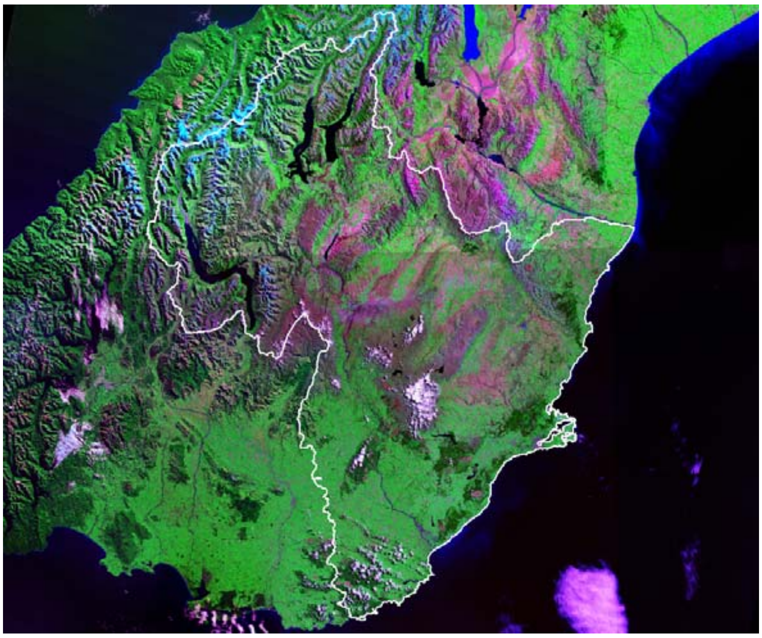
Renewable Energy Assessment



OTAGO REGION

Final Report

23 April 2007

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Executive Summary

This study aims to identify and assess the renewable energy potential in the Otago region and assist Otago Regional Council (ORC) to identify where it can play a role in realising that potential using both regulatory and non-regulatory approaches.

Greater uptake of renewable energy presents national benefits such as enhanced security of supply and reduced climate change effects. This is explicitly recognised in the Draft New Zealand Energy Strategy to 2050 (MEDa, 2006). In addition, greater uptake of renewable energy would allow regions, districts and cities to address issues such as:

- High liquid fuel and electricity costs that could contribute to a significant economic downturn;
- Transmission / distribution constraints leading to supply disruptions and loss of economic activity;
- Uncertainties associated with other conventional energy sources such as gas reserves and coal fired power plants which may lead to local supply shortfalls;

Economic opportunities presented by the application of mature, cost effective renewable energy technologies in the short-term and the development / commercialisation of emerging technologies in the medium-term.

At the same time, the uptake of renewable energy is constrained by a wide range of barriers that not only includes the technical challenges and costs of developing such resources, but also the cultural and environmental concerns surrounding the use of natural resources. Most renewable energy projects have relatively high capital costs for plant and a revenue stream that is linked to the often periodic or intermittent nature of some renewable sources. The potential effects on areas of high cultural, ecological and landscape value mean that there are limitations as to where renewable projects may be acceptable. Most projects attract opposition from some sectors and face long consenting and development times.

An initial assessment of the potential for large-scale renewable energy development in the Otago region is provided in this report. The estimates of renewable energy potential seek to identify major resources that are available and to provide an indication of their relative magnitude. It is to be noted that the assessment has not accounted for how environmental and cultural issues will affect renewable energy potential. Rather, the assessment presents indicative estimates for the amount of renewable energy that could be realised in terms of the resource available outside Department of Conservation lands (as a working, first order definition of what projects may be environmentally acceptable) using technologies that are already economic or are likely to become economic over the course of the next ten years (i.e. the review period of Regional Policy Statements).

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For the Otago Region, this renewable potential comprises:

- Approximately 1,000 MW[1] of wind capacity, depending on the degree of acceptance of adverse effects.
- If carefully planned, approximately 1000 MW of wind capacity could be installed over a number of years.
- Hydro potential of about 930 MW, in small and medium scale projects in areas outside Department of Conservation land and Native Forest areas, compared to the existing installed capacity of approximately 860 MW.
- Wave energy with installed capacity in the order of one hundred megawatts, ignoring environmental constraints and conflicts with other maritime users.
- About 20 million litres of ethanol per year for transport fuel from grain crops currently grown in the region and about 60 million litres per year of ethanol or 250 GWh/year of electrical energy from woody biomass derived from low-grade forestry.
- Considerable potential for the widespread use of geothermal energy for ground source heat pumps, given Otago's climatic extremes.
- Significant potential for solar thermal hot water systems, considerably less for solar photovoltaic.
- No potential for power generation from geothermal sources.
- Limited tidal energy potential.

Development of this renewable potential could be assisted by:

- Increasing the range of expertise within the council such that the council's capacity with regard to renewable energy is commensurate with that of its other functions, *e.g*. soil conservation or water quality.
- Developing an energy plan / strategy.
- Developing spatial representations of renewable energy resources overlaid with information relating to development constraints (*e.g*. outstanding landscapes, areas of high cultural value).
- Establishing a programme of energy forums involving selected councils from across New Zealand to raise awareness of and develop action plans for renewable energy..
- Advocating the implementation of appropriate economic instruments for renewable energy at a national level.

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[1] The unit for measuring power is the Megawatt (MW) (or MW*e*, to differentiate the *e*lectrical output from thermal output). Power is the rate at which energy is generated / consumed, i.e. 1MW means that one million joules of energy is generated / consumed every second. As crude approximations: a full petrol tank in an average size car contains one million joules of energy; a single wind turbine has a 1 MW capacity.

- Working with energy generators, Maori and other interested groups to develop industry codes of practice for renewable energy production.

Regional Policy Statements

- Identifying in the Regional Policy Statement, areas within the region suitable for renewable energy development including wind, hydro, geothermal and marine based generation.
- Including in the Regional Policy Statement a series of objectives and policies outlining how "trade offs" between localised effects and the benefits of renewable energy should be made.
- Amending the Regional Policy Statement to recognise the potential future renewable energy technologies and make high level policy provision for such

Regional Plans

- Amending Regional Plan rules to:
  - review consent thresholds for energy generation using renewable resources with a view to reducing thresholds where appropriate
  - provide longer consent periods for renewable energy projects
  - recognise the potential of and make high level policy provision for future renewable energy technologies

District Plans

- Ensuring that District Plans provide for existing renewable energy generation facilities.
- Working closely with the District Councils within the region to ensure that district plans reflect the renewable energy objectives and policies of the Regional Policy Statement.
- Amending District Plans to:
  - ensure that rules do not preclude renewable energy development in areas identified in the Regional Policy Statement.
  - give effect to the objectives and policies proposed above for the Regional Policy Statement
  - make appropriate provision for various scale energy generation facilities
  - review consent thresholds for small scale renewable energy production (*e.g.* solar and wind) to consider whether they can be permitted activities
  - provide subdivision rules that encourage appropriate site orientation in order to support solar heating and power generation and reduce shading
  - ensure that rules do not unreasonably preclude domestic scale renewable energy production (*e.g.* allows solar panels on roofs) and protect solar access to nearby properties.

Contents

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1 Introduction

1.1 Background

The growth in New Zealand's energy demand over the past three decades has mainly been met by non-renewable sources despite the widespread availability of potential renewable resources throughout the country.

Renewable energy resources face barriers to development that often include high capital costs, difficultly securing access to use natural resources and the practicalities of delivering the energy to where it is to be used. Consequently, the Government has developed energy strategies and made recent changes to the Resource Management Act (RMA) to encourage greater uptake of renewable energy, reduce climate change effects and increase security of energy supply.

While councils and territorial authorities play a significant role in the consenting process for any renewable energy development, this role has (with a few notable exceptions) largely been in reaction to applications. Under the recent changes to the RMA there is a greater requirement on Councils to provide for renewable energy, but as yet there is no coherent knowledge base on the nature of the resources themselves nor a precedent for policy development that meets the new requirements.

1.2 Study Objectives

The Energy Efficiency and Conservation Authority (EECA) has implemented a program of Renewable Energy Assessments to assist councils with their policy and plan reviews and their new infrastructure responsibilities for renewable energy under the RMA.

EECA appointed Sinclair Knight Merz (SKM) to undertake a study whose objectives were to identify, assess, report and advise on the:

- Renewable energy potential in each region.
- Councils' role in realising the potential.
- Council's regulatory approaches.
- Information to enhance councils' knowledge.

By providing reliable renewable energy resource information and analysis, these assessments will help direct accurate targeting of renewable energy development opportunities; raise the profile of renewable energy; and provide a sound underpinning of policy development and private investment in renewable energy.

This report is one of eleven assessments prepared under this program.

In New Zealand there are a total of 85 councils. In addition to 53 district councils and 15 city councils, territorial authorities which fall within the boundaries of 12 regional councils, there are 5 unitary authorities that lie outside the jurisdiction of a regional council and have responsibilities of both territorial and regional councils. After discussions led by EECA, nine regional councils and two unitary authorities (Marlborough and Tasman) were included within the study:

- Auckland Regional Council
- Environment Bay of Plenty
- Environment Canterbury
- Environment Waikato
- Greater Wellington Regional Council
- Horizons Regional Council
- Marlborough District Council
- Northland Regional Council
- Otago Regional Council
- Taranaki Regional Council
- Tasman District Council

Throughout this report, ‘council’ is used as a collective term for regional councils and unitary authorities.

1.3 Report Structure

The remainder of this report is structured in the following manner:

- **Chapter 2 - Drivers** outlines the national-level drivers for renewable energy in terms of: policy, energy use, supply and pricing. This chapter also provides a summary of key barriers to greater uptake of renewable energy.
- **Chapter 3 - Technologies** presents a tabular summary of existing and emerging renewable energy technology options for New Zealand.
- **Chapter 4 - Local Potential** describes the region’s renewable energy resource and provides a preliminary indication of the magnitude of the utilisable resource.
- **Chapter 5 - Enabling Assistance** provides suggestions for how the council could promote renewable energy using non-regulatory methods.
- **Chapter 6 - Regulatory Approaches** summarises the region’s existing regulatory approach to renewable energy and outlines alternative approaches for consideration.

Reports have been prepared for each of the eleven councils using the above structure.

1.4 Data Sources and Quality

This assessment of the renewable energy potential within the regions relies primarily on previously published, publicly available information and data. We have used recent summaries of renewable energy potential, but where possible also reverted to the original sources of data.

Some of these sources are contradictory or very non-specific. While some of the available data (such as the hydro power potential) are quite detailed and have been thoroughly reported, other data (such as the wind energy) are poorly defined by existing assessments and not reliable for identifying more than broad parts of the regions that may have high energy potential.

Commentary on the status of marine energy technologies and their costs has been provided by the New and Renewable Energy Centre (NaREC) in the UK which is an independent test facility and technology assessment specialist.

ASR Ltd, a Marine Consulting and Research company, provided the wave and tidal resource assessment.

The timing and scope of this work has not allowed any extensive new independent assessment of natural resources, although we have re-evaluated some technical and cost criteria for defining resources within the earlier assessments based on our own recent resource evaluations for individual projects or made some preliminary estimates based on published primary information.

Where no energy assessment data has been published (such as tidal current energy) we have made preliminary estimates using suitable guidelines applied to primary data that may be available (such as current velocity in the case of tidal flows). Estimates of the portion of the resource that may practically be used have been made by determining whether any restrictions such as Conservation land may restrict access.

Overall, the resource assessments must be regarded as first order indications of the magnitude and location of each resource. Defining the location, magnitude and probable delivery cost for each type of resource, for each scale of development (from large scale grid-based power generation to micro applications) would be a substantial exercise but could be justified if this were to be the basis for specific designation-based planning approaches.

Existing policy and plan documents for the region have been examined and supplemented by discussions with council representatives.

Interviews have been conducted with TrustPower and Mighty River Power to gain their perspectives on the issues facing the development of renewable energy projects.

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A high level assessment of the risks and vulnerabilities to energy supply is another current energy study in the Otago region.

1.5 Next Steps

Initial discussions with Otago Regional Council suggest that this report may be an initial step towards informing the Council's approach to renewable energy. However, it is likely that there are a number of issues, beyond the scope of the current report, which would be of considerable value to the Council including:

- Building on the Environment Court Te Awhitu decision regarding the benefits derived from renewables, the development and articulation of these benefits within the context of the Otago Region.
- Noting the potential for a substantial increase in power demand (e.g. from population and economic growth) to develop a more detailed understanding of demand projections.
- An understanding of which communities may be at risk post-2012 with regard to non-maintenance of distribution networks.
- Assessing the consequences of development of large scale renewable projects and the role of the renewables in security of energy supply.
- Understanding the role of small scale distributed renewable resources such as solar in the context of energy demand and supply scenario.
- Assessing the potential for renewable energy source to replace coal in industrial and commercial sector as more onerous air quality regulations requiring additional mitigation measures to get consents lead to fuel swapping.
- Developing a more detailed understanding of smaller scale energy measures (including demand side, energy efficiency, small scale renewables, co-generation, waste heat) at the domestic and community scale and within commercial and industrial sites.
- Framing the Regional Renewable Energy Assessment within a longer time period such as 25 or 50 years rather than the 10 years adopted for other Regional Renewable Energy Assessments.
- Greater reference and linkage to climate change impacts / adaptation and how they might affect energy demand and supply profiles and overall energy planning.
- A more detailed understanding of the barriers / opportunities to renewable energy within District Plans.
- An understanding of which communities may be at risk post-2012 with regard to non-maintenance of distribution networks

2 Drivers

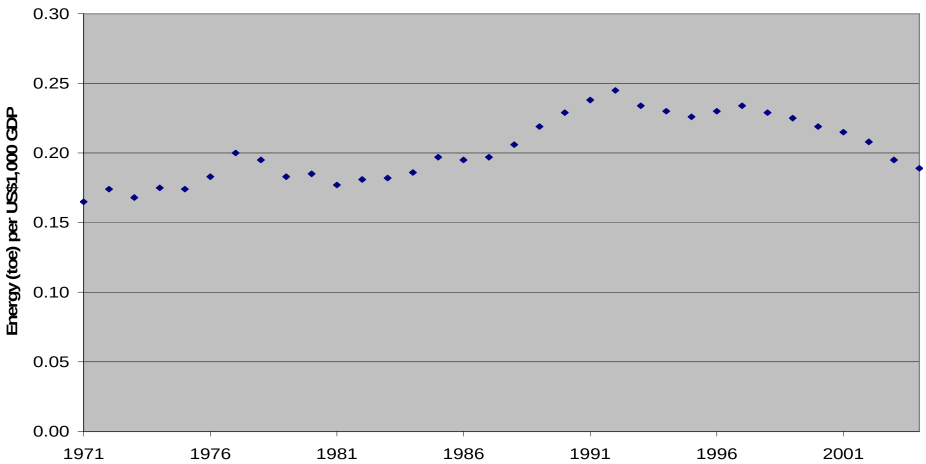
2.1 Introduction

This chapter outlines the national-level drivers for renewable energy in terms of policy, energy use, supply and pricing. In addition, this chapter provides a summary of key barriers to greater uptake of renewable energy.

2.2 Economic Growth

In the majority of countries, there is a very strong link between economic growth and growth in energy supply. Over the years, there has been much discussion of decoupling these two factors in developed countries such that strong economic growth could be achieved whilst reducing total energy supply. Although the energy efficiency of some economies has improved, economic growth has been such that total energy supply has steadily increased.

In New Zealand, the long-term energy efficiency of the economy has improved (Figure 1)[2]. This long term increase in energy efficiency has been brought about by GDP growth that has exceeded growth in total primary energy use (Figure 2). The total primary energy supply figures are distorted to some degree by the geothermal component which includes a large portion of un-used heat energy.



- **Figure 1 Energy efficiency of the New Zealand economy 1971-2004 (OECD[3], 2006)**

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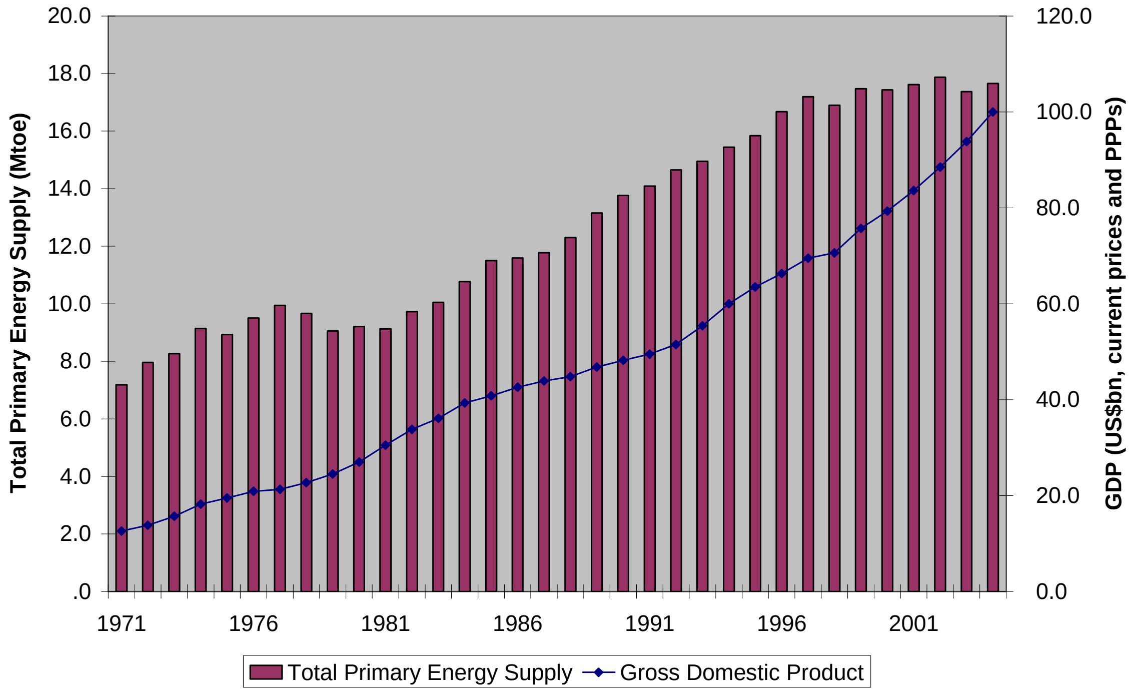
[2] Tonnes of oil equivalent (toe) per thousand US dollars of GDP using Purchasing Power Parity (PPP).

[3] Organisation of Economic Cooperation and Development

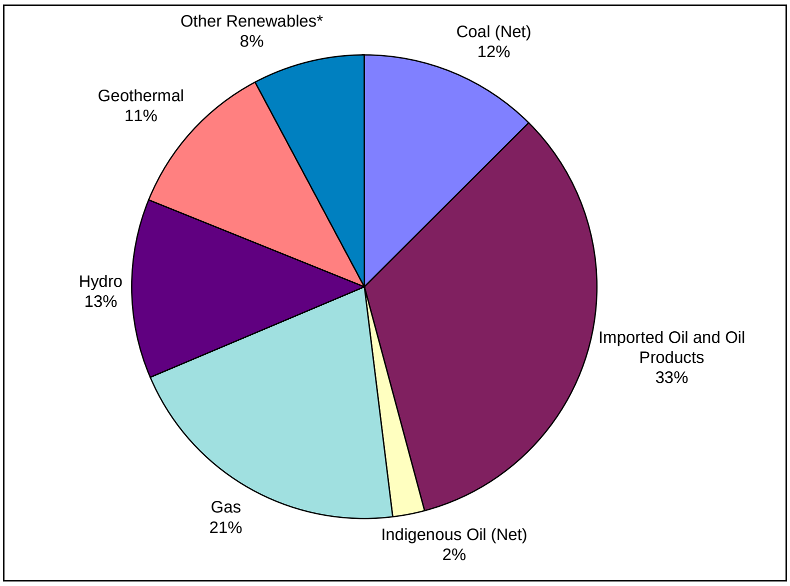


- **Figure 2 New Zealand economy and energy supply 1971-2004 (OECD, 2006)**

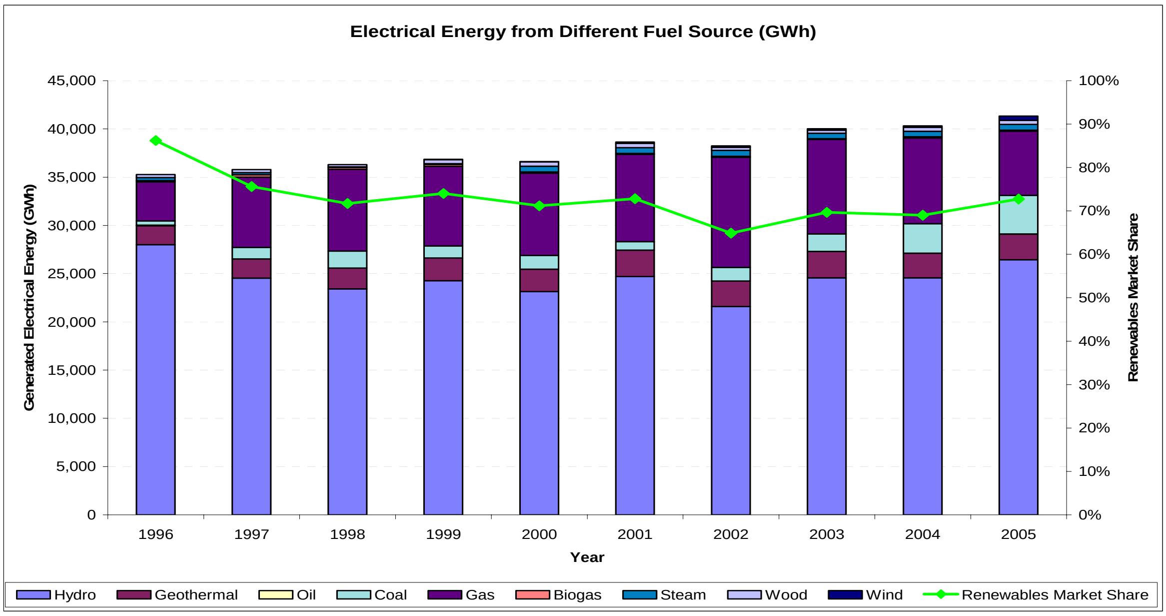
2.3 Current Energy Mix

In 2004, about one third of New Zealand's total primary energy supply was secured from renewable energy sources, one third from imported oil products and the remaining third from indigenous natural gas and a mix of local and imported coal (Figure 3). Of the energy finally used, 40% is for transportation and about 30% is delivered as electricity.

Waste heat used for co-generation of electricity has been reported as a renewable energy in the published energy data, however much of this is derived from coal fired heat (e.g. the Glenbrook Steel Mill) and so is not renewable. As noted above, the renewable energy resource data include all the geothermal heat extracted from the reservoir, making no allowance for the conversion efficiency to electricity. Hence the magnitude of New Zealand's energy derived from renewable sources is effectively over-stated in the published data.



- **Figure 3 New Zealand's primary energy use by source, 2004.NB: Other Renewables* includes electricity generation from wind, biogas, industrial waste and wood, and solar water heating (MEDb[4], 2006).**



- **Figure 4 Electricity Generation from Different Sources**

Source: Energy Data File, 1996-2005, available at www.med.govt.nz

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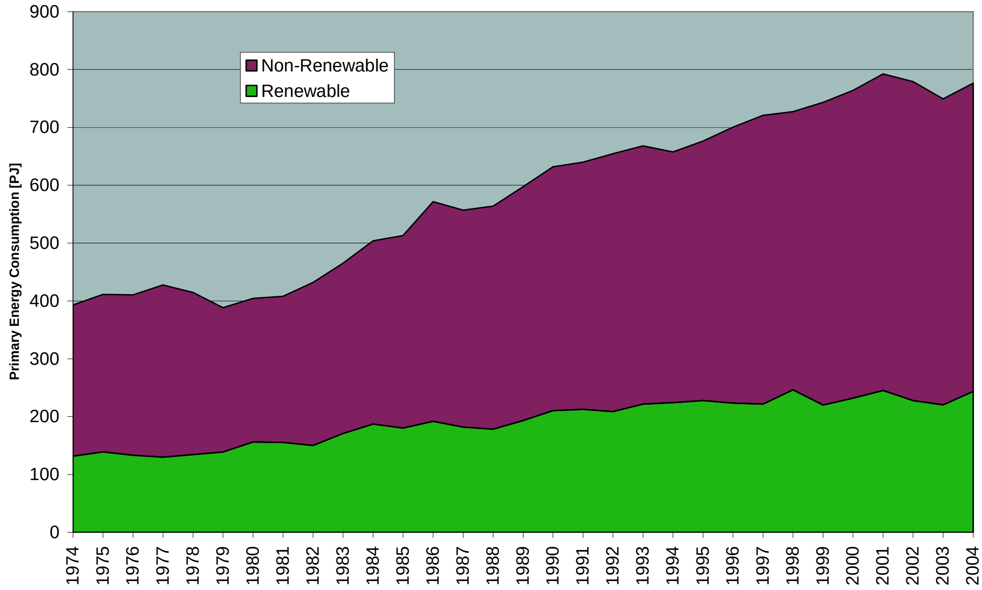
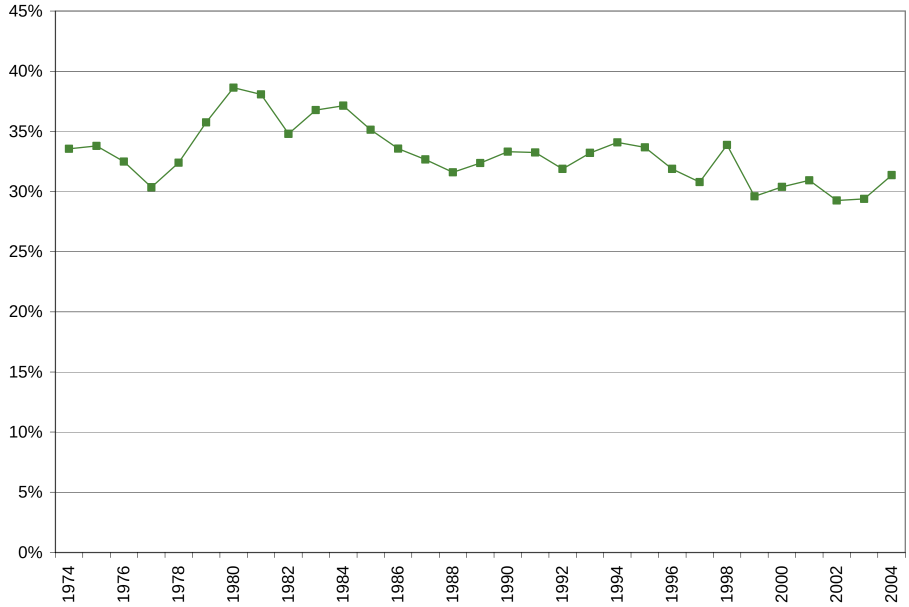
[4] Ministry of Economic Development

Although there has been a growth in total renewable energy use since 1971 (Figure 5), the percentage of energy derived from renewable sources has fallen from 39% to 31% over the same period (Figure 6). The faster growth of non-renewable energy sources is driven largely by the transport sector.



- **Figure 5 New Zealand's primary energy usage 1974-2004 (MEDb, 2006)**

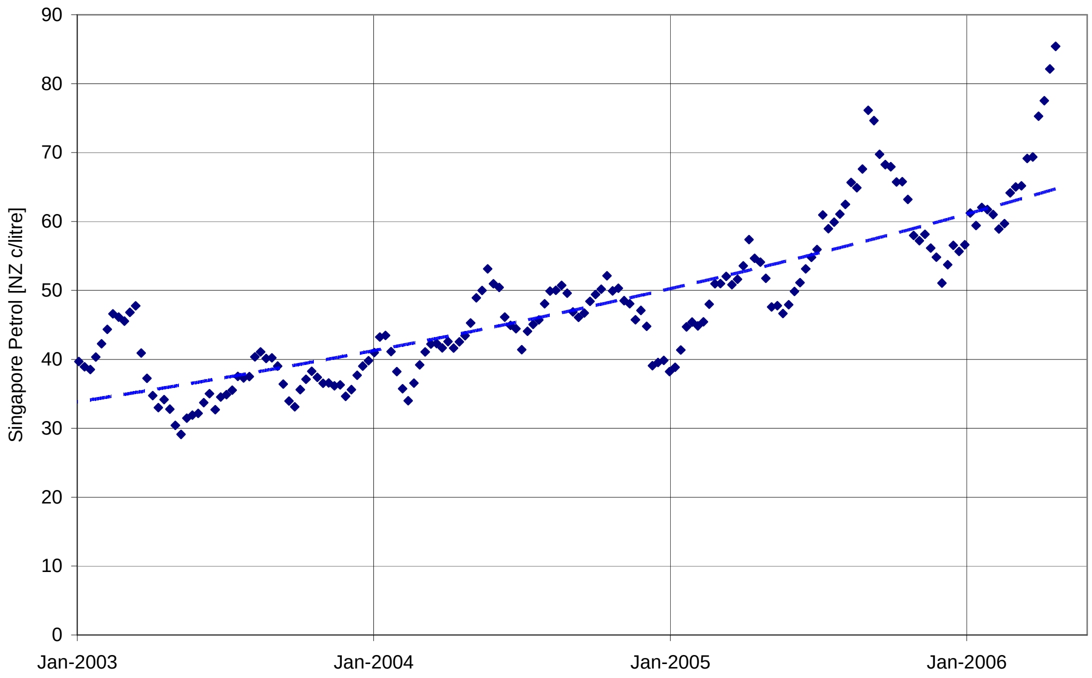


- **Figure 6 New Zealand's primary energy supply from renewable sources 1974-2004 (MEDb, 2006)**

In summary, the majority of New Zealand's current energy supply comprises oil, gas and coal, a large proportion of which is imported. Furthermore, the current proportion of energy from renewable sources is near the thirty-year historic low. If the present situation is be changed, there needs to be a very clear set of benefits for doing so in terms of energy costs, security of supply and climate change.

2.4 Energy Costs

The cost of liquid fuels has grown rapidly over recent years, with the price of basic imported petrol (excluding taxes) doubling since 2003 (Figure 7). This trend is very much greater than that predicted by the Ministry of Economic Development (MED, 2003) in its 2003 projections of future energy costs, where even under the high cost scenario, crude oil was predicted to be US$30 / bbl by 2025. However, by 2006, the cost was over US$70 / bbl. The rapid increase in oil prices is symptomatic of rising energy prices across the board as international demand for raw materials grow, market forces set the price for substitute materials and security of supply concerns continue (e.g. Deffeyes, 2001). Although increases in electricity prices have not been as substantial as those for liquid fuels, certain consumer groups, particularly residential consumers, have seen electricity prices (excluding GST) rise from 12.48c/kWh[5] in 1995 to 16.59c/kWh in 2005, a 30% increase in real terms over ten years (Figure 8).



- **Figure 7 Trends in the cost of imported liquid fuels in New Zealand. Cost of Singapore petroleum (NZ c/litre) (MED, 2006)**

[5] KWh (kilowatt-hour) - the standard unit of electricity supplied to the consumer. Equal to 1 kilowatt acting for 1 hour. Or 1 kWh = 3.60 x 10^6 Joules

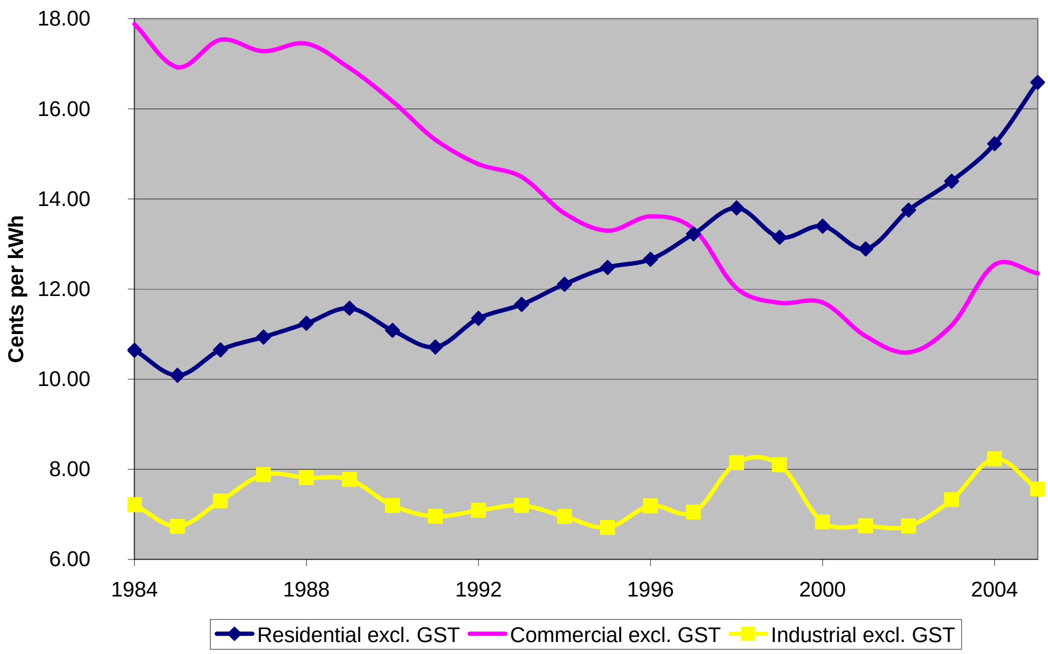


Figure 8 Electricity consumers prices expressed 1984-2005 (Real year end March 2005 prices) (MEDb, 2006)

The concern for New Zealand and other developed countries is that rising energy costs may lead to a decrease in energy demand and this, combined with already high labour costs, will reduce economic competitiveness and soften economic growth.

However, one of the key barriers to greater uptake of renewable energy has been cost, particularly upfront capital costs for electricity, which have typically been higher than comparable costs for fossil fuels. However, this situation changes as international prices for oil, coal and gas continue to increase.

Increasing electricity costs will mean that more renewable projects should be economically feasible as the market price of electricity exceeds their cost of generation (see for example Figure 9 from MED's Energy Outlook to 2025 published in 2003). That MED prediction indicated that renewable energy could in fact dominate the new generation market given suitable market electricity prices.

Similarly, it is expected that biofuels will increasingly become mainstream if high oil prices are sustained.

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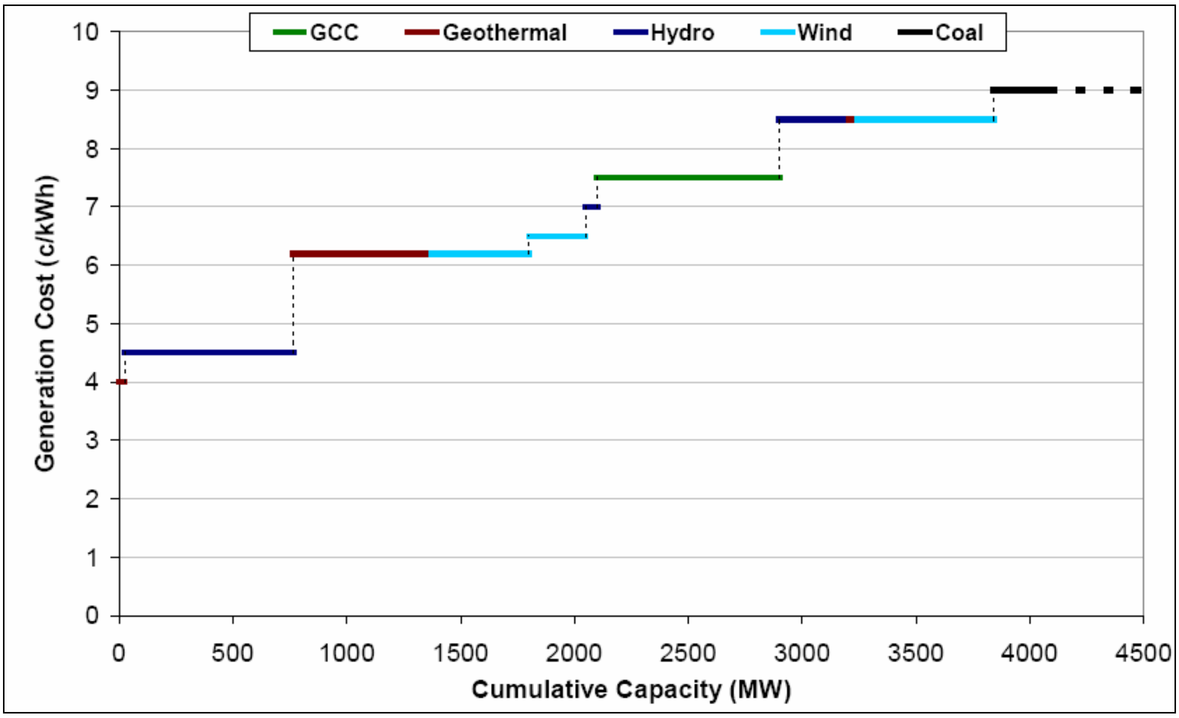

- **Figure 9 Indicative quantities of new generation sources viable at a range of prices (MED 2003)**

NB: GCC stands for Gas Combined Cycle

2.5 Security of Supply

A diversified portfolio of renewable energy supply can improve the resilience of the New Zealand economy to future energy supply problems and price shocks. This is recognised as one of the main goals of the National Energy Efficiency and Conservation Strategy (NEECS).

In general, energy sources present some form of risk, including:

- Continuity of supply, either through exposure to international markets or limited indigenous energy reserves
- Limitations for future growth
- Exposure to international price increases

These are detailed in Table 1 for New Zealand's energy sources.

Table 1 Supply risks to New Zealand's energy sources

Energy Source	Risk
Natural gas	Limited life of Maui field, some new discoveries have been made but there are not currently sufficient to replace Maui and confidently enable major expansion of longer term gas usage. Imported Liquefied Natural Gas (LNG) or Compressed Natural Gas (CNG) is a possible supplement or replacement for indigenous gas reserves. It requires additional infrastructure and presents full exposure to international pricing and supply.
Coal	Supplies of low-sulphur, low-ash coal are presently sourced internationally. This has exposure to international pricing and supply. New Zealand has large reserves of lower grade coal that could form a longer term energy supply if and when barriers to its extraction and use are resolved.
Oil and petroleum liquid fuels	There is limited indigenous production of liquid fuels. Over 80% of liquid fuels are imported, presenting exposure to international pricing and supply.
Hydro	New Zealand's relatively low lake storage volumes mean that available water flows are strongly affected by weather variation. In addition, hydropower's long term generating capacity could be affected by climate change. New hydropower generation projects have been identified for a number of years and several have recently been progressed. However, these projects have faced major barriers in securing water use consents. Resource consents have no automatic right of renewal and are periodically exposed to public review and objection.
Geothermal	Not exposed to climate change. Resources will change under extraction and require some on-going investment to maintain production. Cost of capital for new developments is linked to international commodity prices (steel, generation plant). Barriers to securing resource consents for new projects. Resource consents have no automatic right of renewal and are periodically exposed to public review and objection. Concern over subsidence has affected one consent renewal.
Wind	Some exposure to climate change. Major barriers to securing resource consents for new projects. Resource consents have no automatic right of renewal and are periodically exposed to public review and objection.

Diversification into a wider range of indigenous renewable energy sources could help mitigate these risks in two ways: reducing dependence on international fuel markets; and reducing dependence on a single form of indigenous renewable resource (*i.e.* hydropower). On the latter issue, since encountering several very "dry" years with consequent low levels of electricity reserve (1992, 2001, 2003) and with little new generation capacity being added to the New Zealand system, the government and major generation companies have recognised the need for additional diversified electricity generation. The generation companies have been making substantial effort to develop new power generation from hydro, wind, geothermal, gas and coal but this has had limited success. Section 2.10 highlights the key barriers for renewable energy.

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2.6 Local Benefits

The NEECS recognises the potential benefits for regional economic development that can arise from the development of renewable energy projects. Renewable energy projects (with the exception of biomass plant, where location is an economic consideration) need to be located close to the natural resources upon which they depend and this is usually away from the main urban centres. It is also recognised that for sources such as wind, there is value in having a good geographic spread of projects to increase the likelihood of having a well-balanced system. For the regions, this can mean increased economic activity associated with energy developments and the associated improved strength of local electrical network and supply. Many biofuel resources require sustained agricultural activity to grow and harvest fuels, offering a long term and alternative form of economic activity. In addition, some renewable energy sources such as biofuels and geothermal can have secondary benefits in terms of direct heat use for agriculture or industrial processes, and some hydro projects can enable agricultural irrigation schemes.

During the course of the project, a number of councils highlighted pressing energy-related issues in their region, which could be at least partially addressed by a greater uptake of renewable energy.

- Transmission / distribution constraints leading to supply disruptions and associated loss of economic activity or the potential for supply disruption which could limit future growth and inward investment.
- Uncertainties surrounding the future of local energy sources (*e.g.* gas reserves) or local large-scale power generation plants (*e.g.* coal-fired units) which may lead to a supply shortfall, particularly in combination with distribution constraints.
- Liquid fuel and electricity costs which have the potential to cause a serious economic downturn, particularly in those regions where the local economy is largely dependent on agriculture, forestry and other sectors which are large consumers of liquid fuels.
- Regions where there is a substantial renewable resource, which can be used through the application of mature, cost effective technologies with environmental impacts that are broadly acceptable to the community.
- Regions where there is substantial renewable resource, which could be harnessed using emerging technologies over the next years and which have the desire to become regional, national or international technology leaders.
- Regions where there is considerable expertise of new energy technologies, which would benefit from the development of a regional market for their applications.
- A further factor to consider is that in 2013 lines companies will no longer be obligated under Regulation to continue supplies to (uneconomic) rural customers.

2.7 Climate Change

New Zealand has ratified the Kyoto Protocol, which entered into force on February 16, 2005. New Zealand's target is 100%, which means that New Zealand is required under the Protocol to reduce its greenhouse gas emissions back to 1990 levels on average during the First Commitment Period (CP1 or 2008-2012), or otherwise take responsibility for any excess emissions. It was envisaged that for New Zealand this target would be able to be met through a combination of domestic emissions reductions and increases in carbon sinks. It was also anticipated that more significant emission reductions would need to be negotiated for future commitment periods.

In May 2005, an estimate of New Zealand's CP1 emissions position relative to the target was projected to be about 32 million units (tonnes of carbon dioxide equivalent). In December 2005 the net emission deficit was increased to just below 51 million units, reflecting updated information about deforestation intentions. As of May 2006, New Zealand's net position for CP1 was estimated to be a deficit of 41 million units, within a range of a surplus of 1.4 million units under a lower emissions scenario and a deficit of 76 million units under a higher emissions scenario.

Renewable energy will significantly assist New Zealand to meet its obligations under the Kyoto Protocol whilst helping to meet New Zealand's growing electricity demand without increasing the use of thermal generation, whose greenhouse gas emissions contribute to climate change.

2.8 Resource Management Act

The Resource Management (Energy and Climate Change) Amendment Act 2004 introduced three new matters into section 7 (Other Matters) of Part II of the Resource Management Act 1991 (RMA), requiring all persons exercising functions and powers under the Act to have particular regard to:

(ba) the efficiency of the end use of energy

(i) the effects of climate change

(j) the benefits to be derived from the use and development of renewable energy

To support the section 7(j) amendment, section 2 of the RMA was amended to define "renewable energy" as "energy produced from solar, wind, geothermal, hydro, biomass, tidal, wave, and ocean current sources".

The law relating to these maters has been refined to some extent by the Environment Court in its decision on *Genesis Power Ltd and The Energy Efficiency and Conservation Authority v Franklin District Council A148/2005*. This decision related to a resource consent application to establish a wind farm on the Awhitu Peninsula, south of Auckland.

The Court identified the benefits to be derived from renewable energy to include:

- Security of supply
- Reduction in greenhouse gas emissions
- Reduction in dependence on the national grid
- Reduction in transmission losses
- Reliability
- Development benefits
- Contribution to the renewable energy target.

The Court also gave considerable weight to the positive effects of renewable energy in its consideration of the decision and also found support for the project in its general assessment of Part II of the Act.

The 2004 amendment also removed the regulatory means for controlling greenhouse gases, as at the time when the Amendment Act was being developed, fiscal measures (namely the carbon tax) were being introduced to have the same effect. As a result, councils now cannot make rules which control the discharge of greenhouse gases on the basis that they contribute to climate change, nor can they consider climate issues in relation to resource consents. Rules relating to the control of greenhouse gases for climate change purposes made prior to enactment no longer apply. However, historic resource consent decisions still stand.[6]

In 2005, the Act was further amended by giving additional powers to councils to:

> *''the strategic integration of infrastructure with land use through objectives, policies, and methods:''*

The amendment also provided a wide definition of infrastructure which includes:

> *''(a) pipelines that distribute or transmit natural or manufactured gas, petroleum, or geothermal energy:*
>
> *''(d) facilities for the generation of electricity, lines used or intended to be used to convey electricity, and support structures for lines used or intended to be used to convey electricity, excluding facilities, lines, and support structures if a person—*
>
> *(i) uses them in connection with the generation of electricity for the person's use; and*

[6] A Private Members Bill is currently before Parliament that will effectively reverse these provisions.

(ii) does not use them to generate any electricity for supply to any other person:

These powers may be implemented by providing objectives, policies and methods in regional policy statements that will provide greater direction as to the locations and co-ordination of such infrastructure.

The 2005 amendment to the Act also changed the status of Regional Policy Statements. Previously District Plans were required to be not inconsistent with a Regional Policy Statement. The 2005 amendment altered this so that District Plans are now required to give effect to a Regional Policy Statement. This gives Regional Policy Statements additional powers to direct what provisions are included within District Plans.

Overall recent amendments to the RMA both require and empower Councils to have a greater role in the encouragement of renewable energy generation.

2.9 Draft Energy Strategy

The government has recently published its Draft Energy Strategy (MED 2006). It proposes that as much new electricity generation as possible should be renewable, except to the extent necessary to maintain security of supply. Other key elements of the strategy include:

- Introducing renewable fuels as substitutes for petrol and diesel
- More solar water heating
- More energy efficient homes and buildings
- Funding for the early deployment of marine-based electricity generation such as wave or tidal, worth $8 million over four years
- Consideration of RMA consent applications for wind and geothermal electricity generation projects in groups to better compare national benefits and environmental impacts

The last item is of particular interest to this study and as stated in the Draft Strategy reads:

> *"Action: Consider a consolidated consenting process for wind and/or geothermal generation projects. Further consider the merits of national guidance under the RMA for renewable energy. In the near term, ensure that RMA decision-makers are provided with information held by central government on the energy sector implications, environmental effects and trade-offs associated with renewable energy projects."*

2.10 Barriers to Renewable Energy

There are a range of barriers that have slowed the uptake of renewable energy. These largely relate to the need for individual projects to secure their own "fuel" supply from natural resources while also still having to construct an energy conversion facility (*i.e.* power plant). The locations where these natural resources are found often have other intrinsic value (such as wind resources found in areas of high landscape value, or hydro opportunities in dramatic catchment areas) or the resource itself has other competing uses (such as recreational use of rivers, geothermal features as tourist attractions).

Some of the major barriers to renewable energy are identified in Table 2, along with a brief indication of where councils may have some influence on those barriers:

- **Table 2 Major barriers to renewable energy projects**

Barrier	Description	Council Influence
High capital cost	Projects include the cost of “fuel” gathering as well as energy conversion and hence tend to have high capital cost. Some technologies are new and do not yet have the economies of scale in plant construction compared to conventional energy sources.	No influence
Intensive “fuel” investigation	Intensive investigation is required for determining resource potential. This is very high for geothermal but less for wind and hydro.	Consents for wind measurement towers, geothermal drilling and river weirs
Low energy density	Many renewable projects have a low energy density – requiring large areas for the collection of fuel and for energy conversion plant. However, some types such as wind and geothermal do not preclude continuation of other uses such as farming.	Land use that is allowed within human and natural land zonings.
Long development time	Most have several stages of development, from resource evaluation, consenting and construction. There are associated development risks at each stage.	Consenting process
Wide consultation Community attitude to natural resource uses	The use of natural resources and construction of plant in natural areas demands a high level of consultation often in the face of significant public opposition.	Planning environment Consenting process
Resources associated with natural features or areas of intrinsic or cultural value	Renewable energy can be associated with natural features that have high intrinsic value, such as wind in outstanding landscapes and hydro in natural waterways. These areas may also have special cultural value to Maori.	Landscape planning, natural area identification. Balancing effects of development against amenity values in consent process.
Competing uses for the same resource	Recreation use of rivers and irrigation competes with hydro power. Geothermal surface features have a range of uses.	Balancing effects and benefits from competing uses Resource consents to take water
High “mitigation” fees	Due the fact that objectors can impede the consenting process, many affected	Planning environment

Barrier	Description	Council Influence
	or interested parties now expect substantial fees in return for their agreement to a development. Consent requirements have resulted in a secondary mitigation fee market that is a barrier particularly for smaller projects.	Consenting process
Non-firm nature	Some renewable resources such as solar, wind and marine are periodic or intermittent in nature. This limits their ability to meet peak demand requirements and hence tend not to secure highest market prices.	No influence
Transmission requirements	Most renewable energy projects need to be located close to the energy resource and so are dependent on transmission networks to carry the energy to where it is required. Weak transmission networks limit positioning of projects. Developers may be required to build new transmission lines to service their projects.	Consents and designations for transmission upgrades or new lines
Environmental considerations	Councils may find it difficult integrating increased interest in renewable energy alternatives with local environmental concerns, already identified in existing or operative legislation. For example the use of biomass as an alternative to electricity could be viewed as an air quality problem, rather than an energy supply solution.	Planning environment Consenting process Non-regulatory

Fossil-fuelled projects are also affected by several of these obstacles. The 1,000 MW[7] Huntly plant has been reverted to being fuelled by coal so that the gas it would have otherwise used can be redirected to a new efficient CCGT gas-fired plant under construction. However, the conversion of the Marsden B plant to coal is subject to appeal on conditions by the developer and on environmental grounds by environmental groups opposed to the project.

Recent successful renewable energy projects have included an expansion to the Tararua wind farm and an expansion to the Mokai geothermal plant. That said, the proposed expansions of the

[7] The unit for measuring power is the Megawatt (MW) (or MW*e*, to differentiate the *e*lectrical output from thermal output). Power is the rate at which energy is generated / consumed, i.e. 1 MW means that one million joules of energy is generated / consumed every second. As crude approximations: a full petrol tank in an average size car contains one million joules of energy; a single wind turbine has a 1MW capacity.

geothermal projects at Ngawha (for which the consent has been granted) and Kawerau have faced lengthy appeals because of perceived effects. In addition, the hydro project "Aqua" was reportedly abandoned due to a perception of major public opposition, and several wind farms have faced similar opposition.

Developers report that small renewable projects are no longer viable to consider for development as the costs and delays associated with the consenting processes and the "mitigation" fees can be as great as for large projects. However, if fossil fuel costs and wholesale electricity prices continue to increase in line with recent trends then the higher market return possible for alternative energy sources will tend to enable the development of more renewable energy projects.

2.11 Potential Role for Local Government

While development of renewable energy resources can have benefits that are of national and regional value, these benefits apply to a variety of sectors and are often not manifested in a way that is tangible and of direct value to the individual developer. In the absence of direct financial or other enabling incentives, the wider national and regional benefits therefore may not surmount the barriers to most forms of renewable energy development.

This is the reason that central government has engaged in strategies to promote renewable energy. Some of the barriers to renewable energy development are manifested in the regions and districts, and the councils have a key role in the process for approving or declining these projects and more fundamentally, for establishing policies and plans that proactively support greater uptake of renewable energy. Councils, in fulfilment of their role to promote the sustainable development of their communities, also have a mandate to undertake a range of non-regulatory activities to promote renewable energy. This discretionary role can include advocacy, mapping co-ordination, partnerships and projects that assist in the development of renewable energy projects. The Councils and their policy and planning instruments can therefore have a significant effect on the future uptake of renewable energy in New Zealand.

3 Technologies

This section provides a summary of technologies which are used to utilise renewable energies. Renewable energies are defined by the RMA as:

- Solar
- Wind
- Hydro
- Geothermal
- Biomass
- Tidal
- Wave
- Ocean Current

Of these, hydro and geothermal are relatively mature technologies, solar, wind and biomass are new and to some extent still developing, while tidal, wave and ocean current are still at the development stage.

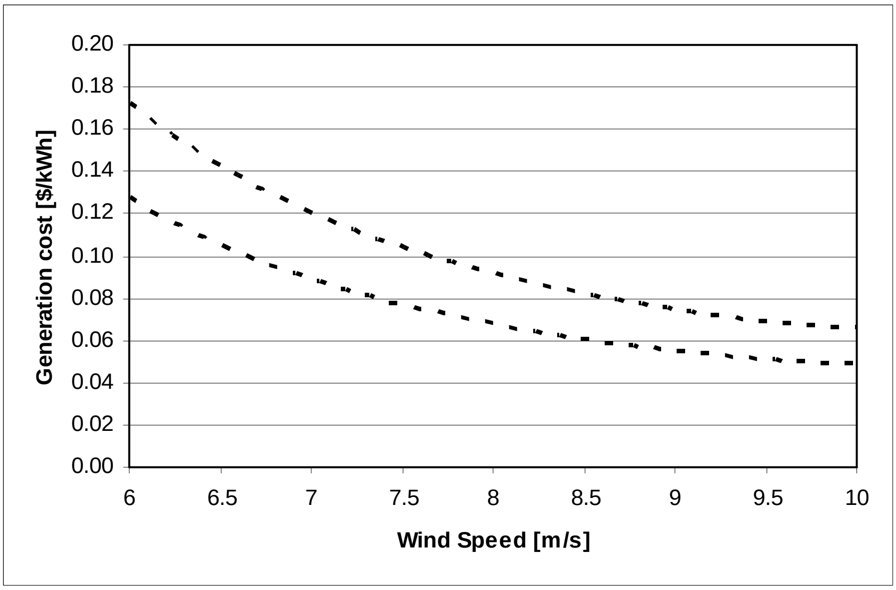
3.1 Technical and Economic Considerations

The following paragraphs comment on some issues that affect cost estimates for renewable energy projects and future price trends. All the listed values in Table 3 for capacity factor and cost are indicative only. Renewable energy projects have generally very project specific cost components and need to be assessed on a case by case basis. Figure 11 (at the end of this section) presents the indicative cost information from Table 3 graphically together with an assessment of each resource's firmness, ranging from wind power (intermittent and difficult to forecast) to geothermal (continuous, available on demand). As for renewable energy projects, cost information for conventional thermal power projects (e.g. coal, gas) depends on a range of factors including size, location, technology, design and consenting requirements. Section 4 of the Draft New Zealand Energy Strategy to2050 (MEDa, 2006) presents information on typical costs for new electricity generation for both conventional thermal and renewable energy projects.

3.1.1 Wind power generation

Figure 10 shows the dependency of the generation costs from large scale wind farms on the average wind speed. Note that this graph is only an indication of likely costs for typical projects. Costs can vary significantly between projects, depending on complexity of the terrain and resulting higher costs for access roads or long distance to the grid with high investment needed for the grid connection. The graph shows that currently the electricity prices require average wind speeds of around 8 m/s for projects to be economically viable. A future increase in electricity prices will make areas with lower wind speeds attractive for developers also.

Wind turbine prices have dropped considerably over the last decade due to a large increase in manufacturing rates/capacities and technology enhancement. However, this trend is not expected to continue. Last year saw a general increase in turbine prices, which was partly due to higher steel prices. Furthermore, some manufacturers were forced to increase prices to avoid financial losses and make the business more profitable. Profit margins have been very small in the past due to a very competitive market.



- **Figure 10 Indication of wind energy generation costs**

NB: The two curves represent a range as generation costs vary significantly for different projects even if they have the same wind speed levels.

3.1.2 Solar PV generation

Solar PV system costs have been dropping significantly over the last decade. Furthermore, the efficiency of solar cells is constantly improving. This trend is expected to continue with further production capacity lowering the costs, and further technology developments increasing the efficiency.

3.1.3 Solar thermal conversion

Technology used in solar thermal conversion systems continues to advance, reducing production cost and increasing system performance. Ongoing improvements to solar conversion surfaces and effective reductions in convection losses ensure solar thermal conversion efficiency continues to improve. It is believed that this technology will remain as the most economic solar conversion system available for installation in both new and existing houses.

3.1.4 Hydro generation

The wide range of cost of generation comes about because of the very site specific nature of projects. The necessary project components and their scale (for example diversion and water conveyance works, environmental mitigation works and choice of equipment) depend very much on the location and the intensity of the potential. Additionally site specific aspects such as topography and geology drive construction costs while local hydrology determines the energy available from the site. Whereas low head schemes have proportionally large (and slow speed) generating units and relatively low civil works investments, the opposite is the case for high head opportunities where the (small, high speed) machine cost tends to be low, but with a relatively high investment in the diversion works and pipeline. The scheme's proximity to electrical grid, access to site and necessary transportation work (new roads vs. existing) can also affect the project cost substantially, as can the cost of capital (own or borrowed from the market) in the prevailing market conditions.

3.1.5 Geothermal power generation

Geothermal development costs have been relatively stable for some time, although drilling costs in particular have risen over the past year. Many of the recent geothermal power developments in New Zealand (*e.g.* Mokai, Rotokawa and Ngawha) have used wells that were drilled by the government many years ago, thus removing a significant cost and risk component. Similarly, expansion of those projects can draw on a production history that allows greater certainty as to the size of the resource and its capacity to sustain the expanded operation. For example, addition of a binary power plant at Wairakei did not require any additional wells to be drilled, and cost much less than the estimated costs in Table 3, which are for a stand-alone binary plant. Costs are significantly higher for green-fields developments where there are no existing geothermal wells, compared with expansion of an existing development.

The energy in ground at ambient (non-geothermal) temperatures (10-15°C in New Zealand) represents a significant energy resource which can be used with ground source heat pumps (GSHP). This technology is used on a large scale in North America and Europe where the climate, high electricity prices and subsidies make this technology economic. These drivers are largely absent in New Zealand and as a result there has been little use of GSHP’s in New Zealand. Use of geothermal heat using ground source heat pumps can save up to 60% on electricity heating costs in a typical New Zealand home but, because of the high installation cost (approximately NZ$12,000), may only be economic for larger commercial buildings.

3.1.6 Marine power generation

Marine power generation costs are expected to drop considerably over the next decade. It is expected that the cost curve will be similar to the wind power generation. However, it must be noted some cost components, especially Operation & Maintenance, can only be estimated with high uncertainty at this stage.

Table 3 Renewable energy technologies

Resource / Technology	Technology Description	Technology Status	Type of Application - size - heat / electricity - peak / base / capacity	Environmental Effects	Costs*
Wind					
Wind turbine	Extraction of kinetic energy from the wind flow Horizontal axis wind turbine 2 or 3 blades Direct drive or gearbox AC generation	Well established Commercially available	Large scale Typical modern turbine size 2-3 MW Wind farms up to 300+ MW Intermittent generation Capacity factor: 35-45% Difficult to forecast	Visual impact Noise Shadow flickering Electromagnetic interference	$1,700-2,100 /kW (installed) approx. 8 c/kWh see comments above
Micro wind	Extraction of kinetic energy from the wind flow Horizontal or vertical axis turbines 2 or 3 blades Direct drive DC generation	Well established Commercially available	Small-scale (<10 kW) Electricity generation or direct drive of water pumps Intermittent generation Difficult to forecast	Minimal visual and noise impact	$7,000-10,000 /kW 30-40 c/kWh
Solar					
Solar Thermal System	Solar radiation transformed into heat System consisting of solar collector and storage Active systems use a pump whereas passive systems rely on gravitational forces	Well established Commercially available	Small-scale, heat	Minimal visual impact	$3,000-6,000 per domestic system 11-17 c/kWh_{th}
Solar Photovoltaic	Solar radiation transformed into electricity Solar cells consisting of semiconductor material (either thick or thin technology) Silicon most common semiconductor material	Well established Commercially available	Small-scale, electricity Intermittent generation	Minimal visual impact	grid connected (incl. inverter): $13,000-20,000 /kW approx. 80 c/kWh

Resource / Technology	Technology Description	Technology Status	Type of Application - size - heat / electricity - peak / base / capacity	Environmental Effects	Costs*
Hydro					
General	Water passing through a turbine rotates the runner which is harnessed to a generator to produce electricity.				
Run of River	Divert part of river flows to power plant, may consist of small barrage or a weir to store little water at the water diversion area. Often requiring tunnelling to move water to location where head drop can be achieved.	Well established Commercially available	Small to medium scale electricity Capacity Factor: 70-80%	Water extraction, aesthetic effects, ecological effects, recreational activities	$3,000-4,500 /kW 4-7 c/kWh
Storage	Dam creates water storage upstream of the diversion to be used to generate power on demand	Well established Commercially available	Medium to large scale electricity, peak load Capacity factor 50-70%	Land inundation, effect on aquatic ecosystems (change in habitat, fish migration), water quality, soil erosion, recreational activities, noise	$3,500-5,000 /kW 7-10 c/kWh
Pumped Storage	In addition to storage at the diversion area, water also stored at the downstream end where spent water is released and pumped back up to reuse it to generate.	Well established Commercially available	Medium to large scale electricity, peak load	Land inundation, effect on aquatic ecosystems (change in habitat, fish migration), water quality, soil erosion, recreational activities, noise	$2,500-4,000 /kW generation costs: N/A (net consumer)
Biomass					
Direct heat	Biomass (such as woodwaste etc) is burnt to generate heat, either directly or as steam or hot thermal oil.	Well established Commercially available	Available from the smallest domestic scale (wood stoves etc) to NZ's largest industries (pulp & paper).	Air quality may be affected by the smaller-scale developments. Large installations will have sophisticated emissions control systems. Fuel transport will have adverse effects.	Woody biomass: $4/GJ
Electrical generation	Biomass is burnt to generate steam for a power plant.	Well established Commercially available	Economics favours the larger-scale developments,	Power plant developments will have sophisticated	20 MW class woody biomass plant:

Resource / Technology	Technology Description	Technology Status	Type of Application - size - heat / electricity - peak / base / capacity	Environmental Effects	Costs*
			typically greater than 25 MWe, but limited by harvesting and transport costs. Capacity factor: 90%	emissions control systems. Fuel transport will have adverse effects.	$3,400 /kW 13 c/kWh
Liquid fuels	Very wide range of options for the production of liquid fuels, including hydrolysis and fermentation to ethanol, oil and tallow esterification to biodiesel, gasification and synthesis to methanol and hydrocarbons, pyrolysis etc).	Some technologies are well-established and commercially available (ethanol, biodiesel, etc), others are at prototype and/or early commercial stages (gasification and synthesis, pyrolysis, hydrolysis etc).	Economics favours the larger-scale developments, largely due to technical sophistication, but limited by distributed nature of the resource and the harvesting and transport costs.	Process plant developments will have sophisticated emissions and effluent control systems. Raw materials transport will have adverse effects.	Tallow and oils to biodiesel[8] Plant capacity 120,000 t/year. Plant capital cost $50 million. Feedstock cost $460/t, product cost $0.45/L. Biomass to Methanol[9] Plant capacity 250,000 L/day. Plant capital cost $250 M. Product cost $1.1/L, $61/GJ Biomass to Ethanol[10] Plant capacity 100,000 L/day. Plant capital cost $128 M. Product cost $1.75/L, $75/GJ

[8] Biodiesel refers to a diesel-equivalent, processed fuel derived from biological sources (such as vegetable oils), which can be used in *unmodified* diesel-engined vehicles. This is in contrast to other vegetable oils which can be used in some *modified* diesel vehicles.

[9] Methanol has the chemical formula CH_3OH. It is the simplest alcohol, and is a light, volatile, colourless, flammable, poisonous liquid with a distinctive odor. It is used as an antifreeze, solvent, fuel, and as a denaturant for ethyl alcohol.

[10] Ethanol is a flammable, colorless, slightly toxic chemical compound with a distinctive perfume-like odor with the chemical formula C_2H_6O. It is often referred to simply as *alcohol* and is the alcohol found in alcoholic beverages.

Resource / Technology	Technology Description	Technology Status	Type of Application - size - heat / electricity - peak / base / capacity	Environmental Effects	Costs*
Gaseous fuels	Biological degradation (anaerobic digestion, fermentation etc) to generate methane gas.	Well established Commercially available	Available from the smallest domestic and/or farm scale bio-digester to municipal effluent treatment for NZ's largest cities.	Process plant may need sophisticated effluent control systems. Raw materials transport may have adverse effects.	
Geothermal					
Conventional geothermal power plant (steam turbine) possibly with binary plant for steam condensing.	Fluid self-discharges from wells. Steam and liquid water flows are separated. Steam is passed directly through a turbine to generate electricity. Binary plant possibly used for condensing steam and heat recovery from hot water. Waste fluids mostly reinjected into the ground.	Well established Commercially available, applicable to high temperature (typically >200°C) geothermal fields	Medium to large scale electricity (base load), plus downstream direct heat potential. Capacity factor 90-95%	Air quality (especially H_2S odour), impact on surface thermal features, shallow aquifers and ecosystems, noise, visual, subsidence, resource depletion	$2,500-3,000 /kW 5 - 8 c/kWh
Binary power plant on medium to low temperature resources	Wells may self-discharge or require pumping. Geothermal fluid heats a secondary (binary) fluid in a closed cycle that is vaporised, drives a turbine, is cooled and condensed.	Well established Commercially available, most applicable to low temperature (120 to 200°C) geothermal fields. Applied in many USA fields usually with pumped wells. In NZ, binary plant presently only used for heat recovery from water on geothermal projects.	Small to large scale electricity (base load), plus downstream direct heat potential Capacity factor 90-95%	Air quality (especially H_2S odour), impact on surface thermal features, shallow aquifers and ecosystems, noise, visual, subsidence, resource depletion	$5,000-7,000 /kW 7-10 c/kWh
"Enhanced" Geothermal systems (including Hot Dry Rock – HDR)	Geothermal reservoirs that have heat but insufficient water or permeability for conventional extraction. Multiple wells required for stimulating fractures and circulation of a fluid through injection-production well couples. Energy converted to electricity Potential on margins of existing NZ fields.	At developmental stage in USA, Europe and Australia. Large heat reserves in some geological environments, hence there is technology development effort.	Projects are likely to be large to enable economy of scale	Effects expected to be minimal compared to conventional geothermal. Some thermal contraction effects (v minor subsidence)	High cost

Resource / Technology	Technology Description	Technology Status	Type of Application - size - heat / electricity - peak / base / capacity	Environmental Effects	Costs*
Direct use of heat: many potential uses, including:	Paper manufacture Timber drying Other industrial processes Space heating Space cooling Horticulture Aquaculture Bathing, spas	Well established Commercially available technology exists for most applications.	Range from very small scale (domestic heat pumps) to large scale industrial plants Capacity factor 90-95%	Depending on the scale of the operation, effects range from negligible to similar to a geothermal power plant	$300-400 /kW$_{th}$ $1-2 /GJ
Ground source heat pumps	Heat pump using the ground or groundwater as a heat source or sink. Can achieve very high efficiencies compared to conventional heat pumps using atmospheric heat sinks. Typically used to heat or cool buildings.	Well established Normally some measure of custom design in NZ, as there are few suppliers. Wider application in USA, Europe, Japan and China.	Range from domestic to commercial building scale.	Minimal effects. If using groundwater, then affects water temperature.	NZ$12,000 estimated installation cost is higher than standard heating-cooling systems. Electrical input ~25-30% of output. Viable for commercial buildings if long term efficiency is considered.
Tidal (Kinetic Energy) **Ocean Current**	Exploitation of velocity component of tide. Flow of water passing turbine blades cause aerodynamic lift. Blades are connected via shaft to electrical generator				
Technology a1[11]	Similar operating principle to vertical axis wind turbine. 2 or 3 blades mounted on a monopole seabed foundation	Large scale 300KW prototype demonstration 3 year sea deployment nearing completion. 1000KW grid connected demonstration prototype	In the order of 1MW per installation Electricity production Base load contributor – Energy BUT source intermittent but highly	Yet to be fully understood but generic issues with: Sub sea noise especially in piling operations Marine mammal collision Risk to marine navigation	Based upon estimates rather than track record: Early full scale prototypes $14,000 to 23,000 /kW Cost of energy range of

[11] These technology (a1, a2, a3, a4, b1, b2, a,b,c,d) are under development and hence have been given a notation to differentiate them from each other.

Resource / Technology	Technology Description	Technology Status	Type of Application - size - heat / electricity - peak / base / capacity	Environmental Effects	Costs*
		planned 2006-2007	forecastable (years in advance) Capacity factor 40-50%	and associated pollution risks Underwater cabling -Seabed and habitat disturbance -Electromagnetic interactions with elasmobranchs	28-43 c/KWh Early production models $5,000 /kW Cost of energy approx. 22 c/KWh
Technology a2	As above but floating Vertical axis rotary device on mooring. Either fully submerged or surface piercing.	Number of 500KW grid connected demonstration prototypes planned 2006-2007	In the order of 1MW per installation Electricity production Base load contributor – Energy BUT source intermittent but highly forecastable (years in advance) Capacity factor 40-50%	As above minus piling issue	as above
Technology a3	Ducted turbine mounted on seabed via concrete foundation	1MW grid connected prototype demonstration planned 2006-2007	In the order of 1MW per installation Electricity production Base load contributor – Energy BUT source intermittent but highly forecastable (years in advance) Capacity factor 40-50%	As above minus piling issue	as above
Technology a4	Reciprocating aerodynamic foils convert mechanical motion into hydraulic rams power take off device.	100KW grid connected demonstration planned 2007	In the order of 1MW per installation Electricity production Base load contributor – Energy BUT source intermittent but highly forecastable (years in	As above minus piling issue	as above

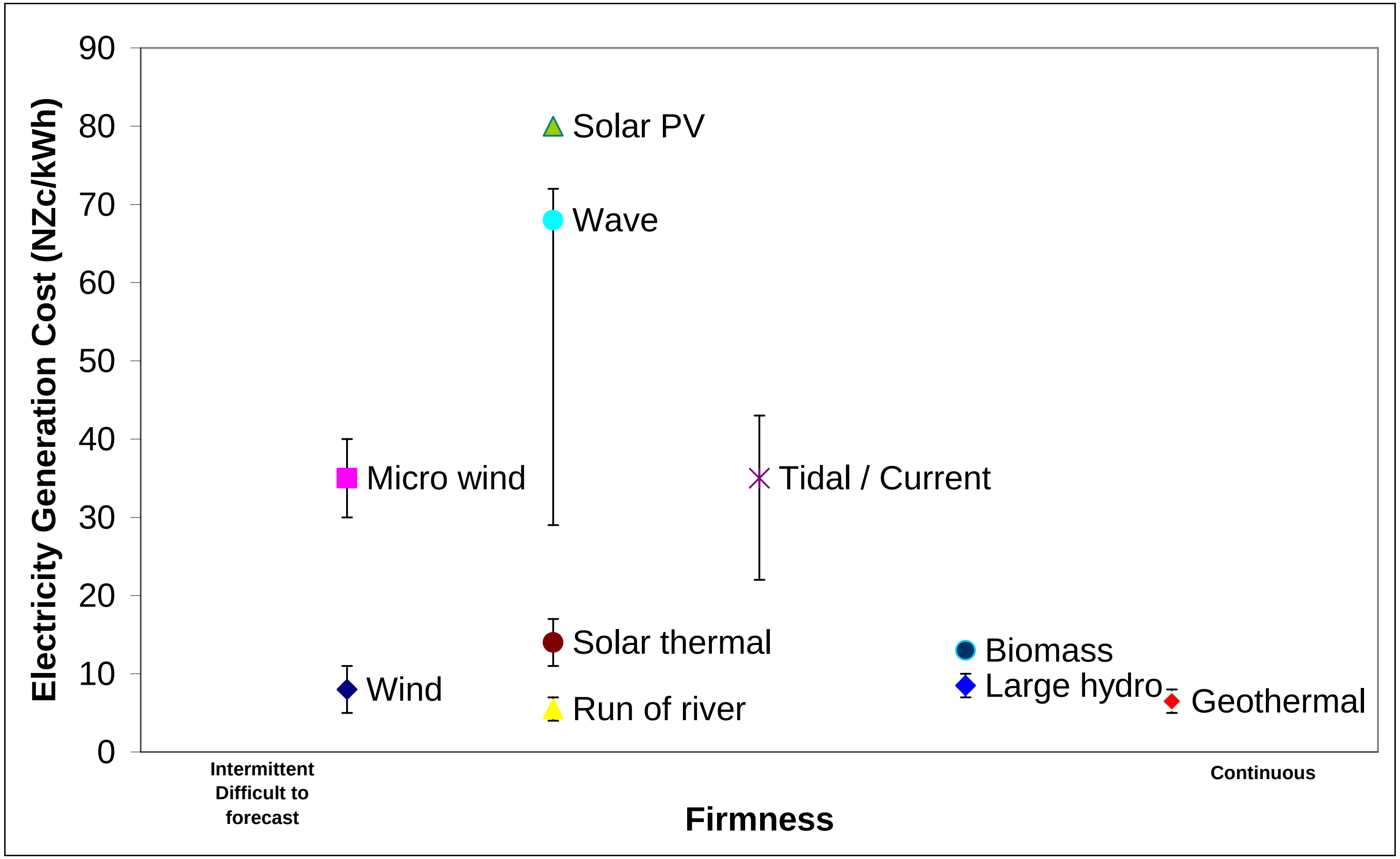
Resource / Technology	Technology Description	Technology Status	Type of Application - size - heat / electricity - peak / base / capacity	Environmental Effects	Costs*
			advance) Capacity factor 40-50%		
Tidal (Head)	Exploitation of head differential between high and low tide.				
Technology b1	Impoundment (dam) of estuary. Gates within the dam allow water to pass upstream of structure. Closure of gates at high tide creates head height differential across dam as tide falls on downstream side. Operation reversed at low tide. Low hydro turbines may then be used to release head and generate electricity.	Well established Commercially available technology exists for most applications.	In the order of 100MW per installation Electricity production Base load contributor – Energy BUT source intermittent but highly forecastable (years in advance)	Profound and irreversible change in estuary eco-system	Existing plants are broadly comparable with the upper end of fossil fuel based generation costs Costs are expected to be much higher in NZ due to the lower tidal range. Minimum tidal range currently considered economic for this technology is considered 5m.
Technology b2	Narrow headlands create 'nature' impoundment as head height can vary across the sides of the land mass. The introduction of piping containing water turbines exploits head driven flow.	Yet to be demonstrated at meaningful scale	In the order of 100MW per installation Electricity production Base load contributor – Energy BUT source intermittent but highly forecastable (years in advance)	Hazard to fish life passing through pipe. Estimated to be little eco-system impact	unknown
Wave					
Technology a	Oscillating water column: Conversion of wave energy into pneumatic energy, channelled through bi-directional air turbine connected to rotary electrical	Demonstrated at 500KW grid connected site. Presently with 4 year of operational service	Intermittent energy source. Forecast ability better than wind, but good reliability only based on future time period estimates of 6-8 hrs.	Yet to be fully understood but generic issues with: Marine mammal collision Risk to marine navigation and associated pollution	Based upon estimates rather than track record: Early full scale prototypes $11,000 to 26,000 /kW

Resource / Technology	Technology Description	Technology Status	Type of Application - size - heat / electricity - peak / base / capacity	Environmental Effects	Costs*
	generator. Can be configured as floating structure, seabed fixed or fashioned into cliffs or breakwaters		Electrical generation 500-1500's KW size range per installation Capacity factor 40%	risks (less if deeply submerged Changes in sediment transportation patterns Underwater cabling: -Seabed and habitat disturbance -Electromagnetic interactions with elasmobranchs	63-72 c/KWh Early production models $7,000 /kW approx. 29 c/KWh
Technology b	Point Absorber: Conversion of wave heave motion into mechanical relative displacement between floating buoy on sea surface and other reference point. Variety of PTO options including; Fluid pumping (water or oil) Hose Pump Direct drive linear generator	Demonstrated at up to 100(?)KW power level in open sea	Intermittent energy source. Forecast ability better than wind, but good reliability only based on future time period estimates of 6-8 hrs. Electrical generation + high pressure water pumping/desalination opportunities 100's KW size range per installation Capacity factor 40%	Yet to be fully understood but generic issues with: Marine mammal collision Risk to marine navigation and associated pollution risks (less if deeply submerged Changes in sediment transportation patterns Underwater cabling -Seabed and habitat disturbance -Electromagnetic interactions with elasmobranchs	as above
Technology c	Overtopping: Use of wall to focus wave energy into central location. Waves of certain size break over head wall and fill floating reservoir. Low head hydro turbines in floor of reservoir are connected to rotary electrical generator(s)	Demonstrated at up to 100KW level in open sea. Advance plans in place to deploy MW size device in 2007	Intermittent energy source. Forecast ability better than wind, but good reliability only based on future time period estimates of 6-8 hrs. Electrical generation 10's MW size range per installation	Yet to be fully understood but generic issues with: Large mammal collision Risk to marine navigation and associated pollution risks (less if deeply submerged	as above

Resource / Technology	Technology Description	Technology Status	Type of Application - size - heat / electricity - peak / base / capacity	Environmental Effects	Costs*
			Capacity factor 40%	Changes in sediment transportation patterns Underwater cabling -Seabed and habitat disturbance -Electromagnetic interactions with elasmobranchs	
Technology d	Attenuator: Semi-submerged, articulated structure of sections linked by hinged joints. The wave motion on these joints is resisted by hydraulic rams, which pump high-pressure oil through hydraulic motors which drive electrical generators	750KW pre production prototype deployed. Commercial order placed for several devices for Portuguese deployment 2006.	Intermittent energy source. Forecast ability better than wind, but good reliability only based on future time period estimates of 6-8 hrs. Electrical generation 10's MW size range 1-2MW size range per installation Capacity factor 40%	Yet to be fully understood but generic issues with: Marine mammal collision Risk to marine navigation and associated pollution risks (less if deeply submerged Changes in sediment transportation patterns Underwater cabling -Seabed and habitat disturbance -Electromagnetic interactions with elasmobranchs	as above

*Sources: General experience of SKM and NaREC gained in a number of different renewable energy projects

EHMS 2005 for solar thermal costs



- **Figure 11 Overview of generation costs and firmness of the different technologies**

4 Renewable Energy Potential

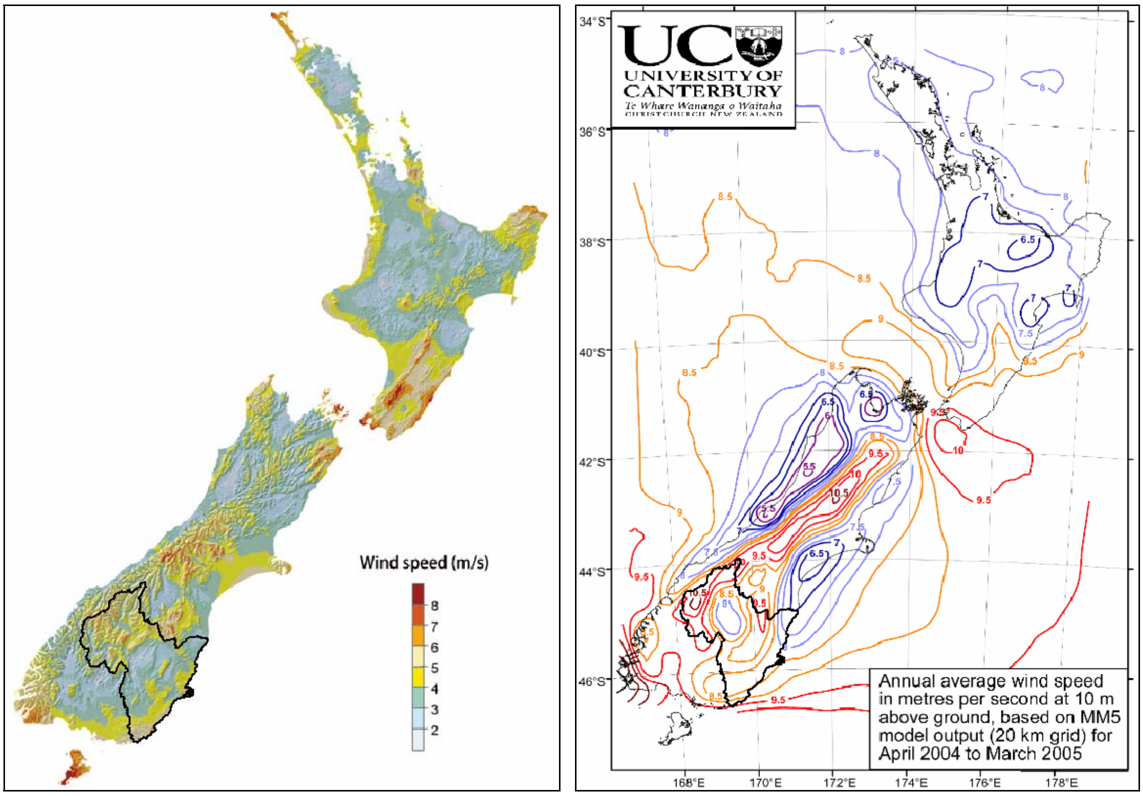
4.1 Introduction

This section reviews the existing and potential future renewable energy potential of the Otago Region, looking in turn at wind, solar, hydro, biomass, geothermal and marine energy. An overview of existing power infrastructure in the region is presented as Map 1 (Appendix C).

4.2 Wind

4.2.1 Wind Resource

Overall, New Zealand has good wind resource due to its location in the roaring forties, but wind speeds vary considerably around the country (Figure 12). Both wind resource maps have limited accuracy but provide a good indication of high wind areas. The NIWA map is derived from met station data whereas the Canterprise map is based on weather model data. The NIWA map is presented as Map 2 in the Appendix C.



- **Figure 12 Median and average wind speed at 10 m height (NIWA 2005a, Canterprise 2005)**

The wind speeds in the Otago region are not among the highest in the country, which are generally found in the southern part of the North Island. However, some areas in Otago are likely to have average wind speeds of above 8 m/s, which is currently the approximate minimum wind speed required for economic wind farms.

Earlier studies (EECA & CAE 1996, EECA 2001a) identified three potential areas in the Otago region with sufficient wind speeds: the coast south of Dunedin, exposed sites in inland Otago and the hills in the South East of the region. The wind speeds were estimated to be 7 m/s for the inland sites and 9 m/s at the coast and SE hills at 50 m height respectively.

These areas are confirmed by the more recently published wind maps. It is estimated that there are a number of sites with wind speeds of around 8-9 m/s at 60-80 m height (this is the hub height range for modern large wind turbines). Most of the terrain is complex though, which requires onsite wind measurements to assess the wind conditions on a project by project basis.

4.2.2 Potential Electricity Generation from Wind

Wind power generation has become a significant contributor to electricity generation in many regions around the world (especially Europe and US). There is currently 60,000 MW of wind power installed worldwide. Germany alone has almost 18,000 installed wind turbines with a total capacity of around 18,500 MW. The development of wind power in New Zealand had been delayed for many years because of very low electricity prices, which made it uneconomic to install wind turbines. Rising electricity prices during the last few years have changed this, and wind farms are now competitive with other forms of electricity generation. New Zealand’s total installed wind power capacity of 170 MW is still very low though when compared internationally.

There are currently no wind farms in the Otago region, but some wind farm developers have publicly announced their plans and projects:

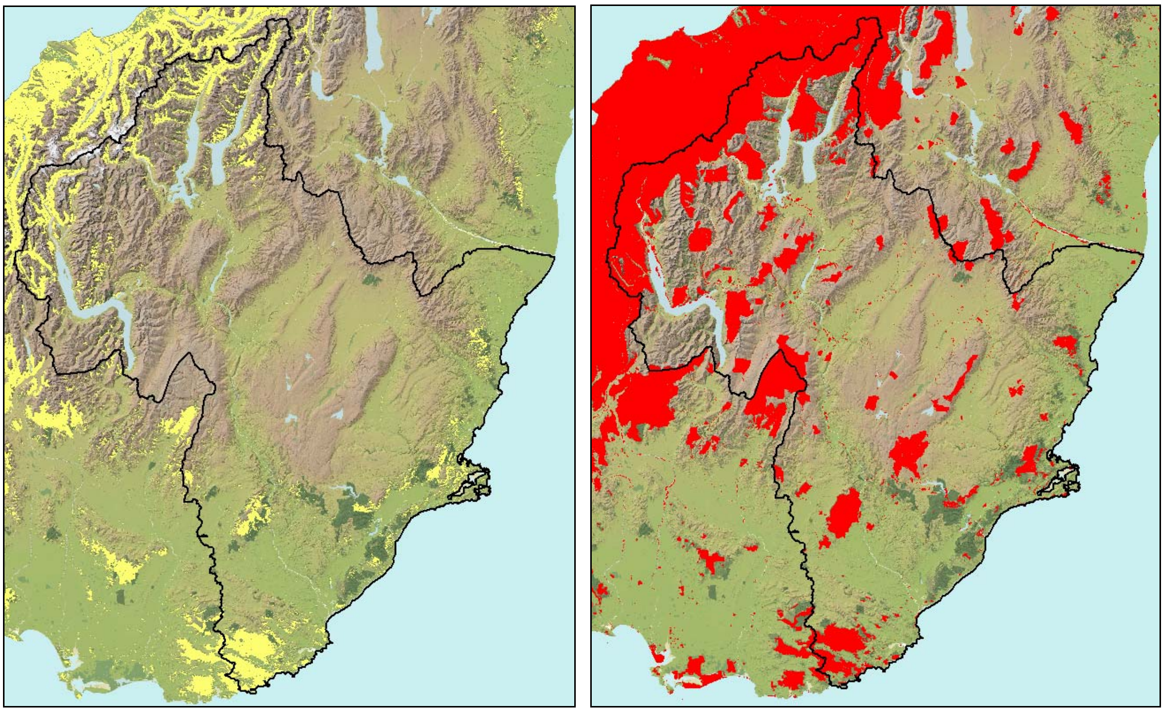
- Meridian Energy, Project Hayes Wind Farm, 600 MW, seeking consent
- TrustPower, Mahinerangi Wind Farm, 200 MW, seeking consent.

In addition, several developers are investigating certain areas of the region, such as Rock and Pillar Range, Cairnmuir Mountains, Mt Benger and Kaihiku Ranges. The envisaged capacities at these sites are not known.

It is not straightforward to accurately estimate the wind power potential for the Otago region. For example, it is not only the wind speed that determines suitable areas, but a range of other factors including location of important natural features, proximity to population, site availability, topography, access and distance to electricity network or grid. SKM has spoken to a number of wind power developers active in the region. Due to the highly competitive market situation, they were not able to provide project locations or planned capacities (other than the above). Those projects will only be made public once all landowner agreements have been signed and when there is high confidence about the viability of the project.

It is not only the wind speed that determines suitable areas, but a range of other factors including location of important natural features, proximity to population, site availability, topography, access and distance to electricity network or grid.

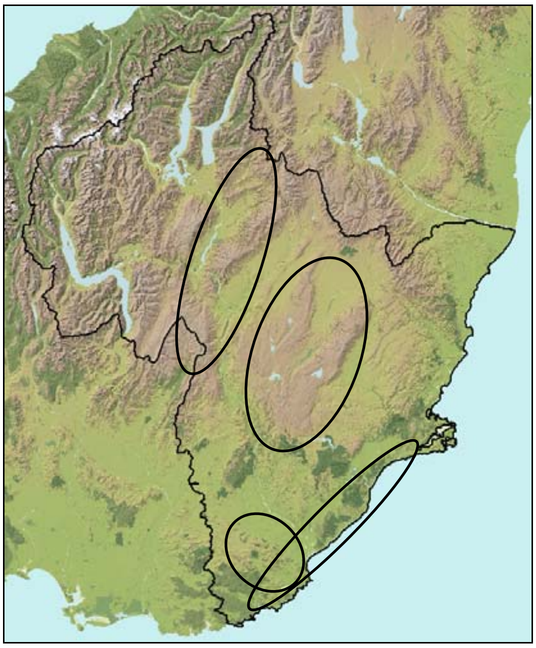
Figure 13 shows areas that will require careful and sensitive planning when proposing wind farms. Native forest and Department of Conservation (DoC) land can lengthen and complicate the consent process. Most of these areas are currently perceived as not suitable for wind farms. It can be seen that it may be difficult to obtain consents for some areas with high wind speeds. Due to the high concentration of native forest and Department of Conservation land in the south east of the region, the potential for large scale wind farm development will be restricted despite the good wind resource.



- **Figure 13 Native forest (yellow) and Department of Conservation land (red)**

Very large wind farms (300+ MW) are likely to be developed due to the region's sparse population and suitable topography, especially in inland Otago where the Mahinerangi and Project Hayes wind farms are proposed. The accumulation of a number wind farms in one area can potentially lead to cumulative environmental effects. The wind farms in the Otago region are expected to be in the 50-100 MW range for coastal and the south east hills sites and 200+MW for inland sites and located some distance from each other so that cumulative effects are less likely. Five to seven wind farms of theses sizes (one to three in the 50-100MW range and three to five in the 200+MW range as a very preliminary estimate) could potentially be developed based on an initial screening of the region taking into account wind resource, topography, population density, distance to grid, accessibility and environmental factors (native forest and DoC land). Map 1 in Appendix B shows the topography, and the infrastructure in Otago region.

If carefully planned, approximately 1000 MW of wind capacity could be installed over a number of years with environmental impacts that were broadly acceptable to local communities, focused in the areas shown in Figure 14 (see Appendix B for a more detailed map). Wind farm development is most likely to be focused in the areas shown in Figure 14 (see Map 3, Appendix C for a more detailed map). The development of wind farms in the Otago region is likely to cause some controversy as it does in other regions of the country.



- **Figure 14 Elevation map with potential wind farm areas**

The development of wind farms in the Otago region needs also to be looked at in a nationwide context. Due to the intermittent nature of wind power there is a limit to how much wind power can be connected to the national grid. A recent study investigated the wind power integration limit (Energy Link & MWH NZ 2005). It was found that 20% of the nation's annual electricity consumption could potentially be met by wind generation. This leads to a potential wind power capacity of around 2,000 MW (based on today's consumption). There is currently only 170 MW of wind power installed in NZ but a number of large projects totalling more than 1,000 MW are under way or are being planned.

Small scale wind turbines (<10 kW) can successfully be operated in areas with lower wind speeds also. The lower hub heights (approx. 10-20 m) of these smaller turbines means more care needs to be taken when siting near local obstacles (*e.g.* trees and buildings). It is unlikely that small scale wind turbines will play a significant role in future electricity generation, but they could become important for remote farms and settlements.

4.3 Solar

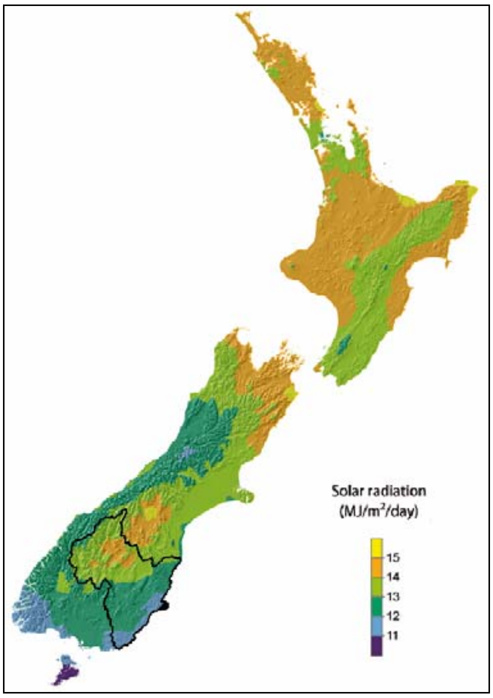
4.3.1 Solar Resource in the Otago Region

Solar radiation across New Zealand is similar to that at many sites in Australia and higher than most areas in Europe (Table 4). Solar radiation for the Otago region is approximately 1350 kWh/m²/yr, with some variations across the region (Figure 15). Inland areas have higher radiation values when compared to coastal sites.

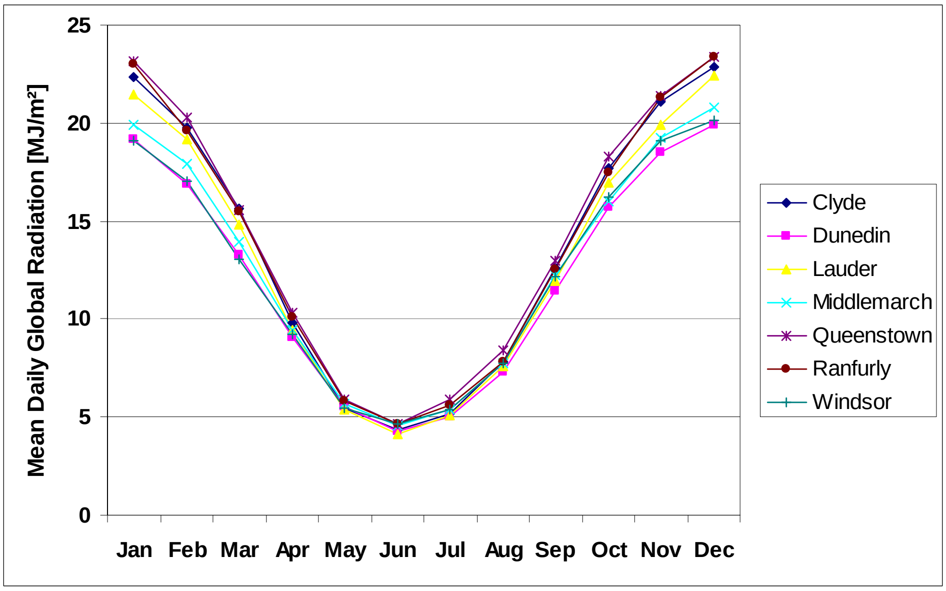
The solar radiation varies greatly over the year. Figure 16 shows the variation at 7 weather stations in the region. The given radiation data is valid for horizontal surfaces. The gain of solar systems can be easily enhanced by tilting the system towards north. Optimum tilting angle is the value of the latitude of the site. For example, an increase in the performance of a solar system in Dunedin of almost 15% can be achieved by tilting the system by 45° towards north.

- **Table 4 Typical values of total global solar radiation for several sites (EECA 2001b, NIWA 2006a)**

	MJ/m² yr	kWh/m² yr
Sydney	6150	1708
Melbourne	5302	1473
Kaitaia	5288	1469
Dunedin	**4450**	**1236**
Gisborne	5386	1497
Paraparaumu	5035	1403
Christchurch	4898	1360
Invercargill	4652	1292
Germany	3609	1003



▪ Figure 15 Solar radiation distribution (NIWA 2005b)



▪ Figure 16 Monthly variation of solar radiation (NIWA 2006a)

4.3.2 Potential for Solar Thermal

Households account for 37% of electricity demand in the Otago Region (EECA, 2004). Of this, about one third is usually for water heating (BRANZ 2004). A standard solar thermal system can produce around 55% of a household's water heating. Hence, the installation of solar thermal technologies has the potential to address some of the region's overall supply issues.

Solar thermal systems are most economic when installed in new buildings. Population growth in the Otago Region has been slightly below the national average for the 2001 to 2006 period. However, the population growth varies between the different districts in the region. The Queenstown-Lakes District has had growth rates higher than the regional and even the national average - in fact it is one of the fastest growing districts in New Zealand. This district has high demand in new housing and is therefore best suited for promotion and installation of solar thermal systems. Additionally, solar radiation levels are also highest in this area.

There is potential for a substantial increase in the uptake of solar thermal use in the Otago region.

4.3.3 Potential for Solar Photovoltaic (Electrical Energy)

The biggest barrier for the large scale uptake of PV is the high cost of the technology. Consequently, uptake has predominantly been for remote power supplies, enthusiast users and commercial developments where renewable energy has additional value as a corporate strategy or image statement. In summary, ***the current high costs of solar photovoltaic means that large scale grid connected uptake in the region is unlikely, however small scale applications, particularly for remote power supply are expected to become more popular.***

4.3.4 Potential for Passive Solar Building Design

Solar space heating can significantly reduce the amount of energy use in new buildings. With solar space heating, the building is designed to maximise the absorption of solar energy. This can be applied to any building regardless of size or use (domestic/commercial). The building design considers building placement and orientation on the site and design features to capture, store and release solar energy in the building. Solar building design not only reduces the energy use, but it also can reduce moisture and condensation, improve sound insulation and provide a generally more comfortable and healthy living environment.

4.4 Hydro

4.4.1 Previous Hydropower Capacity Studies

The potential for developing the hydro-electric potential of New Zealand has been the subject of study for more than 100 years, the milestone reports being:

1) **The Hay Report (1904):** The earliest full assessment of New Zealand's hydro-electric resource was conducted in 1904, when North and South Island reports were tabled in the

House of Representatives. Nearly all of the schemes which have so far been developed were identified in these original reports.

2) **Ministry of Works and Development (1982):** MWD undertook a comprehensive assessment of the country's small and medium scale hydropower potential in the period 1978 to 1985, establishing a consistent assessment methodology to look for sites with a potential installed capacity in the range 500 kW to 50 MW assuming a typical plant factor of around 50%. The work involved a review of maps, gauged river flows and topography to identify opportunities for harnessing water power. Local features of the most promising sites were then assessed and preliminary concepts were devised. A series of reports assessed the potential in the different areas of the Otago region. Some of the relevant documents are –

   - Royds Sutherland McLeay 1982 assessment – Small Hydro-Electric Potential of the Waitaki Electric Power Board District
   - Royds Sutherland McLeay 1982 assessment – Small Hydro Electric Potential of the Otago Electric Power Board District
   - Otago Central Electric Power Board's 1984 assessment – Small Hydro-Electric Resource Assessment, Central Otago Area

   The potential schemes and their scheme parameters are tabulated by catchment area in Appendix A. The locations of the previously identified potentially attractive schemes in the region are shown on Map 7 (Appendix B).

3) **WORKS (1989)**: WORKS Consultancy Services produced a series of reports that provided information on the hydro-electric potential in different regions of New Zealand. The series intended to cover the whole of New Zealand. The potential in the Otago Region is covered in the series titled *National Hydro-Electric Resource Assessment Region 11 Waitaki and Otago* that discusses larger schemes identified in other publications and lists smaller schemes in the region.

4) **WORKS (1990):** Another nationwide survey was undertaken by WORKS which summarised the large schemes (>10 MW) from previous studies and went on to consider the practicability of some of the major schemes including some very large opportunities in South Island. This study concluded that the Otago region has a potential of 1,385 MW from 22 schemes. It identified a 20 MW scheme on the Taieri River and 1,365 MW from 21 schemes on the Clutha River.

5) **Ministry of Economic Development (2004):** In their 'Waters of National Importance' report, East Harbour Management Services considered the hydro-electric resources of New Zealand. A 'publicly known' nationwide future hydropower potential of around 2,500 MW is considered, recognising also that there are possibly a significant number of opportunities not publicly identified. In the Otago region, 10 schemes with a total installed capacity of 452 MW were considered in the 'high' and' medium' confidence category. Among these, 412 MW was

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made up from 6 schemes on the Clutha River and 40 MW from 4 schemes on the Taieri River and its tributaries.

6) **EECA Renewable Energy Industry Status Report (2005):** On behalf of EECA, East Harbour Management Services went on to report on the nationwide potential for additional renewable power generation. On a national basis, the report estimated an additional annual hydro potential of some 4,260 GWh (equivalent to around 900 MW with a typical plant factor of 50%). Cost estimates were based on escalating the MWD data from the 1980's. In the Otago region, the report found 13 potential schemes in a medium confidence level below 16c/kWh (@10% weighted average cost of capital (WACC)) having a total estimated installed capacity of 364 MW.

7) **Ministry of Economic Development (2005):** East Harbour Management Services reported on the overall scope and cost ranges for generating electricity and heat from renewables. In the Otago region 13 possible hydro schemes were again identified with a total installed capacity of 364 MW.

8) **Electricity Commission (2005):** As part of the Electricity Commission's Statement of Opportunities a report was compiled by Parsons Brinckerhoff which provided a summary of all previously identified schemes – large and small. The report included cost estimates escalated from the MED report and developed ranges of possible cost (on a theoretical basis only) for schemes not previously estimated. The report summarised the schemes from previous references.

4.4.2 Background

For this hydro assessment the region has been divided into five areas that combine several catchments within them. The major rivers and lakes in these areas are given in Table 5.

- **Table 5 Otago Region – Catchment Areas, Major Rivers and Lakes**

	Catchment Area	Major River(s)	Lakes
1.	Waitaki – Waikouaiti Rivers	Waitaki, Awamoko, Kakanui, Shag, Waianakarua, Waikouaiti,	
2.	Taieri	Taieri, Deep Stream, Lee	Mahinerangi, Waipori, Waihola
3.	Lower Clutha	Clutha, Manuherikia, Manor burn, Teviot, Tuapeka, Waitahuna, Fraser, Pomohaka	Roxburgh, Onslow, Tuakitoto
4.	Upper Clutha	Clutha, Hunter, Makarora, Matukituki, Motatapu, Cardrona, Lindis, Timaru	Wanaka, Hawea, Dunstan
5.	Kawarau	Kawarau, Nevis, Dart, Rees, Greenstone, Von, Lochy, Shotover, Arrow	Wakatipu, Sylvan, Diamond

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4.4.3 Developed Hydropower Resources

The existing total hydropower capacity in the Otago region is 864 MW as follows:

- **Table 6 Otago Region – Developed Hydropower**

Scheme	River	Scheme Rating (MW)	Year	Owner/Operator
Clyde	Clyde	432	1992	Contact Energy
Roxburgh	Clyde	320	1956 to 1962	Contact Energy
Teviot (5 stations)	Teviot	10	1924 to 1982	Pioneer Generation
Roaring Meg (2 stations)	Roaring Meg	4.2	1935, 1945	Pioneer Generation
Falls Station	Falls Dam	1.2	--	Pioneer Generation
Fraser	Fraser	2.8	1956	Pioneer Generation
Wye Creek	Wye Creek	1.3	1926	Pioneer Generation
Glenorchy	Oxburn Dam	0.4	1968	Pioneer Generation
Waipouri 1A	Waipouri	11	--	TrustPower
Waipouri 2A	Waipouri	54	--	TrustPower
Waipouri 3	Waipouri	7.6	--	TrustPower
Waipouri 4	Waipouri	8.2	--	TrustPower
Paerau Gorge	Taieri	10.0	--	TrustPower
Patearoa	Taieri	2.25	--	TrustPower

4.4.4 The Market for Hydropower Development

Since the cornerstone MWD (1982) report, the electricity industry in New Zealand has undergone significant changes. Different scheme design drivers apply today, affecting the way that the originally conceived schemes would be viewed as investment opportunities, in particular the need for a developer to keep to a minimum the risks and uncertainties associated with environmental effects, ground risk and hydrology.

Though hydropower technology is relatively mature, some technological improvements have been made in civil works, and plant construction and equipment efficiency. For example, the use of a tunnel boring machine might nowadays allow a dam to be avoided and for an alternative scheme layout to be considered. Additional infrastructural development such as new roads and transmission/distribution lines may have helped to improve project economics, though conversely, more onerous consenting changes and environmental requirements may make some projects less feasible.

4.4.5 Possible Future Hydropower Potential

The following sections describe the hydro potential in the different catchment areas.

Waitaki – Waikouaiti Rivers

The region consists of the area of the lower end Waitaki River catchment that falls within the Otago Regional Council area and the area drained by rivers that originate in the northern flanks of the Kakanui Mountains and flow into the Pacific Ocean. The region experiences relatively low annual rainfall (in the range of 800 mm and less) and is bordered on the north by the Waitaki River and on the south by the catchment area of the Taieri River.

On the Waitaki several alternative schemes have been identified in past studies that use the potential between the Lower Waitaki Irrigation Scheme canal and the Waitaki River. Among these two smaller alternative schemes are located at the Awamoko siphon area and at Stewart Settlement area and would have a potential of around 1.3 MW. A larger alternative scheme named McPherson Road 2 would have a capacity of 2.33 MW and would consist of a connection between the main race and the upgraded Stewart Settlement race to convey higher flows. Other potentials identified in the region are two hydropower schemes in conjunction with a proposed Waireka – Kakanui irrigation scheme that would have capacities of 9.7 MW and 1.8 MW, a 600 kW scheme on the North Branch of the Waianakarua River and a 1.2 MW scheme on the Kakanui River.

Taieri

The area includes the catchment of the Taieri River and its tributaries and the Otago Harbour area.

The Taieri River has its headwaters in the Lammermoor Range and initially flows northwards then turns southwards and flows to its mouth located south of Dunedin. It is a moderate sized river that drains a large low rainfall area between the Waitaki and the Clutha catchments. River flows are highly seasonal with very high flood flows and extremely low flows in summer and autumn.

In earlier studies the river has been assessed to have some potential for small scale hydropower development but is considered to have no potential for larger schemes. This is attributed to the catchment topography where most of the river features wide and shallow valleys with poor drainage. Schemes identified are two schemes with a potential of around 6.7 MW and 3 MW on the middle reaches, an 8 MW scheme on the Taieri Falls and an 18 MW scheme further downstream.

Other schemes identified in the region are on the tributaries of the Taieri River. These range from a 1.5 MW scheme on the Kye Burn to a 7 MW scheme on the Lee Stream. A 5 MW scheme was also identified on the Deep Stream; this scheme is currently being implemented in part by TrustPower.

Upper Clutha

Because of the size of the Clutha River it has been considered in two sections – the upper and lower reaches separated at Cromwell. A large tributary of the Clutha River, the Kawarau River, also meets it at this juncture.

The catchment of the upper reach of the Clutha extends from Cromwell to the headwaters of the river located near the Haast Pass. The region is bordered to the north west by the Haast catchment and catchments of the Ahuriri and Ohau Rivers and other rivers located in the West Coast. The two large lakes – Wanaka and Hawea dominate the catchment and serve to regulate the flows in the Clutha River. The main tributaries of the river in this region are the Hawea, Cardrona, Makarora, Matukituki, Lindis and Wilkin rivers. The upper reaches of the catchment experience some of the highest annual rainfall in New Zealand (>6,400 mm) while the Cromwell area experiences among the lowest (< 400 mm). Winter precipitation falls as snow and the river flow is highest in the spring from the snow melt.

Several medium to large potential schemes in the range of 30 MW to 180 MW have been identified on the Clutha River and on the lakes. The schemes identified at Luggate (90 MW) and Queensberry (180 MW) were part of the plan to develop the potential of the Clutha River along with the Clyde scheme in the 1980's. A large scheme that could use the difference in levels between the Hawea and Wanaka lakes has been assessed to have a potential of around 100 MW, with an additional option to operate as a storage scheme. However the 1973 *Lake Wanaka Preservation Act* prohibits any works that alters the natural level of Lake Wanaka. An additional five schemes ranging between 30 MW to 40 MW have been identified in different reaches of the Clutha River.

The upper reaches of the Clutha River have recreational value, namely scenery and water sports. Additionally, several sections of the river and the Hunter River are considered nationally important fisheries. These could preclude further development of the hydropower potential.

Lower Clutha

The Lower Clutha consists of the reach of the Clutha River below Cromwell to its mouth to the south of Dunedin. The river flows generally south and southeast, splitting into two branches below Balclutha to reach the sea through the Matau and Koau mouths. The major tributaries of the Clutha River in this region are the Manuherikia and Pomahaka rivers. The catchment is bounded on the north by the catchment of the Taieri River while Old Man Range, Umbrella Range and the rivers flowing southwards form the southern boundary.

Two large and one medium scheme in the region have been considered possible in earlier reports. Largest among them is a 340 MW scheme at Tuapeka Mouth that would comprise a dam/powerhouse arrangement raising the water level by around 45 m in the area. An alternative scheme would include a lower dam and a number of schemes between Tuapeka and Dumbarton.

Another large scheme of 110 MW might be possible at Dumbarton Rock that would include a dam raising the water level by around 11 m and an adjacent powerhouse. An alternative arrangement for the scheme would consist of a powerhouse further downstream and a canal 4.5 km in length. Another scheme identified in the earlier studies is a 81 MW scheme that would consist of a dam/powerhouse arrangement located a short distance upstream of Balclutha, however this scheme was considered to have a high environmental consequence, namely inundation of large areas of high quality land.

Several smaller schemes ranging from 1 MW to 7 MW have also been identified in the region. Two of these schemes are located on the Manuherikia River with one in conjunction with the irrigation scheme. Others are on Dunstan Creek and Beaumont River with another 6 MW scheme identified on the Pomohaka River.

In a recent study Bardsley et al (2006) postulated the concept of a pumped storage scheme that would involve pumping water from the Clutha River to a new lake in the Onslow-Manorburn basin near Roxburgh. The storage lake would be created by constructing a dam near the outlet of the present Onslow Reservoir and a second dam near the Manorburn Reservoir exit. A power station near Teviot might provide over annual storage (dry year reserve) increased peaking capacity, and help level out fluctuating wind farm output. The potential from such a scheme has not been included in this assessment.

Kawarau

The Kawarau River has its headwaters in the mountains of the main divide adjoining Fiordland. The catchment is bordered on the north by the catchment of the upper reaches of the Clutha River, on the west by the rivers flowing to the West Coast and on the south by rivers flowing southwards in the Southland region. The major tributaries in the region are the Rees and the Dart rivers located upstream of Lake Wakatipu and the Shotover and the Nevis Rivers located below the lake. Most of the flow in the Kawarau River is from the high regional rainfall (>4,800 mm annually) in the main divide. Although Lake Wakatipu regulates the flow in the river to some extent, it is highest in the spring resulting from the snow melt.

Potential for large schemes in the region is limited to the Nevis and Kawarau Rivers. A 45 MW scheme with two dams has been postulated on the Nevis River with an upper dam at Nevis Crossing and a lower dam 2 km downstream. Another large scheme on the Kawarau River that would comprise of a dam near Gibbston (around 35 km upstream of Cromwell) and a series of canals and tunnels conveying water to a powerhouse located on the shores of Lake Dunstan. The scheme would have a potential output of around 160 MW.

Other smaller schemes identified in the region are on the Arrow River, Doolan Creek and the Moke Lake. Several schemes have also been identified on the Roaring Meg, Wye Creek and Fraser River which appear possible to be developed in addition to the existing schemes.

The Kawarau River currently is under a Water Conservation Order 1997/38.

4.4.6 Micro Hydro

For the reasons of its dispersed nature of the resource, technical and regulatory complexities, proportionally high development overheads, landowner issues etc, the ‘micro’ hydro potential of the area has not been identified.

4.4.7 Other Possible Hydropower Options

Having assessed the potential for conventional new hydro installations (developing head and diverting flow to generate electrical power by conventional water turbines), other means of increasing the contribution of hydropower include:

Rehabilitation and/or Uprating of Existing Plant

Modernisation and refurbishment of the water turbines and generators at existing hydropower schemes can typically realise an increase in output of 10 to 20% and/or (depending on their relative value in the power market) additional energy across the operating envelope of typically 2 or 3%.

Alternative Technologies

There are some experimental technologies that in the future may become viable to harness hydro potential. Helical turbines for example (for ‘ultra low head’ applications) are a reaction crossflow machine, developed between 1993 and 1995 at Northeastern University in Massachusetts. The turbine operates in the streamflow and extracts energy from the stream velocity. Steep reaches in rivers with water velocities >1.0 m/s can provide potential sites for machines in series.

Other new technologies evolving, intended to reduce the complexities and capital costs of small hydro schemes, and for ‘modular’ applications, include siphon type turbines, variable speed and PMG generators and plastic pipelines. For the very small schemes, waterwheels with gearboxes or belt-drives can still have a place.

4.4.8 Summary

In summary:

- Around 5 ‘large’ scale hydropower projects with a total installed capacity of around 890 MW and 9 ‘medium’ scale schemes totalling around 400 MW were identified in the Otago region, totalling around 1,300 MW. Among these, the Kawarau River has an existing Water Conservation Order. Among the 1,300 MW, a total of 447 MW from 4 schemes appears to be within or near the Department of Conservation land or Native Forests while a total of around 850 MW from 10 schemes appear to be outside the DoC land or Native Forests.

- In addition approximately 32 ‘mini’ or ‘small’ scale projects with a combined capacity of approximately 110 MW are believed to be possible in the region. Among these, 8 schemes with installed capacity of 27 MW appear to be within or near the DoC land and Native Forests while a total of around 80 MW appear to be outside.

The installed hydro capacity within Otago region is 865 MW. The remaining hydro potential is about 1,400 MW in large, medium and small scale projects. Of these about 930 MW appears to be outside the Department of Conservation area or native forests. The micro hydro potential has not been assessed.

4.5 Biomass

4.5.1 Biomass Resource in Otago Region

The resources for the production and use of biomass as a renewable energy resource include agricultural crops, dairy and livestock farming, forestry and the residues associated with production and processing of those.

Otago region is not regarded as a major source of crop-derived biomass, with much of the region at relatively high altitudes and having a low rainfall. A proportion of the region is suited to pastoral farming, principally sheep, although dairying is increasing in the south and north-east of the region as indicated in the regional land use map (Figure 17). Areas considered suitable for energy cropping are probably limited to the coastal plains and restricted to areas where the slope is no greater than 8^{O}.

4.5.2 Agricultural Crops for Energy

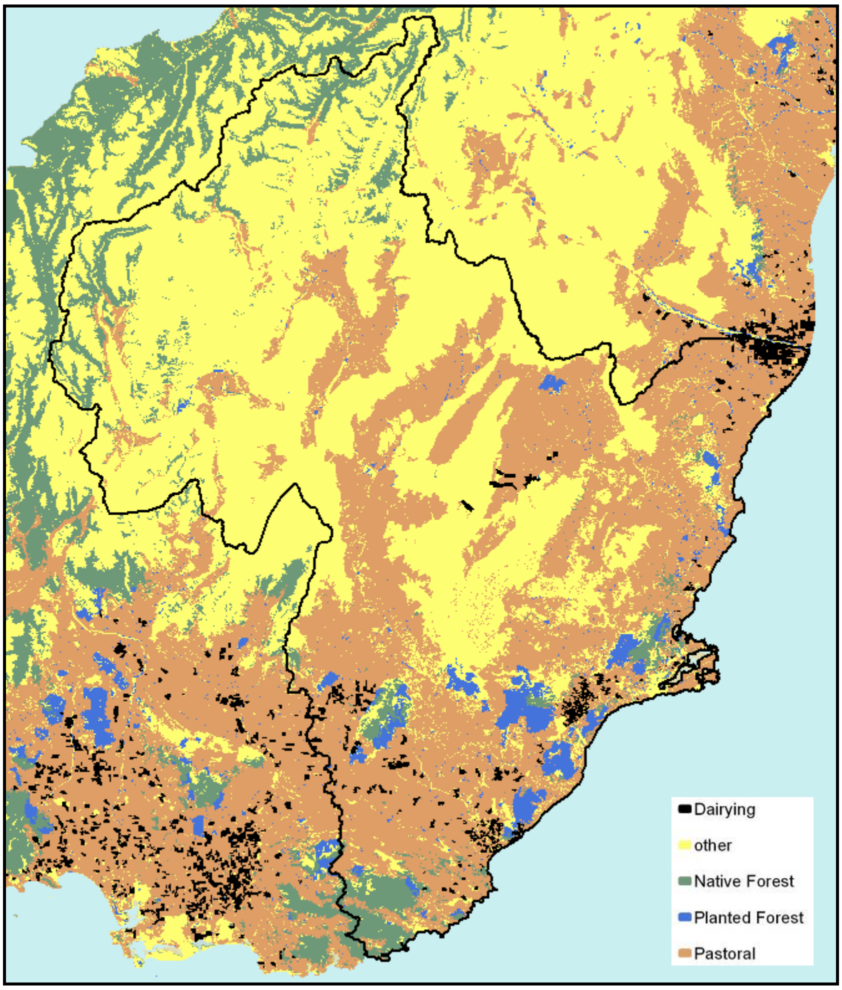
Several crops can be grown in New Zealand that are suitable for renewable energy production, including both thermal and electrical energy and transport fuels. These include:

- grain crops - maize, wheat, oats and barley
- root crops - fodder beet, sugar beet, potatoes
- oil-seed crops - rape, linseed,
- herbaceous crops – kale, sweet sorghum, grass and lucerne

New Zealand produces around 950,000 t/year of grain and seed crops (Statistics NZ, 2002) with barley, wheat and maize grain being the leading components. Peas and other pulses contribute an additional 33,000 t/year. The starches in grains and pulses are readily converted to sugars and then fermented to produce ethanol. These crops are the basis of the very large “corn-based” fuel alcohol industry in the US. Blends of 10% ethanol in gasoline, known as "gasohol", are widely available throughout much of the US.

Oil seed production in New Zealand is much smaller, at around 5000 t/year, and also highly variable. Most of the oil-seed production is based in the lower South Island. Vegetable oils are attracting increasing interest as a raw material for the production of transport fuels, especially "biodiesel", but it is unlikely that these crop-based routes to transport fuels could compete with New Zealand-sourced tallow for biodiesel production.

Starch, sugar or cellulose-based feedstocks from New Zealand sources are unlikely to compete with imported ethanol from Brazil or Australia.



- **Figure 17 Otago land use map**

Otago region is a minor producer of grains, at just 61,000 t/year, with barley being the largest contributor at 43,000 t/year (Stats NZ, 2002). This production was derived from only 11,000 ha, indicating that the level of production could be increased significantly using more of the available arable land in the region. The current level of grains production (around 61,000 t/year, principally barley) could provide for the manufacture of 30 ML/year of ethanol.

The climate and soils on the eastern side of the Otago region are well suited to root crops and yields averaging around 10 ODt/ha may be achieved with beet crops in particular, i.e. sugar beet and fodder beet. The manufacture of transport fuel from beet crops grown on the currently cropped 11,000 ha could deliver around 20 ML/year of ethanol.

Oil seed cultivation is not common in the Otago, presumably because of production economics rather than an adverse climate or unsuitable soils as oil-seed production is well established in both Southland and South Canterbury. Yields of oil-seed rape in Southland are typically in the order of 1.8 ODt/ha, equivalent to nearly 700 L/ha yr of oil for biodiesel from this crop. Oil seed yields for the Otago region are not known.

4.5.2.1 Forestry and Wood Processing Residues

Forestry has the potential to be a very major supplier of biomass for several types of renewable energy.   New Zealand has around 1.75 million hectares of planted production forestry which is being harvested at a rate of 50,000 ha/year, producing around 22 million cubic metres of timber.

The Otago region included nearly 130,000 ha of planted production forestry in 2005 (MAF, 2005) by far the greatest proportion being in the Clutha district in the region’s south-east. 40,000 ha of this area is classified as “unpruned and without production thinning”, indicating that it would be valued at the lower end of the scale, suitable for pulping, fibre-based manufacture (MDF *etc.*) or for energy.

Production of liquid fuels from just the “unpruned and without production thinning” forestry resource in the Otago region, without recovery of the harvesting residues, could result in around 135 ML/year of methanol or 60 ML/year of ethanol. Use of this material in a “dendro-thermal” power plant for electrical generation could support an aggregate generation plant capacity of around 30 MW_e and could generate some 250 GWh/year.

4.5.2.2 Short Rotation Woody Biomass for Energy

In areas identified as suitable for the supply of woody-biomass, and where subsidies are available for sustainable energy production, it is increasingly common to find the cultivation of fast-growing, coppicing species such as willow, poplar etc. This is usually grown as fuel for dendro-thermal power plants, but may also be used as a cellulose feedstock for the production of ethanol via hydrolysis, fermentation and distillation.

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Small-scale cultivation trials of *Salix* (shrub willow) are currently underway in Taupo with the expectation that the production would form the basis of fuel ethanol and possibly bio-polymer industries. The suitability of such fast-growing and machine-harvestable sources of woody biomass, and the relative economics of production, will not be known for several years.

4.5.2.3 Livestock Farming – Dairy and Meat

As indicated in Figure 17, the Otago region includes large areas of pastoral farming although stocking levels are relatively low in the central area.

Dairy processing residues

Otago is a minor dairy region in New Zealand, with around 530 dairy farms and an aggregate dairy herd of more than 200,000. The region produces and processes around 700 ML of raw milk per year. Much of the milk from this region is converted to products such as skim-milk and full-milk powders, but there are several other products, especially cheeses, from which lactose-containing whey is produced. Some of these lactose-containing streams are concentrated for transport to Edendale, the South Island's only lactose processing and refining facility.

In the North Island additional lactose streams of appropriate quality are fermented and the ethanol recovered by distillation at three sites. No such facilities are available within the Otago region.

Dilute dairy effluent streams, some containing residual biodegradable materials, may be amenable to anaerobic digestion, producing biogas. Although of relatively low calorific value, this biogas may be used directly for heat-raising or electrical generation.

The lactose-containing effluent streams, for which recovery or processing are regarded as uneconomic, are typically disposed of to local waterways or spray-irrigated onto adjacent farms.

Meat processing by-products

New Zealand produces almost 150,000 t/year of animal fats (*i.e.* tallow) from meat processing plants. In past years much of New Zealand's tallow production was used locally for soap manufacture, but most is now exported. Tallow may be used in the manufacture of biodiesel by means of a relatively straightforward esterification process.

Of New Zealand's 150,000 t of tallow produced in the year ending March 2006 (J O'Connell, pers. comm., Statistics New Zealand), some 147,800 t was exported. Of this tonnage, more than 400 t was edible grade tallow with an average value of around NZ$1,300/t FOB. The balance of nearly 147,400 t consisted of inedible grades with an average value of NZ$500/t FOB.

There are several meat processing plants and abattoirs in the Otago region, some of which have rendering plants to recover tallow. Accurate figures are difficult to obtain, but around 3,500 t/year of tallow is exported from Dunedin and more that 78,000 t/year from Timaru, servicing the South Canterbury as well as North Otago sectors. We have estimated that the Otago region produces at least 4,000 t/year of animal fats that could be converted to biodiesel.

4.5.2.4 Municipal Solid Waste

Municipal solid waste (MSW) is included in this investigation and report on the basis that the organic portion in particular may be regarded as a renewable resource. The population of nearly 200,000 in the Otago region generates around 115,000 t/year of household waste, of which around two thirds is organic. The remainder is principally glass, metals and building materials.

In addition to the household waste, another 100,000 t/year of solid waste is estimated to be produced by business and industry, of which at least 50% is likely to be organic – largely paper, cardboard and assorted plastics.

Anaerobic digestion

The anaerobic digestion of wet organic wastes (other than plastics) produces biogas, typically a mixture of methane and carbon dioxide with the methane content ranging from about 45% to 60% (CAE, 1992), sometimes as high as 80% by volume (dry basis) (East Harbour, 2005) and a calorific value between 12 and 30 MJ/m^3.

No New Zealand councils or waste disposal contractors are known to be using bacterial digestion processes for disposal of solid wastes, although appropriate technology is available.

Anaerobic digestion of MSW occurs naturally in landfills where it is a by-product of spontaneous bacterial action. Relatively few of NZ’s older landfill facilities were set up specifically to maximise the production of biogas, to contain it or to provide for its recovery and use. Although a few of the older landfill facilities have been subsequently developed for landfill gas production, the recovery rates are modest and much of the methane is lost to the atmosphere.

As older landfill facilities are closed, however, the newer and larger landfills are required to comply with the National Environmental Standard which was introduced in 2004. Under this standard, there must be provision to destroy the methane, either by flaring the gas or using it as an energy source.

Waste combustion

Waste combustion is widely used in many other parts of the world, Europe in particular, where landfill disposal of waste is becoming increasingly unacceptable.

Of the nominal 200,000 t/year of MSW generated in the Otago region, almost 125,000 t/year is combustible material with an average calorific value of around 10 MJ/kg. Despite the relatively low calorific value, combustion of this material would produce around 70 GWh/year of electricity.

4.5.2.5 Sewage

Domestic sewage and liquid industrial wastes are collected from almost all municipal areas and reticulated to central plants for treatment and disposal. Typical quantities of domestic wastewater amount to 200 L/person-day, equivalent to a volumetric flowrate of 21,000 m^3/day for the city of Dunedin.

Total (dissolved and suspended) solids in the wastewater are expected to be in the range of 700 to 1000 g/m^3, amounting to as much as 23 t/day of total solids.

Anaerobic digestion

Treatment of sewage typically involves a flocculation and sedimentation stage to increase the solids concentration and then sludge digestion by aerobic and/or anaerobic processes. Anaerobic digestion produces between 0.75 and 1.12 m^3 of biogas for every kg of volatile sewage solids destroyed, amounting to as much as 3000 m^3/day for Dunedin City. This biogas will have a methane content of between 65 and 70%, by volume, equivalent to nearly 900 kW_{th} on a continuous basis.

Sewage sludge drying and combustion

Sewage solids have been segregated, dried and burnt for over 100 years and modern sewage treatment plants around the world are routinely disposing of sewage solids in this manner. Where sewage solids are recovered from treatment plants in New Zealand they are usually disposed of to landfill, although there are two provincial cities where sludge drying and alternative disposal options are available. Sewage sludge drying and combustion trials are underway in both Hamilton and Auckland with the objective of reducing the high costs of transport and landfill disposal.

Combustible solid recovered from Dunedin's digested sewage sludge has a calorific value of around 16 MJ/kg (bone dry basis). Despite the apparently high calorific value, the net recoverable energy from the combustion of sewage solids is relatively low, mainly due to the high energy demand associated with drying, sterilisation of the emissions and odour control.

4.5.3 Technology

4.5.3.1 Transport Biofuels

A range of transport fuels may be produced from biomass sources. These include:

- Biodiesel – from oil-seed crops, oil-bearing plants such as jatropha, and animal fats, via transesterificaton

- Ethanol – via direct fermentation from sugar, grains and root crops as well as via hydrolysis and fermentation from cellulosic material such as wood, straw *etc*.
- Methanol – via gasification of almost all biomass and catalytic re-combination of the resulting synthesis gas
- Biogas – via anaerobic digestion of almost all biomass
- Pyrolysis oil - by the pyrolysis of biomass material and the subsequent separation and refining of the produced liquid.

Biodiesel

Biodiesel is a clean burning transport fuel produced from renewable resources including oil-seed crops and animal fats. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a fuel blend that can be used in compression-ignition (diesel) engines with little or no modifications. Biodiesel is simple to manufacture, biodegradable, non-toxic, and is free of sulphur and aromatics.

The technical definition for biodiesel (NZS7500:2005) is "a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats. Typically these are methyl esters or ethyl esters, however higher alkyl groups can be used." The New Zealand standard appears to follow the US standards (ASTM D 6751 in particular) reasonably closely.

A biodiesel blend (Bx) is a blend of biodiesel with mineral diesel fuel, where "x" represents the volume percentage of the biodiesel component in the blend. Biodiesel blends in New Zealand are presently limited to no more than 5% biodiesel by volume.

Ethanol

The production of ethanol from agricultural biomass is well developed technology. Very large quantities of ethanol are currently manufactured from cane sugar (cf. Brazil) and grains (cf. the USA) specifically for transport fuels.

Starches in grains and pulses (and even potatoes) are readily converted to glucose and then fermented to produce ethanol. Sugars may be extracted directly from crops such as sugar cane, sugar beet etc. The majority of ethanol currently produced in Australia is from wheat by-products (EECA, 2006). Sugar cane is expected to become more widely used in Australia for ethanol production, but does not grow well in New Zealand. Root crops, such as sugar beet, are readily grown in most areas of New Zealand and extraction of the sugar is straightforward.

Cellulose, which is the major component of wood, straw, corn, etc, may also be converted to pentose sugars by hydrolysis. Much of the early work on the hydrolysis of woody-biomass relied on cooking at high temperature and pressure with a dilute mineral acid. This relatively energy-

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intensive process has been partially replaced by enzymatic hydrolysis, which requires expensive enzymes but takes place under less stringent conditions.

Dilute sugar solutions are fermented using typical brewery technology to produce ethanol. The dilute ethanol solution is usually concentrated to around 94% by distillation. Ethanol must have a very low moisture content if it is to be used for blending with petrol and it is therefore distilled again with a ternary component to produce fuel-grade ethanol

The distillation stage is very energy-intensive and several processes, including membrane separations, are under development.

Bioethanol is the basis of the very large “corn-based” fuel alcohol industry in the US. Blends of up to 20% ethanol in gasoline, known as “gasohol”, are widely available throughout many states.

Methanol

Methanol was originally known as “wood alcohol” as it was obtained by the destructive distillation (similar to pyrolysis) of wood. This process is not used in the manufacture of methanol on an industrial scale. The most common route to methanol is from natural gas via the production of synthesis gas and the catalytic reforming of that to form methanol.

Synthesis gas:	$2CH_4 + H_2O + O_2 = CO_2 + CO + 3H_2$
Gas shift:	$CO_2 + H_2 = CO + H_2O$
Methanol synthesis:	$2H_2 + CO = CH_3OH$

Synthesis gas may be produced by the combustion of almost any biomass under appropriate conditions. Clean woody-biomass is very well suited to the production of synthesis gas as it has a very low ash content.

Methanol is not proposed as a transport fuel for New Zealand (EECA, 2006), despite extensive transport fleet trials of methanol-fuelled vehicles in the 1980’s, but is a necessary component in the manufacture of biodiesel.

Pyrolysis Oil

Many forms of biomass will produce a mixture of hydrocarbon-based liquids and gases when pyrolysed, *i.e*. heated to high temperatures under oxygen-starved conditions. The resulting liquid may be further refined and separated to provide a range of potentially useful streams including fuels, solvents *etc*. The technologies require relatively severe processing conditions, and are at an early stage of development relative to the process routes identified above, and are not discussed further.

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Biogas

Biogas is generated as almost any biomass is broken down by biological processes.

4.5.3.2 Electricity generation

The generation of electrical energy from biomass is widely practised around the world and the technologies and economics are well understood. Biomass – typically woodwaste, bagasse or straw – is burned to generate steam which is used to power an electrical generator. The combustors range from simple "Dutch ovens", through reciprocating and vibrating grates, to bubbling and circulating fluid bed boilers. Biomass is also increasingly co-fired with coal in stoker and pulverised-fuel boilers.

The largest-scale example in New Zealand is at the Carter Holt Harvey pulp and paper mill at Kinleith, where approximately 200,000 t/year of woodwaste is burned in a specially-designed boiler to produce high pressure steam. Most of the HP steam is passed through a back-pressure turbine, generating up to 40 MWe of electricity.

In the Otago Region a co-generation scheme is in operation at the Blue Mountain Lumber site where biomass wastes from the sawmilling process are used to generate electricity as well as providing heat for timber drying.

4.5.4 Summary of Resource Potential

There is potential for production of both transport fuels and electrical energy from biomass in Otago Region. This comprises about 20 million litres of ethanol per year for transport fuel from grain crops currently grown in the region. In addition, about 60 million litres per year of ethanol or 250 GWh/year of electrical energy could be derived from woody biomass from low-grade forestry.

4.6 Geothermal

4.6.1 Power Generation

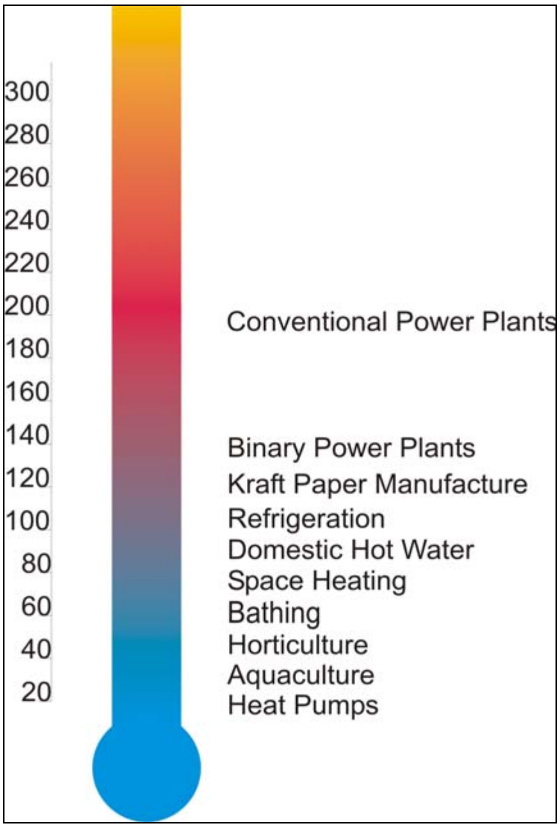
It is possible to generate power from geothermal fluids at temperatures as low as 80°C using binary power plant technology. However in New Zealand, power is only generated in binary plants from geothermal fluids at more than 120°C for economic reasons.

Such temperatures are found in high temperature geothermal fields in the North Island (Taupo Volcanic Zone and Northland), but not in the Otago Region. The Dunedin volcanic centre was active approximately 10-13 million years ago, and there is no evidence of a geothermal system associated with that volcanic activity. Thus there is little chance, using available technologies, that geothermal power generation will occur in the Otago Region.

4.6.2 Direct Use

Geothermal fluids at a range of temperatures generally less than 150°C are used in New Zealand for direct heat applications (Figure 18). Low temperature systems in the South Island are mainly located along major faults, particularly the Alpine fault (northwest of Otago), but no warm springs or elevated groundwater temperatures are known within the Otago region (Mongillo & Clelland 1984, Cave *et al* 1993).

Nevertheless, even with normal geothermal gradients, temperatures just a few metres below the surface will be higher than ambient air temperature in many areas of Otago for much of the time. There is some evidence of a heat flow anomaly in coastal Otago, with 50% higher heat flow than measured in most other parts of the country, which may be associated with a cooling magma body deep beneath the Dunedin volcanic centre (Godfrey *et al* 2001).



- **Figure 18 Temperatures (°C) Required for Direct Use Geothermal Applications**

Horticulture (greenhouse) geothermal heating systems have been installed in several areas, particularly in the Bay of Plenty and Waikato Regions. Similarly, geothermal fluids are used in

aquaculture (prawns, tropical fish), various **industrial applications**, and for **space heating** in other regions.

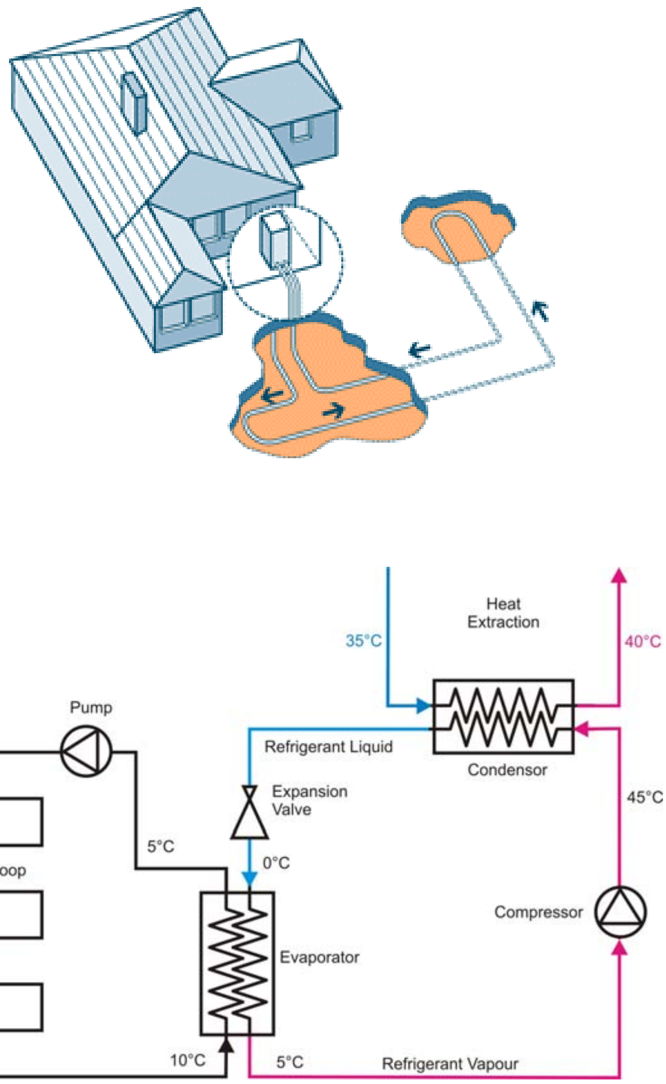
By far the most widespread use of low temperature geothermal resources in New Zealand is for **bathing**. Hot baths and spa complexes have been developed at many of the high and low temperature systems throughout New Zealand.

Elsewhere in the world, **ground source heat pumps** have become widely used since the 1980s. Heat pumps permit the extraction of heat from warm ground or groundwater, in a similar way to standard air conditioning, only instead of using ambient air for the heat source (or sink), warm ground or groundwater is used (Figure 19). Ground source heat pumps are much more efficient than standard air conditioning units because in winter, when heating is required, the ground is warmer than the air (even away from thermal areas), and in summer, when cooling is required, the ground is often cooler. The only energy required is that needed to pump the circulating fluid through the system. This technology is used on a large scale in North America and Europe where the climate, high electricity prices and subsidies make this technology economic. These drivers are largely absent in New Zealand and as a result there has been little uptake of the technology here.

All other factors being equal, gound source heat pumps are most cost effective in areas with climatic extremes (cold winters and hot summers) because the pump provides both heating and cooling and is used for longer periods and at high rates. This applies to Otago, and particularly to Central Otago. As a result, the capital investment can be recovered in a relatively shorter time.

Thain *et al*. (2006) provide estimates of annual costs for space heating and assisted water heating using GSHP in New Zealand. For a typical household with an electricity price of 12c/kWh, and space heating for 800 hours per year, the annual heating cost (space and water) is $520 compared to $1320 for electricity alone, *i.e.* a saving of $800 per year (~60%). However, this is not a sufficiently high saving to compensate for the initial high capital cost (about $12,000). On this basis, it is unlikely that GSHP's will find favour for domestic heating in the short term.

For larger commercial buildings which often require heating and air-conditioning, and for some large residential apartments or communities, economies of scale may make GSHP's economic, particularly where there are elevated temperatures in shallow aquifers.



- **Figure 19 Schematics of a ground source heat pump system.**

4.6.3 Summary of Resource Potential

The only real potential for geothermal energy use comes from ground source heat pumps, which can be used throughout the region, and are particularly attractive in Central Otago due to the greater climatic extremes in the region.

4.7 Marine

Appendix B presents an assessment of the tidal and wave resource in Otago region.

In summary, there is very limited potential to use the tidal resource in the Otago region to generate electricity using current technologies. The Otago Harbour would not be considered economic for tidal energy in the near future. However, future generations of tidal devices might change this. Capacity would be dependant upon the size and shape of future devices.

The potential for using wave resource for power generation is somewhat better but still limited. The wave energy resource for the west coast of the Otago area is described as having;

- locations of significant wave focusing close to shore, with areas of average wave energy between 21-25 kW/m
- good probability of wave energy exceeding and persisting at utilisable levels
- highly predictable wave generating storms in the Southern Ocean

A wave farm off the coast of Otago would produce approximately 460 MWh per device annually. Devices positioned at one of the hotspots created by the offshore bathymetry and in the south of the Otago area would have a higher output of between 20-30%. Hence, a one hundred-device wave farm of 750 kW Pelamis (total capacity of 75 MW) would have an output of approximately 50 GWh.

5 Enabling Assistance

5.1 Introduction

Although the focus of the current study has been to assess renewable energy resources and regulatory approaches at the regional level, there are a variety of non-regulatory methods (referred to here as ‘enabling assistance’) which could also be developed to encourage greater renewables uptake. This chapter presents a number of such approaches for consideration by councils, particularly for those regions where there is a clear and pressing energy issue such as those outlined in Section 2.6.

5.2 Renewable Energy Expertise

Renewable energy can be viewed as a development activity with potentially adverse local environmental impacts but with national energy benefits (*e.g.* security of supply) and international environmental benefits (*e.g*. climate change). As such, the inclusion of renewable energy in the Resource Management Act (RMA) needs to be recognised as a departure from the norm for councils who have primarily been responsible for managing regional environmental resources. At the same time, the inclusion of renewable energy in the RMA is consistent with the councils’ role in the meeting of national and international objectives on issues such as biodiversity.

As such, with a number of notable exceptions, the majority of councils have limited in-house expertise on issues relating to energy and renewable energy. This is perhaps unsurprising given councils’ core functions under the RMA, the relatively recent inclusion of renewable energy in the RMA and the rapid development in renewable energy technologies. However, it is clear that if the councils are to play a role in the greater uptake of renewables through either regulatory or non-regulatory approaches, then additional expertise is required. Whilst the requirements for renewable energy expertise will vary between councils, it will largely be determined by the region’s and council’s aspirations and the renewable resources available in the region. For example, regional councils may decide to: provide technical advice to applicants of renewable energy projects; develop pilot and demonstration projects; identify barriers to renewable energy; initiate programmes to overcome these barriers with partners; and co-ordinate advocacy for projects and information sharing across the sector.

5.3 Renewable Energy Plans / Strategies

The urgency and type of energy issues varies substantially between regions. For those regions with one or more pressing energy issues, such as those outlined in Section 2.6, councils may wish to consider the development of an energy plan / strategy. This would typically be positioned as an economic development or infrastructure plan / strategy rather than an implementation mechanism under the RMA. Such an approach would provide for design flexibility, speed of implementation and the ability to consider wider, non-renewable energy issues. A preliminary indication of this regional approach is provided by the Southland Regional Energy Strategy (2004).

5.4 Resource / Constraint Mapping

The issue of developing spatial representations of renewable energy resources overlaid with information relating to development constraints (*e.g.* outstanding landscapes, areas of high cultural value) was raised at a number of discussions with councils. Whilst Chapter 4 provides an indication of the magnitude and location of renewable energy resources in the region, more detailed information would be required to prepare resource maps of value to regional policy statements and plans. This type of more detailed information is likely to be held by a disparate group of organisations including renewable energy developers, research organisations and regional / district councils. For instance, with regard to wind resources, extensive field studies have been undertaken by developers and historic records are held by meteorological departments. The most detailed and reliable information is commercially sensitive and as such, is unlikely to be made available to councils. However, broad-scale resource maps could be developed in a cost effective manner by combining information held by public institutions with commercially available numeric models or numeric modelling capabilities.

It is to be noted that mapping also presents a potential new constraint to greater renewables uptake in that broad scale resource mapping may overlook small high potential areas. Furthermore, constraint mapping without adequate consultation with the renewable energy sector may inadvertently screen out areas of medium or high potential. As such, decisions on whether and how to develop resource / constraint maps requires careful consideration. Developers also express concern that once detailed resource maps are available, landowners can demand much higher access or “mitigation” fees, presenting a secondary barrier to renewables.

5.5 National Renewable Energy Forums

In order to promote good practice on both regulatory methods and enabling assistance and develop a deeper appreciation of the issues associated with renewable energy, a programme of forums involving selected councils from across New Zealand could be established. Alternatively, renewable energy could be brought into existing forums, such as those for the Chief Executives of councils.

5.6 Economic Instruments

RMA financial contributions are to be taken, and used, for a purpose specified in the relevant plan. These could be used to charge a greater contribution to energy generation methods that create the greatest environmental damage. For example non-renewable generation that creates air discharges could be charged on the basis of the volume of type of discharges produced.

The rules providing for such contributions would have to be written into a Plan and would be a requirement on resource consents. There are a number of issues with such financial contributions.

Firstly the process of placing the required rules into a Plan is complex and may take a considerable effort and time. The environmental effects that the financial contribution relates to will need to be fully justified and defined accurately in terms that can be translated into monetary terms.

There is also a case that can be argued that the environmental effects of emissions are national in nature and reducing such emissions creates national benefits. It may therefore be that any economic instruments are better justified at a national level rather than at the local level.

Other economic instruments such as carbon taxes, tax incentives for renewable energy projects and variable electricity pricing (giving advantages to renewable energy) are not available to councils and will rely on Central Government implementation. Councils may have an advocacy role in respect of these matters.

6 Regulatory Approaches

6.1 Current Regulatory Approaches

6.1.1 Regional Policy Statement

The lead regional policy and regulatory document in the Otago Region is the Otago Regional Policy Statement. The Regional Policy Statement was made operative in September 1998. This Policy Statement is due for review in 2008. As such this RPS is a first generation policy statement and was developed prior to the latest amendments to the Resource Management Act.

The Regional Policy Statement contains a chapter on energy (Chapter 12). This chapter contains a number of objectives, policies and methods concerning renewable energy as follows;

> *Objective 12.4.3 – To encourage use of renewable resources to produce energy*
>
> *Policy 12.5.2 – To promote the sustainable management and use of energy through;*
> *(a) Encouraging energy production facilities that draw on the region's renewable energy resources; and*
> *(b) Encouraging the use of renewable energy resources, in a way that safeguards the life-supporting capacity of air, water, soil and ecosystems and avoids, remedies and mitigates adverse effects on the environment, as a replacement for non-renewable energy resources: and*
> *(c) Encouraging the sustainable development of Otago's renewable resources*
>
> *Method 12.6.2 – Continue to give priority to the allocation of water to existing hydro-electric power generation systems in Otago except;*
> *(a) Where it is determined that the water is required for the needs of other significant values: and*
> *(b) Where these values cannot be provided for elsewhere in the locality,*
>
> *Method 12.6.3 – Develop policies and strategies that encourage and promote the use and development of renewable resources.*
>
> *Method 12.6.4 – Consider the use of renewable energy sources and the efficient use of energy within the transport sector through the Regional Land Transport Strategy.*

This chapter of the RPS also contains a number of objectives, policies and methods relating to energy efficiency.

6.1.2 Regional Plans

The Otago Regional Council has the following regional plans;

- Regional Plan - Air – Operative January 2003
- Regional Plan - Waste – Operative April 1997
- Regional Plan Water – Operative January 2004

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- Regional Plan Coast – Operative September 2001 (under review).

The Regional Plan Air contains a policy aimed at supporting Government policy on climate change and the emission of greenhouse gases. The Regional Plan Water contains a policy that recognises the water needs of hydro-electricity generation.

6.1.3 Territorial Local Authorities

There are five Territorial Local Authorities within the Otago Region. The current regulatory approaches of the Councils are summarised below.

6.1.3.1 Waitaki District Council (Part)

The Waitaki District Plan was made operative in July 2004. The Plan does not appear to have any specific energy policies

6.1.3.2 Dunedin City Council

The Dunedin City District Plan Operative in Part on 19 April 2004. The balance of the District Plan was made Operative as at 3 July 2006. The Plan appears to contain no provisions relating specifically to renewable energy.

6.1.3.3 Clutha District

The Clutha District Plan was made operative in June 1998.

The Plan makes specific provision for upgrading existing electricity generation facilities and provision for new generation facilities although this provision is not limited to renewable energy. The District Plan also contains a policy encouraging the use of renewable energy.

6.1.3.4 Central Otago District

The Central Otago District Plan was notified in 1998 and is currently subject to appeal. The Plan makes specific provision for upgrading existing electricity generation facilities and provision for new generation facilities although this provision is not limited to renewable energy and provides for new power generation also. The District Plan also contains a policy encouraging the use of renewable energy.

6.1.3.5 Queenstown Lakes District Council

The Queenstown Lakes District Plan was made partially operative in March 2003. The Plan contains a number of provisions encouraging renewable energy especially concerning the ability of individual dwellings to provide for their own solar heating provision. The District Plan also contains a specific hydro-generation zone that applies to existing or proposed hydro-electricity generation sites in the District.

6.2 Potential Regulatory Approaches

The following policy suggestions examine some ideas concerning how the Otago Regional Council may be able to provide for renewable energy use and generation through its Regional Policy Statement and Regional Plans.

6.2.1 Identification of Suitable Renewable Energy Locations

Regional Policy Statements and Plans can assist the provision of renewable energy by identifying the potential locations where forms of renewable energy generation that have specific locational constraints may be appropriately located. Resources that have potential locations that can be identified typically include geo-thermal resources, wind-power sites, areas of high solar access, hydro and marine based energy sources. These locations can be illustrated on maps within the Policy Statement or a Regional Plan.

The development of this mapping should include the identification of any potential environmental effects that may limit or preclude the utilisation of the resource in terms of sustainable management of natural and physical resources. For example, some areas suitable for wind generation may also be in areas of outstanding landscape value. Some rivers that may be able to be used for hydro electricity generation may have high environmental values that would preclude such development.

Following the 2005 amendments to the RMA, Regional Policy Statements can where appropriate direct District Plans to make suitable provision for the development of renewable energy in locations identified in such mapping. Alternatively the mapping can be used to give policy direction to resource consent processing at both regional and district levels. The maps can also be used to develop appropriate rule packages in the Regional Council’s own Regional Plans concerning the use and taking of water and the coast etc.

While such locational based policy development has not to date been used extensively in Regional Policy Statements and Plans the approach is valid and is starting to be used more frequently. For example the Auckland Regional Policy Statement already details the Metropolitan Urban Limits on a map. A mapping approach is also enabled via the 2004 amendment to the Resource Management Act that enabled the establishment of aquaculture management areas. A similar approach is also taken in the geothermal chapter of the Environment Waikato Policy Statement and the Environment Bay of Plenty Rotorua Geothermal Regional Plan.

Recommendations

1) That the Regional Policy Statement identify areas within the region suitable for renewable energy development including wind, solar, hydro, geothermal and marine based generation. The location of these areas should be developed taking into account the potential effects of such generation facilities and the sustainable management of natural and physical resources.

2) That District Plans should be amended to ensure that rules do not preclude renewable energy development in areas identified in the Regional Policy Statement. (For example landscape protection areas should not identify areas deemed suitable for wind power generation in the Regional Policy Statement.)
3) That Regional Plans and District Plans provide for existing renewable energy generation facilities as already occurs in some Districts in Otago.

6.2.2 Non-Locational Policy Development

Some renewable resources are not locationally constrained or there may be insufficient information about a resource and its effects available to develop a locational approach (*e.g.* biomass generation).

Regional Policy Statements and Plans can assist the provision of renewable energy by developing detailed policy on how “trade offs” between various resources can be made. It is considered that this approach is mandated by the changes to the Resource Management Act that requires Councils to have particular regard to the benefits to be derived from the use and development of renewable energy. This approach essentially considers the benefits of renewable energy and looks at various “trade offs” between the local and wider benefits of that development and the localised environmental effects that may result from renewable energy generation and transmission within the context of sustainable management of natural and physical resources. If direction on such decision making is not specified by the Regional Council, then it is difficult for Councils to balance the benefits of renewable energy against other environmental effects when considering consent applications. It is considered that these policies need to be as detailed as possible so as to give firm direction.

An example of this approach can be illustrated by policies concerning the provision for wind power. Policies can be developed that would give guidance concerning within which landscapes wind power generation turbines may be appropriately located after having considered the visual effects of wind turbines.

Recommendations

1) That the Regional Policy Statement include a series of objectives and policies outlining how “trade offs” between localised effects and the benefits of renewable energy should be made.
2) That District Plans be amended to give effect to the Objectives and Policies developed in (i) above.

6.2.3 Consents

Discussions with industry players have indicated that consenting issues are a significant disincentive to the development of some forms of renewable energy. There are a number of consenting options that Regional Councils can investigate that would provide encouragement for the development of renewable energy.

Ways in which consenting can be modified include the use of incentives within the consenting processes to encourage the use of renewable energy. Incentives could include:

- greater air discharge thresholds for biomass energy generation (where this can be supported by appropriate ambient air quality),or
- reduced consent thresholds (types) when based on renewable resources, or
- longer consent periods before consent renewal for use of renewable resources than for non-renewable resources.

Codes of practice for renewable generation can be used within consenting processes. Such an approach requires the development of codes of practice, and compliance with these will be accepted instead of the need to comply with rules, or alternatively result in simpler forms of resource consent where compliance with the code of practice is achieved. This technique is reasonably common in Resource Management Act plans with some other issues. Regional Energy Strategies and Regional Energy Forums may be suitable avenues for developing codes of practice around a number of renewable energy resources. These will likely need development in association with generators, District Councils and other interested parties.

Recommendations

1) That Regional Plan rules be amended to provide greater air discharge thresholds for biomass energy generation where this can be supported by ambient air quality.
2) That Regional Plan rules be amended to reduce consent thresholds for energy generation based on renewable resources.
3) That Regional Plan rules be amended to provide longer consent periods for renewable energy projects.
4) That the Regional Council work with energy generators, District Councils, Tangata Whenua and other interested bodies to develop industry codes of practice for renewable energy production.

6.2.4 Domestic or Small Scale Developments

The scale of potential renewable energy projects may also be considered by Councils in setting policy, consents thresholds and notification requirements within plans. In some cases it may be just as difficult to obtain consent for a small scale project that has a low level of local environmental effects as for a large renewable energy project, as plans do not always make distinctions between small and large scale effects. This tends to encourage large scale projects that may have more significant effects than a series of smaller scale projects.

For example, small scale hydro generation projects that do not use dams or do not divert significant volumes of water could be rendered subject to lower consent thresholds than large projects. For example, a wind farm with only one or two turbines will have less visual effects than a large wind farm, yet often a similar consent process is required for both. This situation could be changed by setting scale thresholds for resource consents whereby smaller scale projects are made subject to controlled or restricted discretionary activity consents whereas larger scale projects require fully discretionary resource consents. Domestic scale generation may be able to be a permitted activity.

Solar access can be affected by the layout and orientation of buildings, streets and sites sizes. District Plans are able to significantly influence these aspects of energy access.

At the District level for example, Franklin District Council makes specific provision for some small scale renewable energy generation as permitted activities in rural areas as does the Whakatane District Council for solar panels.

Recommendations

1) That the Regional Policy Statement, Regional Plans and subsequently District Plans be amended to make appropriate provision for various scale energy generation facilities.
2) That the Regional Policy Statement, Regional Plans and subsequently District Plans be amended to allow small scale renewable energy production (including solar and wind) as permitted activities.
3) That District Plan subdivision rules provide site orientation provisions in order to support solar heating and power generation.
4) That District Plans rules should be amended to ensure that development control rules (e.g. maximum height rules) do not unreasonably preclude domestic scale renewable energy production (e.g. allows solar panels on roofs) and protect solar access to nearby properties.

6.2.5 District Plans

Section 75(3) of the Resource Management Act requires District Plans to give effect to a Regional Policy Statement. Regional Councils are therefore able to give direction to the types of rules and policies that the constituent District Councils are able to place in District Plans that directly control land use.

Good practice would dictate that this power should be used in conjunction with a collaborative approach to issues with District Council. Regional Councils are well positioned to influence how District Plans in their region provide for renewable energy generation through specific policy direction within Regional Policy Statements. The nature of the energy resources within the region are such that each District has its own unique range of resources. The response of each District is likely to be different based on the nature of resources in each District.

Recommendation

1) That the Regional Council work closely with the District Councils within the region to ensure that District Plans reflect the renewable energy objectives and policies of the Regional Policy Statement.

6.2.6 Future Proofing Policy Statements and Plans

In developing the next generation of Regional Policy Statements and Plans, Councils should have regard to the potential developments in renewable energy that may occur in the region over the life of the Policy Statement or Plan.

For example, many regions have large areas of coastline that may be suitable for one or more forms of marine electricity generation through the life of a Regional Policy Statement or Regional Coastal Plan. Because this technology is still evolving, polices (and rules in Regional Coastal Plans) could consider how new technologies may be used in the future, what potential environmental effects may result and the circumstances in which such technology may be put in place. In effect polices may be developed in a way that future proofs the policy statement/plan by making provision for new technology to the extent possible under current levels of knowledge.

Recommendations

1) That the Regional Policy Statement and Regional Plans be amended to recognise potential future renewable energy technologies and make high level policy provision for such technologies.
2) That the Regional Council monitor the state of technology development and make changes to the Regional Policy Statement and Regional Plans to make appropriate provision for developing technologies.

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Appendix A Previously Identified Hydro Schemes

No	Catchment Area/River	Mean flow	Head	Capacity	Energy [1]	Remarks
		(m3/s)	(m)	(MW)	(GWh)	
	Waitaki – Waikouaiti Rivers					
O1	McPhersons Rd			2.3	10.1	Alternative at Awamoko 1.3 MW
O2	Waiareka-Kakanui Irrigation - No. 1			9.2	40.3	
O3	Waiareka-Kakanui Irrigation - No. 2			1.8	7.9	
O4	Wainakarau R [2]			0.6	2.6	
O5	Kakanui R			1.2	5.3	
O6	Waikouaiti [2]			1.0	4.4	
	Taieri					
O7	Taieri Falls			8.0	35.0	
O8	Middle Taieri No. 1			6.8	29.6	
O9	Middle Taieri No. 2			3.0	13.1	
O10	Lower Taieri River			18.0	78.8	
O11	Kye Burns			1.5	6.6	
O12	Deep Stream			5.0	21.9	Currently being implemented by TrustPower
O13	Lee Stream [2]			7.0	30.7	
	Upper Clutha					
O14	Cameron Ck [2]			40.0	180.0	
O15	Siberia Stream [2]			32.0	140.0	
O16	Big Hopwood Burn [2]			35.0	160.0	
O17	Lake Hawea			100.0	260.0	Also listed as having a capacity of 214 MW in some studies
O18	Lake Hawea at Minaret Burn			30.0	140.0	
O19	Luggate			90.0	435.0	
O20	Queensberry			180.0	860.0	
O21	Lindis			35.0	150.0	
O22	Motutapu [2]	3.2	45	1.7	7.4	
O23	Staircase Creek	0.65	532	4.7	20.6	

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No	Catchment Area/River	Mean flow	Head	Capacity	Energy [1]	Remarks
		(m3/s)	(m)	(MW)	(GWh)	
O24	Falls Burn	0.34	330	1.3	5.7	
O25	Luggate Creek	0.6	330	2.6	11.4	
O26	Timaru River	2.8	80	2.4	10.5	
	Lower Clutha					
O27	Dumbarton Rock			110.0	480.0	
O28	Tuapeka Mouth [2]			340.0	1590.0	
O29	Barnego			81.0	440.0	
O30	Manuherikia R			1.1	4.8	
O31	Manuherikia R Irrigation			6.7	29.3	
O32	Dunstan Creek			3.2	14.0	
O33	Beaumont River			2.1	9.2	
O34	Pohahaka River [2]			6.3	27.6	
O35	Lauder Creek			1.6	7.0	
O36	Thompsons Creek			2.5	11.0	
O37	Dunstan Creek			2.5	11.0	
O38	Benger Burn			1.0	4.4	
	Kawarau					
O39	Nevis			45.0	200.0	
O40	Kawarau			160.0	990.0	
O41	Doolan Creek [2]			2.5	11.0	
O42	Roaring Meg			7.6	33.3	
O43	Upper Fraser			7.0	30.7	
O44	Arrow River			1.8	7.9	
O45	Moke Lake[2]			2.3	10.2	
O46	Wye Creek [2]			3.0	13.1	

Notes:

[1] Energy estimated at 50 % plant factor.

[2] Potentially within or close to Department of Conservation land or Native forests areas.

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Appendix B Marine

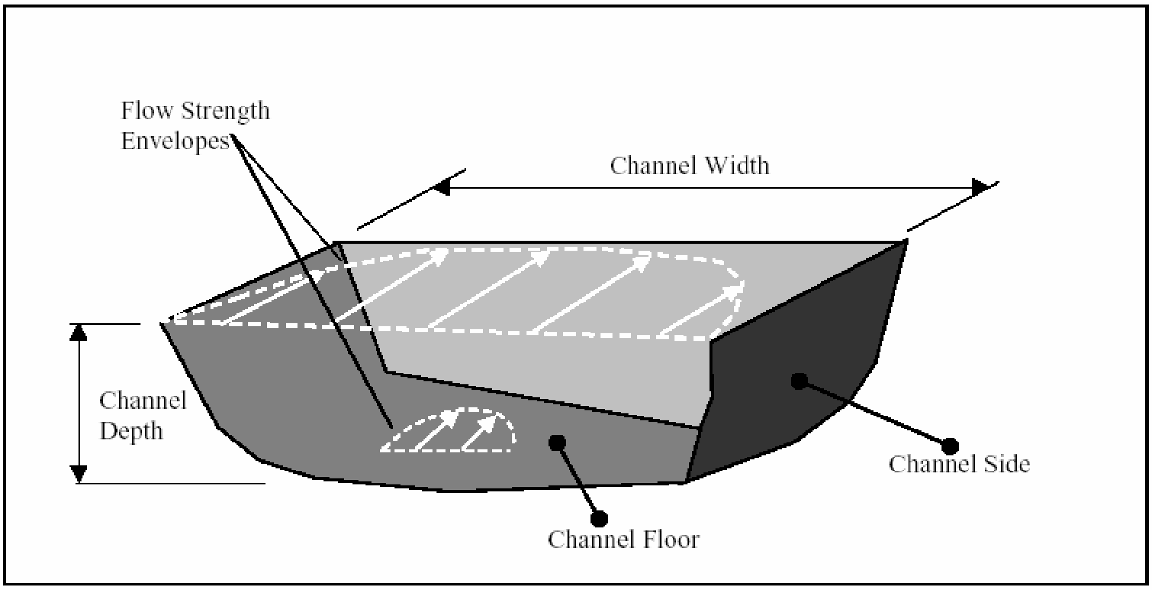
B.1 Tidal Resource

Tides are the periodic rise and fall of large bodies of water caused by the gravitational attraction of the sun and moon. Since the earth is rotating, two tide cycles occur each day. At periodic 28 day intervals, the alignment of the moon, sun and earth causes an additive effect, creating stronger tides and conversely at other times, weaker tides. Localised bathymetry concentrates tidal flows in certain regions into areas of highly energetic activity.

A number of factors come into play when estimating and assessing the extent of the resource and its ‘harvestability’. These can be grouped into two categories: ‘site’ and ‘technology’. Site assumptions are focussed around the extent of the resource itself while the technology group is focussed around the technical issues of harnessing the resource. A critical decision in determining the extent of the resource is based around estimating the flow velocity and its variability dependant upon the lunar cycle. As a complete set of detailed data for every site of potential interest is seldom available, certain assumptions or extrapolations must be made.

Typically these will concentrate upon;

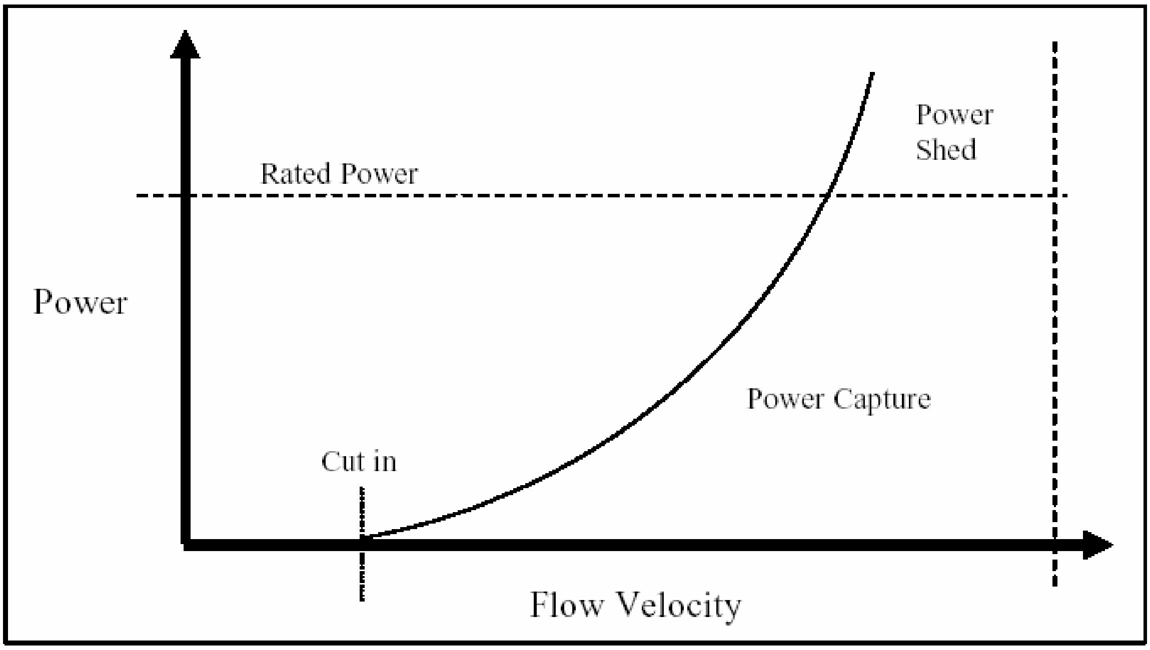
- Influence of the boundary layers on flow rates (both seabed and channel sides) and the effect they have on flow through the channel cross section between ‘mean peak spring velocities’ and ‘neap’ flows (Figure 20)
- Variance of flow within tidal ‘ebb’ and ‘flood’
- Presence of bathymetry variations that cause ‘hot’ and ‘cold’ spots
- Thresholds of energy extraction beyond which tidal flow pattern will change in response to the extraction itself (*i.e.* channel blockage effects).



- **Figure 20 Cross sectional view of tidal channel**

Factors influencing ‘harvestability’ are largely technology dependant:

- Efficiency of devices to capture energy and convert it to electrical power (Figure 21). As devices operate in flow environments that are far from constant, design compromises result in the device being designed to only operate across a selected range of conditions. Typically the device will have a ‘start up’ flow velocity, below which it does not operate, and a ‘rated power’ beyond which it does not operate. Below the cut in and above the rated power, the device will ‘shed’ power.
- Reliability of the device and the speed with which repairs can be executed.
- The density of device deployment or spacing within an array.
- The location of the device relative to boundary layers.
- The transmission efficiency of the electrical connection relative both to land and the end user proximity.
- Needs of other maritime users.



- **Figure 21 Generic device power capture graph**

The tidal range in New Zealand is low (2 to 4 m) compared to many other places around the world (up to 10 m in the UK). Nevertheless there are some sites around New Zealand with significant tidal currents. Most promising are the areas around headlands, together with Cook and Foveaux Straits and the entrances of some natural harbours. Previous New Zealand studies identify a maximum tidal current in unconfined sandy harbours of approximately 1.5-2.5 m/s.

Numerical modelling is a powerful tool in physical systems. The models are able to examine systems to unravel the complexity of the multiple processes that may occur simultaneously. Also, the models can be used in forecast mode to predict future outcomes. For example, the models take measured point data to provide detailed spatial information on waves, currents and sediment movement. The models can then be used to simulate a much broader range of cases and to assimilate the full dataset into an overall prediction of impacts of coastal structures.

The only significant tidal current area of the Otago region is the Otago Harbour. Other estuaries in the Otago area are not of sufficient size to warrant investigation, however micro and /or niche utilization mat be possible at sites such as Karitane, Taieri Mouth, Clutha River Mouth, New Haven and other estuaries in the Catlins Coast.

B.2 Otago Harbour

Otago consists of a long, much-indented stretch of generally navigable water separating Otago Peninsula from the main urban areas of Dunedin. The harbour was formed from the drowned remnants of a giant shield volcano, centred close to what is now the town of Port Chalmers.

Substantial container port facilities exist at Port Chalmers, halfway along the western shore of the harbour. A channel along the western side of the harbour is regularly dredged, allowing fairly large ships to sail all the way to the heart of Dunedin. The dredging of this channel, the Victoria Channel, was a major technological undertaking for the fledgling settlement of Dunedin in the mid 19th century. The eastern side of the harbour is shallow, with large sandbanks exposed at low tide.

The tidal currents in the dredged channel are not of sufficient velocity to warrant a “tidal diamond” on the navigation chart NZ6612. For the purposes of this report it will be assumed that the maximum velocities of 1.5 m/s with a cross channel distance of 280 metres and a depth of 14 metres. Using a simplifying assumption that two tidal cycles occur every day, multiplying by the number of days per year and by the estimated water depth at that point, the annual power per unit width is found. A simplified cross sectional area of the location indicates the total annual power. With an assumed that the flow rate of 1m/s for the upper 80% of the water column, the total annual power resources are calculated as 3,555 MWh.

The average New Zealand household consumes 8,000 kWh or 8 MWh of electricity annually hence from the simplistic figures the tidal flows could provide power for almost 444 homes. However, this energy would be subjected to losses in transformation and transmission. With tidal energy it must also be noted that although the energy is 100% predictable the output will fluctuate with the tidal cycles and may not be generated at times when it is needed.

B.3 Generation capacity

- Most tidal power technologies presently being developed are designed for water depths that would correspond to the depths found in the locations of high tidal energy. For example, Marine Current Turbines require water depths of between 25-35 m. However even the strongest tidal flows found in the region are well below 2m/s, the lower threshold expressed by device designers.
- The dredging of the shallow Otago harbour also makes the possibility of tidal current energy utilisation in this location difficult and unlikely.

The Otago Harbour would not be considered economic for tidal energy in the near future. However, future generations of tidal devices might change this. Capacity would be dependant upon the size and shape of future devices.

B.4 Wave Resource

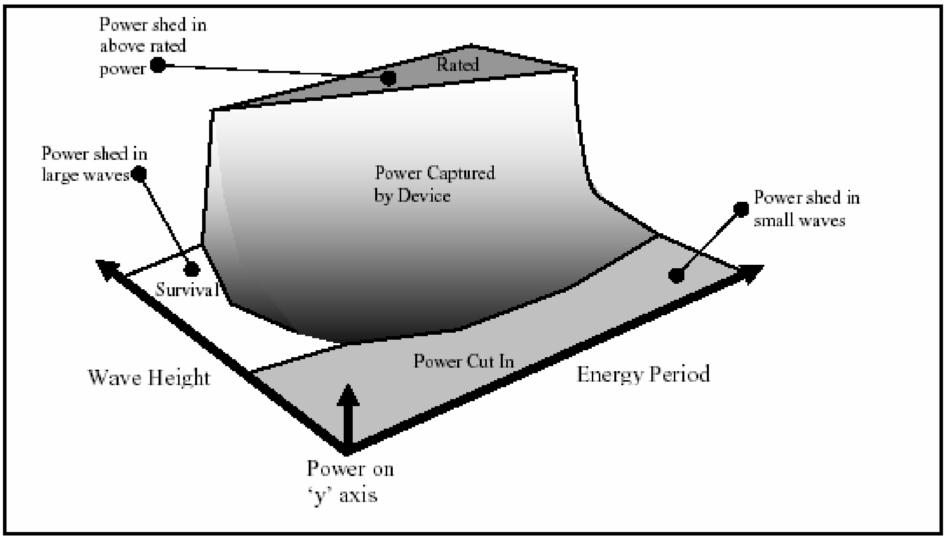
Ocean waves are created by the conversion of kinetic wind energy acting across the surface of an area of open water, where the energy within the wind acts upon the surface friction of the water such that with time it creates an orbital water particle motion. The open space expanse over which the wind and water have opportunity to interact is referred to as the fetch. The interaction between the wind and sea is such that the energy transfer between the mediums will continue until such a point that either equilibrium is reached (this is known as a fully developed sea) or that the fetch length is such that the waves enter shallow waters and break. Wave energy additionally has a directionality component related to the wind direction driving the fetch. As wave energy propagates nearer to coastal regions, it experiences several physical changes whose additive effect is to reduce the levels of energy resource found in shallow coastal waters as compared to their deep water ocean counterparts. Seabed features may however produce a focusing effect, concentrating wave energy. The driving factor in this transformation is water depth. As deep water waves enter coastal waters (deep water is where the water depth is greater than half the wave length), a transition in the wave characteristics occurs. Whilst the wave frequency remains the same, three factors change:

- The wave length shortens
- The wave amplitude increases
- The wave velocity reduces

The above changes are underpinned by the fundamental mode change of the wave's water particle velocity path from circular to elliptical. This is caused by the influence of the seabed and its friction acting upon the wave propagation. Variability in the seabed topography (bathymetry) can result in focusing refraction concentrating wave energy in some locations, resulting in wave energy hotspots. Eventually waves will break when the "over steepness" resulting from the shortening wavelength as waves interact with the seabed causes the velocity of water particles at the wave crest to exceed the velocity of the wave form, surging the crest ahead. As with the tidal case study, the estimates of both the total and attainable wave resource are based upon a set of assumptions that significantly impact the overall results. These assumptions are summarised:

- Distance to land mass for grid connection
- Single device capture efficiency
- Device availability
- Device spacing within array
- Transmission efficiency
- Minimum allowable site area
- Site survey data
- Needs and rights of other maritime users

Many of the above are directly analogous with the tidal situation. However wave device power capture efficiency is somewhat different. Unlike tidal, where the dominant variable in the power calculation is velocity, with waves, power capture is a combination of wave period and height (Figure 22), thus creating a three dimensional scenario. Typically a device will be designed such that below a certain threshold or 'cut in' the device will shed power. Above a certain threshold associated with its rated power, the device will also shed power, and in high energetic storm conditions the device may shed power as a survivability strategy.

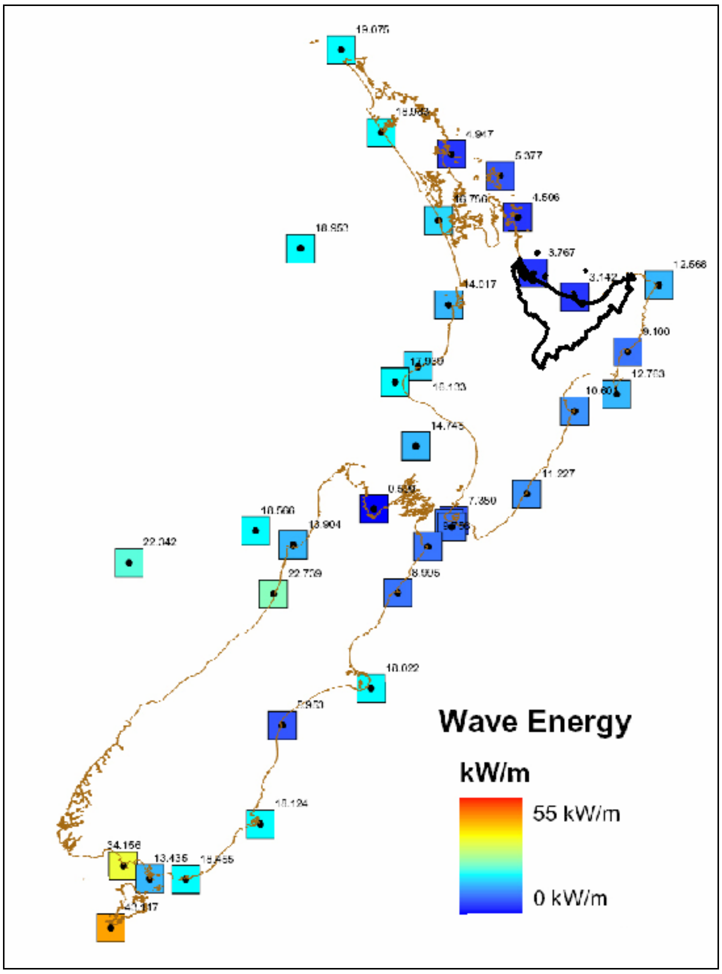


- **Figure 22 Typical wave device power capture**

In New Zealand, the weather systems that are driven up from the southern ocean play a major influencing role. It follows that offshore and coastal regions exposed to these influences will contain a greater abundance of wave energy than more sheltered areas. Waves from storms and weather events to the north east of New Zealand are less intense, less stable and less predictable.

Wave energy is often expressed in terms of the average "kilowatts per meter of wave front", kW/m (Figure 23). This single figure, while providing a comparable generalisation, fails to describe the resource in terms of the:

- Spatial variability (that may result in hotspots)
- Temporal fluctuations of swell events
- Predictability of generation storm events.



- **Figure 23 Average wave energy (kW/m) (Frazerhurst 2006)**

The Otago area is represented in Figure 23 with average wave energy of 18 kW/m. This level of annual energy is on lower end of a useful average (20 kW/m).

B.5 Hotspots

Wave refraction transformation across the shallowing seabed can be modelled using numerical models such as WBEND model from the 3DD Suite©. The inputs of this model are monochromic representative waves or a full wave spectrum combined with a model grid of the bathymetry. Iterations signifying the wave climate can be combined create a hotspot map indicating special locations where wave height (and hence energy) is intensified. Conversely, this modelling also identifies locations where wave energy is lacking or shadowed.

Figure 24 demonstrates the hotspot map of part of the Otago coast derived from a WAM (Wave Analysis Model) 20 year wave hindcast with the model WBEND (part of 3DD Suite©)

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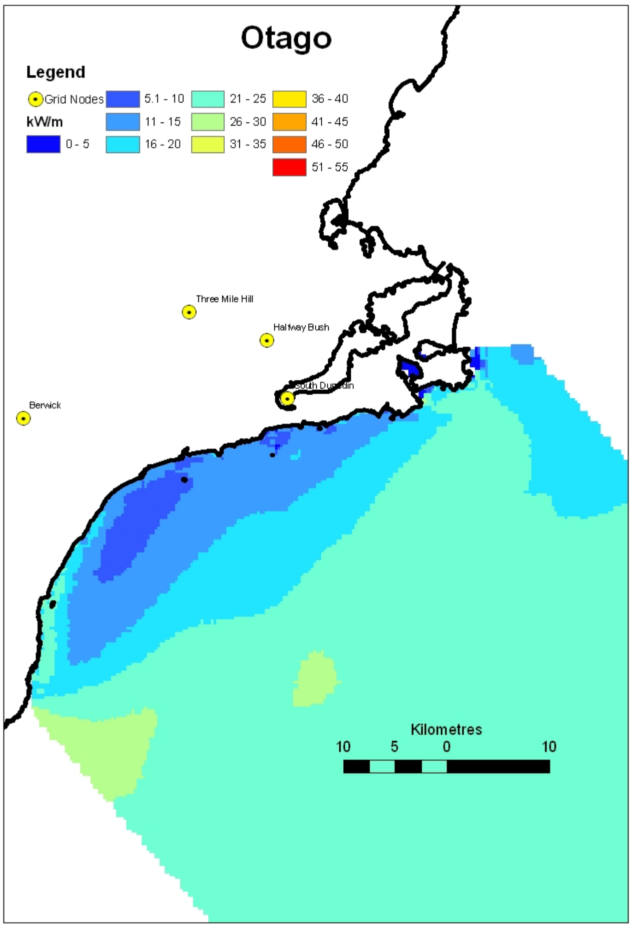
transforming waves from deep to shallow water and combined into a weighted average of wave energy.

Significant wave energy of a higher annual average (26-30 kW/m) than the offshore wave climate is greater in the southern section of this map and a location in the centre of this map where a ten kilometre ridge focuses energy (Frazerhurst 2006). These hotspots may represent locations that would be useful for the location of wave energy plants. Transmission savings due to the reduced distance from shore may also be possible. Modelling of the southern section of the Otago coast is expected to reveal greater energy than that expressed in Figure 24. The undulation bathymetry may also provide focusing at further enhancing averaged wave energy.



- **Figure 24 Weighted Average Wave Energy for Coastline Adjacent to Otago**

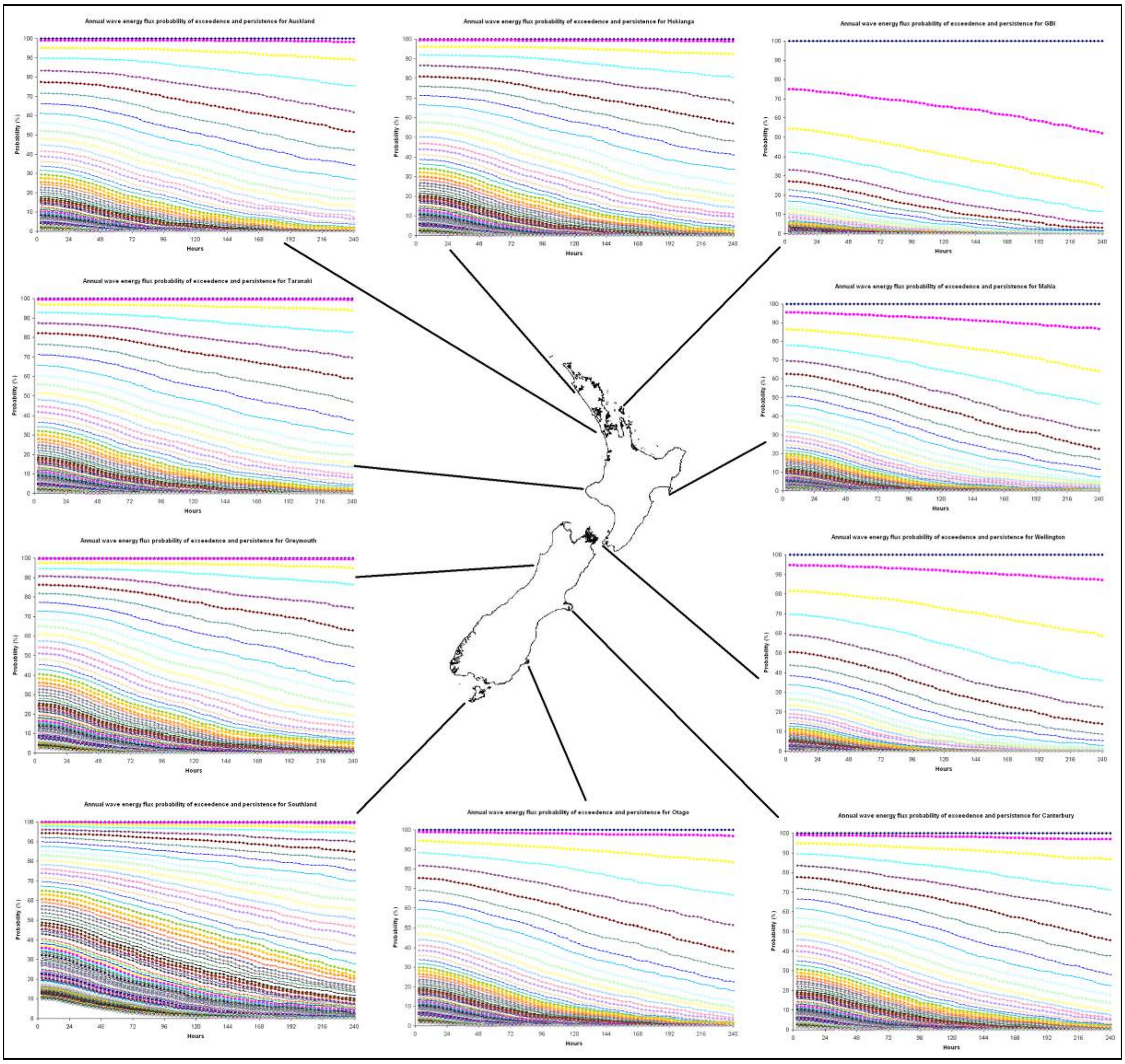
Note: Derived from WAM 20 year wave hindcast and digitised bathymetry 200m x 200m cells. This modelling has not been calibrated. (Frazerhurst 2006).

B.6 Exceedance-persistence

Exceedance-persistence provides a method to identify the temporal dimension of wave energy fluctuations (Frazerhurst 2006). Wave characteristics for a location are expressed as a three hourly time series in the 20-year hindcast. Analysis of this time series identified the percentage probability of wave energy levels being greater than set values (exceedance). In this example these set increments were one kW/m from 0 kW/m to 100 kW/m. Analysis also identified the probability (%) that the these energy levels would continue over time (persistence), in this study these time increments were set at the 3 hourly temporal resolution of the hindcast and probability calculated out to 10 days (240 hours) persistence (Frazerhurst 2006). Figure 25 shows the graphed results for the major aspects of New Zealand.

The probability (%) of the kW/m being exceeded is on the y axis and persistence (hours) is on the x axis. Each colour represents one increment of energy (kW/m). Hence blue is 0 kW/m, purple is 1 kW/m, aqua is 3 kW/m, etc. The appearance of "bunching" of lines in the lower left hand side of each chart represents higher wave energy. The distance this bunching spreads towards the top right hand side of each graph provides a contrast and comparison for each costal aspect.

The southeast of the South Island is represented by the Otago graph. This graph has a similar bunching of the exceedance–persistence lines to the west of the North Island and the west South Island. This representation can be described as having a very good probability of significant wave energy events that persist for a several days. This temporal pattern of energy input is useful to the electricity generation industry (Frazerhurst 2006).



- **Figure 25 New Zealand coastline and exceedance-persistence graphs representative of major coastline aspects (Frazerhurst 2006).**

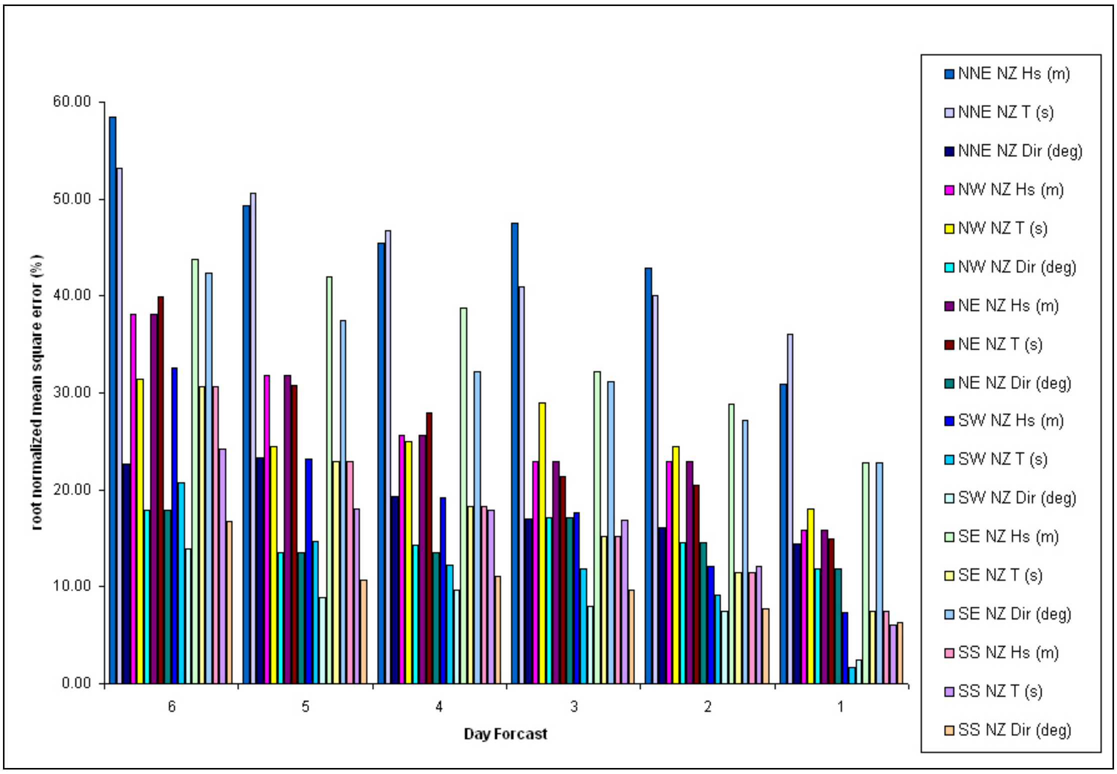
B.7 Predictability

A potential disadvantage of some renewable energy sources is the intermittent fluctuations in the primary “fuel” supply. This leads to an uncertainty of the capacity and availability of these generation methods compared to biomass or non-renewable energy sources such as the combustion of fossil fuels. Waves have a greater predictability than other renewable energy sources, particularly wind and solar energy. Forewarning of wave energy events to a location of conversion devices will mean that several advantageous processes may be possible. These include:

- Assessment of the following day(s) wave energy generating capacity
- Pre-tuning of conversion converter devices

- Scheduling of device maintenance.

Wave energy events can be predicted using wave-forecasting models whose effectiveness is dependant on the stability of the pattern of atmospheric conditions where the waves are generated. This predictability can be evaluated by comparison of daily predictions with a present or "now" forecast. This comparison (provided that model has an established validation history) means that rather than an evaluation the model's ability to predict wave characteristics, the predictability of an aspect of coastline, and its associated low-pressure systems, is assessed. This is an important point as the waves generated represent an "echo" of the activity in a section of the ocean. The ability to predict the waves from a location represent the predictability of the climatic conditions of that particular section the ocean and hence the ability to predict output of a wave energy converter plant. An example of the predictably wave height period and direction can be seen in Figure 26.



- **Figure 26 Wave Forecasting**

Wave forecast characteristics were collated for several months and each day's "now forecast" compared to previous predictions. Wave climate characteristics (wave height (metres), period (seconds) and direction (degrees)) were compared and the percentage root normalized mean square errors (RNMSE) for six locations around New Zealand calculated. The graph above shows the

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error (y axis, %) for each locations characteristics for the time (x axis, days out from "now forecast") from the "now forecast" (Frazerhurst 2006).

The predictability of waves surrounding New Zealand is divided by exposure to two separate locations of wave generating systems:

- Storms and low pressure systems traversing the southern Tasman Sea and Southern Ocean
- Tropical depressions and low pressure systems wandering the northern Tasman Sea and the Pacific Ocean to the northeast of New Zealand.

Exposure to the southern locations results in significantly greater predictability than the northern locations. The Otago coast is exposed to both the swells from the Pacific, to the east, and the Southern Ocean with swells from the latter dominating. Therefore the predictability of swells approaching from the south is highly predictable.

B.8 Utilisation of the wave energy

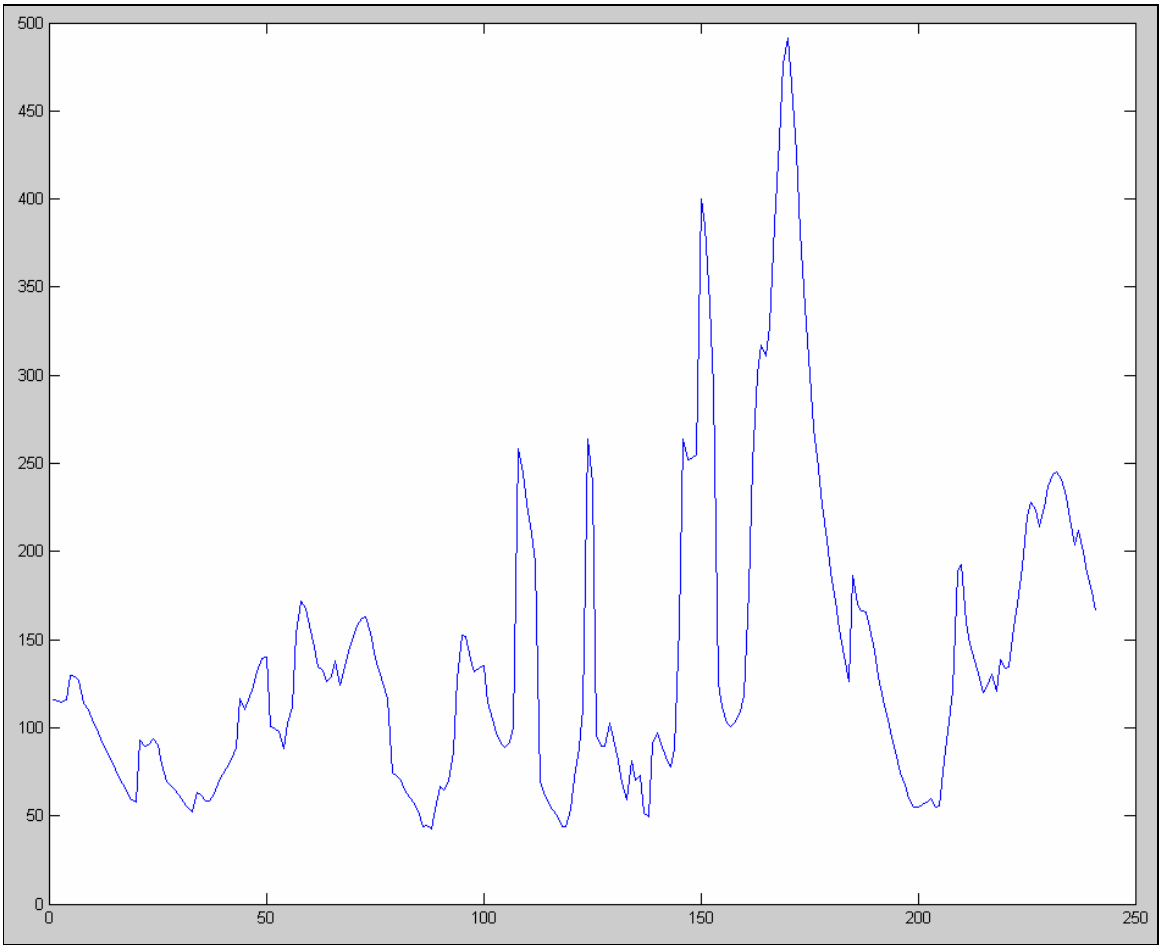
Wave energy converter devices perform differently in different wave conditions. A method of quantifying these performance differences is the use of a capture width ratio (CWR) matrix (Table 7).

- **Table 7 Capture Width Ratio matrix for the Pelamis wave energy converter device derived from ERPI studies (www.epri.com)**

Hs	Tp (sec)															
(m)	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
5.5	2.3	2.3	2.3	2.3	3.21	2.91	2.5	2.08	1.59	1.35	1	0.83	0.83	0.83	0.83	0.83
5	2.3	2.3	2.3	2.3	3.21	2.91	2.5	2.08	1.59	1.35	1	0.83	0.83	0.83	0.83	0.83
4.5	2.3	2.3	2.3	2.3	3.21	2.91	2.5	2.08	1.59	1.35	1	0.83	0.83	0.83	0.83	0.83
4	2.3	2.3	2.3	2.3	3.21	2.91	2.5	2.08	1.59	1.35	1	0.83	0.83	0.83	0.83	0.83
3.5	2.3	2.3	2.3	2.3	3.21	2.91	2.5	2.08	1.59	1.35	1	0.83	0.83	0.83	0.83	0.83
3	2.3	2.3	2.3	2.3	3.21	2.91	2.5	2.08	1.59	1.35	1	0.83	0.83	0.83	0.83	0.83
2.5	2.3	2.3	2.3	2.3	3.21	3.38	3.02	2.42	1.83	1.35	1.1	0.83	0.83	0.83	0.83	0.83
2	2.3	2.3	2.3	2.3	3.57	3.38	3.02	2.42	2.04	1.49	1.1	0.83	0.83	0.83	0.83	0.83
1.5	2.3	2.3	2.3	2.3	3.57	3.86	3.42	2.71	2.04	1.49	1.1	0.76	0.76	0.76	0.76	0.76
1	2.3	2.3	2.3	2.3	3.57	3.86	3.42	2.71	2.04	1.49	1.1	0.76	0.76	0.76	0.76	0.76
0.5	2.3	2.3	2.3	2.3	3.57	3.86	3.42	2.71	2.04	1.49	1.1	0.76	0.76	0.76	0.76	0.76

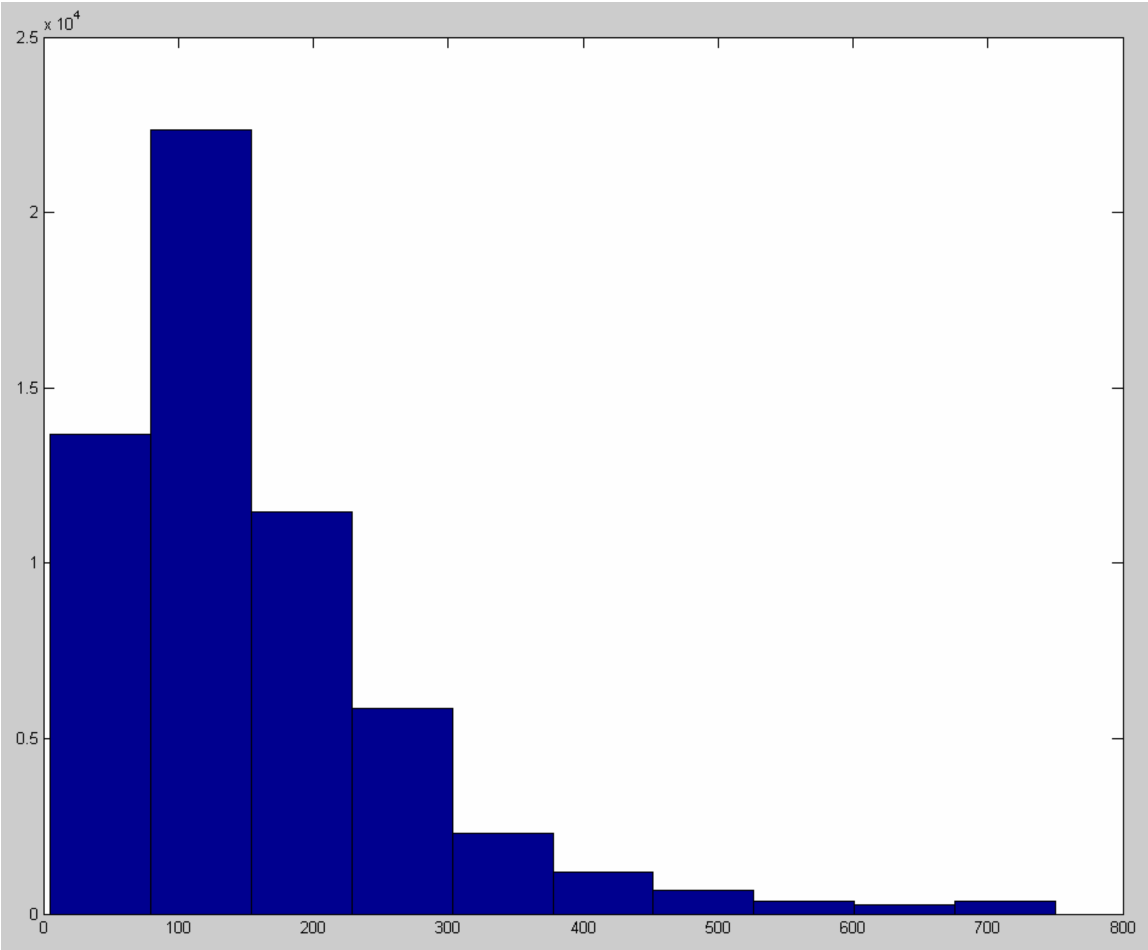
The table shows that for a 4 metre significant wave height at 7 seconds peak period, the device is converting 3.21 times it actual widthThe CWR describes the apparent width of wave front a device will convert. Hence for a 4.63 metre wide 750 kW Pelamis (www.oceanpd.com) in seas of 2 meters significant wave height and a peak period of 10 seconds, the capture width is 11.2m (CWR of 2.42, multiplied by the actual width of 4.63m). Using the energy calculation of H^2 x T x 0.42 (where H is wave height, T is peak period and 0.42 is the spectral coefficient) the energy in these condition is 16.8 kW/m. Hence the output of a Pelamis device would be 188 kW.

This above methodology was applied to all (58,440) hindcast wave characteristics from 1979 to 1999 to produce the output of wave energy for this twenty year period if a 750 kW Pelamis had been in place. Figure 27 shows the output of a thirty day sample form the Otago data set. The device tops out at 750 kW. Figure 28 shows a histogram of the device output. The capacity factor for the device would be 21%, i.e. total cumulative power produced / total cumulative power produce if outputting 750 kW.



- **Figure 27 Modelled wave energy output from 750kW Pelamis for thirty-day period.**

  Note: Kilowatts on the y-axis and three hourly intervals on the on the x-axis. The device tops out at 750kW.



- **Figure 28 Histogram of energy output from 750 kW Pelamis for 20 years.**

  Note: Kilowatts on the x-axis and number of three hourly outputs on y-axis. The device tops out at 750 kW.

The total cumulative power produced of 9,207,724 kW divided by the number of hours in twenty years, 175,320 equals the average power per hour, 52.52 kW. Average power output (52.52 kW) times the hours per year, 8,760 equals 460 MWh on average each year. These single device figures can than be multiplied by the number of devices in each wave farm.

B.9 Generation Capacity

The wave energy resource for the coast of the Otago area is described as having;

- Locations of significant wave focusing close to shore, with areas of average wave energy between 21-25 kW/m
- Good probability of wave energy exceeding and persisting at utilisable levels

- Highly predictable wave generating storms in the Southern Ocean

A wave farm off the coast of Otago would produce approximately 460 MWh per device annually. Devices positioned at one of the hotspots created by the offshore bathymetry and in the south of the Otago area would have a higher output of between 20-30%. Hence, a one hundred-device wave farm of 750 kW Pelamis (total capacity of 75 MW) would have an output of approximately 50 GWh. The average New Zealand household consumes 8,000kWh or 8MWh of electricity annually hence; from the simplistic figures, the wave farm outputs could provide power for 6250 homes. However, this energy would be subjected to losses in transformation and transmission.

Appendix C Resource Maps