visual impact is to avoid locations where turbines are seen by many people. However, in wilderness areas, the intrusion of wind generation developments can be visually unacceptable because of their associations with the developed or built environment.

It is likely that a number of wind farm developments will be located close to settlements, and therefore seen by people. It is recommended that various aspects of a wind farm development be considered in relation to visual effects.

Site location, size, tower design, colour, and layout and spacing are all important factors in terms of visual impact. As well, access roads, site buildings, and any additional electricity transmission requirements may require consideration in any specific development.

Visibility and the form and pattern of the existing landscape will largely influence the acceptability of any wind farm development. In New Zealand it is likely that higher ridges and coastal locations will be the most frequently sought locations for wind farms. Contours and, in rural areas, existing landscape features such as trees, hedges and roads, must be taken into account in any visual evaluation. Because of the size, shape and need for good 'wind runs', wind farms cannot be concealed behind planting.

The following generalisations can be made in terms of reducing visual effect:

- All turbines in a wind farm should be of similar size and style.
- Blades should always rotate in the same direction.
- If the site is flat, a regular layout along straight lines is preferred to a random scatter of turbines. This does not hold for variable terrain.
- Light colours - pearly grey and white - have been found to be most appropriate colours for all parts of the turbines in Northern Europe, where they tend to be seen against a sky background. If the background is other than sky, darker colours may be appropriate.
- Distance and scale of the landscape is a major consideration. In an open or grand landscape, wind farms can be of minor intrusion. However, the human eye is often drawn to 'artificial' vertical features, regardless of distance, making them seem bigger than they really are.

The 40 metre high Brooklyn wind turbine in Wellington.

Beyond the above generalisations it is not possible to give guidance in terms of good practice. Each development will need to be considered on its merits in terms of site and locality-specific considerations such as distance, backdrop, landscape scale and number of potential viewers.

Information provided to a consent authority should generally include a plan showing areas from which the turbine or farm will be visible, and a number of photomontages or simulations of potential development from one or more viewpoints. These should include backdrops of different weather conditions and times of day to emphasise any difference in light conditions.

Various methods have been used to try to measure the visual effect. One common method is to identify locations within a certain distance from the wind farm that turbines can be seen from. These combined areas are referred to as a Zone of Visual Influence (ZVI). It is relatively easy using computer modelling although sometimes expensive for large or complicated sites. Interpreting the significance of visibility will generally be subjective and experience of landscape assessment experts is useful to bring a qualitative interpretation to the quantitative information.

A second method of assessing visual effects is to consider responses to public surveys.

The cumulative effect of several wind farms visible from a single locality (intervisibility) has been noted in the UK. There is as yet no information as to how such cumulative effects may be assessed.

Some local authorities may prefer clustering of wind farms in some areas, on the basis that other areas will remain free of wind farms. Other local authorities may prefer dispersal.

An additional visual issue may arise in cases where a new construction access route is required, which would then be retained as a long-term maintenance and replacement road.

The large and long loads associated with wind turbine construction require particular road geometry, which may not be totally sympathetic to the local topography, particularly in steep country.

The location and design of access roads, effects on vegetation, disposal of cutting spoil, and treatment of exposed faces, must all be evaluated in terms of the long-term effect on the landscape. Proposals should include appropriate remediation of scars, and spoil management, as well as careful initial design.

Similarly the visual impact of new transmission lines must be evaluated. If new transmission lines involve land disturbance, the visual impact of this must also be considered.

Shadow flicker and blade glint can also create particular visual effects.

Shadow flicker or strobe effects inside houses may result from a turbine that is located in a position where the blades pass across the sun, causing an intermittent shadowing. This potential effect occurs only where a turbine is in close proximity to a dwelling, and at very low sun angles. It is unlikely to be an issue in New Zealand because the separation distance required for noise mitigation is usually more than enough to prevent occurrence of shadow flickers.

Blade glint (the regular reflection of sun off rotating turbine blades) can be a temporary nuisance. Its occurrence depends on a combination of circumstances arising from the orientation of the nacelle, angle of the blade, and the angle of the sun. The reflectivity of the surface of the blades is also important, and this is to some extent influenced by colour and age of the blade. Matt surface finishes can be specified to minimise effects. Blade glint is an aspect that can be a potential distraction to drivers if roads are aligned towards turbines, and can be noticed over considerable distances - as much as 10 to 15km. Effects should be minimised with appropriate turbine layout at the design stage.

Te Apiti wind farm on a cloudy day.

5.4.3 Effects on communications

Radio, television and microwave transmission can potentially be affected in several ways by individual turbines and wind farms:

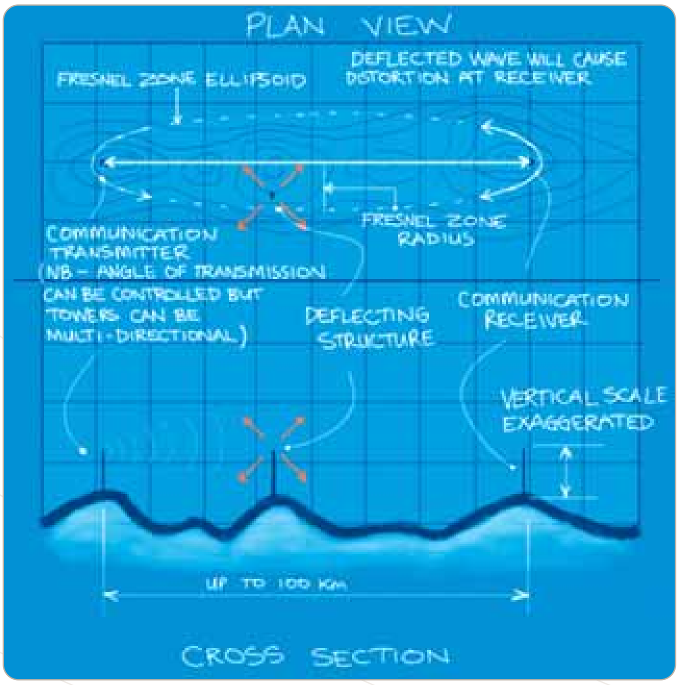
- The tower may obstruct, reflect or refract the electromagnetic waves used in a range of communications systems for transmission.
- The rotating blades may have similar effects, on a time-variable basis. If the blades are made of metal, or have metallic cores, these can act as an aerial to on-transmit the communication. This may cause, for example, ghosting in local TV receivers.
- The generator itself can produce electromagnetic interference, although this can usually be suppressed by shielding design and good maintenance of turbines. In practice, a generator is little different from any other electrical machine, and only in rare circumstances is a wind turbine generator likely to be a potential problem.

In general terms, these effects will be relatively limited, as the tower and blades are slim and curved, and consequently will disperse rather than obstruct or reflect electromagnetic waves. Where blades are of a material transparent or absorbent to waves, as most are, any problems are minimised.

However, the location, size and design of the turbines may be important, depending on the location and nature of the communication transmission facilities.

In New Zealand, numerous communication systems use high points in the landscape, and it is inevitable that there will be some concern expressed by communications users. Communications users may be as diverse as cellular phone companies, local and national utilities, and emergency services such as ambulance and coastguard.

Generally, the communications systems most likely to be affected are those which operate at super high frequencies (particularly microwave systems operating at frequencies above 300MHz). These rely on line of sight between transmitter and receiver. Any obstruction in the vicinity of a straight line between these two points may cause interference and signal degradation.

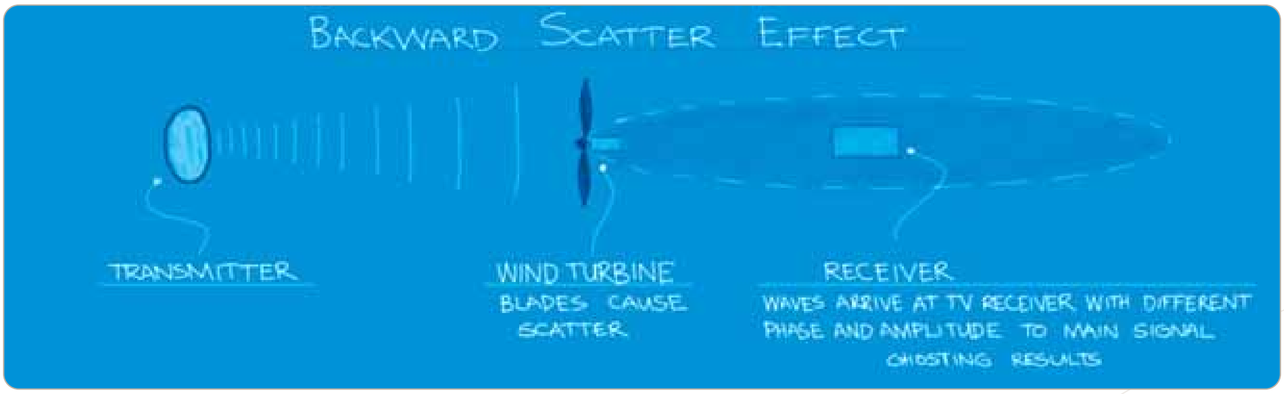


Potential effect of structure on microwave links, in plan and cross-section.

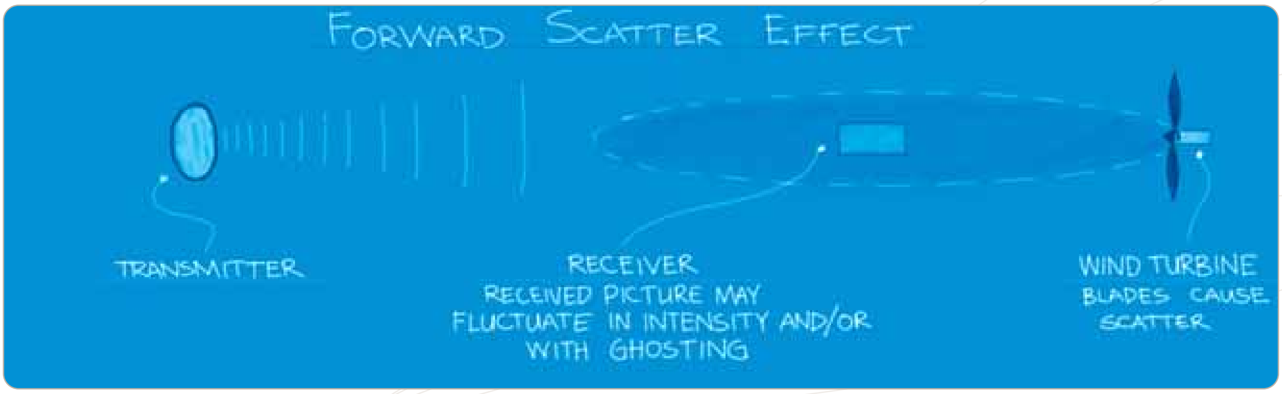
The key area of potential interference is called the first Fresnel zone. This is an area around and between the transmitting and receiving stations based on transmission frequency, distance and local atmospheric conditions. A turbine within the first Fresnel zone may be acceptable, particularly if it is a solitary obstacle with a width less than 0.3 times the radius of the zone. However, every case needs to be considered on its particular circumstances. Potential effects can be calculated from information about the signal, the local conditions, and the turbine design and location.

For all electromagnetic effects, means of mitigation, avoidance, and remedy can be found. These may include specific location of any particular turbine, choice of wind turbine generator type, tower design, or specific blade material. Shifting or enhancing existing communications installations may also be a possibility. A small shift in a line of sight radio path can make a large difference to whether the path is obstructed by the turbine or not.

For any proposed wind farm, the best way to identify and address potential adverse effects is for an applicant to identify and consult with communications operators at an early stage. It is possible, but unusual, that statutory separations may be indicated on plans relating to, for example, Telecom designated sites or airports. Normally the consultation process will identify concerns. Potential developers should have generally resolved issues through private agreements, before seeking approval to proceed, and include evidence of these in their resource consent application.



Potential for interference with TV reception - backward scatter effects.



Potential for interference with TV reception - forward scatter effects.

5.4.4 Carbon dioxide emissions

No carbon dioxide (CO_2) is emitted when electricity is generated from a wind farm. However, similar to other forms of generation, a small amount of CO_2 is emitted during the construction and maintenance of a wind farm. This occurs mostly during the manufacturing of components and when vehicles are used in transporting materials and people to and from the wind farm site.

In New Zealand the net CO_2 effect is negative because electricity generated from a wind farm displaces other forms of electricity generation which have, on average, higher CO_2 emmissions. Wind power developments in New Zealand displace on average 0.62 tonnes of CO_2 per MWh of wind power generated. Some developments may save more or less if it can be demonstrated the wind farm is displacing specific fossil fuels.

5.4.5 Bird deaths

Overseas literature on wind farms indicates there are five potential impacts on bird life:

- Collision
- Direct habitat loss
- Indirect habitat loss (during construction, and disturbance to nesting, feeding sites, and habitual flight paths)
- Electrocution from associated infrastructure
- Cumulative impact

In general, it appears that local resident birds of most types grow accustomed to the presence of local turbines, and will avoid them. Turbine blades have a maximum tip speed of approximately 50-100m/s (50-80m/s on land-based turbines), and are able to be seen and avoided by most birds, including birds of prey and sea birds. Water birds and night feeding sea birds have been found in Australia to be at slightly greater risk than other birds. However, hazard effects are seen as adverse to individual birds, rather than as affecting whole species.

Numerous studies overseas have compared bird mortality caused by wind farms with that experienced from buildings, stretches of roads, motorways, and transmission lines. The studies have found wind turbine effects to be significantly lower than other causes. Different countries have recorded different rates of bird deaths per year relative to the number of turbines, with three countries reporting 0.13, 2.2 and 6. In the United States the highest rates of bird mortality resulted from rather dense siting of turbines within areas with relatively high bird populations. Even so, with over 15,000 wind turbines sited around the U.S., it has been found that approximately 3000 times as many birds die from colliding with vehicles and other structures as compared with turbines.

While overseas evidence suggests that the total impact of wind farms on birds is small, it should not be dismissed. It is good practice for developers to seek advice on the main flight paths of birds so the number of bird deaths can be minimised. In addition, developers would need to avoid any impacts on rare or unusual species.

With wind farms in New Zealand at a relatively early stage, potential bird death rates are not known. They are expected to be low, however, as migratory paths in New Zealand are rarely over land, and there are relatively few large-bodied flying birds. After 10 years of operation, no bird deaths related to the Brooklyn wind turbine have been reported. Tararua Wind Farm has had approximately ten recorded bird (magpie) deaths in five years.

It would, however, be good practice for applicants to seek advice on particular characteristics of local species with the Department of Conservation. If it seems that there may be special concerns, then further specialist advice should be sought.

Measures to mitigate and manage effects on birds include:

1. Site selection

   Maintain sufficient setbacks from high bird use areas; avoid migration routes, and features that attract birds.

   Locate wind turbines in areas that support fewer species such as intensive agricultural, pastoral or industrial areas.

2. Reduce perching opportunities
3. Off-site mitigation

   Increase the security of birds off-site, to secure conservation status of the species by conserving other nest sites, breeding areas, and over-wintering grounds.

4. Quantifying potential effects

   Undertake scientific surveys both before and after development by using standardised investigation and measurement methods of bird utilisation rates and bird mortality.

5.4.6 Other ecological issues

The most likely effect of wind farms on the environment is the possible disturbance of existing species and habitats during the construction phase.

Wind farms frequently occupy agricultural land which is regularly disturbed by agricultural practices, and where ecology and habitats are already highly modified. It is unlikely that there will be any ecological concerns associated with development in such areas. In New Zealand, large tracts of farm land have little remaining natural vegetative cover and because of this there are very low populations of native birds in such areas. Introduced species which have readily naturalised, such as magpies, starlings and mynas, along with water fowl in some areas, form the bulk of the bird populations in these localities.

Where a wind turbine or a wind farm is to occupy non-agricultural land, it is appropriate to confirm that no representative, rare or endangered habitats or species will be affected. If there is any chance of this, specialist advice should be sought.

As wind turbine foundations occupy only small areas of land (about 1%), generally local ground habitat re-establishes quickly. However, the local ecology may experience some wider temporary disruption due to land disturbance for construction activities. Such effects should be minimised or avoided. For example, construction activities can avoid key times of the year, such as nesting periods, or specific turbine locations can be adjusted to avoid plant specimens. Experience in Australia as well as Europe suggests that local species, including territorial birds and animals, readily re-establish in a wind farm locality.

5.4.7 Effects on culturally significant sites

Many iwi and/or hapu have strong associations with particular mountains, coastal areas or other landscape features. A tribe may be known by its mountain. In addition, many high points have traditional associations with ancestors, or as lookouts. These associations may be apparent from place names, or from tribal traditional record.

Particular account should be taken of waahi tapu and other important sites. Consultation, as required under the Resource Management Act, with local iwi, and at times with hapu, is essential to ensure that wind farm developments are respectful to tribal associations and traditions.

5.4.8 Effects on intrinsic values of areas

As well as cultural values associated with sites, people may have strong feelings or associations with some areas. For example, areas may have wilderness or remoteness values, historic associations, or may contribute to the 'sense of place' for a nearby settlement. These values are often difficult to identify and define, but are 'intrinsic' to the area. Effects on intrinsic values should be addressed seperately to visual impacts.

The consultation process may assist in identifying and addressing such values. An assessment of community regard for wind farm sites can be undertaken as part of investigations for wind farm projects.

5.4.9 Archaeological and historic sites

Relatively little ground disturbance is associated with wind turbines or wind farms. However, the preferred wind farm locations, including land in coastal and ridge locations, may potentially contain archaeological evidence or material. This is because of the importance of such areas in pre-European, and sometimes more recent, times.

The Historic Places Act 1993 covers all sites and artefacts which are more than 100 years old, and requires a procedure, including cessation of work if any evidence of an archaeological or historic site or any artefacts are found. It is preferable that Department of Conservation records are inspected and a surface investigation carried out, if appropriate, prior to approvals being given. Opportunities to avoid or mitigate damage should be built into any application affecting an archaeological or historic site.

5.4.10 Effects on other land uses

As wind farms affect the productivity of only a small part of the land they occupy, they tend to have little effect on other land uses. Wind turbines can co-exist with many types of land use. Exceptions are urban development (particularly residential areas), forestry areas, and sensitive activities such as airports and, as discussed above, some communications facilities.

Once a wind farm is established, it is likely that its owner will strongly discourage nearby planting of trees, or any other activity which may influence wind in the vicinity.

One way to achieve a suitable buffer area free of trees may be for owners to enter into direct contracts with adjoining landowners.

5.4.11 Aviation effects

Because of the height of the turbine tower and blades, if there is an airport in the vicinity, flight path envelopes must be avoided. The Civil Aviation Authority should be consulted about the need for warning lights on the tower (light on blades poses a particular problem due to their rotation). Reasonable separation from airports is preferable.

Air strips in rural areas are usually not protected by any designation or Civil Aviation requirements. If there are air strips in the vicinity, potential developers should consult with owners and users to ensure that potential adverse effects are avoided or mitigated.

In the UK there is some concern that an increasing number of turbines will reduce the effectiveness of aviation radars that are within their zone. Plot filters for radars have been developed to minimise the effect of wind turbines, by differentiating the Doppler effect.

Individual circumstances will dictate the degree and cost of modification required. With the correct knowledge of the design and manufacture of a particular radar, and the configuration used in a particular situation, these issues can be investigated. The likely success of a modification can be established at the resource consent planning stage.

5.4.12 Public safety

Most wind energy developments will not be on land available to the public, so public safety should not be an issue. However, this issue sometimes arises, for example if a public walkway coincides with a wind farm, or if the public are invited into the vicinity to view the working wind farm at close quarters.

Most wind turbines currently available meet international engineering design and manufacturing safety standards. Refer to the IEC 61400 series, which includes IEC 61400-1, Wind Turbine Safety and Design. This includes tower, blade and generator design. There is an international quality control assurance programme for turbines, and a number of relevant standards.

In addition, foundation design and commissioning checks address potential failure due to extreme events such as earthquakes or extreme wind loadings, as well as frequency tuning of the different parts of the structure to avoid failure due to dynamic resonance.

International experience to date has indicated very low risks associated with tower collapse, components falling from towers, and blade throw. Risks appear to be reducing further as technology improves. Publications such as Wind Power Monthly and Wind Stats provide current information on industrial accidents and failures of components.

5.4.13 Other effects

There may be special considerations in terms of effects relating to specific developments. For example, a public viewing area or education centre may involve additional buildings, access, traffic management and parking considerations, and higher levels of security for any switchyard. All of these would need to be evaluated in terms of visual effects, traffic generation, and public safety. However, the techniques to address these effects are well understood, and suitable means of avoiding, remedying and mitigating any potential adverse effects should be able to be found.

6. Maintenance and monitoring

Turbines require ongoing maintenance. For a larger wind farm, it is likely that one or more turbines may be temporarily out of operation at any time.

Maintenance checks and any actual maintenance involves little vehicle movement - perhaps one vehicle per day for a small farm, less for a single turbine. Maintenance is done in situ with access via the tower. It is rare that a nacelle is removed for maintenance. Occasionally large components or blades may be replaced or a tower may be lowered.

Monitoring of wind farm performance is done electronically, and has no environmental effects. However, it is likely that most farms will have one or more separate anemometer masts associated with them to monitor the general wind situation. These will be located where they are not affected by the turbines, generally 100-200 metres from the closest turbine.

These masts will be equivalent in height to the hub height of the nearby turbines, maybe 40-50 metres high, and are likely to be fixed by guy wires. They are visually less prominent than the turbines themselves. An average anemometer tower is approximately 10cm in diameter, although lattice towers may be triangular in section and up to 20cm wide at the base. Lattice towers may need to be metal-clad for the initial three metres to discourage people from climbing them.

7. Replacement and reinstatement

A wind farm could be developed as a permanent installation or may be relatively temporary (20-25 years). Although it is reasonably practical to reinstate land once wind turbines have reached their life end and been removed, this prospect, in areas of good wind resource in New Zealand, seems unlikely given that a good site could be used on a permanent basis once initial consent has been obtained.

Wind turbines installed in the past are likely to be superceded commercially by larger capacity generating turbines, which continue to increase in size. For example, in New Zealand the first commercial scale turbine was 225kW in 1993 and the most recent is 1650kW in 2004. The average size turbine installed worldwide is 520kW with the largest off-shore turbines designed at larger than 4000kW.

Wind farms may be regarded as permanent land use activities, which, like other land uses, may undergo upgrade, maintenance and change over time. An existing wind farm could be replaced with a smaller number of larger turbines in the future. Technological development may allow turbines, nacelles, blades, and even towers to be progressively changed to make better use of the wind resource.

However, the first layout of a wind farm will tend to set the pattern for future use of the site. Progressive change to taller, larger turbines, for example, may be technically difficult because of potential interference with remaining turbines. The visual impact of a different size and style of turbines, or a mix of turbine types, may warrant careful consideration for some sites.

As a resource consent issue, it is appropriate to consider providing for maximum opportunity to vary turbine size, type, and specific siting over time. This will allow progressive upgrading, replacement at the end of the machine's life or replacement of obsolete technology, and will also allow for competitive tendering of initial and replacement turbines.

8. Glossary

Anemometer
A device for measuring wind speed.

dB(A)
The unit used for defining noise levels. This is the "A" weighted sound pressure measurement, adjusted to mirror the normal human hearing range.

Feather
Pitching of blades to the position where the turning force is zero.

Gearbox
A large component in the wind turbine that changes the rotational speed of the output shaft (generator end) relative to the input shaft (rotor blades end).

Generator
A device and component of the wind turbine that converts mechanical energy to electrical energy.

Guy wire
A wire used for supporting a structure.

Hapu
A sub-tribe or extended family-based grouping of Maori people.

Iwi
A Maori tribal group or organisation.

kV
An abbreviation for kilovolts, a thousand volts. A unit used for the measurement of electrical force.

kW
An abbreviation for kilowatt, a thousand watts. A unit used for the measurement of electrical power.

MHz

An abbreviation for megahertz, a million hertz. A unit used for the measurement of electrical frequency for a cycle of a regularly pulsed signal such as radio waves.

MW

An abbreviation for megawatt, a million watts. A unit used for the measurement of electrical power.

Waahi tapu

A sacred or tapu site, location or resource.

Wind farm

A collection (group) of wind turbines installed in proximity to one another and electrically interconnected prior to grid connection.

Wind speed

A measurement of the speed of prevailing wind over a discrete time period. Measured in metres per second.

Wind turbine

A device for generating electrical power from the wind. Also known as a Wind Turbine Generator, or WTG.

DID YOU KNOW:

The average amount of electricity consumed by a New Zealand household in a year is 8,000 kilowatt hours (kWh).

8,000

There are 1,000 kilowatt hours in a megawatt hour (MWh), 1,000 megawatt hours in a gigawatt hour (GWh) and 278 gigawatt hours in a petajoule (PJ).

A 660 kilowatt wind turbine running for an hour at full capacity will generate 660 kilowatt hours of electricity.

9. References

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10. Footnotes

[1] A public opinion survey was conducted by UMR Research as part of the Nationwide Omnibus in May 2004. The telephone survey was of a nationally representative sample of 750 New Zealanders 18 years of age and over. A full copy of the research and the methodology can be found at www.eeca.govt.nz.

[2] 2003 European Best Practice Guidelines for Wind Energy Development.

[3] Standards New Zealand. 1998 NZS 6808:1998 Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators.

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