Technical information to support the implementation of the National Policy Statement for Renewable Electricity Generation

Comment [BW1]: The guide over steps its purpose. It should not be setting policy and should not present a view on what is good field management. The guide can explain the options for field management which can include alternatives to infield injection

TECHNICAL GUIDE

- Draft
- February 2012

Contents

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1. Introduction

This guide is intended to assist the implementation of the National Policy Statement for Renewable Electricity Generation (NPS REG) by providing an explanation of technical terms and concepts relating to the New Zealand electricity market and renewable electricity generating technologies.

The NPS REG was developed to support the Government's target of generating 90% of electricity from renewable sources by 2025, providing this does not affect security of supply.

This guidance includes the following:

- Overview of the New Zealand electricity system and market
- Explanation of the renewable electricity target – 90% by 2025, as declared in the New Zealand Energy Strategy
- Summary of the most common types of renewable electricity generation technologies
- Explanation of technical elements of Policies A, B, C, F and G of the NPS REG
- Common technical terminology

This guidance should be read in conjunction with the Ministry for the Environment NPS REG Implementation Guide which is available from their website (www.mfe.govt.nz/rma/central/nps/generation.html).

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Electricity in New Zealand – Background Information

2. New Zealand Electricity Industry

The electricity industry has the following main components:

- Generation (electricity production stations which compete to offer electricity into the market) and retail (electricity retail companies which compete to buy wholesale electricity and compete to retail it to consumers)
- Transmission (the high voltage network known as the national grid)
- Distribution (local lines ~~companies~~).

Comment [BW2]: These dot points are a mix of description of physical assets and companies owning those assets. Given the description of the transmission system is in terms of assets, then the distribution system should be described in the same terms

The generation and retail component of the electricity industry operates within a competitive market based system. The transmission and distribution systems are natural monopolies that are regulated particularly with a view to curbing excessive expenditure on asset development and encouraging high availability to minimise the cost and inconvenience to consumers. A number of government agencies have a role in the industry through electricity market policy and regulatory functions.

Further information on the different components of the electricity industry is provided in this section of the guide and is available from the Ministry of Economic Development website (www.med.govt.nz/sectors-industries/energy/electricity/industry).

2.1. Electricity Industry Overview

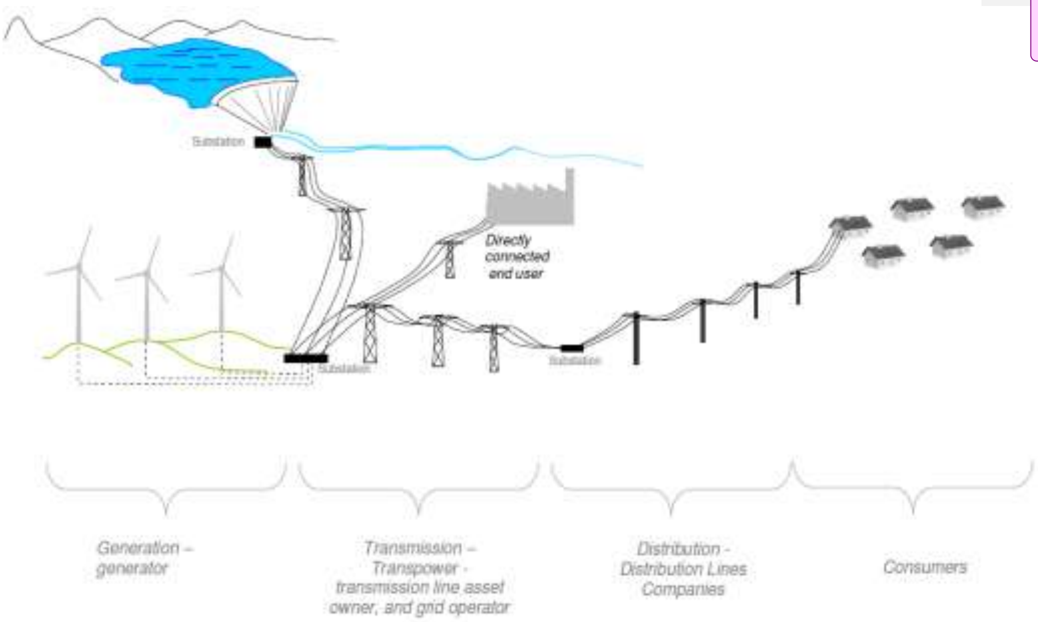
New Zealand's electricity is generated using a diverse range of energy sources (e.g. hydro, geothermal, wind, gas, coal). New Zealand has historically generated a high proportion of its electricity from renewable sources, and has relied heavily on hydro with thermal sources also being used. Recently the proportions of energy generated using wind and geothermal have increased. Once generated, electricity is transported through the country by the Transpower owned and operated national grid. It is then delivered locally to the final consumers by lines companies called distribution companies, which operate the local electricity distribution network.

A small number of industrial consumers are directly connected to the national grid and some of these also have on-site generation as well. A small proportion of electricity is not directly connected to the national grid. It is either supplied from generation which links directly into local distribution company networks or is generated within the consumer premises. Retailers are companies that purchase electricity from the wholesale market and sell it to individual consumers.

Figure 1 overleaf shows the electricity industry.

Figure 1 Electricity industry

Comment [BW3]: It is interesting that wind which contributes only 3-5% of electricity is illustrated while geothermal which contributes 14% is not. Perhaps this should be corrected



2.2. Electricity Market Overview

The electricity market in New Zealand is an open-access competitive market based around market rules developed by the industry and Government. Electricity market policy and regulatory structure functions are carried out by three main bodies: The Ministry of Economic Development (MED), the Electricity Authority and the Commerce Commission. Information on these agencies and the different components of the electricity system is given in the following sections.

The electricity market provides the structure for:

- Managing security such that electricity supply and demand are matched at all times;
- Provision of efficient prices to signal the current and forecast cost of electricity including transmission losses and constraints, and security costs (security constrained dispatch).

- MMarket participants (generators, retailers and others) to interact and trade electricity.

The electricity generators offer a certain quantity of electricity at a certain price (at a certain location) into the wholesale market every half hour, while the retailers ‘bid’ anticipated electricity demand. The price of the electricity for each half hour is set by stacking up the offers from the lowest price until the demand is met. Some renewable electricity, such as wind, is always offered at a very low or zero price so that it is taken up, but all successful offersit receives the price of the most expensive electricity required (i.e. the top offer of the stack). This is termed marginal-cost pricing, and is a very efficient approach to pricing.

2.3. Generation and retail

There are five large generator companies and a number of smaller companies. The five large generator companies that supply the wholesale market are:

- Contact Energy (www.contactenergy.co.nz)
- Genesis Power (www.genesisenergy.co.nz)
- Meridian Energy (www.meridianenergy.co.nz)
- Mighty River Power (www.mightyriverpower.co.nz)
- Trust Power (www.trustpower.co.nz)

Approximately 60% of New Zealand's electricity is generated by hydro stations, with the balance from geothermal stations, gas, geothermal, coal, wind and bioenergy plants.

Comment [BW4]: repeated

Electricity generators can also act as retailers, with the five large generators above also being large retailers along with a number of smaller companies. The retailers purchase electricity from the wholesale market and sell it to individual customers. The customers range from small households to large industrial users. Distribution companies can also be generators and retailers (though with certain restrictions, to avoid monopoly behaviour).

2.4. Transmission

The majority of New Zealand’s electricity is generated at remote locations and requires an efficient transmission system to transport it to the main centres. Approximately Over 40 power stations supply electricity to the national grid.

Comment [BW5]: Based on a count of power stations shown connected to the grid in Transpower’s Annual Planning Report with additions of the new geothermal stations at Kawerau and Nga AwaPurua

Transpower is the state owned enterprise that owns and operates the National Grid, the high voltage transmission system throughout New Zealand, which enables electricity to be transported from regions having electricity surpluses to those with electricity deficits. The grid consists of around 12,000 km of transmission lines (known as power lines) and ~~170~~ 182 substations and switchyards.

Comment [BW6]: Taken from Transpower’s APR

Transpower’s power lines operate at voltages above 50 kilovolts and include the high voltage direct current (HVDC) lines that connect the South Island to the North Island between Benmore in the Waitaki Valley and Haywards just North of Wellington. When electricity is transmitted at high voltages, there is less electricity loss from resistance.

Transpower’s two primary roles are as grid owner and system operator. As Grid Owner, Transpower manages the assets that transmit electricity around the country (high voltage cables and pylons along with other electrical equipment necessary for the national grid such as transformers). In this role, Transpower undertakes condition monitoring and maintenance of existing grid assets and planning and installation of new grid assets. As System Operator, Transpower manages the real time operation of New Zealand’s power system ensuring the appropriate quantity and quality of electricity supply in real time.

A National Policy Statement on Electricity Transmission was gazetted in 2008 recognising the national significance of the national grid in RMA policy statements and plans and decision making.

Further information about Transpower is available on their website (www.transpower.co.nz).

2.5. Distribution

Distribution companies, also called lines companies, own the local distribution lines that bring electricity to the consumers from the national grid. While the majority of consumers receive their electricity from their local distribution network, a few large users are connected directly to the national transmission grid. Distribution networks may also source some electricity directly from small generators who connect into ~~to~~ the distribution network. This is known as distributed generation.[1]

The regions covered by different distribution companies are shown in www.electricity.org.nz. There are currently 2~~8~~9 local lines companies, the major ones being:

Comment [BW7]: See http://www.comcom.govt.nz/electricity-information-disclosure-summary-and-analysis/ - Orion was missing

1) Vector (www.vector.co.nz)
2) Powerco (www.powerco.co.nz)
3) Orion (www.oriongroup.co.nz)

[1] If the distributed generation’ is connected behind a load (eg a cogeneration plant at a sawmill), it may be termed embedded generation.

4) Wellington Electricity Lines (www.welelectricity.co.nz)
4)5) Hawkes Bay Power (Unison) (www.unison.co.nz)
5)6) WEL Energy (www.wel.co.nz)
6)7) Delta Utility Services (Aurora) (www.electricity.co.nz)
7)8) WEL Energy (www.wel.co.nz)

2.6. Electricity Authority

The Electricity Authority is the independent regulator with the objective "to promote competition in, reliable supply by, and the efficient operation of, the electricity industry for the long-term benefit of consumers". It replaced the Electricity Commission in 2010 following changes to the electricity industry made by the Electricity Industry Participation Act 2010. The key functions of the Electricity Authority are:[2]

- Registering industry participants and maintain a database of information on all electricity industry participants and connection points (see terminology section)
- Developing, administering, and enforcing the Electricity Industry Participation Code 2010
- Facilitating market performance through information, best-practice guidelines, and related services
- Undertaking sector reviews
- Acting as Market Administrator and contracting market operation service providers
- Promoting consumer switching
- Monitoring sector performance against the Authority's statutory objective.

2.7. Commerce Commission

The Commerce Commission is New Zealand's primary competition regulatory agency[3]. It is an independent Crown entity and is not subject to direction from the government in carrying out its enforcement and regulatory control activities. In the electricity sector, the Commerce Commission acts as a body that maintains suitable pricing. For example, the Commerce Commission regulates the price of transmission charged by Transpower. In addition, the electricity industry is subject to the provisions of the Commerce Act and the Fair Trading Act.

[2] The Electricity Authority's website contains further detail (www.ea.govt.nz/about-us/).
[3] The Commerce Commission's website contains further detail (www.comcom.govt.nz/electricity).

2.8. The Ministry of Economic Development

The Ministry of Economic Development (MED) develops and implements electricity sector policy, particularly relating to the governance and market structure[4]. MED also monitors market performance, including competition issues and electricity prices.

MED facilitates, leads and implements the Government’s economic development g~~a~~oals. The overarching goal of the government is to grow the New Zealand economy to deliver greater prosperity, security and opportunities for all New Zealanders.

The Ministry leads the production and co-ordination of policy advice related to economic, regional and industry development and is also the Government’s primary advisor on the operation and regulation of specific markets and industries, including energy and telecommunications. It sets overarching energy policy and regulation.

2.9. Energy Efficiency and Conservation Authority

The Energy Efficiency and Conservation Authority (EECA) is a Crown entity established by the Energy Efficiency and Conservation Act 2000[5]. EECA’s statutory mandate is to encourage, promote and support energy efficiency, energy conservation and the use of renewable sources of energy[6]. EECA is one of a number of agencies implementing aspects of the Government’s energy policy particularly in the areas related to energy efficiency, energy conservation and renewable energy.

In fulfilling its functions, EECA works across all sectors of the economy. EECA’s activities are aimed at reducing barriers to the uptake of energy efficiency measures and renewable energy in New Zealand.

2.10. Ministry for the Environment

The Ministry for the Environment (MfE) is actively involved in the energy sector[7]. It is charged with several elements of the government’s Climate Change programme, including coordinating cross government policy development. The Ministry is also involved through the development of national instruments and guidance under the Resource Management Act. MfE developed the NPS REG and contributes to Ministerial Call-Ins under the RMA for nationally significant energy proposals. MfE work closely with MED and EECA.

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[4] MED’s website contains further detail (www.med.govt.nz/sectors-industries/energy/electricity).
[5] Energy Efficiency and Conservation Act 2000, s 20.
[6] Energy Efficiency and Conservation Act 2000, s 21
[7] MfE’s website contains further detail (hwww.mfe.govt.nz).

2.11 Regional and District Councils

In New Zealand environmental management is devolved to local councils. Regional Policy Statements and Regional Plans of regional councils set out the policy framework for the sustainable use of natural and physical resources. District plans produced by district and city council provide the policy framework for amenity issues.

All electricity producers are required to obtain consents from the relevant local authorities for their activities. For any take, use or discharge of natural resources or the discharge of contaminants, a resource consent is needed from the relevant regional council. Consents are also needed from the relevant district council for land use, noise effects and other amenity issues.

3. Meeting demand and the renewable electricity generation target

3.1. Background

A reliable and robust electricity system providing electricity at affordable prices is vital for New Zealand businesses and consumers and therefore for New Zealand economy wide. To provide the electricity New Zealand needs to maintain society's current standard of living, the electricity system is required to meet both current demand (when, and at the levels, that it occurs), and to also meet growing future demand. Any supply disruption results in high costs across society and the economy. Over the long term, New Zealand's electricity demand is forecast to grow. Demand has been growing at an average rate of 1.6% per annum. Recently growth has slowed but is assumed to pick up again shortly and average 1.2% per annum out to 2030[8]. Despite improvements in ~~how~~ the use of energy ~~is used~~, new electricity generation will be required.

The Ministry of Economic Development (MED) regularly carries out modelling of New Zealand's energy supply and demand, and its Energy Outlook is available online.[9] 2010 Energy Outlook demand growth projections consider a range of demand growth rates with the Reference Scenario (which uses an assumption of business as usual continuing in terms of broad trends in key economic drivers, policy settings, and technology and fuel choices~~.~~) being based on 1.4% demand growth per annum. New electricity supply will need to be developed to meet ongoing demand growth whether New Zealand's demand grows at a low or high rate. In addition to meeting future demand growth new generation will be required to replace existing power stations as they retire. For example, Huntly Power Station is expected to be phased out over time, with 2 units forecast to be retired in the near term.

The Government's renewable electricity target is that 90% of electricity be generated from renewable sources by 2025 (based on an average hydrological year[10]) providing this does not affect security of supply. The target is contained within the New Zealand Energy Strategy 2011- 2021.[11]

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[8] Ministry of Economic Development – *New Zealand's Energy Outlook 2011 Reference Scenario* p.6
[9] www.med.govt.nz/templates/StandardSummary____36.aspx
[10] This is included because generation from hydro is variable from year to year depending on the amount, timing, and location of rainfall in New Zealand.
[11] The New Zealand Energy Strategy 2011-2021: Developing our Energy Potential p 6.

The target wording is silent on whether this is on a gross or net basis, though net generation has the stations own loads subtracted from the gross generation. The prime government document for recording annual electricity generation is MED's Energy Data File[12]. Table G.2a of that report, which shows the percentage of renewable electricity generation in the total mix, is based on net generation i.e. after subtraction of the power stations' own consumption and losses.

A greater increase in renewable electricity generation is required in order to meet the target while maintaining security of supply. The target was set following the consideration of modelling carried out by EECA, MED, and the Electricity Commission in 2007, indicating that it is challenging but achievable. It used a model that predicts the commissioning of new electricity generation plants based on expected generation costs and electricity and fuel prices.[13] The modelling showed that there are sufficient quantities of new renewable energy resources available in New Zealand to meet the target without incurring substantial costs or eroding security of supply.

3.2. Path to 2025

Figure 2 below shows the percentage of electricity generation by fuel source between 2000 and 2010.[14] This shows that the percentage of electricity generation that is renewable is variable from year to year largely because of different levels of hydro generation, but has typically been between 65% and 75%, with the balance consisting of fossil fuelled thermal generation (gas and coal). Most of the renewable generation comes from hydro ~~and geothermal~~, with increasing amounts from geothermal and wind.

[12] Ministry of Economic Development – *New Zealand Energy Data File*

[13] Modelling was carried out by EECA, MED and the Electricity Commission, and is available online at www.med.govt.nz/upload/52211/The-implications-of-higher-proportions-of-renewable-electricity-by-2030.PDF.

[14] The underlying data and further information is available from the Ministry of Economic Development, www.med.govt.nz/templates/ContentTopicSummary____21417.aspx. Data for 2010 is provisional.

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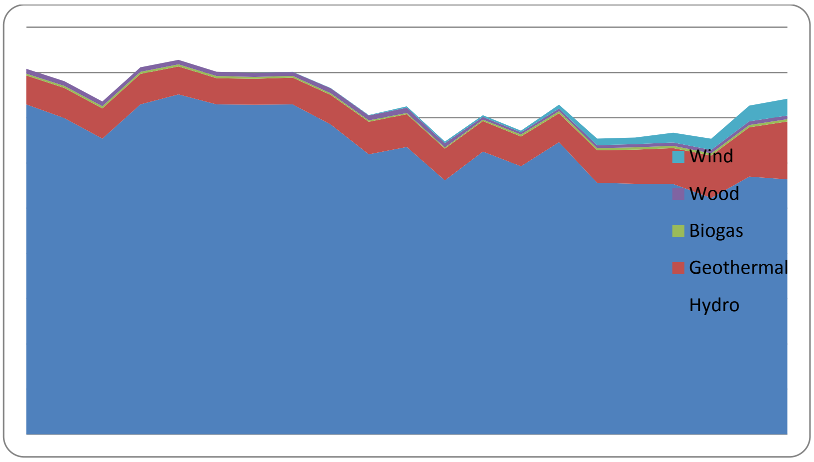
Figure 2 Renewable eElectricity generation sources 1990 – 2010 (% of national net GWwh)



There will need to be a significant increase in renewable electricity generation to meet the 90% renewable electricity target covering both new demand and retired fossil fuel generation. The amount varies depending on differing predicted demand growth rates but if the growth rate averages at 1.6% per annum based on historical rates, approximately an additional 15,000 to 16,000 GWh per annum renewable electricity generation will be required in 2025. This represents an increase over the 2010 renewable electricity proportion of 56%. ~~This equates to about 3,400 MW of new capacity and is equivalent to approximately 25 wind farms the size of Wellington's West Wind wind farm, or 5 hydro schemes the size of Manapouri.~~

At this point it is worth considering load factors for varying forms of generation. The load factor in its simplest form is the ratio of generation achieved in a year over the theoretical maximum based on the capacity of the plant. As examples, hydro load factors will be restricted because through certain times of the year station operators will be trying to improve storage for anticipated low inflow and high demand periods, while wind farms may have generation restricted by low wind flows (or high wind flows which require the blades to be locked). Combinations of thermal plant and hydro are used to follow load so this means that the load factors of thermal stations is also restricted. As a rule, plants with the highest load factors in New Zealand's network include gas-fired combined cycle plants (which operate on take-or-pay gas supply agreements) and geothermal plant (which generally operate on a base load basis unless restricted by resource constraints). As examples wind load factors can be around 45% in New Zealand (exceptionally high by World standards) but geothermal load factors can be around 95%.

Comment [BW8]: Rather than invent a simplistic scenario, it would probably be better to extract information from an Energy Outlook scenario which would also include retirement of Huntly units

Comment [BW9]: It is not reasonable to equate GWh to a MW capacity as that is a function of load factor.

An increase across all renewable sources of electricity generation, (hydro, wind, and geothermal and possible alternatives), is needed to meet the target.

4. Renewable electricity generation technologies

New Zealand has significant existing renewable electricity generation and many opportunities for more electricity generation from renewable resources, which can be summarised as:

- Hydro
- Geothermal
- Wind
- Biomass
- Solar
- Marine (wave, tidal, and ocean currents)

Renewable electricity generation exists in New Zealand in a wide range of sizes from micro-generation to large scale generation. The generator can provide the electricity direct to a user, to the distribution network, or the national grid.

The nature and indicative extent of the current renewable energy potential can be derived from sources such as EECA's regional renewable energy assessments[15] and the NIWA EnergyScape™ maps[16].

Further detail of each type of renewable electricity generation is given in the sections below.

4.1. Hydro

New Zealand's geography is well suited to hydro electricity generation. Hydroelectricity has been the backbone of New Zealand's electricity supply system for decades, and hydroelectric dams are a well-known feature of the New Zealand landscape. Hydroelectric generation facilities currently supply approximately 60% of New Zealand's electricity depending on the quantity and timing of rainfall. Hydroelectricity is a flexible form of renewable energy, and in some cases water may be stored and used weeks later (rather than needing to be consumed immediately, as in the case of solar and wind generation). This makes it well suited to provide electricity on the national reserve electricity market (to generate power quickly in the case of system disruptions caused by the connection of large loads, or the sudden disconnection of another generator).

[15] www.eeca.govt.nz/central-and-local-government/local-government/renewable-energy-planning-resources
[16] www.niwa.co.nz/sites/default/files/imported/__data/assets/pdf_file/0010/96733/Summary-of-resource-maps_H2.pdf#EnergyScape%20summary%20of%20maps

Water is typically stored by means of a lake or dam, and when released, flows through a dedicated pipe (a “penstock”), and turns a turbine. The turbine is attached to a generator, which generates electricity. The amount of energy available through a hydroelectricity scheme primarily depends on two factors:

1) The height of the water above the turbine (the head)
2) The amount of water passing through the turbine (the volume)

Different types of hydro technology and their uses

Comment [BW10]: Should probably mention pumped storage though it is not a feature of the New Zealand environment yet.

Hydroelectricity schemes are readily adaptable to all scales (from farm-scale in kW to large multi MW schemes), and do not necessarily require dams, or complex penstocks. Typically schemes can be described by the water flow, being *run-of-river*, meaning the hydro scheme maintains a close to normal water flow, compared to *storage* schemes that store water at the top of the scheme to be used when electricity is required. *Out-of-river* is where water is taken from one watercourse and returned to another watercourse via a series of pipes. Run-of-river schemes may be dammed to force water to take a particular path, or alternatively a fast-flowing natural path may already be formed by a river. In the latter case, an “in-flow” turbine system may be placed in the river. While these are the most common interpretations of the terminology, there is some discrepancy in different terminologies used in the industry. In particular, *run-of-river* is sometimes used to describe schemes that stay within their natural course, not diverting to other waterways.

New Zealand has a wealth of hydro generation opportunities, but very little storage hydro. This means that the amount of generation available month to month is highly dependant on rainfall in key catchment areas. Hydro storage therefore needs careful management in maintaining security of supply. During a dry period, dam levels may be low, and the available water may be required to preserve the aquatic ecosystems. Additionally, in winter, when power consumption is often greatest, some of the water is locked away as snow on mountain tops, and cannot be used until the spring thaw. This problem is avoided through a diverse mix of energy sources. For example, using geothermal electricity generation which is very consistent, and wind energy where it is not correlated with hydro variability. In addition, hydro schemes in different regions may not experience dry years at the same time.

Hydro operational and maintenance considerations

The key operational and maintenance considerations for hydro schemes are that:

- The penstock must be kept clear of debris, the impeller clear of algae, and artificial dams must be de-silted. This may involve taking the turbine out of service so that the penstock and impeller may be cleaned, and dredged. The silt trap at the dam inlet should be drained and the silt extracted with excavating machinery and shovels.
- Water quality should be monitored as per the project approval conditions. Small schemes may not require monitoring if there is a reasonable expectation that there will be no effect on flow volume or water quality.

Further information on hydro energy

- EECA (www.eeca.govt.nz/efficient-and-renewable-energy/renewable-energy/hydro-energy)

4.2. Geothermal

Geothermal power is a significant contributor to New Zealand's electricity supply. Geothermal energy is the energy stored in the form of heat beneath the Earth's surface. It is a renewable energy source, delivering heat and power 24 hours a day year-round (providing baseload electricity generation or other heating requirements). New Zealand has limited locations appropriate for commercial geothermal electricity development, ~~and~~but significant high temperature resources are ~~concentrated around~~found in the Taupo Volcanic Zone with an outlier at Ngawha in Northland. These are premium resources by world standards due to their temperature and permeability at accessible depths. In many cases existing land uses are compatible with geothermal development.

The three essential ingredients for a geothermal system are heat, permeability in the rock and a heat transfer medium (almost always water).

There are three primary sources of heat for geothermal systems. One source is simple conduction through the Earth's crust from the magmatic core. New Zealand's oil and gas wells encounter a thermal gradient of about 30^{o}C increase for every kilometre of depth drilled. A second source of heat is through the decay of radioactive elements within crustal rocks. Development of such resources requires fracturing of the hot impermeable rock and setting up a network of production and injection wells circulating introduced water. Alternatively, permeable aquifers above these higher temperature rocks can be developed. There are demonstration systems using these techniques in other parts of the world, and New Zealand

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may have some settings that would be attractive by world standards though would not be commercial for pure electricity generation.

The other physical process that generates heat is deformation of the crust adjacent to tectonic plate boundaries, particularly subduction boundaries. A subduction boundary crosses the North Island and has resulted in the generation of sufficient heat to produce volcanism along a line roughly from Mount Ruapehu to White Island, referred to as the Taupo Volcanic Zone. Because of the association with tectonic plates, this Zone is fractured allowing rain water to percolate to great depth, becoming heated and rising to the surface again in large convection cells. Areas where the hot water reaches the surface are geothermal resources which could be developed. New Zealand's geothermal electricity developments have been based on this type of resource, although the source of heat for Ngawha which lies at the top of the North Island is uncertain.

Temperatures in these geothermal fields can exceed 300^{o}C, but despite these temperatures the fluid in the deep reservoirs is usually in a liquid state because of the great pressures from the water column and sometimes from the rock itself which suppress boiling. The heat is accessed by drilling into the reservoir. If the well intersects a permeable part of the reservoir then water will flow up the well and will start to flash off steam as the pressure decreases as the fluid rises.

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The water contains minerals sourced from the rocks and gasses (some with magmatic origins). The water will often have high concentrations of salts (hence it is known as a brine), will have silica and will have other natural trace elements such as arsenic, boron and mercury which must be suitably managed. The magmatic gasses include carbon dioxide and traces of methane but in concentrations substantially less than would be found from the combustion of fossil fuels in a thermal power station. Hydrogen sulphide is also emitted and this can have an offensive odour at some concentrations and can have health implications at higher concentrations.

The geothermal fields are frequently characterised by natural discharges of fluids and gasses. Thus discharges from a geothermal development may be to an environment influenced by the nearby geothermal field. Hydrogen sulphide odours may already be present. Surface waters may already be unacceptable for irrigation. Surface activity can include springs and in rare cases, geysers which can be a tourist attraction or can have special significance for local residence and Maori. Extracting geothermal fluid from wells reduces deep pressures and thus can modify surface activity.

At the surface, usual practice is to separate the steam and brine phases discharging from wells. Either or both phases can be used for electricity generation. The fluid is piped to a power station where either steam is used directly in a steam turbine or either phase can be passed through a heat exchanger so a secondary fluid can be vapourised and run through a gas turbine. For efficient power generation the power station is based on what is known as a Rankine cycle which includes a turbine, a condenser, pumps and a working fluid cooler (cooling tower or fin fan condenser). In the cases where a secondary organic fluid such as pentane is heated by the geothermal fluid the plant design is known as an organic Rankine cycle (or more commonly as a binary cycle plant). To avoid the heat exchangers or condensers being gas-locked, the geothermal gasses are extracted and vented above the cooling tower for adequate dispersion. If a steam cycle is used, a significant portion of the condensed steam (condensate) can be evaporated from the cooling tower.

Usual practice is then to collect brine and surplus condensate and reinject this into the ground. This avoids disposal of potentially toxic fluids at the surface and can help in the managing of reservoir pressures and can also be used for targeted purposes such as managing the response of known subsidence bowls or preserving pressures in reservoirs that supply important springs. Alternative strategies include injection back into the field or outside the field. In some cases it may be acceptable to dispose at the surface but the developer will have to put a case for a sustainable fluid collection and disposal strategy.~~Geothermal activity often occurs at thin points of the earth's crust. Heat is used to create steam or binary fluid vapour, which then turns a turbine. The heat is brought to the turbine on the surface by pipes. The water may be injected, in the case of dry rock systems, or drawn directly from hot underground aquifers. The water usually contains naturally-occurring dissolved pollutant gasses; however geothermal power is still substantially less emissions-intensive than fossil fuels.~~

Comment [BW11]: Pollutant is an inappropriate term for a naturally occurring substance.

Geothermal power developments have a high capital cost as a result of the drilling necessary, typically to 1.5 to 3 km depth, and of the fluid collection and disposal system linked to a turbine operating at relatively low pressure. The high capital cost coupled with relatively low rewards from electricity sales drives investors to maximise returns through baseload operations over long operating lives i.e. they are incentivised financially towards steady sustainable development.

Geothermal heat resources have accrued over geological periods of time, whereas geothermal station designs and steamfield plans can be based on 25 to 50 year operation. Heat is mined through this period, though not to exhaustion – rather so that the station may still operate at near full load at the end of this period. A particular resource will take centuries to recover to temperature levels that existed when it was first tapped, so recovery is slower than for other renewables. While each geothermal development can be designed for short term sustainability, long term sustainability of the collective geothermal resource is ensured through the protection of specific geothermal fields nationally.

Geothermal fields are only a renewable and it will be necessary for the developer to show how their proposed development is sustainable.sustainable energy source if they are well managed. Even though geothermal power is sustainable, extraction should not exceed the natural rate of underground heat generation, and water should not be permanently removed from underground, otherwise local temperatures may be lowered, and adjacent geyser systems may be depleted. In the long-term, excessive extraction of water and heat from a geothermal resource will result in its depletion and reduced power output. The warm exhaust geothermal fluids drawn from the ground are often pumped back underground to minimise the heat drawn from the system. Any development will involve perturbation of the reservoir. Pressures and temperatures will alter. Certain areas of the field will be identified by the developer for production while other areas may be designated for reinjection of fluids, with some flexibility built into the plans so that an adaptive approach can be taken to field management to rapidly respond to changing conditions and to account for uncertainties associated with the reservoir. Sound management of the field will be based on coordinated strategies across the whole resource, and based on good monitoring and modelling information. Eventually a field may be rested, after which recovery of pressures and eventually temperatures will be a function of the total fluid withdrawn and the natural rate of fluid recharge into the reservoir.

Comment [BW12]: Restricting extraction to the natural recharge rate is overly restrictive and is unlikely to be economic in any situation. We are unaware of any power stations operating in the world that work to this restriction. Waikato Regional Council policy recognises that large-scale geothermal extraction mines heat and instead focuses on controlled depletion that enables both current and future generations to have access to the geothermal energy of a particular geothermal system.

Comment [BW13]: In the NZ situation, geothermal systems supporting geyser fields are protected from large-scale extraction. Large-scale development can only occur on those systems designated for development because, among other criteria, there are no geysers on them. Therefor it is unnecessary to describe the effect of electricity generation on geyser fields in the NZ context.

Matters to consider for sustainable use of the resource include:

- The level of certainty of scientific information on the particular system;
- The size of the geothermal energy resource compared with the proposed development;
- The rate at which the energy within the geothermal system is proposed to be extracted, and the timeframe over which any proposed rate of take of geothermal energy is predicted to be able to be sustained;
- The overall management of the geothermal resource, including the depth and locations of the proposed take and return of geothermal fluid, and the impacts of such management on the longevity of the resource; and
- Once extractive use has commenced, how closely observed effects match the modelled or predicted effects, by review of pressure, temperature, chemistry, surface water flow or level, subsidence and vegetation monitoring.

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Different types of geothermal technology and their uses

High temperature geothermal systems can be used for generation and/or, and the waste heat energy from the exhaust steam may also be used for for primary production and industrial direct heat usesdirect heating and binary fluid cogeneration. Where chemistry allows[17], it is possible to have various uses in a cascade arrangement, progressively extracting more heat.

High temperature electricity generation is usually based on:

- A back pressure steam turbine (e.g. at the Kawerau mill where steam passes through a back pressure turbine before being used for mill process steam supplies),
- A condensing steam turbine (e.g. at Ohaaki or Nga Awa Purua where a vacuum is created at the back end of the turbine by a condenser, and for which the cooling water for the condenser is sourced from the condensed steam itself recirculated through cooling towers),
- A binary cycle plant (e.g. at Ngawha or Te Huka where heat from the geothermal fluids is exchanged with a secondary working fluid such as pentane which flashes to a gas and is then passed through a gas turbine before recirculation), or
- A hybrid system, also called a geothermal combined cycle plant (e.g. Mokai or Rotokawa which uses a combination of a back pressure steam turbine exhausting at just over atmospheric pressure to a heat exchanger for a binary cycle plant that acts as the steam condenser, with other binary cycle plant for the brine.

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In geothermal systems, “low temperature” generally refers to temperatures of 150ºC or less. Low temperature geothermal systems can be used to replace direct heating equipment in domestic and commercial buildings and for primary production and industrial direct heat uses, but can also be used to generate power in binary cycle plantfluid systems[18].

Geothermal operational and maintenance considerations

Examples of the common ongoing requirements for geothermal electricity generation facilities include that:

- Well temperature should be monitored to prevent resource depletionMonitoring and management of reservoir conditions with a view to maintain long term operation of the plant. This involves monitoring well temperatures, pressures and chemistry to understand the deep reservoir and to detect reservoir changes, and monitoring flows to better

[17] The concern is chiefly around silica which can start to deposit in pipelines and wells if the brine becomes too cool for the concentration of silica present.

[18] Binary fluid cycle systems are where the geothermal temperature is not sufficient to created steam, so the heat is transferred from the hot water totake advantage of a fluid with a low evaporation point which will evaporate and drive the turbine instead.

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understand the cause of changes and to assess the effects of changed strategy. A numerical reservoir model will be developed and refined to assist long term modelling of operational scenarios and their effects.

- Groundwater and air quality should be monitored to detect signs that the geothermal well may have spread or fractured undergroundMonitoring and management (through avoiding, remedying or mitigating) of sensitive environmental issues such as air quality, noise, ground water quality and availability, subsidence, and sensitive vegetation and surface feature changes.
- Minimising the risk of hydrothermal eruptions especially in built environments.
- The pPipes and vessels containing and conveying the steam and brine are pressure vessels, which require regular inspection and maintenance to ensure longevity and to comply with regulations should be inspected regularly for corrosion and cracking caused by heat stresses and harsh environments. De-scaling (removal of solid deposits) will also be necessary; however the frequency depends on the purity of the water/steam.
- Some equipment, such as valves and pumps, requires regular repair or replacement to compensate for corrosion and erosion.
- Scaling in wells and pipelines may be a problem in some fields. In some cases it can be avoided by using antiscalants, in other cases it may need to be removed regularly.
- Plant will be shut down for routine inspection and maintenance every few years.
- Some redundancy and flexibility in plant design will enable routine maintenance on an ongoing basis without interrupting plant operation
- New wells may will be required if the availability or quality of geothermal fluid declinesthrough the life of a development to compensate for changing conditions in the reservoir and to take account of changing production and reinjection strategies over time.
- Note that geothermal environments are often naturally high in hydrogen sulphide concentration. In extreme unmanaged situations this can present a health danger, but on a routine basis involves protection of electrical and electronic components from corrosion.
- While fluid collection and disposal systems can be spread over several kilometres of adjacent land to the power station, appropriate design can allow multiple land functions. Thus steamfields can be located in farmland or surrounded by forestry, and pipes can run through industrial or residential areas.
- There may be competing developers on a field, in which case joint management meetings will be required to ensure operations and their effects are within the bounds of the overall field management plan.

Further information on geothermal energy

- EECA (www.eeca.govt.nz/efficient-and-renewable-energy/renewable-energy/geothermal-energy)
- The New Zealand Geothermal Association (www.nzgeothermal.org.nz)

4.3. Wind

Wind is moving air created by the sun heating various parts of the earth's surface to different temperatures, combined with the rotation of the earth, creating large areas of differing air density and pressure.

The principle of producing electricity from wind generation is using the moving air to turn rotor blades of the wind turbine that in turn is connected to an electricity generator. The amount of energy generated by a turbine depends on the size of the turbine, the minimum, average and maximum wind speeds, and quality of the wind (smooth, fast flowing air is better than slow, turbulent air). For example, a single 1 MW turbine operating at a 45% capacity factor will generate about 3.9 million kWh of electricity in a year.

The amount of electricity that can be generated is determined by the wind speed at the site. The key factor affecting the economics of a wind energy facility is the speed of the wind in and around it. The relationship between the wind speed and the energy contained within it is not linear. Generally, a 10 per cent increase in wind speed will lead to a 20 per cent increase in power output.

Wind speeds increase with distance above ground level. In addition, power output rises dramatically with rotor diameter. Increases in tower height expose the rotor to faster and less turbulent wind and also allow for proportionally larger rotors. These factors combine to increase the amount of wind energy harnessed.

A wind farm is comprised of one or more wind turbine generators (wind turbines).The infrastructure associated with a wind energy facility will usually comprise wind turbines, an electrical substation and control building, electrical cabling between turbines, a construction compound (temporary), road access and on site tracks and crane hard stands. Some wind facilities will also have anemometer masts to measure wind speeds.

New Zealand has an excellent wind resource in terms of both quality and extent. This is because of New Zealand's latitude amidst the prevailing "roaring forties" westerly winds. New Zealand's long coastline and elevated inland topography provide consistent and relatively strong winds during most of the year. Wind speeds vary around the country but there is significant potential resource at around 8 to 10 metres per second which is within the range of wind speeds required for economic wind farms. On a regional basis there is a clear concentration of very high quality wind resource in the lower North Island (Hawkes Bay, Manawatu and Wellington) and Canterbury, Otago and Southland. However, other regions such as from coastal Waikato northwards have a very good wind resource as well.

Because of the variable nature of wind, wind farms produce electricity intermittently and the timing of which cannot be controlled or planned. This issue is offset by taking full advantage of the flexibility provided by New Zealand's hydro generation resources. New Zealand is fortunate because it has a large proportion of hydro electricity generation with storage which is controllable and can be used to provide generation flexibly to respond quickly to wind energy intermittency. without incurring large operating costs. Hydro is therefore an ideal partner for wind generation. Wind is also able to complement hydro; during periods of high wind generation output, hydro inflows can be stored for later use.

Wind variability can also be minimised by encouraging the development of geographically and technologically diverse renewable generation. With wind generation spread through out the country the effect of the wind not blowing in one location is reduced.

The introduction of new technologies and practices, most notably improved wind forecasting, smart meters and electric vehicles will also assist.

While characterised as a variable over short time scales - minutes and hours - over longer time scales – seasons and years – wind is a comparatively reliable natural resource.

It is estimated that wind energy generation could make up to 20% of New Zealand's electricity system, a substantial increase on the current (2010) 4 %.

Different types of wind technology and their uses

Three-blade horizontal axis wind turbines (HAWTs) are generally found in commercial installations, and are the most commonly used type of wind turbine. Smaller, two bladed turbines are also operating in New Zealand. As the wind passes through the turbine, it loses energy (as it is turned into electrical energy) and flows more slowly. Because of this disruption, HAWTs must generally be sparsely spaced so as not to cast wind shadows on other turbines. Vertical axis wind turbines (VAWTs) can have some advantages for very small scale generation.

Wind farm operational and maintenance considerations

Wind turbines are physically large, and subject to a great deal of mechanical stress in outdoor conditions. Roads that are suitable for crane access are necessary to construct the turbines, and must be available post-construction for access to perform routine and emergency maintenance.

Further information on wind energy

- EECA (www.eeca.govt.nz/efficient-and-renewable-energy/renewable-energy/wind-energy-in-nz)
- The New Zealand Wind Energy Association (www.windenergy.org.nz/)
- NIWA (www.niwa.co.nz/news-and-publications/publications/all/wa/13-4/wind).

4.4. Biomass

Biomass is the common name for organic materials used as renewable energy sources such as wood, crops, and organic waste (e.g. wood waste, crop harvest waste). Much waste biomass is available through household rubbish, forestry, agriculture, and other industries dealing in organic matter.

Burning biomass releases carbon dioxide when combusted, but is similar to the natural carbon cycle (compared with fossil fuels, which have been removed from the carbon cycle for millennia) because carbon dioxide is absorbed by plants as they grow.

Biomass may be used in solid form or converted to liquid (biofuel) or gas (biogas) for use in electricity generation. Solid biomass (such as wood) can be burnt with the heat used directly in industrial plant or to heat water to generate steam for a turbine to produce electricity (or both). Biofuels such as biodiesel and bioethanol are more commonly used for transport rather than electricity generation, although they can be used to replace equivalent fossil fuels in thermal generation.

Biogas is produced by decomposition of living material in oxygen starved conditions (such as landfills and at waste treatment plants) and may be burnt directly or in a gas engine to produce electricity.

Different types of biomass technology and their uses

Due to the specialised nature of the combustion furnaces (sloping grate or fluidised bed furnaces) and pressurised boiler systems required to generate electricity (as opposed to just direct heat), electricity generation opportunities are generally found with food or forestry processing plants, where waste husks and bark are available.

With adaptation of furnaces and boilers, it is generally possible to co-fire biomass with coal. This can present an opportunity to make use of waste organic matter, and reduce the amount of coal burned.

Beyond burning plant matter, many other opportunities exist to harness biomass by-products, including biodiesel, waste water treatment plants, solid waste, hydrogen, and landfill gas, all of which may be used to generate electricity or burned for direct heat.

Further information on biomass energy

- EECA (www.eeca.govt.nz/efficient-and-renewable-energy/renewable-energy/bioenergy)
- Bioenergy Association of New Zealand (www.bioenergy.org.nz)

4.5. Solar

Solar energy is the radiant energy of the sun that can be converted into other forms of energy, such as heat or electricity.

There are two main ways in which solar energy is converted to electricity. It can be converted directly via photovoltaic panels and indirectly whereby solar energy is concentrated to create heat which is used to generate steam which is passed through a steam turbine. In New Zealand, only photovoltaic panels are useful due to the relatively low ambient temperature and sunlight characteristics. There are different kinds of solar cells and two are currently commercially available in New Zealand: thin film and crystalline silicon cells Crystalline cells are smaller and more efficient than thin cells and are commonly used in most industrial, commercial, and domestic generating situations. A single panel consists of many cells placed adjacent to one another, mounted in a frame. An array comprises many panels.

When sunlight strikes the silicon on photovoltaic panels, electrons in the silicon atoms are liberated to move (conduct) through the semiconductor. Not all sunlight is converted into useful electricity; low energy light (in the infrared spectrum) may not have enough energy to liberate the electrons from the silicon atoms, whereas high energy ultra-violet light has more energy than the amount required to liberate the electron, and so the excess is converted to heat. Because of this unused energy, solar cells are generally around 15% efficient in New Zealand. Photovoltaic systems range in size from large scale power stations, to building roof-tops and stand-alone devices.

Solar array operational and maintenance requirements

Solar arrays:

- Are often mounted to building roofs, which entail their own access hazards
- Create no noise and have no moving parts and few maintenance requirements beyond cleaning
- Do not require highly-skilled trades people to install

- Are available in "off the shelf" configurations, easily sourced by the general public
- Lose efficiency over their life, declining at a rate of about 10% per decade, and manufacturers typically quote a lifespan of around 25 years. However, they are easily removed and replaced.

Further information on solar energy

- EECA (www.eeca.govt.nz/efficient-and-renewable-energy/renewable-energy/solar-energy-in-nz)
- Solar Association of New Zealand (www.solarindustries.org.nz)

4.6. Marine

Marine energy involves using the kinetic power of water in the sea to generate electricity. Marine resources for electricity generation can be divided into wave, tidal and ocean current resources.

Tidal and Ocean Current

The energy from the tides comes from drawing water through estuaries in the earth-moon gravitational field. Several types of tidal turbine design exist, such as *Tidal Stream Turbines* (like an underwater wind turbine, turned as water flows by), *Tidal Barrage* (which extends across the narrow mouth of a bay), and *Dynamic Tidal Power Barrier* (an underwater barrier extending off the coast of sufficient size to cause a head on one side of the barrier, which may then be drawn through penstocks and turbines to the other side of the barrier).

Although not yet widely used[19], tidal power using tidal stream turbines has potential for future electrical generation due to a large number of sites around New Zealand coast where narrow passages and straights between islands and mainland can produce very high tidal flows. The greatest constraints that have prevented wide adoption to date are the relatively high cost of the infrastructure compared to other renewable energy generation opportunities, and a lack of suitable sites with high tidal ranges if using the barrage and barrier type technologies. Tidal stream turbines do not require the same amount of infrastructure as tidal barrier and barrage type installations, but are a young technology.

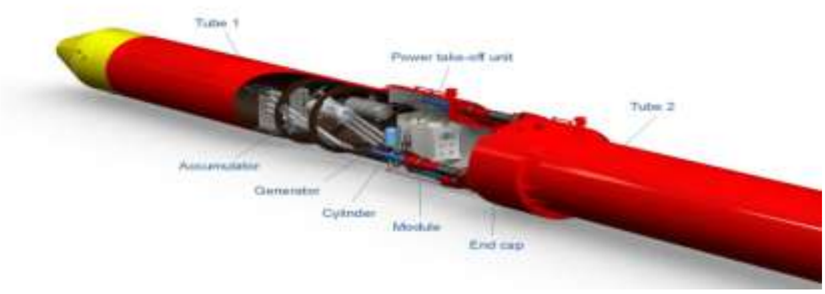
Ocean current electricity generation facilities operate in a similar fashion to tidal electricity generation as described above, although tidal is more likely to be feasible in the near term.

[19] At the time of writing, no marine electricity generation is operating in New Zealand.

Wave

Despite the infancy of the technology, there is a very wide variety of proposed wave electricity generation designs, which use different methods to harness the energy contained in the movement of water known as waves. One of the early examples of a wave electricity generation facility is the Scottish Pelamis, shown in Figure 3.

Figure ~~2~~ 3 Pelamis wave electricity generation facility (Source: Pelamis Wave Power)



Tidal stream turbines have generally seen the greatest implementation internationally. Tidal barrages alter the estuary ecosystem similar to a dam, and dynamic tidal power barriers are conceptual; economic scale dynamic tidal barriers are estimated to be around 30km long.

Operational and maintenance requirements for marine electricity generation

Requirements for marine electricity generation assets vary greatly because of the variety in types and designs of the technology. Operation of the marine electricity generation is likely to be fairly straightforward given that their effects are likely to be low. However, consideration of storms is necessary, particularly for wave electricity generation. Maintenance is typically more difficult than many other forms of electricity generation because it is underwater; however, so are some hydro generation assets that have been safely maintained and operated for many years. Some designs, as mentioned above, can be raised above sea level to ensure safe and easy maintenance. The maintenance would generally require the use of ships and/or submersibles, which could require a new wharf facility in the area.

Further information on marine energy

- EECA (www.eeca.govt.nz/efficient-and-renewable-energy/renewable-energy/marine-energy)
- Aotearoa Wave and Tidal Energy Association (www.awatea.org.nz).

Renewable Electricity Generation National Policy Statement – Information on Policies

5. Policy A: Benefits of Renewables

A. Recognising the benefits of renewable electricity generation activities

POLICY A

Decision-makers shall recognise and provide for the national significance of renewable electricity generation activities, including the national, regional and local benefits relevant to renewable electricity generation activities. These benefits include, but are not limited to:

a) maintaining or increasing electricity generation capacity while avoiding, reducing or displacing greenhouse gas emissions;

b) maintaining or increasing security of electricity supply at local, regional and national levels by diversifying the type and/ or location of electricity generation;

c) using renewable natural resources rather than finite resources;

the reversibility of the adverse effects on the environment of some renewable electricity generation technologies;

d) avoiding reliance on imported fuels for the purposes of generating electricity.

Policy A requires a broad understanding of the nature, extent and location of relevant developed and undeveloped renewable resources and the associated national, regional and local benefits. The nature and extent of the current renewable energy potential can be derived from sources such as EECA's regional renewable energy assessments[20], and the NIWA EnergyScape™ maps[21] and from consultation with generators. The associated benefits can occur on a local, regional and national scale.

[20] www.eeca.govt.nz/central-and-local-government/local-government/renewable-energy-planning-resources

[21] www.niwa.co.nz/sites/default/files/imported/__data/assets/pdf_file/0010/96733/Summary-of-resource-maps_H2.pdf#EnergyScape%20summary%20of%20maps

Maintaining or increasing electricity generation capacity while avoiding, reducing or displacing greenhouse gas emissions

One of the principal contributors to climate change is greenhouse gas emissions generated from human activities, such as the burning of fossil fuels for electricity generation. Renewable electricity generation contributes towards meeting electricity demand without emitting greenhouse gases (other than the small amount emitted during construction or fugitive greenhouse gas emissions associated with geothermal generation facilities).

The operation of gas and coal generation emits 0.37 kt and 0.93 kt CO_2e per MW hour of electricity respectively, and geothermal varies from field to field but on average has much lower CO_2e emissions[22]. Whereas the operation of hydro and wind powered generation has zero emissions. This means that renewable energy is well placed to allow for increased electricity generation while avoiding or reducing greenhouse gas emissions. Renewable electricity generation therefore has the potential to make a contribution to the achievement of New Zealand's national and international climate change commitments[23]:

- New Zealand is a signatory to the Kyoto Protocol, which came into force on 16 February 2005. The protocol is the principal international response to climate change. Under the protocol, New Zealand is responsible for reducing its greenhouse gas emissions to 1990 levels by 2012 or otherwise take responsibility for any surplus emissions. New Zealand is actively participating in international climate change negotiations to assist in the development of a global, legally-binding and comprehensive agreement on climate change to replace the Kyoto Protocol. A new agreement is expected to be produced by 2020.

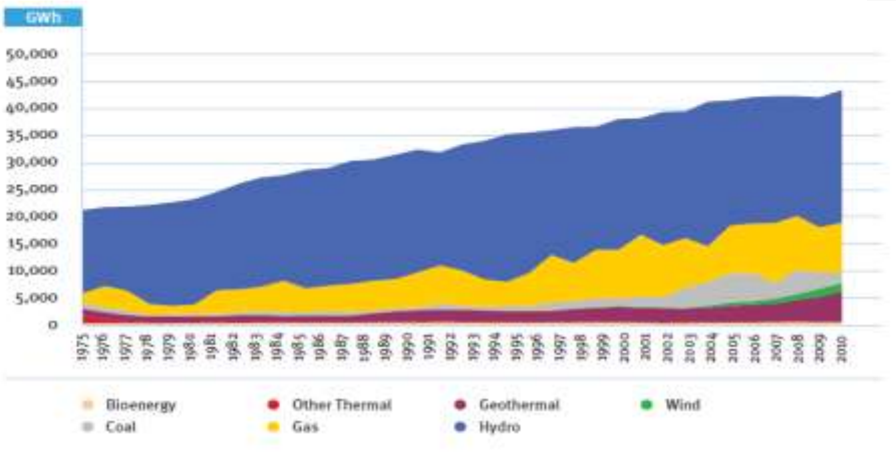
- New Zealand's national climate change target is for a 50% reduction in New Zealand's greenhouse gas emissions from 1990 levels by 2050.

~~In~~ By 2009, New Zealand's total greenhouse gas emissions had increased by 19% above 1990 levels[24]. Electricity related emissions had increased by 72% above electricity emissions in 1990[25] . The increase is due to electricity generation capacity in the last ten years being

[22] Concept Consulting - Climate Change Office 2003 – *An Electricity Emission Factor* - p.2
[23] www.mfe.govt.nz/issues/climate/policies-initiatives/index.html and www.mfe.govt.nz/issues/climate/international/index.html
[24] Ministry for the Environment, New Zealand's Greenhouse Gas Inventory 1990–2009, page 25, (15 April 2011) www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-2011/greehouse-gas-inventory-2011.pdf
[25] Ministry for the Environment, New Zealand's Greenhouse Gas Inventory 1990–2009, pages 33

predominantly made up by additional fossil fuel based thermal generation (coal and gas), shown in Figure 4.

Figure 4 Electricity generation in New Zealand by fuel type, 1975-2010



Maintaining or increasing security of electricity supply at local, regional and national levels by diversifying the type and/or location of electricity generation

Security of Supply

Security of electricity supply has several elements to it and is fundamentally the ability of the electricity system to meet the demands of electricity consumers, meeting both current demand (as it varies throughout the day and the year), and meeting growing future demand. Security of supply requires sufficient generation capacity and fuel to meet demand. The nature of electricity means that, once generated, it cannot be stored within the power system for any material time. Electricity must therefore be generated on demand and coordinated on a moment to moment basis to maintain supply to consumers.

Renewable electricity generation can improve the security of New Zealand's electricity supply by achieving the following:

- Increased generation capacity i.e. maintaining sufficient levels of generation capacity and fuel to meet existing and future demand

- Diversified type and location of electricity supply i.e. having a variety of generation capacity and type that contributes to a robust and resilient electricity system
- Increased reliability and affordability of supply i.e. having a consistent supply of electricity that can be relied upon while reducing exposure to international fuel costs.

Meeting Demand

Security of electricity supply is of significant importance at all geographical scales. At a local level, security of supply is vital for the functioning of businesses and households and for people's health and wellbeing. Regionally, it is essential for the operation of industries and core services, while on a national level, key infrastructure and the continued functioning and growth of the economy relies on a constant and reliable supply of electricity.

Over the long term, New Zealand's electricity demand is forecast to continue to grow and new generation will need to be built in order to meet growing demand for electricity and replace retired generation assets. At a regional and local scale, renewable electricity generation can supply electricity to areas that are expected to experience higher demand growth and that are currently net importers of electricity from the transmission grid.

Diversification

Diversity is another important element of maintaining and improving security of electricity supply. The electricity system will be more resilient to sudden and unexpected changes, such as fuel price shocks or natural disasters, if electricity is obtained from a diverse range of generation sources. Each resource type performs a specific role. Wind farms are relatively fast to construct and provide excellent supply in regions where wind is abundant. Wind generation complements existing renewable energy sources, typically allowing hydro resources to be stored during dry periods. Geothermal generation operates at higher load factors compared to hydro and wind generation, providing a reliable and cost effective supply of baseload electricity generation. Hydro storage based generation is a good form of backup - storage can be transmitted immediately when other resources such as wind stops, or can be saved to be used later when demand is high and other forms of generation such as wind are scarce.

Geographic diversity of the electricity system as a whole is also important and adds to the system's resilience. For example, wind generation spread throughout the country reduces the effect of wind intermittency in any one location. Diverse types of renewable energy also improve security of supply at various scales. Hydro and geothermal generation usually serves at a regional scale, while wind farms can be installed relatively close to the source of electricity demand, such as Project West Wind in Wellington. Small scale hydro, ~~and~~ wind and geothermal [26]generation facilities can be installed onsite or very close to the demand source, thereby minimising load on the national grid and reducing transmission losses which are effectively wasted supply.

[26] Refer to the following report for geothermal examples: http://www.nzgeothermal.org.nz/publications/Reports/DistributedEnergyReportFinal23June08.pdf

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Reliability

Renewable electricity generation can add to the reliability of electricity supply. For example, geothermal energy is an ideal baseload source of electricity, while wind and hydro are relatively reliable natural resources over timeframes greater than one month. The inter-annual wind electricity variation is typically 10%, while rainfall variation is approximately 20%. Renewable energy resources are also a relatively reliable economic resource. For example, once a wind farm is built the cost of producing electricity from the wind depends primarily on the average annual wind speed, which is relatively constant from year to year. The cost of electricity produced is not affected by international fuels prices for scarce local fuel resources. This assists in maintaining security of electricity supply.

Using renewable natural resources rather than finite resources

The utilisation of renewable resources such as hydro, wind, tidal, solar, geothermal[27] and biomass does not deplete finite resources. ~~These renewable technologies utilise energy that is free for electricity generation, for example, wind, hydro, solar, and waves are do not deplete when utilised.~~ This means that it could be sustainably used for current and future generations. While geothermal and biomass are renewable sources, they must be carefully managed to ensure that they remain a source in the future.

Comment [BW14]: This is redundant repetition of the first sentence. The conversion of energy to electricity obviously depletes the local energy found in wind, hydro etc but it does not deplete the energy sources.

Conversely, fossil fuels which are used in thermal generation are finite resources. The availability of fossil fuels is declining, and coupled with growing demand globally it increases the risk and expense of sourcing these resources. This impacts on the operating cost of electricity provision if a large portion of New Zealand's electricity generation is dependent on fossil fuels. Although thermal generation typically has a relatively lower "upfront" capital expenditure, in the long run it has a significant higher ongoing expenditure on fuel as well as adverse global environmental effects compared with renewable energy[28]. Because of the offer system for electricity, there is a flowon effect through the whole market. As an example, hydro must be offered into the market at a price that reflects anticipated fossil fuel generation or lakes may be drawn down to levels that do not allow ready availability.

The reversibility of the adverse effects on the environment of some renewable electricity generation technologies

[27] In the case of geothermal energy there can be controlled depletion of a local resource, but this can be restored over periods of decades or centuries because of the effectively infinite source of heat below the affected area, assisted by flow of fluid back into the reservoir and deep convestion.

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[28] Energy Efficiency and Conservation Authority (2009) Renewable Generation and Security of Supply, EECA: Wellington.

Reversibility has been defined as to whether an adverse effect is considered to be reversed to a state where offsite adverse effects are no more than minor[29]. Research shows that adverse environmental effects from hydro-electricity, geothermal[30] and wind technologies are all largely reversible. For example a wind farm can be decommissioned in its entirety with all turbines and other above ground structures being removed and turbine footing removed and turbine footing covered and re-vegetated.

Reversibility is based on the restoration timeframe, costs of removal and restoration, and the level of treatment required. However, there is differing ease in reversing the adverse effects across the different renewable types as shown in Table 1Table 1 below. In general, adverse effects from wind farms are the most easily reversed, followed by geothermal, then from hydro which takes the longest and is the most expensive to restore[31].

Table 1 Typical reversibility of renewable energy developments

	Timeframe for Reversal of Significant Effects	Environmental Risk Following Removal	Typical Decommissioning and Restoration Costs as Proportion of Construction Cost
Onshore Wind Farm	Short	Low	4 - 8%
Geothermal	Short for local visual and amenity effects. (Timeframe for reversal of geothermal steam-field related effects is moderate to long. (Subsidence is not	Low (This has not been required in New Zealand because of the sustainable nature of developments but will be a function of the competence of decommissioning)	5 - 10 20%

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Comment [BW15]: This table lacks substance

Comment [BW16]: Advice from MRP

[29] Oldham, K (2008) Reversibility of Renewable Energy Developments, SPX Consultants: Auckland.
[30] Some aspects of geothermal development are not fully reversible. Subsidence is not reversible, but the permanent lowering of land is generally of minor impact, unless there is a risk of flooding or there are buildings/infrastructure located at the edge of a significant subsidence bowl. Where surface discharges are depleted or cease, while total discharge will be restored, it is not certain that the original features will recover and new geothermal features may develop. Any ecosystem rendered extinct by the cessation of flow will be replaced by new ecosystems, possibly with reduced biodiversity and resilience.
[31] Oldham, K (2008) Reversibility of Renewable Energy Developments, SPX Consultants: Auckland.

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	reversible. Effects on surface features are usually not reversible though features may reappear/ regenerate over decades or centuries.) .)		
Run of River Hydro	Short to Moderate	Low	25 - 50%
Storage Hydro	Moderate	Medium	35 - 150%

Thermal generation often has a lower degree of reversibility in comparison to renewable technology, due to the associated adverse environmental effects and costs. [32]

Avoiding reliance on imported fuels for the purposes of generating electricity.

Renewable energy projects utilise a local renewable energy resource reducing the reliance on imported fossil fuels for the purposes of generating electricity. The cost of electricity produced from renewable electricity generation is not affected by international fuel prices for scarce local fuel resources and so can provide a natural hedge, or insurance, against rising and volatile carbon prices and fossil fuel prices. Fossil fuel generation by comparison has lower 'upfront' capital costs and higher ongoing fuel costs when compared with renewable alternatives. Fossil fuel generation is therefore exposed to variations, inflation and volatility in the price of fossil fuel over time. Reliance on fossil fuels makes thermal generation vulnerable to escalations in fuel prices.

Thermal generation in New Zealand relies on both domestic and imported coal[33], in which case coal prices in New Zealand are to some extent linked to the international market and are

[32] Oldham, K (2008) Reversibility of Renewable Energy Developments, SPX Consultants: Auckland.
[33] Wolak, F (2006) Preliminary Report on the Design and Performance of the New Zealand Electricity Market, Standford University.

subject to global supply and demand. In the future it is also possible that this may be the case for gas[34]. There is currently no import or export of natural gas in New Zealand, the price of gas is primarily determined by domestic supply and demand. However there is uncertainty of the long term supply and stable price of gas resources as the remaining gas in the Maui field is decreasing, and no new major gas fields are under development currently[35].

Comment [BW17]: Given the diversity of gas supply as shown in the Energy Data File, this does not read right. Table E 3c shows Pohokura gascurrently exceeds Maui supply by almost 60%

By contrast, these price risks are not generally encountered with renewable technologies as the fuel source is not subject to commodity price volatility. Also, the effective price of all fossil fuels will be influenced by carbon prices because of the associated greenhouse gas emissions. New Zealand faces a cost for such emissions and this cost is difficult to predict over time. Production of electricity from renewable resources creates few emissions reducing New Zealand's net exposure to carbon abatement costs.

There is the risk that New Zealand will be required to rely heavily on imported fossil fuels in the future if the current share of thermal generation continues. Conversely, these risks do not exist in the case of renewable technologies because the fuel (wind, water, sun) for generation is free and available in New Zealand.

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[34] Energy Efficiency and Conservation Authority (2009) Renewable Generation and Security of Supply, EECA: Wellington
[35] Electricity Commission (2009) Coal Prices and Availability Study, www.nzbcsd.org.nz/_.../Sustainable_Energy_Futures_Project_Report.PDF

Other Benefits

There are also a range of other benefits that can result from renewable electricity generation facilities rather than fossil-fuelled ones, including:

- ~~Reduction in transmission line losses if the facility is closer to a demand load and/ or embedded in a local distribution network.~~
- Development of specialist green skills and experience that can be exported overseas, such as New Zealand's geothermal skills that are in demand for new geothermal projects around the world.
- Clean green destinations and branding that support the reputation of New Zealand for the benefit of tourism, exports, and net migration.
- Where renewable energy displaces thermal electricity generation, local air quality may be improved.

Comment [BW18]: Auckland is always importing electricity. Major long term swings in supply/demand are accounted for particularly from Huntly. Almost all renewable energy options are further away from Auckland than Huntly. Consequently transmission losses will be greater for renewables than for Huntly thermal generation.

In addition to these, there a number of benefits of new renewable electricity generation facilities, that can also be true of new fossil fuel electricity generation facilities, such as:

- ~~Reduction~~ Delays in increases in the price of electricity.
- Increased employment and economic activity during the project's construction.
- Increased employment and economic activity during the ongoing operation of the generation facility.
- Increased utilisation of existing infrastructure and resources, therefore increasing economic efficiency.
- Construction of new infrastructure, such as roads, that can be used for other purposes.

Benefits specific to hydro electricity generation

- Hydro electricity, particularly that with storage capacity, can complement New Zealand's growing wind generation portfolio and allow New Zealand to maximise this. Hydro storage can be managed to be utilised quickly when needed to compensate for the short term variability of wind generation. It can do this without incurring large costs. It can also be saved to be used later when demand is high, or other forms of generation are scarce; effectively acting as batteries. In the future, with an increasing share of generation being met by renewables, this feature will become even more important.
- Hydro electricity with storage is controllable and predictable, and well correlated with demand.
- Hydro electricity also provides both instantaneous reserves and frequency keeping.

- Electricity generation must be continuously matched to demand on a moment-to-moment basis to ensure that the entire electricity system is maintained in a stable and secure state. For example, even a small increase in demand, without a corresponding increase in supply, will cause the system frequency[36] to fall as rotating generators give up stored energy and slow down. If this imbalance is not corrected immediately, the system frequency will continue to deteriorate and generation equipment will automatically disconnect from the grid to avoid catastrophic damage. If this were to occur, the imbalance would rapidly worsen, eventually leading to wide spread supply disruptions[37].
- Frequency keeping and instantaneous reserves are two means[38] to ensure system frequency is maintained at acceptable levels. Frequency keeping involves the use of generators able to correct relatively normal changes in frequency. Instantaneous reserves are used to cover for larger, unexpected reductions in frequency such as could occur if a large power station "tripped" or malfunctioned. Instantaneous reserves can include both generation and demand side resources, both of which must be able to respond rapidly to unexpected reductions in frequency.
- The creation of lakes contributes to tourism and provides recreational opportunities. New Zealand's two main rowing race courses are based on hydro electricity generation facility dammed lakes.
- Hydro scheme infrastructure can also be used for irrigation.
- Hydro scheme lakes can be used as a source of water for fire fighting.

Benefits specific to electricity generation using wind resources:

- Utilises New Zealand's high quality and extensive wind resource.
- Predictable over longer time frames.
- The relatively high proportion of hydro generation has meant that New Zealand's electricity system has been vulnerable to periods of low hydro inflows (commonly referred to as "dry years") leading to high wholesale market prices and public savings campaigns. Wind generation, will contribute to a more balanced portfolio of renewable generation technologies, reducing the electricity sector's exposure to dry year risk.
- Wind generation has the advantage that, subject to wind resource availability, it can be installed relatively close to sources of electricity demand, thereby reducing losses from transmitting electricity on the national grid.

Comment [BW19]: This is debateable. While West Wind may be an exception, generally suitable sites for wind generation are remote as there are no cities on windy hill tops and urban residents are unlikely to welcome the noise and visual effects of wind farms

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36 The rate at which electricity alternates (nominally 50 cycles a second or 50 Hertz in New Zealand)
37 Concept Consulting. (2009). *Renewable generation and security of supply*. Page 14. www.eeca.govt.nz/node/6906.
38 Other means are also employed. For example generators are dispatched (or instructed) at regular intervals by the system operator to follow the underlying trend in demand.

- Wind farm developments can co-exist with other land uses such as agricultural activities creating sustainable, mixed land use. They can provide an income stream which will enhance existing farm activities.
- It is also benign as regards air quality, avoiding the emission of contaminants into the air such as sulphur dioxide, nitrous oxide or carbon dioxide.
- Turbines can attract tourism and provide recreational opportunities such as mountain bike tracks or hiking within wind farm locations.

Benefits specific to electricity generation using geothermal resources

- Utilises New Zealand's high quality geothermal resource.
- It provides the only source of renewable electricity baseload generation i.e. a consistent source of electricity.
- The continuous nature of the fuel source as constant ~~steam~~ fluid from geothermal reservoirs provides very high power station capacity factors well above 90 per cent. Once a geothermal electricity station is generating it will operate continuously except for planned maintenance cycles and forced outages.
- It is extremely reliable as it is neither dependent on nor affected by weather conditions
- New Zealand's main geothermal resources are located in the North Island in close proximity to the largest electricity demand centres and therefore result in reduced transmission losses in the electricity system resulting in the efficient end use of electricity.
- Generally the power stations have a small footprint and low height and therefore a low visual impact.
- Geothermal generation currently represents the lowest cost generation options available from all fuel types including fossil fuel options. This suppresses the price of electricity in the long term with major implications for the economy.
- It is possible to use steam condensate for irrigation purposes.
- Developments frequently are based on partnerships with Maori so there are flow on benefits to this sector of society.
- Developments draw on the world-leading expertise of New Zealand geothermal consultants and hones their skills for the international market
- Developments are compatible with other land uses such as farming, tourism and forestry.

Benefits specific to electricity generation using marine resources

- Marine energy devices, particularly submarine tidal current turbines, have limited visual or noise impacts on humans. Effects on marine life are also likely to be negligible. Even surface-piercing devices, such as wave point absorber or attenuator devices are unlikely to be visible, if located sufficiently far offshore. Although seawater in the region is not particularly turbid, except during storms, most marine life does not navigate visually.

Comment [BW20]: Unfortunately we may have to disagree. It is true for resources such as those at Kawerau or those feeding into the network around Taupo and northland, but where generation simply feeds into the grid then it displaces coal relative to Auckland demand and so represents a longer transmission distance and greater losses

- Tidal/ocean current turbines are unlikely to generate significant audible noise.
- Tidal current resources can be predicted accurately many years in advance. This predictability means that tidal current generation lends itself well to integration into the electricity system even though the resource is intermittent, as the tidal current varies from zero to maximum flow rate between high and low tides, and the period of maximum flow rate, and therefore maximum generation, also varies daily with tide times.

6. Policy B: Practical Implications

B. Acknowledging the practical implications of achieving New Zealand's target for electricity generation from renewable resources

POLICY B

Decision-makers shall have particular regard to the following matters:

a) maintenance of the generation output of existing renewable electricity generation activities can require protection of the assets, operational capacity and continued availability of the renewable energy resource; and

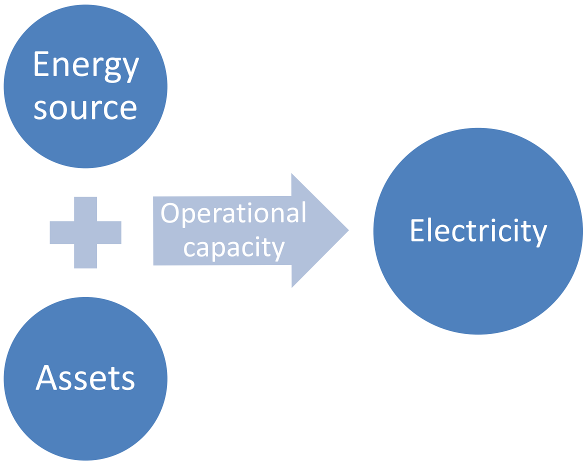
b) even minor reductions in the generation output of existing renewable electricity generation activities can cumulatively have significant adverse effects on national, regional and local renewable electricity generation output; and

c) meeting or exceeding the New Zealand Government's national target for the generation of electricity from renewable resources will require the significant development of renewable electricity generation activities.

Policy B requires an understanding of the composition and operational requirements (e.g. wind farm access; dam inlet de-silting) of the existing renewable electricity generation activity assets, the location and associated operational capacity and the threats to existing generation activities and assets (eg, minimum flow levels). Subparagraphs (a) and (b) emphasise the need to protect existing generation in order to achieve the renewable electricity target while subparagraph (c) focuses on the new generation required to meet the renewable electricity target.

Maintenance of the generation output of existing renewable electricity generation activities can require protection of the assets, operational capacity and continued availability of the renewable energy resource

Maintenance of the generation output of existing renewable electricity generation activities requires the protection of the energy source, the generation facility (power plant) and the operational process. Electricity output is created through the following process:



A change to any one of these components or processes will alter the output of electricity. The assets refer to the things that enable the generation of electricity. Principally, this is physical generation items, such as turbines and hydro dams. However, it may also include other things required for the generation of electricity such as intellectual property. The operational capacity is the level of power that can be produced by the electricity generation facility within the operating constraints. For example, the operational capacity of a hydro scheme may be lower than its maximum theoretical capacity if it is limited to a maximum water flow rate that is less than the maximum that the turbines could make use of.

Even minor reductions in the generation output of existing renewable electricity generation activities can cumulatively have significant adverse effects on national, regional, and local renewable electricity generation output

While the impact of reducing electricity generation output by a relatively small amount at one existing station is minor, the cumulative effect of this occurring in multiple electricity generation facilities is significant. For example, a 5% reduction in the output of each of New Zealand's hydro power stations in 2010 would have resulted in approximately 1,200 GWh less electricity, which is enough to supply approximately 150,000 households[39].

[39] Based on a typical household electricity consumption of 8,000 kWh per year, and 2010 provisional hydro electricity generation of 24,470 GWh (www.med.govt.nz/templates/MultipageDocumentTOC____41150.aspx).

MOTUKAWA HYDRO SCHEME

The TrustPower owned Motukawa hydro scheme generates electricity from the flow of water that is diverted from Manganui River to Waitara River in Taranaki via a man made storage lake. The difference in elevation between the two rivers is approximately 100m. The hydro scheme has a total capacity of 5 MW and an average annual output of 22 GWh.

The hydro scheme has been supplying electricity since the 1930s. The scheme was re-consented in 2001 through the Taranaki Regional Council. In particular, these consent conditions relate to abstraction rates, discharge rates, lake levels, residual flow, and flora and fauna. These consent conditions alter both the quantity (and timing) of the energy source, and the allowable operating process. Trustpower has estimated that adhering to these consent conditions has reduced electricity output from the hydro scheme by 6-7% compared to operation under the previous set of conditions.

Meeting or exceeding the New Zealand Government's national target for the generation of electricity from renewable resources will require the significant development of renewable electricity generation activities

A significant amount of new renewable electricity generation capacity from a range of resources will need to be built in place of new and existing thermal electricity generation in order to reach the renewable electricity target. The amount of thermal electricity generation plants will need to decrease. Section 3 of this guide presents information on the renewable electricity target. In addition renewable generation will need to be built to replace a proportion of existing thermal electricity generation.

7. Policy C: Practical Constraints

C. Acknowledging the practical constraints associated with the development, operation, maintenance and upgrading of new and existing renewable electricity generation activities

POLICY C1

Decision-makers shall have particular regard to the following matters:

a) the need to locate the renewable electricity generation activity where the renewable energy resource is available;

b) logistical or technical practicalities associated with developing, upgrading, operating or maintaining the renewable electricity generation activity;

c) the location of existing structures and infrastructure including, but not limited to, roads, navigation and telecommunication structures and facilities, the distribution network and the national grid in relation to the renewable electricity generation activity, and the need to connect renewable electricity generation activity to the national grid;

d) designing measures which allow operational requirements to complement and provide for mitigation opportunities; and

e) adaptive management measures.

POLICY C2

When considering any residual environmental effects of renewable electricity generation activities that cannot be avoided, remedied or mitigated, decision-makers shall have regard to offsetting measures or environmental compensation including measures or compensation which benefit the local environment and community affected.

Policy C requires an understanding of the Practical constraints associated with renewable electricity generation activities. Practical constraints can limit their ability to avoid, remedy or mitigate adverse effects and that this, in turn, can present challenges to new and existing activities in RMA planning and consenting processes.

The need to locate the renewable electricity generation activity where the renewable energy resource is available

Renewable electricity generation must be located where the resource is available. Storage and transport of energy is most efficient as electricity rather than other forms of energy such as movement, heat, or solar. Therefore, the energy should be converted to electricity at the source of the energy such as the river or geothermal field. In order to be viable, wind farms must be located in locations where the wind is consistently strong, which is often on ridgelines. Biomass plants should be located near the source of the biomass, because of the financial and energy costs of transporting biomass long distances.

Logistical or technical practicalities associated with developing, upgrading, operating or maintaining the renewable electricity generation activity

There are often practical constraints to developing, operating, maintaining, operating, and upgrading renewable electricity generation activities. In wind farms for example, the site of individual towers depends not only on the wind resource but also ground stability and suitable access as well as visual and noise effects.

The location of existing structures and infrastructure including, but not limited to, roads, navigation and telecommunication structures and facilities, the distribution network and the national grid in relation to the renewable electricity generation activity, and the need to connect renewable electricity generation activity to the national grid.

Electricity generation facilities are dependent on access to a range of existing infrastructure, such as roads and a connection point to the distribution or transmission network. This means that some locations with extremely good renewable energy resources may not be suitable for renewable electricity generation because of the lack of supporting infrastructure. Selecting locations is also dependent on the combination of the locations of high demand and transmission and distribution capacity constraints.

WAITAKI *HYDRO SCHEME*

The Waitaki hydro scheme consists of eight electricity generation facilities on the Waitaki River, North of Dunedin. Some of the generation facilities are owned by Meridian Energy, and some are owned by Genesis Energy. The largest generation facility in the scheme is Benmore, with a capacity of 540 MW.

The Waitaki scheme has involved the flooding of a number of braided rivers, and the flow of other rivers has been diverted and reduced. To help offset the effects that the scheme has had on the rivers, a conservation programme was established in partnership with the Department of Conservation. This programme has resulted in over 100 ha of wetlands being established, some of which have predator-proof fences to protect the abundant native wildlife. Salmon, trout, and eels are also supported with various measures. Further, consent conditions require extra river flows to be released at pre-notified times to allow for recreational use such as kayaking.

TAUHARA STAGE II GEOTHERMAL

Contact Energy has received resource consent for Stage II of the Tauhara Geothermal development. Stage II will consist of a 250 MW electricity generating station, fuelled by the heat energy of the Tauhara steam field. The Tauhara field underlies Taupo urban area and land to the east ~~is North-East of Taupo~~.
The location of the project is controlled by a number of factors:

- *Located on the steamfield (i.e. close to the renewable energy resource)*
- *Close to suitable grid transmission lines*
- *Distance away from Taupo township and rural residences*
- *Good topography for construction of power station*
- *Good road access*
- *Distance from seismic faults*
- *Good elevation for air discharge dispersion*
- *Compatible adjacent land uses*
- *Not visible from Lake Taupo shore*

Designing measures which allow operational requirements to complement and provide for mitigation opportunities

Comment [BW21]: Possibly bring the earlier Waitaki Hydro Scheme example under this heading

Mitigation of social and environmental impacts from renewable electricity generation can in some cases be embedded within the design of the renewable electricity generation scheme rather than isolated measures.

Adaptive management measures

An adaptive management approach is consistent with precautionary management as it enables informed decisions to be made regarding future mitigation of adverse effects that may arise over time. Adaptive management has been applied to geothermal electricity generation facilities where there is a degree of uncertainty regarding environmental effects (such as land subsidence) and allows for issues that may arise over time to be addressed in a flexible and comprehensive manner.

Comment [BW22]: Note that although the following box fits this location in the guide it could also sit in section 4.2 under geothermal operational and maintenance considerations

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NGATAMARIKI GEOTHERMAL

Ngatamariki Power Station is ~~an proposed~~ a 802 MW geothermal generation facility currently under construction near Taupo, led by Mighty River Power and Tauhara North No. 2 Trust ~~that~~ which will provide baseload electricity to the national grid.

Operation of geothermal electricity generation facilities provides further understanding of the characteristics of the steamfield, so adaptive management is commonly used in geothermal developments. The operators of Ngatamariki will extensively monitor the ~~site~~ geothermal resource and land overlying it for various ~~things~~factors, including reservoir temperature and~~,~~ pressure~~, and subsidence~~. This monitoring will feed into regularly updated models of the steamfield. These models will help the operators decide the best methods of operation, such as

KAIPARA HARBOUR TIDAL MARINE ENERGY

Crest Energy hasve received resource consent for a planned 200MW tidal marine electricity generation system. The system is to consist of 200 turbines sitting on the harbour floor of the Kaipara Harbour. The turbines will be approximately 24 m high, sitting approximately 7 m below the surface of the water. This project is likely to be New Zealand's first marine electricity generation system. The environmental effects of the project are somewhat less certain than most other renewable electricity generation projects because of the worldwide lack of experience in the application of this technology. Therefore, an adaptive management approach is required. This will be achieved by a process of staging, monitoring, and reviewing. The project will be carried out in three stages of 3 turbines, 17 turbines, 20 turbines, 40 turbines, and the final 120 turbines. Each stage will involve extensive environmental monitoring, which will be reviewed by the Northland Regional Council, who will decide whether the project can move on to the next stage.

When considering any residual environmental effects of renewable electricity generation activities that cannot be avoided, remedied or mitigated, decision-makers shall have regard to offsetting measures or environmental compensation including measures or compensation which benefit the local environment and community affected.

Offsetting can provide alternative benefits to an affected community to compensate for any residual adverse effects from renewable electricity generation activities. Offsetting can be a direct offset to the effect, such as establishing an artificial wetland at a degraded site to compensate for biodiversity loss due to river flooding, or an indirect offset such as supporting a local school to compensate for visual and noise impacts of a wind farm.

TONGARIRO HYDRO SCHEME

Genesis Energy owns and operates the Tongariro Power Scheme ("TPS"). The TPS encompasses two power stations, Tokaanu (240MW) and Rangipo (120MW) and uses a series of lakes, canals and tunnels to divert water into the two power stations from an extensive catchment area extending over 2400km. There are two main diversions: the Eastern Diversion that diverts waters from the Moawhango and and Wahianoa headwaters into the Tongariro River then ultimately into Lake Rotoaira, and the Western Diversion that diverts waters from the headwaters of the Whanganui Riverinto Lake Rotoaira.

As part of re-consenting the TPS in 2002, Genesis Energy was required to consider the impact of hydro generation activities on the population of Whio (Blue Duck) on the Tongariro River. After detailed ecological studies and extensive consultation, multiple stakeholders, including the Department of Conservation, agreed that adverse ecological effects on the upper Tongariro River would be offset by enhancing Whio habitat on the Western Diversion. This offset was achieved through a mitigation package including minimum flows and the establishment of the Central North Island Blue Duck Charitable Trust. The minimum flows were designed to improve Whio habitat. The Trust is focused on enhancing existing and new Whio populations in the central North Island, primarily through predator control.

WAIRAKEI GEOTHERMAL POWER STATION

Contact Energy owns and operates the Wairakei Geothermal Power Station, which has been producing electricity from geothermal fluid for more than 50 years. It was the world's first large-scale producer of electricity from wet steam.

The introduction of the Resource Management Act 1991 required that all existing operations seek consents under the RMA for their operation by 2001. As a condition of reconsenting the Wairakei Power Station, Contact Energy was required to offset the adverse effects of their operation on land, air and the Waikato River. One of the measures they undertook was the establishment of the Wairakei Environment Mitigation Charitable Trust to facilitate the enhancement, protection and management of a variety of geothermal and natural resources characteristics located within the Waikato Regional Council's boundary. Funding is allocated to research for the protection and enhancement of: the variety of the geothermal characteristics with "Protected Geothermal Systems" as defined in the Waikato Regional Plan and other geothermal systems; and Aquatic habitat and amenity (including rivers, lakes and wetlands), water quality or fishery values in the upper Waikato River catchment area (Lake Taupo outlet to Ohakuri Dam).

One million dollars was set aside for distribution to a range of environmental enhancement activities and research, including control of pest plants in geothermal areas, restoration of geothermal and freshwater wetlands, and research into geothermal biodiversity.

Examples of practical constraints of renewable electricity generation activities

Hydro electricity generation facilities

The size of the power station and associated infrastructure is site specific and dictated by the watercourse, and the complexity of the water flow. In many cases, the biggest part of the project will be a dam, however for schemes like Manapouri (where water flows from Lake Manapouri to the sea via the Manapouri power station and Doubtful Sound), long tunnels are necessary. The turbine house is situated at the foot of the penstock, usually at the base of the dam. Large stations that are connected to the grid will also generally require an area of flat land to be covered in gravel and used as a switchyard, where all of the transformers and circuit breakers are situated. The penstocks can be seen coming down from the left of the dam to the generator building, while the water coming down from the right of the dam is excess water, known as a spillway.

Comment [BW23]: "Left" and "right" appear to be referring to a specific image.

Many thousands of cubic meters of concrete (often in difficult, mountainous terrain) are usually required for large hydroelectric schemes. The turbine, generator, and penstock is generally designed and manufactured "on demand" and the performance characteristics of the equipment are governed by the inherent physical geography of the scheme.

Constraining factors for hydro generation include:

- a significant fall and a significant proportion of river flow
- a source of water that will provide a reasonably constant supply
- sufficient depth of water at the point at which the water is taken from the watercourse
- proximity to grid connection
- other resource consents both up and down stream.

Geothermal electricity generation facilities

The environmental footprint of the generation building is fairly low; the generation buildings occupy land about the size of a sports field[40]. Figure 5 is a photo of the 140 MW Nga Awa Purua geothermal power station illustrating the land area required for generation buildings.

However, accessing the various underground hotspots aquifers and feedzones may require extensive pipework over several square kilometres of land. Multiple land uses may be able to be accommodated, with farming and forestry being common land uses in the area covered by the steamfield fluid collection and disposal system. Figure 5 is a photo of the 140 MW Nga Awa Pura geothermal power station illustrating the land area required for generation buildings.

Although geothermal generation results in fugitive greenhouse gas emissions, the level of emissions is much lower than coal or gas generation facilities. The level of greenhouse gas emissions relative to the amount of electricity produced varies significantly between different geothermal fields.

The Ngatamariki geothermal projectposal, for example, utilises a steam field that is estimated to produce relatively low levels of greenhouse gas emissions – approximately 50 g of CO_2e per kWh of electricity generation compared to typical emissions from modern gas generation facilities of 380 g of CO_2e per kWh and 900 g of CO_2e per kWh from typical coal-fired electricity generation facilities.

[40] For quantification of development area of geothermal power developments in New Zealand see "Concurrent Land use in Geothermal Steamfield Developments by Kevin J. Koorey, Ajith D. Fernando, Proceedings World Geothermal Congress 2010 http://www.geothermal-energy.org/304,iga_geothermal_conference_database.html

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Figure 5 Nga Awa Purua geothermal power station (Source: Sinclair Knight Merz)

The key constraining factor for geothermal generation is that current ~~technology~~ economics restricts electricity generation from geothermal resources to high temperature geothermal reservoirs, which are only located in the Waikato, Bay of Plenty and Northland Regions. To be viable, electricity generation occurs in generally large scale generation plants, though a developer has embedded a geothermal generator in a large factory. ~~Given the amount of electricity that is typically generated by geothermal energy plants, they need to be able to be linked into a transmission network able to absorb the additional electricity generated.~~

The rare environment associated with geothermal resources has lead to a number of Councils placing varying degrees of protection on specific resources. Thus potentially accessible resources for development are constrained.

Wind farms

Wind turbines must be spaced in order to generate efficiently. The physical location of the wind farm often means it is necessary to connect to a local distribution network, rather than the transmission network, making the electricity generation facility an embedded generation facility. The method of harnessing the energy in moving air depends on the nature of the wind. For large turbines, careful selection of turbine locations is needed to consider:

- The consistency and strength of the wind (e.g. on ridgelines rather than behind hills with limited turbulence)
- The local bird life
- The visual effect of the turbines
- The accessibility of the location for construction and maintenance
- The cost of the conductors required to transmit the electricity from where it is generated to where it may be used.

Comment [BW24]: Perhaps the whole sentence should be deleted because existing geothermal power plant outputs range from 2 MW to nearly 200 MW

Considered together, these requirements mean that wind farms are usually located in high country, and may be considerable distance from the nearest grid connection.

The lifespan of wind turbines is expected to be around 25 years, meaning from around 2020 existing New Zealand wind farms are likely to begin replacing their turbines. The new turbines could be significantly different to the original turbines, thus changing the environmental effects. In the 1990s turbines installed in New Zealand were less than 1MW per turbine, whereas modern turbines are 2 – 3 MW. Modern turbines typically have taller towers and longer blades. Stage I and II of the Tararua wind farm (1999 and 2004) used 0.66 MW turbines with 40 m towers and 24 m blades, whereas Stage III, completed in 2007, used 3 MW turbines with 65 m towers and 45 m blades.

Constraining factors for medium to large scale wind energy generation are associated with the following requirements:

- locations with strong and consistent winds, generally ridgelines, where wind speed is greatest
- adequate spacing between turbines that both minimises capital cost and the need for adequate separation between turbines to lessen energy loss through wind shadowing from upwind machines
- proximity to a suitable transmission line or substation
- the capacity of the local electricity distribution grid
- open land without current or future obstacles to the wind flow
- good access for wind farm construction and maintenance
- suitable geology for access tracks and turbine foundations

Biomass

Constraining factors for biomass generation include:

- Land area to generate feedstock
- Proximity to and availability of feedstock – biomass is a low value, high volume commodity that significantly increases in cost with even short transport distances.
- Proximity to landfill gas source – electricity generation plants need to be located at or near the landfill site to reduce the need to pipe the gas over long distances
- Proximity to grid connection – a plant needs to be located close to existing grid infrastructure with the capacity to accept the proposed generation capacity.

Solar panels

Due to limitations in silicon manufacturing, single solar panels are not much larger than a table. A 2m × 1m panel generates around 250W at peak sunlight levels. They may be combined in an array. Apart from the physical space the array occupies, space for the inverter should be considered (to convert the DC electricity the panels generate into 50Hz AC). A 1.5 kW domestic inverter will generally take up as much space as a domestic switchboard, whereas a large solar array on the roof of a commercial building will require a kiosk substation, about the size of a golf cart. Solar arrays are best suited to locations of strong sunlight, which is reasonable in New Zealand.

There are no key geographic factors that prevent the use of photovoltaic systems other than a preference to be north facing. Photovoltaic cells do not generate electricity at night, and they are less effective in cloudy weather, meaning that if utilised as a stand alone system, either a storage system or complementary power system is usually required. Shadows from trees and structures can also reduce their performance.

However, to be most efficient, they should be inclined at an angle of 20 – 40 degrees (depending on latitude) and orientated facing due north. Where this is not possible, to function well, they should be inclined at between 10 – 60 degrees and orientated facing from east to west (within 90 degrees of due north).

Marine electricity generation facilities

Marine electricity generation is a new industry, so the full range of set ups is not yet known. The infancy of the industry also means that the current examples of marine electricity generation are probably not as large as they will become.

The type of marine electricity generation that is most likely to be viable in New Zealand in the next two decades is the tidal turbine farm. This is essentially an underwater wind farm, driven by ocean water moving in and out of an estuary or harbour due to the tide. These would be largely invisible from above the water, because they would be placed on the floor of the harbour. Some designs are completely submersed, deep enough for ships to pass over them. Others are attached to towers that rise above sea level, as shown below. This lets the turbines be raised up above sea level for maintenance.

Tidal turbine raised for maintenance (Source: Marine Current Turbines)

Wave electricity generation cannot be described in generic terms because there is a wide range of designs, with very different characteristics. Dynamic tidal barriers are also difficult to describe because they are currently only conceptual.

All types of marine electricity generation require connection of the electricity to a consumer, distribution network, or the national grid. This requires a submarine cable, which will emerge from the sea and connect to the network or consumer via switchgear. This could involve a small building, or some outdoor electrical equipment and transmission lines from the coast to the connection point.

Constraining factors associated with marine energy generation include:

- proximity to on-shore grid connection
- speed and height of tidal currents and sea levels

8. Policy F: Small and community-scale electricity generation

F. Incorporating provisions for small and community-scale renewable electricity generation activities into regional policy statement and regional and district plans

POLICY F

As part of giving effect to Policies E1 to E4, regional policy statement and regional and district plans shall include objectives, policies, and methods (including rules within plans) to provide for the development, operation, maintenance and upgrading of small and community-scale distributed generation from any renewable energy source to the extent applicable to the region or district.

Small and community-scale distributed electricity generation is the generation of electricity that is either used directly by the producer or exported to the local distribution network. This is in comparison to most of New Zealand's electricity, which is generated by large centralised power stations, which are often a large distance from consumers. To reach the consumers the electricity is transported over the national grid.

There is a wide range of small and community-scale electricity generation occurring in New Zealand. This ranges in size from a household with a single solar panel, through to hydro or wind electricity generation schemes that can be over 5 MW. Figure 6 shows a typical small scale hydro scheme that could supply part of a farm of household's electricity needs directly, while Figure 7 shows part of the 36 MW Mahinerangi wind farm, which is connected to the local distribution network. Small scale hydro schemes that produce electricity directly for a household or farm are often as small as half a kilowatt (0.0005 MW). Another common form of distributed generation is co-generation, whereby both heat and electricity are generated together. For example, a timber mill may burn sawdust and off-cuts to generate heat for timber-drying kilns, but then use any excess steam to generate electricity that can be used by the mill or exported to the distribution network.

Figure 6 Small scale hydro electricity generation

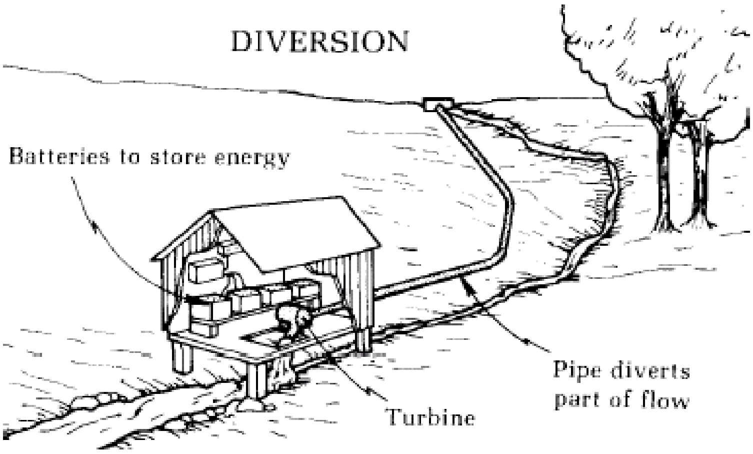

Figure 7 Two turbines in the twelve-turbine Mahinerangi wind farm (Source: Trustpower).

Small scale generation may not be financially competitive with large scale generation in some situations due to economies of scale. The economies of scale apply to the efficiency of the generating asset, as well as the efficiency of the organisation. For example, a regular homeowner or farmer is unlikely to have the skills or knowledge to assess and understand the feasibility of electricity generation on their property. However, there are a number of benefits of small and community-scale generation:

- The amount of electricity lost during transport through transmission wires is less due to the proximity to the electricity consumers.
- Generating all of a household or organisation's electricity can avoid needing to connect to the local distribution network. In remote areas, the cost of connection can be more expensive than the cost of small scale electricity generation equipment.
- Avoiding the use of the national grid means less upgrades to the national grid will be required.
- Small scale generation increases the diversity of New Zealand's electricity system, thus increasing the security of supply.
- Distributed generation avoids the need to connect to the national grid where the nearest national grid transmission line might be a significant distance away.

Further information on hydro energy

- Sustainable Electricity Association New Zealand (www.seanz.org.nz/)
- EECA guidance document on domestic scale distributed generation (www.eeca.govt.nz/sites/all/files/dg-guidance-for-local-govt-may-2010.pdf).

Further information on geothermal energy

- NZGA report on geothermal distributed energy (http://www.nzgeothermal.org.nz/publications/Reports/DistributedEnergyReportFinal23June08.pdf)

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9. Policy G: Enabling identification of renewable electricity generation possibilities

G. Enabling identification of renewable electricity generation possibilities

POLICY G

Regional policy statements and regional and district plans shall include objectives, policies, and methods (including rules within plans) to provide for activities associated with the investigation, identification and assessment of potential sites and energy sources for renewable electricity generation by existing and prospective generators.

Policy G requires an understanding of the key activities that are generally carried out to confirm the feasibility of renewable electricity projects.

9.1. Hydro-electric feasibility investigations

- Stream flow rates measurements are required to form a reliable estimate of available power. Long term stream flow measurements are required to estimate potential generation at a site. Long-term measurements (greater than a decade) are generally not available, and so these may need to be extrapolated from the size of the catchment and previous years' rainfall data.
- Geotechnical studies for suitable dam locations are necessary – not only for concrete dams, but to avoid mudslides and hill slips in earth dams. This often involves drilling, which would be done by a drilling unit on a vehicle (a tractor, an excavator, a trailer, or a purpose-built vehicle). The drilling requires site access and water in-take and discharge, and may result in noise and subsidence.
- An environmental study is required to determine the impact of the proposed scheme options on aquatic life, and downstream water-dependent ecosystems.

9.2. Geothermal feasibility investigations

- Prospective locations are identified by collating existing scientific data ~~and identifying anomalies in the earth's crust~~. Alternatively, investigation could be driven by an existing property owner interested in whether the property has potential for geothermal development. There have been regional scientific surveys undertaken by GNS Science or its forebears, and in many cases the Crown has drilled some exploration wells in the 1960's, 70's and 80's though access to this information is controlled by Treasury. ~~The surface exploration is required to understand the extent of drilling opportunities.~~
- Developers will then undertake further scientific surveys using the latest techniques. These are often non-invasive techniques such as Magneto-telluric (MT) resistivity surveys, backed up by geochemical surveys. Efforts will also be directed at securing exclusive access rights to land under the prospective resource to minimise the risk of 'free riders' gazumping development efforts through early application for development consents.
- Once land access is secured developers are likely to seek consents for exploration drilling. After prospective well locations are identified and wells are designed, then wells are drilled to establish sub-surface geology and in-situ fluid type and temperature. Once sufficient exploration wells are drilled and tested (through combinations of fluid injection, natural heating and discharge) then a developer may be in a position to assess the potential of the resource with enough confidence to commit to a resource consent application. This will require the development of a conceptual model of the field.
- Other investigations will include geotechnical investigations for detailed station and steamfield design, and transmission studies to determine the best options for exporting the electricity.
- Prior to the application, a suite of environmental studies will be done to support the consent application and to establish the feasibility of the design. Regional councils with high temperature geothermal resources in their areas have geothermal policies which define the issues that prospective developers need to address. These studies will include flora and fauna surveys and surveys of geothermal features (possibly highlighting areas to be avoided by the development), groundwater surveys and plans for managing storm water during construction, air dispersion modelling (which may necessitate revision to the station concept to manage ground level hydrogen sulphide levels), noise studies (more an issue if there are noise-sensitive people or animals nearby), assessment of traffic impacts during construction and operation, and of social effects. Baseline surveys are likely to be undertaken with a view to assessment of subsidence, but subsidence will only occur (for geothermal reasons) once sections of the resource start to depressurise through development.

- Combinations of geophysics, geochemistry, geology and measurements from wells will lead the developer to an assessment of resource capacity, initially through a stored heat calculation. Common practice is to prepare a numerical reservoir simulation model that includes specific assumptions about the nature of the reservoir, but reliable calibration of these models requires long term discharge of the resource to be able to cause sufficient change to pressures. Where a development is part of a larger developed field then calibration should be possible. The numerical modelling of geothermal resources is a well-developed science which can be applied at an early stage of exploration. New Zealand scientists and engineers are amongst the international leaders in this particular field.
- After obtaining development consents, factors that affect the optimum development include readiness of the electricity market to receive the electricity, developer's confidence in the capacity of the field and in the production/reinjection strategies they have put in place, and exchange rate. To mitigate risk, the developer may choose to stage the development. Staging a development with several years between stages can enable calibration of the reservoir model and confirmation of production/reinjection strategies.
- After obtaining consents, once the developer is confident of the investment environment, they will proceed with drilling for production and reinjection wells and the testing of these. This will enable detail design of the fluid collection and disposal system.
- ~~After prospective locations are identified, wells are drilled in order to sample prospective locations. Several wells are necessary, including exploration wells (where temperatures and rock structure are evaluated), and test wells (where small-scale demonstration production is tested). After many wells have been drilled, geophysicists may map the area in 3D and provide a conceptual model of the geothermal resource size. Geotechnical studies are also required to avoid subsidence and the formation of new craters and geysers.~~
- ~~Depending on the depth of the well, a drilling rig may either be mounted to the back of a truck for shallow holes, or be assembled onsite as a steel lattice structure to drill deep down.~~
- ~~An environmental study should be commissioned to determine the impact of the proposed scheme options on local ecosystems. This should include consideration of the local air and groundwater quality.~~

Comment [BW25]: While small scale unit was installed at Wairakei prior to commissioning and a scaling /corrosion test rig was installed at Ohaaki, demonstration plants are not the norm for New Zealand

Comment [BW26]: While this is true it is a detail not affecting feasibility

Comment [BW27]: I see this comment is written to reflect style in section 9.1 but I have covered this above

9.3. Wind farm feasibility investigations

- Electrical technical study: Due to the electrical characteristics of wind turbines, the process to connect a wind farm to the grid is technically complex, and requires engineering studies into the effect on the grid at the proposed connection point.

- Wind monitoring: Identifying the regions with consistent strong winds may be done from meteorological data, but obtaining site-specific data involves erecting wind monitoring instruments. Generally, prospective locations are chosen on ridges, or natural wind tunnels created by valleys. It is necessary to erect several wind towers and monitor wind over a period of a few months to a few years. The wind towers may be 10-30m high, and finding consistent winds of 5-25m/s is the aim.

9.4. Solar array feasibility investigations

Compared with the other renewable technologies listed in this document, the feasibility investigation for a solar array in a New Zealand context is relatively simple, and comprises:

- Structural assessment of building roofs to determine whether they can bear the weight of the panels.
- Characteristic weather patterns, including the proportion of cloudy days, and probability of extreme weather events that could damage the panels, such as salt spray, debris from strong winds, heavy snow, or hail.
- The insolation (average solar radiation intensity (“irradiance”), in kilowatt hours per square metre, per day – $kW.h/m^2.d$). This may be measured with a small pyranometer, or estimated based on local weather records and the location latitude.
- Consideration of shadows and ability to achieve optimum panel placement and angle (for example, the southern face of a sloping roof is likely to be shadowed during winter).
- Consideration of the electrical protection requirements of the local network when an electricity generation source is added.
- Consultation with the local distribution network and the national grid system operator for installations greater than 1 MW.

10. Common Technical Terminology

Connection – a power station must connect to a distribution network or the national grid if it is to export the electricity to other consumers. The point of connection usually involves additional electrical equipment, such as an electricity transformer. The national grid has approximately 200 grid exit points where the national connects to direct users and distribution networks. Consumers must connect either to the distribution network or the national grid to access electricity. Direct connection to the national grid is only suitable for very large users near the national grid transmission lines.

Develop Renewable Electricity Generation – the process of establishing a renewable electricity generation project, which includes feasibility studies, design, planning, and construction.

Distribution Network – a distributor's lines and associated equipment used for the conveyance of electricity on lines other than lines that are part of the national grid[41] 35 .The distribution networks operate at a lower voltage than the national grid and provide the final connection to the majority of consumers. These include the overhead power lines seen in suburbs.

Distributor – a business engaged in distribution of electricity, such as Orion[41][41].[42]

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Electricity Generation Capacity – the theoretical maximum power that can be produced by an electricity generation asset, typically measured in Megawatts (MW). The actual power produced is less than the maximum and a capacity factor is the average proportion of maximum power that is actually realised over time. The amount of electricity produced is the power multiplied by time, and is hence typically measured in Megawatt hours (MWh). For example, a 1 MW wind turbine will, on average, produce less that 1 MWh per hour because there will be times when the wind is not blowing. Even if a generation facility is operating 100% of the time, there are inefficiencies inherent to the various types of electricity generation that prevent the full capacity being utilised.

Generation Output – amount of electricity produced, which is the power multiplied by time, and is typically measured in Megawatt hours (MWh), Gigawatt hours (GWh) or Kilowatt hours (kKWh).

[41] From the National Policy Statement for Renewable Electricity Generation.
[42] ~~From the National Policy Statement for Renewable Electricity Generation.~~

Formatted: English (New Zealand)

Imported Fuels – the main fuel imported for electricity generation is currently coal for the Huntly power station. In the future, liquefied natural gas (LNG) could also be imported. Most renewable energy sources are not readily transportable and thus not imported.

Maintain Renewable Electricity Generation – the maintenance of existing renewable electricity generation assets, which can include testing, replacing, or refurbishing some physical parts or operating procedures.

National Grid – the lines and associated equipment used or owned by Transpower to convey electricity[41]. The national grid is operated at a higher voltage than distribution networks to reduce electricity losses. The national grid feeds the distribution networks as well as directly supplying electricity to a few large electricity users. This includes the power lines on large lattice towers through the country side.

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New Zealand's Electricity Generation – the total amount of electricity that is exported to distribution networks or the national grid and electricity that is used directly by the generator.

Operate Renewable Electricity Generation – the use of a renewable electricity generating asset to generate electricity.

Renewable Electricity Generation – generation of electricity from solar, wind, hydro-electricity, geothermal, biomass, tidal, wave, or ocean current energy sources[41]. These energy sources are not finite, and generally produce less greenhouse gas emissions than fossil fuel energy sources.

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Renewable Generation Electricity Generation Activities – the construction, operation and maintenance of structures associated with renewable electricity generation. This includes small and community-scale distributed renewable generation activities and the system of electricity conveyance required to convey electricity to the distribution network and/or the national grid and electricity storage technologies associated with renewable electricity[41].

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Security of Electricity Supply (aka Security of Supply) – when the electricity generation and transmission/distribution system supplies consumers with electricity in a continuous, reliable, and consistent manner and is resilient to shocks and change. From a generation perspective, security of supply is achieved with sufficient electricity generation capacity and diverse sources and locations of electricity generation.

Small and Community-Scale Distributed Electricity Generation – renewable electricity generation for the purpose of using electricity on a particular site, or supplying an immediate community, or connecting into the distribution network[41]. This differs from most large generation, which connects to the national grid.

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Upgrade Renewable Electricity Generation – the improvement of an existing renewable electricity generation asset. This can be tweaking with new technology to increase the efficiency of the plant, or replacing aged equipment.

CO_2e – a measure of greenhouse gas emissions that accounts for differences in the global warming potential of different gases by calculating the amount of CO_2 that would produce equivalent warming over a standard length of time (typically a 100 year time horizon is used). CO_2e is measured by mass, usually in tonnes.