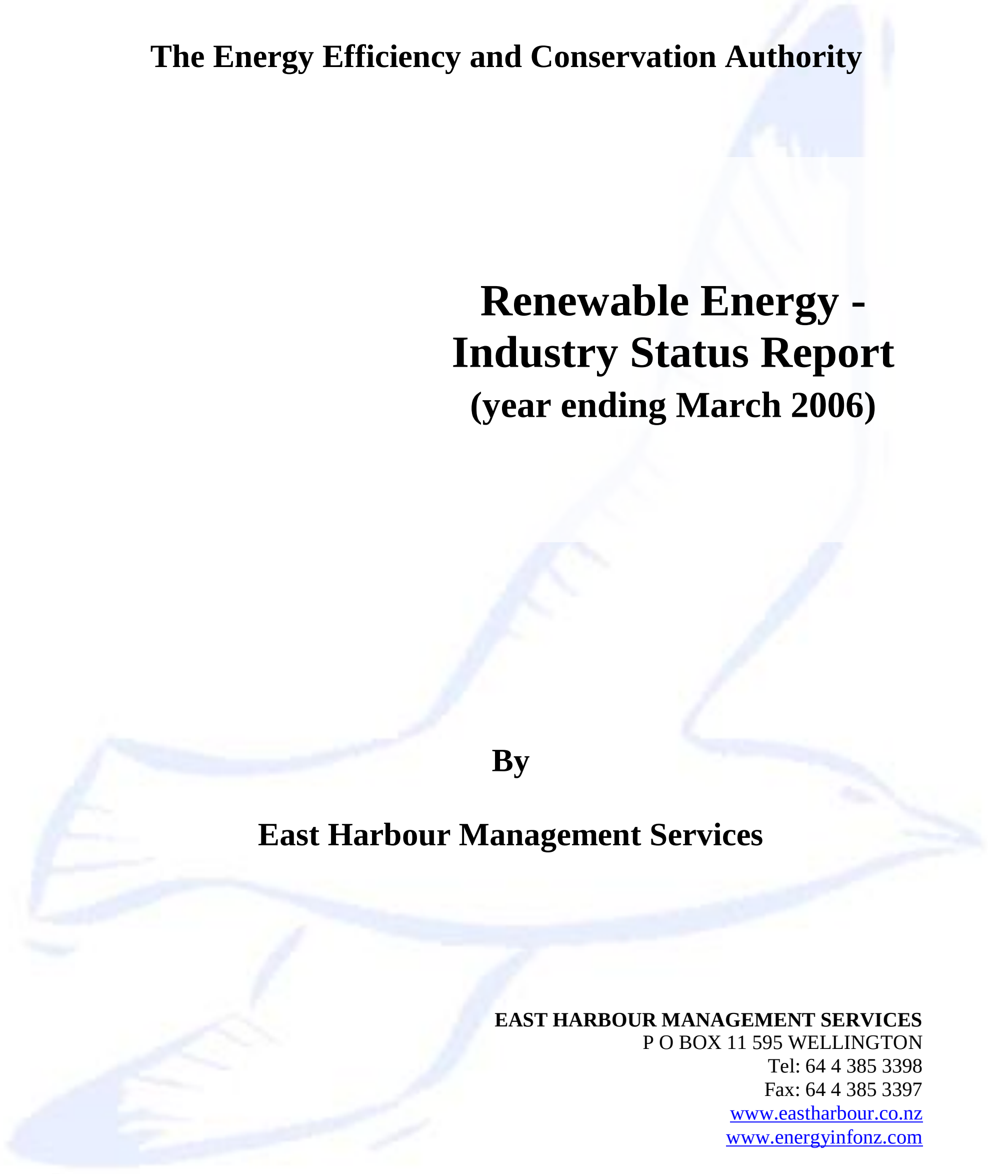

Prepared for

The Energy Efficiency and Conservation Authority

Renewable Energy - Industry Status Report

(year ending March 2006)

By

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Notes:

1. The report focuses on useable energy at source from renewable energy resources, because this is what is pragmatically measurable.
    - Hydro, wave, tidal and wind useable energy is measured as direct output from the electricity generator.
    - Solar primary energy is measured as direct output from the collector.
    - Geothermal primary energy is measured at the well head.
    - Bioenergy is measured as direct output from the heat plant.
    - Solar space heating is not measured.

2. To allow comparison with other studies the following methodologies are followed:

    Electricity
    - Primary energy for electricity generation (excluding PV) is useable energy at source plus generator losses.
    - Consumer energy from electricity is useable energy at source less 9.5% allowance for transmission and distribution losses.

    Heat
    - Primary energy from bioenergy sources is useable energy at source plus heat plant losses.
    - Consumer energy from bioenergy sources is the same as useable energy at source.
    - Primary energy from solar is the same as useable energy at source.
    - Consumer energy from solar is the same as useable energy at source.

    Transport
    - Primary and consumer energy is the same as useable energy at source.

3. Throughout this report, energy is referred to in petajoules (PJ) except for electrical energy which is referred to in gigawatt-hours (GWh). Conversion is 1 PJ = 278 GWh. Where it is useful for comparison purposes both units will be presented. Where PJ and GWh are referred to, these are on a per annum basis.
4. WACC is the Weighted Average Cost of Capital. This is used to determine the minimum return required of an investment, based on inflation and the cost of debt and equity to the project developer/owner.
5. A long-term average exchange rate of NZ$1.00 to US$0.60 was used to derive the cost profiles in this report.
6. Where the term "source" is used with Figures and Tables, this includes the source, or the data source(s) for the respective Figure or Table.

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Executive Summary

For the year ending June 2005, the Ministry of Economic Development assessed that 241 PJ (32%) of total measured primary[1] energy used in New Zealand was obtained from renewable energy sources.

This Renewable Status report indicates that an estimated 212 PJ of energy was useable[2] at source, and this led to an estimated 150 PJ of measured consumer[3] energy. The contribution to useable and consumer electricity, heat and transport energy from each renewable energy form outlined in the report is shown in Table 1.[4] Throughout this report reference is principally made to useable energy at source with reference only to consumer energy when referring to the Renewable Energy Target.

Table 1 Renewable Energy in New Zealand (June Year, 2005).

Renewable Energy Source	**Useable Energy (Nett) at Source**			**Consumer Energy (Nett) * PJ pa**
	Electricity PJ pa	**Heat PJ pa**	**Transport PJ pa**	
Hydro	93.5			84.7
Geothermal (Electricity)	60.8	2.8		11.0
(Direct Use)		14.6		14.6
Wind	1.9			1.7
Bioenergy (Woody Biomass)	5.0	31.3	0.0	35.9
(Municipal landfill, sewage)	0.1	0.2	0.0	0.3
(Food processing/Agricultural)	0.0	1.6	0.0	1.6
Solar (Hot Water)		0.2		0.2
(Photovoltaic)	0.01			0.0
(Space Heating)		Not Measured		
Sea Energy (Wave)	0			0
(Tidal / Ocean Current)	0			0
SUBTOTAL RENEWABLE ENERGY	161.4	50.6	0	**150.0**
GRAND TOTAL RENEWABLE ENERGY	**212.0**			

* Electrical transmission and distribution losses of 9. 5%.
# Ethanol containing 0.43 PJ of energy is produced from renewable energy sources but not included as it was not generally used as an energy product.

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[1] Primary energy is energy as it is first obtained from natural sources.

[2] The report focuses on useable energy at source from renewable energy resources, because this is what is pragmatically measurable.

- Hydro, wave, tidal and wind useable energy is measured as direct output from the electricity generator.
- Solar primary energy is measured as direct output from the collector.
- Geothermal primary energy is measured at the well head.
- Bioenergy is measured as direct output from the heat plant.
- Solar space heating is not measured.

[3] Consumer energy from electricity is useable energy at source less 9.5% allowance for conversion, transmission and distribution losses.

[4] Table 1 summarises the information outlined in the report. Some of the data differs from that in the Ministry of Economic Development Energy Data File as this report uses some more recent information on bioenergy sources.

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This report summarises changes in the use of renewable energy for the period between 2000 – 2005. It is estimated that since 2001 (baseline for the 30 PJ Renewable Energy Target) an additional 11.32 PJ of renewable energy has been installed. A further 15.27 PJ of renewable energy is under construction or committed and 34.33 PJ under serious investigation. (Wind energy forms the bulk of the developments) This transfers into an equivalent of 10.22 PJ of consumer energy which has been installed, 13.77 PJ under construction or committed and 30.9 PJ under serious investigation. The report does not attempt to predict the uptake of renewable energy by 2012.

Hydro

In the period from January 2000 to December 2005 approximately 745 GWh (2.68 PJ (2.44 PJ consumer)) of additional hydro generation has been commissioned or is under construction.

Hydro is a mature technology but new ways of applying the technology, while meeting appropriate environmental and community conditions, have resulted in most new projects being enhancements, small or out-of-river canal type projects, with modular generating plant. River impoundment schemes with water storage have not been attractive because of the need to purchase substantial areas of land. Residual river flows are now a major determining factor of scheme size and acceptability.

The report[5] estimates that there is 4260 GWh pa (15.3 PJ) of currently untapped hydro resource that could be developed in the future at estimated costs of up to 10c/kWh, but current community concerns make it unlikely that investors would investigate opportunities until they can have more certainty of outcome. A way to reduce risk is to invest in small or mini schemes for niche electricity generation.

Interest in new hydro opportunities is increasing but because of the expense of investigations and the lack of certainty of outcomes when seeking resource consents, only large and mid-sized energy companies are undertaking serious investigations of opportunities that will contribute significantly to additional renewable energy. The cessation of Project Aqua investigations has demonstrated the level of concern developers have about the lack of certainty over water rights, the risk to investment, and also the potential for higher costs when detailed investigations of site conditions are made. Renewed resource consents and changed Regional Plans are putting further constraints on existing developments such as those involving Wanganui waters and the Waitaki River system.

Increasing interest in mini and microhydro schemes is occurring and this is expected to broaden as the cost of energy from fossil fuel sources increases.

Geothermal

In the last year 53.4 MW (444 GWh pa) of electricity generation and a small amount of heat capacity has been installed giving an additional 1.60 PJ pa (1.45 PJ consumer) of energy from geothermal investments. An additional 3.75 PJ pa (3.39 PJ consumer) is under construction or committed, drilling is occurring with a view to loading up existing underutilised capacity by a further 1.65 PJ pa (1.50 PJ consumer) and it has been estimated that a further 0.45 PJ pa (0.41 PJ consumer) is being progressed for development.

Geothermal energy has provided a steady stream of electricity since the 1950s but new investment initiatives have languished in recent years initially because of the availability of low-cost gas alternatives, and more recently because companies were building up expertise and development portfolios, or were pre-occupied in securing ongoing access to steam for existing developments. There have always been community precautionary concerns about possible extractive effects on other resource users. To provide greater certainty for developers and communities more recent developments have been based on a limited proportion of a field's potential sustainable output, through staged development.

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[5] EHMS - 2004

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Geothermal energy has principally been used for process heating (world's largest geothermal heat application at Kawerau), electricity generation, commercial, recreational and community heating. Significant further opportunities in these areas remain along with greater use for direct industrial heating such as has occurred for the Mokai glasshouses.

Barriers to an increased focus on direct heat applications will be:

a) the cost of well drilling and resource development which are generally beyond the means of smaller businesses that could offer a large number of opportunities,
b) associated resource risks, and
c) the need to locate the industrial process heat applications relatively close to the geothermal field with associated land access issues.

Geothermal energy could also provide significant additional energy from deep heat or hot rock sources but this is still in the development stage internationally and is unlikely to be economic in New Zealand for some years. Small geothermal heat pumps are becoming more common in Europe. The anticipated cost of extraction of energy from these sources will be a major barrier to investigation and eventual investment, though it could be noted that such developments are already considered commercially attractive in countries where government subsidies are available.

While there appears to be niche opportunities for geothermal heat pumps in New Zealand, barriers to uptake include lack of awareness of the option, and a lack of experienced installers.

The lack of development rights or exploration licences is a major barrier to exploration of new resource areas. Developers have been frustrated by difficult land access negotiations prior to seeking consents. Reconsenting of existing developments has proved frustrating.

Wind

Investment in wind energy projects is growing as projects using large electricity generating turbines are becoming economic. In the last four years 131 MW (526 GWh, 1.89 PJ) of grid-connected capacity has been installed and an additional 217.5MW (820 GWh, 2.95 PJ (2.66 PJ consumer) have consents or are under construction. An assessed 9.56 PJ (8.61 PJ consumer) of sites are being progressed for development. Most other good large-scale sites are under some degree of investigation. Investment in some of these sites with very high wind speeds is, however, constrained by transmission requirements from isolated locations, and the need to address a wide range of community concerns to perceived noise issues and changes in landscape values.

Some wind energy projects in New Zealand are being developed in conjunction with similar developments in Australia with economies of scale reducing costs for New Zealand investments.

Small wind turbines (<5kW) are currently not economic for grid connection but with increasing energy prices may become economic for many niche opportunities post 2007. In particular these could arise for rural or distributed industrial applications as electricity distribution lines age and become more expensive to maintain or upgrade.

Internationally, new wind developments are occurring at off-shore locations. While this is a trend that could be expected to also occur in New Zealand, different seabed conditions and generally unfavourable sea depths, and the additional costs for off-shore installation will likely result in low uptake of this option in the foreseeable future.

The value of wind energy can often be enhanced by the synergies of linking the non-firm[6] wind energy with hydro storage, essentially using the hydro storage as a battery for the wind energy. This is an area where opportunities can be expected to arise.

Bioenergy

In the last five years an additional 4.5 PJ of mainly heat energy has been obtained from bioenergy investments.

Energy from solid or liquid biomass is well established and uses proven technologies. Currently most bioenergy comes from process waste woody biomass and this is not expected to change. Other than in the pulp and paper industry little bioenergy currently comes from the processing of liquid manufacturing waste (meat processing, dairy processing, sewage).

Bioenergy is currently used principally for heat production. Unless in a cogeneration application, it is currently uneconomic to generate electricity from bioenergy and even with cogeneration the economics are marginal unless the scale is large. With the increased cost of other sources of energy for generating electricity, analysis shows that generation of electricity from bioenergy may become more attractive in future.

Woody biomass from forest processing waste is already in short supply in some regions and, as the cost of energy increases throughout the decade, forest residue may become economic for use as a fuel. With the amount of forest residue available it is unlikely that purpose grown short rotation crops will be an economic source of energy for some years, other than as a backup source of fuel.

Waste woody biomass is usually utilised on-site with minimal preparation into a fuel form. By processing sawdust into a pellet form the opportunities for gaining higher value by delivery to other off-site users are enhanced.

While processing of municipal solid waste-to-energy via combustion is technically possible and can meet required air emission conditions, the cost of processing the refuse into a form suitable for use as a fuel and the need to still handle the non-combustible materials is still the biggest barrier to greater use of this technology. However, as communities become concerned about the location of landfill sites, greater interest is expected to be taken in these opportunities.

Extraction of methane gas from landfills occurs in 12 sites in New Zealand. As new landfills are built they can be designed so that gas from decomposition of the waste is collected. Extraction of landfill gas has proven to depend on good landfill design and management, and due to concerns over landfill gas emissions, the mandatory capture of landfill gas from large landfill sites is required by The National Environment Standard. The Standard came into force on 8th Oct 2004 for large current operational (or future) landfills requiring all gas to be destroyed (flared or used for heating or electricity generation). Several councils are presently investigating the use of landfill gas.

Processing of liquid organic waste from industrial plant (e.g. meat and food processors) or dairy sheds is an untapped source of energy that is currently little utilised. In some regions of New Zealand community concerns about receptive land or waterways is creating a tightening of environmental discharge conditions and this is increasing the need for research into appropriate technologies. Energy price increases combined with the environmental drivers is improving the economic benefits of implementation.

Ethanol production has been undertaken from dairy process by-product for a number of years. With the removal of barriers for the introduction of ethanol as a blend with petrol for use as a transport fuel the

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[6] Within the report energy is referred to as being non-firm if it is not controllable in terms of quantity because of wind or tide pressure fluctuations etc. However, the energy may be reasonably predictable as can occur with tides and wind. .

opportunity exists for increased production of ethanol from renewable energy sources. Government has signalled that it wishes ethanol blend petrol to be available by 2008. Limits of a 3% blend are being sought by the automotive importers. The use of biodiesel is common overseas and there are very few technical barriers to its introduction in New Zealand. To date, the majority of barriers to the use of renewable transport fuels are policy and commercial issues and significant progress is being made in these areas. The most feasible feedstock for biodiesel production in New Zealand is tallow, a by-product of the meat industry, and there is already one pilot production facility operating locally using this feedstock.

Solar

Annual installation of solar water heating systems has increased in number by over 250% and area by over 900% throughout the last four years and currently 0.2 PJ of electricity otherwise needed for heating water is avoided annually. Interest in solar water heating is changing from it being viewed as an 'alternative' energy source to becoming accepted as a more mainstream source of energy for heating water. The growth in installations in residential dwellings is already creating a flow-on interest for use of solar energy as a pre-heat option for commercial applications.

The New Zealand solar water heating industry has been consolidating its capacity and capabilities through establishment of quality assurance programmes (Code of Practice, Accreditation, installer training) by partnering with EECA. Government seed funding for promotion activities has been a principal initiator for market transformation.

While the worldwide production of electricity from photovoltaic cells is experiencing a rapid uptake which will result in significant reductions in cost over the next decade, currently photovoltaic cells are only economic for niche applications. The increased use of photovoltaic cells will depend on international research and manufacturing capacity and economies of scale reducing costs. Changes in the regulatory arrangements for connection to electricity networks, including net metering, will encourage more grid-connected installations. These changes will lead to an increase in the uptake of photovoltaic energy over the next few years which could be similar to the high levels of uptake currently occurring overseas (but from a very low base).

The New Zealand photovoltaic industry has commenced establishment of an action programme aimed at heightening awareness of applications where photovoltaic cells could be appropriate. Unit standards for the training of electricians and service technicians as installers and designers of photovoltaic systems are under development. When acceptable training courses are available, an accreditation scheme will be established to improve the level of confidence in the ability of the industry to implement the technology.

The utilisation of passive solar energy in the design of buildings is a significant renewable energy opportunity which is difficult to quantify. Its implementation through good building design is well understood by few architects and fewer building developers, and not many new home owners. However, in practice, many opportunities are lost because of cost concerns. Greater uptake will arise as the housing stock is replaced, provided education and promotion of the benefits are increased.

Marine Energy

The technologies for extracting energy from sea waves and tidal currents are well understood but can often be difficult or very expensive to implement. Both wave energy devices and moored tidal turbines are relatively immature technologies however significant research being undertaken internationally will be transferable to New Zealand. First commercial installations can be expected within the decade.

Generation from barrages using tidal range requires specific geographic and tidal range conditions, and involve large-scale and expensive construction works. There is little opportunity for this technology in New Zealand (due to the low tidal range), and the adverse impact on local ecological systems such as mudflats and the wider estuarine environment could be considerable.

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The harsh marine environment research undertaken for off-shore wind turbines and the several demonstration plants in Europe can be expected to make a considerable contribution to the development of wave and tidal current technologies.

Current Position of Renewable Energy in New Zealand

Recent investment decisions by major energy companies demonstrate that the use of renewable energy within the New Zealand energy market has reached a position where it is gaining greater acceptance as an integrated and mainstream energy investment option. The key drivers for this have been the pending reduction in the availability of gas from the Maui field, with the increases in the cost of oil, gas and coal, the need to reduce greenhouse gases and the need for new electricity generation facilities or significantly enhanced energy efficiency.

Many renewable energy forms are now becoming economic propositions with the result that potential investors (large and small) are looking to renewable energy as an integral source of their secure energy supply.

Within New Zealand renewable energy investments generally only proceed when investors see that there is likely to be an appropriate financial return on their investment. In order to price in public good benefits of renewable energy (CO_2 reduction, health, employment, self-sufficiency, recreation) the Government has become involved in the sector through establishment of the Renewable Energy Target under the NEECS, currently being revised.

Despite the difficulty of financing large projects, the goodwill for renewable energy is evidenced by the support for projects "on the fringe" where some personal investors are prepared to invest and take a reduced rate of return for financing "good projects" e.g. Windflow. At the leading edge of some technologies it has been enthusiasts investing largely for benevolent reasons.

The current level of investment in renewable energy projects shows that some renewable energy opportunities are economic without the use of Government subsidies. However, most require some additional financial encouragement such as was demonstrated by the interest in emission credits under the "Project to Reduce Emissions" mechanism. In addition there are renewable energy forms that are uneconomic in most New Zealand applications. Many renewable energy industry players are very small businesses and do not have the financial resources to fund research development or promotion and so, left alone, the growth of the sector will be slow. In order to increase the speed of uptake of some technologies, support from Government may be required.

The non-economic barriers to increased uptake of renewable energy are, however, substantial as they generally involve community attitudes and aspirations towards the use of resources or perceived effects.

The renewable energy industry in New Zealand has a number of new players who are often small businesses with limited experience. It also has areas of previous strength (hydro, geothermal) which have declining technical capability because of the low number of projects that have been proceeding in recent years. For both these groups it is difficult to get projects investigated and progressed. On the other hand there are a number of mid-sized companies that are able to develop commercially sound projects.

The value of renewable energy is also enhanced by the way it is integrated with reliable sources of energy which are often fossil fuel based (e.g. solar water heating is boosted by electricity or gas in periods of low sunshine). A sustainable energy maximising objective is achieved through using renewable energy as a base energy source, and using fossil fuels where they are most valuable as a firming energy source.

Renewable energy technologies have evolved to the point that they are able to supply energy to a vast range of applications, from micro to macro-scale. For example:

- micro portable systems, providing energy for specific high value consumer applications (e.g. micro PV providing power for calculators),

- household/small business-scale technologies, providing energy (at the point of consumption) to consumers (e.g. small-scale wind turbines, geothermal heat pumps, solar water heaters, PV systems),
- medium-scale technologies, designed for local area energy supply, i.e. “distributed generation” systems, and
- large-scale energy supply technologies, designed for centralised public supply through commercial energy networks (e.g. hydro power station).

There is also a wide range of costs associated with renewable energy supply. Cost differences generally lie in the individual characteristics and the “maturity” of the technologies including the scope for further improvements through technology “learning”, economies of scale, etc.

Many renewable energy applications fall into the trap of only being compared against wholesale electricity prices when they should be considered on a “total value” basis. Because of the diversity of applications and the “value added”, quite a wide range of costs can be supported in particular circumstances. At one end of the spectrum, large-scale centralised supply technologies compete within a wholesale market where energy investors seek commercial rates of return compared with alternative generation such as gas or coal fired plants (i.e. typically at 7-8c/kWh). Towards the other end of the spectrum, small-scale renewable systems might be competing with the cost of supporting high cost/low use infrastructure (such as rural power lines, or diesel/petrol generator sets). In those circumstances costs of 100c/kWh or more for renewable energy systems may still provide an economic alternative. In between these extremes lies a wide range of other applications, all having particular “value thresholds” at which various renewable energy technologies may be competitive.

Many new entrants to the energy market have a very commercial approach and as a result are finding new conceptual ways of developing previously uneconomic projects. It is changes in technology and conceptual thinking that allow off-the-shelf modular plants to be installed in commercially focused projects. In some energy forms such as hydro, geothermal and solar the energy conversion plant have been reducing in size, whereas in wind the improving project economics have been driven by economies of scale to have larger turbines on higher towers. A value of renewable energy technologies is that because of often small size, and thus reduction in investor risk, renewable energy technologies can be used for new innovative uses.

Where possible this report has identified the cost of supply for each of the technologies, but the important point to make here is that the applicability of these costs depends on *context,* i.e. the particular circumstances of the application, the value added, and other costs avoided.

The most significant barrier to greater uptake of renewable energy has been its cost relative to other energy sources. As the cost of extraction of gas and coal increases, and in particular if a carbon dioxide charge is introduced, renewable energy will become more attractive as a source of energy.

The next major barrier is the access to capital. While by its nature renewable energy may have low operating costs, most investment in renewable energy opportunities requires high upfront capital expenditure, compared with lower capital cost (but higher fuel and other operating costs) for non-renewable opportunities. (Bioenergy is the exception in some circumstances.) Renewable energy investments have long-term operating lives beyond the timeframe for many investors who look for short periods for return on their investment. While this is not necessarily a major issue for large-scale energy companies, it is usually difficult to get financiers to recognise the long physical life of the investment. The lack of a finance market prepared to recognise the value of investment in renewable energy makes it difficult for small/medium energy providers and users to participate.

Renewable energy projects often require extensive investigation and wide consultation with other parties. This is costly and is undertaken without any certainty that the project will obtain resource consents and proceed. Few parties are able to fund such investigation and consultation.

Community attitudes and concerns towards the location of some renewable energy projects can be a major barrier to the increased uptake of many opportunities. Often these attitudes are prevalent regardless of any possible positive effects. Community concerns need to be addressed with factual information. Obtaining and presenting well researched factual information on possible effects is expensive and often has to be repeated for similar consent applications. The need to obtain and provide such information makes investment by parties without large financial resources extremely difficult. Collective preparation of such information could reduce applicants' consent application costs.

Renewable energy is often non-firm (wind, solar, tidal) and has to be used when it is available rather than being available when it is needed. This limits its value and consequently it is sold at lower prices than firm controllable energy. Until ways of storing non-firm renewable energy or better ways of integrating it into the market are developed it will continue to be treated as a lower value product. Geothermal, hydro and biomass energy is however considered firm, and depending on how it is used a baseload supply of heat or electricity.

The size of many renewable energy opportunities is limited by the amount of energy that can be used on-site. It is often difficult to find a buyer for quantities of energy that are surplus to on-site use. This limit on size means that economies of scale are not achievable. With an inability to find a buyer for surplus energy, or one that will offer a reasonable price, assuming transmission is not an issue, a number of potential projects are not financially viable.

The common perception that renewable energy is "alternative" results in some investors unnecessarily considering projects to be high risk. Thus, projects become difficult to finance.

Much renewable energy is very site specific with the result that its conversion into useable energy may be some distance from where it could be used. The need to convert the energy into a transportable form can result in additional costs compared with its use on the site of source.

New Zealand has a very small renewable energy research and development capability and often relies on adopting internationally developed technologies. A fast-follower approach is very appropriate for the sector and funding needs to be focused on monitoring international experience, adapting it for New Zealand use, demonstrating its potential, and in particular provide support for applied practitioners/potential investors to gain "hands on" knowledge of international experience.

New Zealand's electricity system is operated on a market-basis. Renewable technologies can come in a size that offer small discrete increments to generation (or demand reduction) and so avoid the market disturbances associated with installation of a large gas or coal plant. Hence, renewable energy options have strategic value for existing generators.

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Contents

EXECUTIVE SUMMARY 3
1 INTRODUCTION 12
2 BACKGROUND 12
3 LITERATURE SUMMARY 12
4 CURRENT USE OF RENEWABLE ENERGY IN NEW ZEALAND 13
5 HYDRO ENERGY 26
6 GEOTHERMAL ENERGY 33
7 WIND ENERGY 43
8 BIOENERGY 50
9 SOLAR ENERGY 67
10 MARINE ENERGY 83
11 NEW AND EMERGING TECHNOLOGIES 94
12 REFERENCES 98
APPENDIX A – GOVERNMENT RENEWABLE ENERGY POLICIES 100
APPENDIX B – MARKET PARTICIPANTS 108
APPENDIX C – OPERATIONAL HYDRO GENERATION PLANT 119
APPENDIX D – OPERATIONAL GEOTHERMAL PLANT 123
APPENDIX E – OPERATIONAL WIND GENERATION PLANT 124
APPENDIX F – OPERATIONAL BIOENERGY PLANT 125
APPENDIX G – FOUNDATION FOR RESEARCH, SCIENCE AND TECHNOLOGY INVESTMENTS IN RENEWABLE ENERGY RESEARCH 127

Field Code Changed

1 Introduction

The Energy Efficiency and Conservation Authority (EECA) has a mandate to encourage, promote and support renewable energy. It is required to research, monitor and publish information on the status of the renewable energy industry in New Zealand. This report is a third edition of the Status Report prepared in 2006 and has been prepared to help fulfil these requirements.

The report has been prepared by interviewing a number of the key players in the industry – industry associations, energy companies, researchers and investors. The report is based on publicly available information although a number of commercial parties have provided helpful information on their own current and planned investment intentions. This information has been taken into account when reporting on each technology.

The renewable energy industry has been reviewed on a technology basis as there are a number of different drivers for each technology. However, the energy market participants' interests in renewable energy are not generally technology focused as renewable energy covers many different roles according to consumer energy requirements.

2 Background

For this review renewable energy is defined very broadly to cover resources and technologies which may contribute to New Zealand's renewable energy to 2012.

The review covers all sizes of potential applications and takes into account existing and potential participants in the renewable energy market. Descriptions of market participants are included in Appendix B.

Because of the nature of renewable energy the input resource energy is often not measurable or measured. The reference to primary energy is often confusing because of this difficulty of measurement. For the purposes of this report the focus is on the measurable useable energy at source.

For consistency with other reports primary source energy is also identified where appropriate.

The review of the status of renewable energy has been undertaken within the context of international renewable energy trends. International research and the status of each technology are not explored in detail – it is assumed that the reader has a familiarity with each technology so only salient points relevant to New Zealand renewable energy activities are referred to.

3 Literature Summary

The information available to assist the uptake of renewable energy in New Zealand is spread between websites, reports and general publications. Most recent information is available from the EECA and renewable energy association websites.

General references of renewable energy are;

- CAE/EECA, 'Possible Energy Use Trends for NZ 2000/2010', CAE-2000
- CAE/EECA, 'Renewable Energy Opportunities for New Zealand', CAE-1996
- Eden Resources, 'Renewable Energy Opportunities for NZ' Report for Ministry of Commerce, ER-1993
- SKM/CAE, 'Electricity Supply and Demand to 2015', CAE-2002
- East Harbour, 'Availabilities and Costs of Renewable Sources of Energy for Generating Electricity and Heat' Report for the Ministry of Economic Development, MED-8-2004

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- East Harbour, 'Wood Processing Strategy: Energy Issues for the Wood Processing Sector in NZ, Report prepared for the Wood Processing Strategy Steering Group, EHMS-2002
- Ministry of Economic Development, 'Energy Outlook to 2025', MED-2003
- Ministry of Economic development, New Zealand Energy Data File, MED-2006
- SKM, 'Power Generation Options for NZ, Report for MED SKM-2004
- SKM, "Review of Current and Future Personnel Capability Requirements of the NZ Geothermal Industry', October 2005

Other information is available from the EECA website www.eeca.govt.nz

Several regional entities have undertaken regional energy assessments which include renewable energy:

- East Harbour, Southland Regional Energy Assessment, Report for Venture Southland, EHMS-2003
- East Harbour, Tairawhiti Regional Energy Assessment, Report for Tairawhiti Development Taskforce, EHMS-2005
- Canterbury Regional Council, 'Canterbury Regional Energy Strategy', ECAN website.

Specific information on each form of renewable energy is outlined in each relevant chapter.

4 Current Use of Renewable Energy in New Zealand

4.1 Current Market Use for Renewable Energy

The Ministry of Economic Development's (MED) January 2006 Energy Data File[7] identified that in the year ending June 2005, renewable energy accounted for 241 PJ (32%) of New Zealand's total annual primary energy supply (764 PJ).

In 2004/05, 39% of renewable primary energy came from hydro sources, 36% came from geothermal and 25% from other renewable energy sources (Figure 1).

Renewable energy can be converted into the useable forms of electricity, heat and liquid transport fuel. The suitability of each renewable energy source for each useable form is shown in Table 2. Table 2 also shows each renewable energy source where storage is achievable and where other non-energy uses can be derived.

Within New Zealand renewable energy is used as a principal source of electricity generation – where 73% was derived from renewable energy sources in 2004/05 (Figure 1c). In addition 53.4 PJ of renewable energy was used as a direct source of heat. This is mainly in the wood processing sector where bioenergy and geothermal sources are utilised. A small percentage of renewable energy can be found in ethanol made from dairy waste (whey) but it is not currently generally used as a source of liquid transport fuels.

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[7] MED-4-2005 (this doesn't seem a conventional reference style)

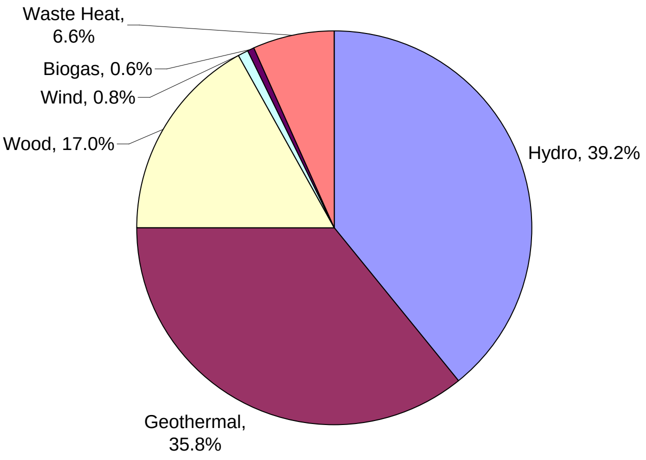
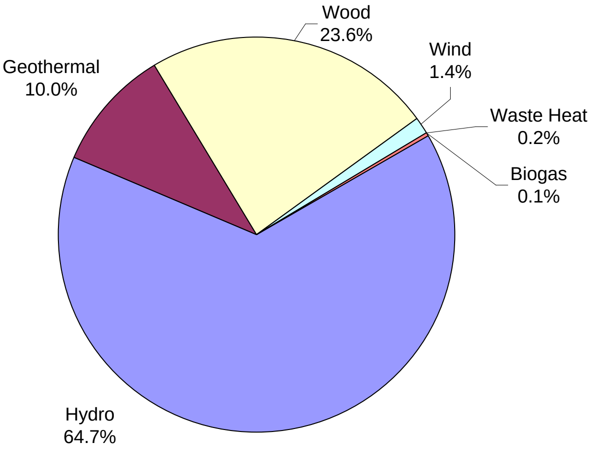


Figure 1 **a) (Above) Renewable Primary Energy for June Year 2005.**
b) (Below) Renewable Consumer Energy for June Year 2005.



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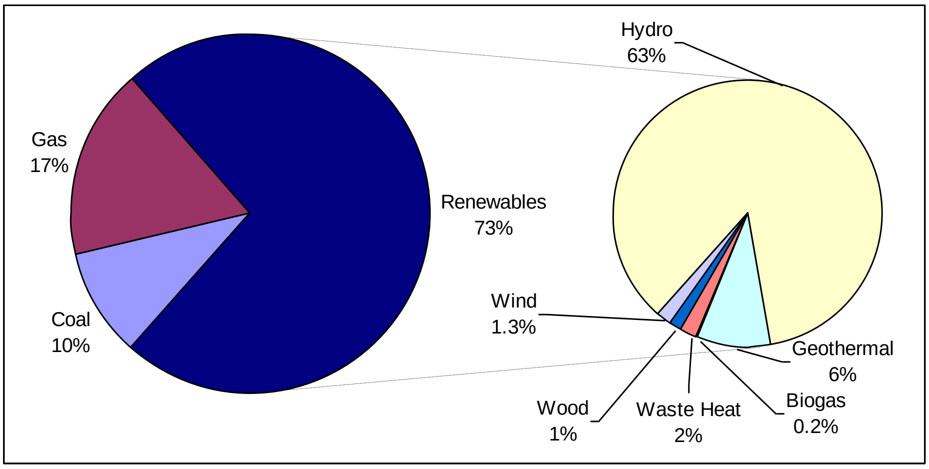

Figure 1c Electricity Generation by Type

Table 2 Renewable Energy Sources and Their Potential Uses.

Resource	Electricity	Heat	Transport	Storage	Other Uses
Hydro	Yes	No	No	For impoundment schemes	Irrigation (non-energy)
Geothermal	Yes	Yes	No	Has to be used as extracted	Minerals (non-energy), tourism
Wind	Yes	No	Yes	No	Minor recreational transport
Biomass (Woody)	Yes	Yes	Yes	Yes	Potential fuel source for transport, feedstock (non energy)
Biomass (Landfill Gas)	Yes	Yes	Yes	Has to be used as extracted	Potential fuel source for transport, feedstock (non energy)
Biomass (Food/Agriculture)	Yes	Yes	Yes	Yes	Potential fuel source for transport, feedstock (non energy)
Solar Thermal	Yes	Yes	No	Yes	Thermal plant pre-heater
Photovoltaic	Yes	Yes	Yes	Batteries	Off grid energy (electrical)
Ocean	Yes	No	No	Has to be used as derived	Minor recreational transport

* Availability is dependent upon storage lake levels and water use constraints.

The Energy Data File (Figure 2) shows that for the September year 2005, 235 PJ of primary renewable energy resulted in 154 PJ of consumer energy.

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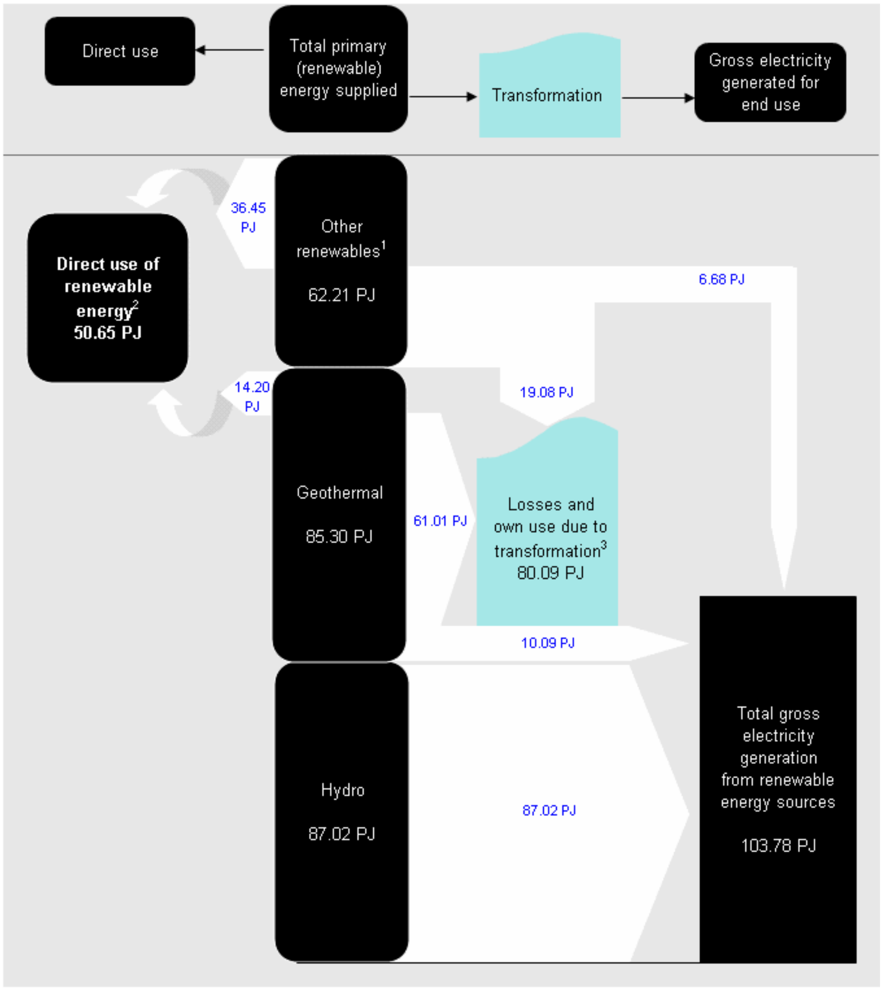

* Other renewables include wind, biomass, biogas and wastes

Figure 2 **Renewable Energy Flow for September Year 2005.**

Source: MED-2006.

Information from industry associations and owners of specific renewable energy plant has been collated and is shown in Table 3.

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Table 3 Renewable Energy Used in New Zealand (June Year, 2005).

Renewable Energy Source	Energy Used (Nett) at Source			Consumer Energy (Nett) * PJ
	Electricity PJ	**Heat PJ**	**Transport PJ**	
Hydro	93.5			84.7
Geothermal (Electricity)	60.8	2.8		11.0
(Direct Use)		14.6		14.6
Wind	1.9			1.7
Bioenergy (Woody Biomass)	5.0	31.3	0.0	35.9
(Municipal – landfill, sewage)	0.1	0.2	0.0	0.3
(Food processing/Agricultural)	0.0	1.6	0.0	1.6
Solar (Hot Water)		0.2		0.2
(Photovoltaic)	0.01			0.0
(Space Heating)		Not Measured		
Sea Energy (Wave)	0			0
(Tidal / Ocean Current)	0			0
SUBTOTAL RENEWABLE ENERGY	161.4	50.6	0	**150.0**
GRAND TOTAL RENEWABLE ENERGY	**212.0**			

* Electrical transmission and distribution losses of 9.5%[8]
\# 0.43 PJ pa of ethanol is produced from renewable energy sources but not included as in 2004 it was not generally used as an energy product.

Components of renewable energy used at source for each of the five (June) years 2000/01 – 2004/05 are shown in Figure 3. Renewable energy use has increased slightly despite the modest increase in installed capacity. .

It should be noted that for pragmatic measurement reasons:

- Hydro, wave, tidal and wind primary energy is measured as direct output from the turbine.
- Solar primary energy is measured as direct output from the collector.
- Geothermal primary energy is measured at the well head.
- Bioenergy is measured as direct output from the heat plant.
- Solar space heating is not measured.

The information in Table 3 has been compared with that collected by the MED and published in the Energy Data File (Figure 3). Areas of difference between the two databases are with data recently collected by the Bioenergy Association and Forest Research on bioenergy plant actually installed. There are also differences in the periods data relates to and the presentation of the data. This has been checked for consistency. The Energy Data File in their energy balances, aggregates "own use" and losses. In this report "own use" has been included in the useable energy. Where there is a cogeneration plant installed, the Energy Data File balance accounts for the electricity and not the heat component. The report includes

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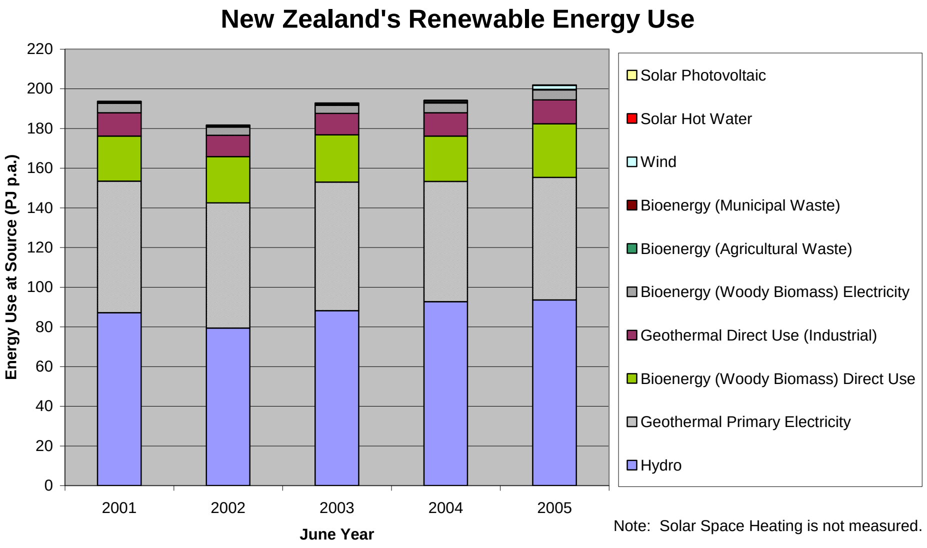
[8] A significant number of the projects outlined in this report would be embedded and serve to reduce the overall transmission loss of 9.5% as used in this report. The output from these would provide greater consumer energy, however specific losses information is not available so the MED standard losses are used.

the heat component using the efficiencies quoted for cogeneration in the Energy Data File. This gives slightly higher figures in Table 3 than in the Energy Data File.



Note: Solar Space Heating is not measured.

Figure 3. **Renewable Energy Use in New Zealand (2001-2005).**

Because hydro and to a lesser extent geothermal dominate the amount of renewable energy used the contribution of smaller sources gets lost in the display. To show their contribution Figure 4 has been drawn in a slightly different way using a logarithmic scale for the annual energy used. This at first glance does not give the relevant contribution of each source but closer inspection of the scale does so.

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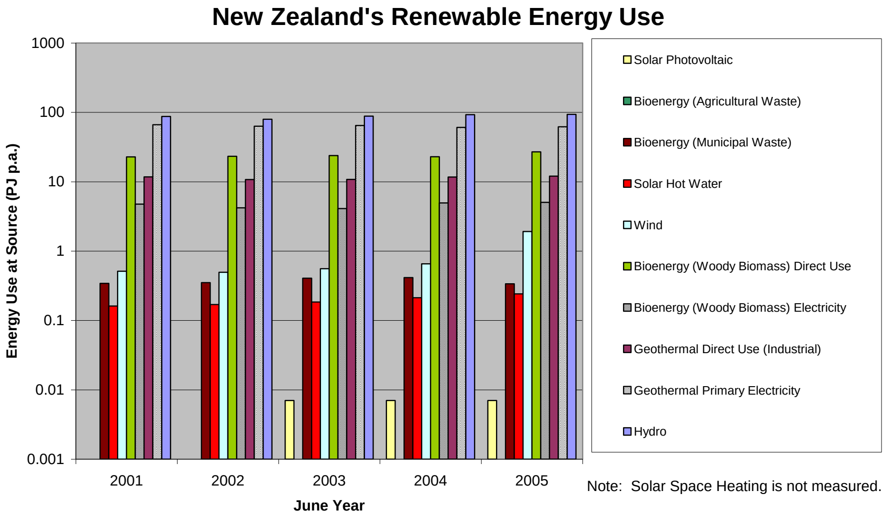

Note: Solar Space Heating is not measured.

Figure 4 **Renewable Energy Use Showing Contributions From Each Energy Form**

4.2 Total Renewable Energy Uptake Since 2001

The Renewable Energy Target of 30 PJ of additional consumer energy from renewable energy sources by 2012 is outlined in Appendix A. The target was based on growth from April 2001. Since that time and up until April 2006 11.32 PJ of new additional energy from renewable energy sources has been installed and 15.27 PJ committed[9]. A further 34.33 PJ of projects are under serious publicly announced investigation.

The annual amount of energy available from installed or committed investments in renewable energy at source since April 2001 is shown in Table 4 and the equivalent installed or committed renewable consumer energy capacity in Table 4a. Energy at source is available for conversion to other energy forms where as consumer energy is that amount of energy that is directly used by consumers. The difference is the losses through conversion or transport of the energy.

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[9] A "committed" project is one that has consents with no outstanding appeals.

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Table 4 Uptake of Renewable Energy at Source from April 2001, Projects Installed, Committed and Publicly Announced Investigations (as at April 2006).

	Installed to April 2006 **PJ pa**	**Committed** **PJ pa**	**Publicly Announced Investigations** **PJ pa**
Hydro	2.70	0.	7.2
Geothermal	1.78	5.70	0.45
Wind	2.38	9.57	28.72
Bioenergy	4.9	0	0.0
Solar	0.05	0.00	
Transport Fuel	0.00		
Total	**11.81**	**15.27**	**36.37**

Table 4a Uptake of Renewable Consumer Energy from April 2001, Projects Installed, Committed and Publicly Announced Investigations (as at April 2006).

	Installed to Dec 2005 **PJ pa**	**Committed** **PJ pa**	**Publicly Announced Investigations** **PJ pa**
Hydro	2.44	0.00	6.48
Geothermal	1.61	5.16	0.41
Wind	2.16	8.61	25.99
Bioenergy	4.4	0	0.0
Solar	0.05	0	
Transport Fuel	0		
Total	**10.66**	**13.77**	**32.88**

4.3 Price Relativities

Analysis of possible future renewable energy use in New Zealand is outlined for a range of scenarios in the report “New Zealand Energy Outlook to 2025” published by the MED in October 2003. A range of energy prices and future possible trends is covered in that report.

The MED report assumes that between 2000 and 2005, the primary supply of gas is forecast to decrease by approximately 40% (the depletion of Maui Gas). This brings the end of an era of low-cost energy in the North Island region with flow-on effects nationally. The MED analysis indicates that the subsequent forecast increased cost of future gas supply could bring forward a combination of wind, hydro and geothermal electricity generation opportunities in the 6-7c/kWh price band as substitutes for gas and coal (Figure 5).

Analysis undertaken by East Harbour provides an indication of the relative economics for a range of energy sources. Figure 6 shows cost curves for electricity generation, and Figure 7 curves for heat production, both of which include a $15/t carbon dioxide charge.

With the narrowing of the gap between fossil and renewable energy there will now be significant opportunities arising where renewable energy projects will be financially viable.

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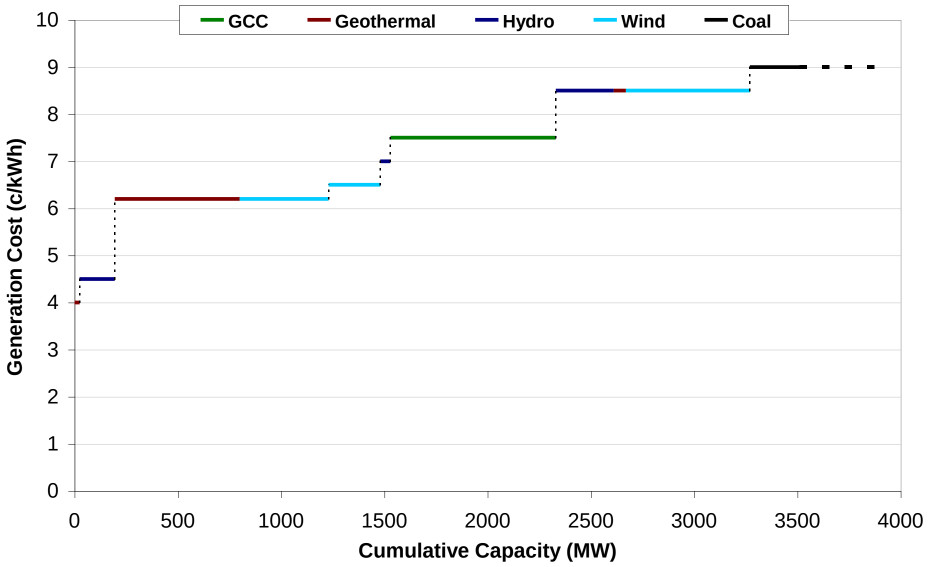

Figure 5 Assumed New Plant Generation Costs.

Note GCC refers to Gas Combined Cycle plant Source: MED-2003.

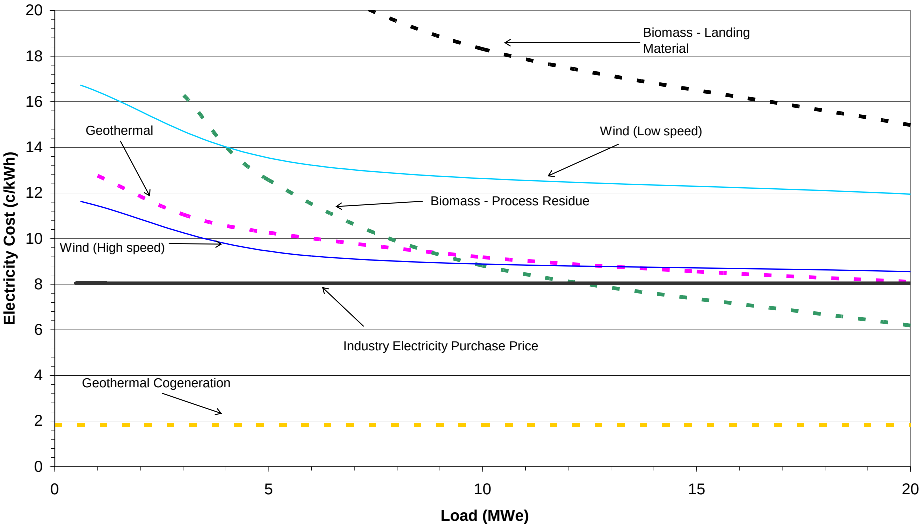

Figure 6 Electricity Generation Cost Curves.

Source: East Harbour 2005

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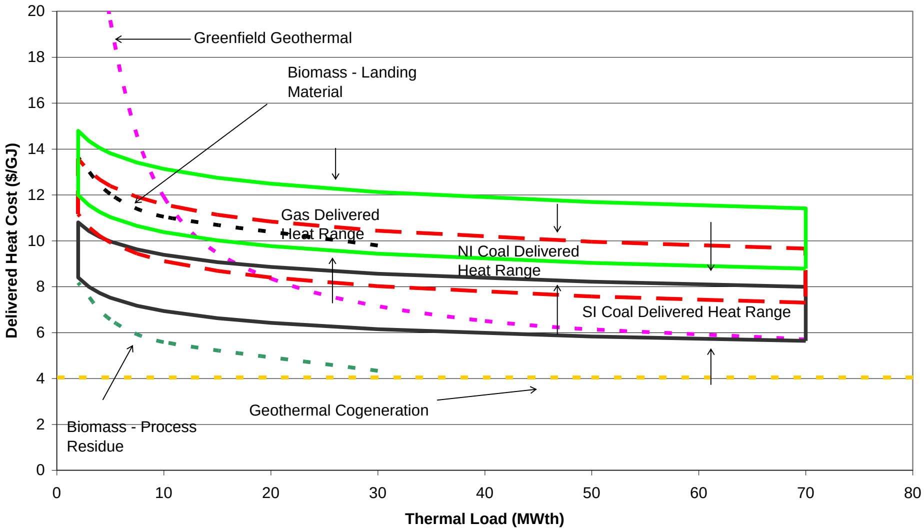

Figure 7 **Heat Production Cost Curves.**

Source: East Harbour 2005

4.4 Possible Future Demand for Energy - 2025

The MED Energy Outlook report shows the result of analysis of possible future energy use in New Zealand, and is outlined for a range of scenarios [10].

The Energy Outlook[11] baseline scenario (Figure 8) forecasts renewable primary energy supply to increase to approximately 315 PJ[12] (39.5% of the total primary energy) by 2012. This is an 85 PJ increase above the 2000 supply. This scenario assumed that Project Aqua (cancelled in March 2004) would proceed before 2012[13].

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[10] MED are producing an updated analysis in July 2006

[11] MED-2003

[12] Note: 2003 Energy Outlook baseline scenario excludes waste and biogas renewable energy supply.

[13] No more recent analysis excluding Project Aqua has been undertaken.

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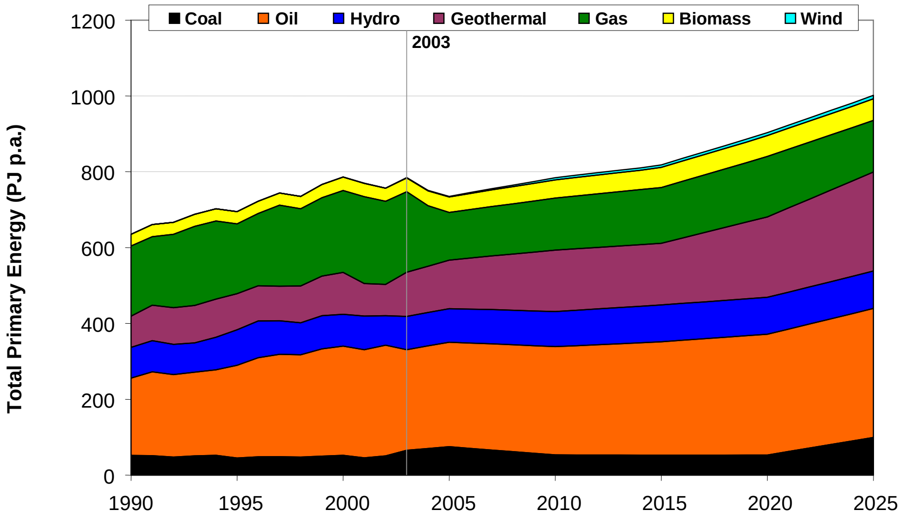

Figure 8 **Total Primary Energy Supply 1990-2025.** Source: MED-2003.

4.4.1 Hydro 2000-2025

The Energy Outlook modelling shows that hydro could be the second largest contributor to primary renewable energy growth from 2000 to 2025 (approximately 15 PJ (18% growth)). Since that modelling took place Project Aqua has been cancelled, so its expected contribution of 5.75 PJ from 2009 and 10.5 PJ from 2012 will not occur. The generation cost threshold that MED believes could be met from possible hydro projects is shown in Table 5.

Table 5 **Cost of Additional Hydro Generation Capacity.**

Timing	Total Cost c/kWh	Potential Capacity MW	Potential Supply PJ pa
Project Aqua (now cancelled)	~~4.5~~	~~570~~	~~11.6~~
Medium Cost: 2006–2025	7.0	50	0.9
High Cost: 2006–2025	8.5	280	4.9

Source: MED-2003.

4.4.2 Geothermal 2000-2025

The MED modelling shows that if all currently known projects were committed then geothermal energy could be the largest (approximately 50 PJ (45% growth)) contribution to growth in annual primary renewable energy supply from 2000 to 2025 (Table 6). However, the amount of useable energy from geothermal sources depends on the application and conversion mechanism employed (direct heat, e.g.

steam, or geothermal electricity plant[14]). The MED analysis does not identify the direct heat opportunities.

Table 6 Cost of Additional Geothermal Generation Capacity.

Timing	Total Cost c/kWh	Potential Capacity MW	Potential Supply PJ pa
2006-2010	4.0	25	0.7
2011-2020	6.2	225	6.5
2021-2025	6.2	380	10.8
2006-2025	8.5	60	1.7

Source: MED-2003.

4.4.3 Wind 2000-2025

Wind energy is modelled by MED as possibly contributing approximately 6 PJ extra to annual renewable primary energy supply by 2025 (Table 7). Of this, 284 MW (4.0 PJ) has already been committed since the MED report was completed.

Table 7 Cost of Additional Wind Generation Capacity.

Timing	Total Cost c/kWh	Potential Capacity MW	Potential Supply PJ pa
2006-2010	6.2	190	2.7
2011-2020	6.2	240	3.0
2021-2025	6.5	250	2.7
2006-2025	8.5	600	6.5

Source: MED-2003.

4.4.4 Biomass 2000-2025

Over the period 2000 to 2025, the contribution of biomass to annual primary energy growth is suggested by MED as approximately 15 PJ (40% growth). The majority of biomass energy is contributed by the wood processing sector and is not costed as it is assumed to be from process waste.

4.5 Market Participants

The renewable energy market is very diverse with many participants for whom renewable energy is only a small part of their business activities. Other participants whose business is dependent on renewable energy activities tend to be small businesses with few staff and limited financial resources.

Where participants are an integral part of the industry capacity and capability they are referred to in the sections on specific renewable energy sources. Where they are a government agency or an investor only, they are referred to in Appendix B.

4.6 Government Renewable Energy Initiatives

Several Government policies which have an effect on renewable energy are described in Appendix A of this report. The four key government policies that impact on the uptake of renewable energy are:

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[14] MED assumes 15% efficiency for geothermal electricity generation.

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4.6.1 Sustainable Development Programme of Action

As part of the Government's Sustainable Development Programme of Action a discussion document was prepared on sustainable energy and released in October 2004. It was the result of a collaborative interagency work programme coordinated by the Ministry of Economic Development. This discussion document presented a policy framework for sustainable energy which describes the following key objectives of sustainable energy policy:

- Energy system is reliable and resilient
- Energy production and use is environmentally responsible
- Energy prices are efficient and fair

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The formation of a national energy strategy (see section 4.6.4 below) is a logical extension of preparatory work undertaken as part of the development of the Sustainable Energy discussion document.

4.6.2 The National Energy Efficiency and Conservation Strategy (NEECS)

The National Energy Efficiency and Conservation Strategy -- Towards a sustainable energy future (the NEECS or Strategy) were published in September 2001. The Strategy establishes objectives, targets and policies in relation to energy efficiency, energy conservation and the use of renewable sources of energy across all sectors of the economy. The strategy includes sectoral Action Plans which map out areas of action, implementation responsibilities across government agencies and records key milestones.

The Strategy established two high-level national targets, to

- achieve at least a 20% improvement in economy-wide energy efficiency by 2012; and
- achieve a 30PJ increase in the supply of energy from renewable sources by 2012.

The Energy Efficiency and Conservation Authority has recently completed a review of the Strategy – in which there was consultation with government agencies with a key stake in the sustainable energy future of New Zealand.

In March 2006 he Minister of Energy has announced his decision to replace the current strategy. The current work programme to develop a replacement Strategy will set the future direction and redesign government policies and programmes to support greater uptake of energy efficiency and the supply of renewables. The replacement Strategy will be closely tied to the development of a national energy strategy (see section 4.6.4 below) and follow a similar timeline. It is expected that new strategies will be published in the first half of 2007.

4.6.3 Climate Change Policy

Various climate change policies and initiatives have been developed to meet the government's requirements under the Kyoto Protocol. Many of the interventions under this policy initiative encourage the uptake of renewable energy; an example of this is the Climate Change Office run Projects to Reduce Emissions programme which allocates carbon credits to projects that will reduce carbon dioxide emissions. All of the projects currently supported under this mechanism are renewable energy projects.

Detailed information on these and other government policies that influence the uptake of renewable energy are described in Appendix A.

The climate change Projects to Reduce Emissions mechanism supported fifteen projects in the first bidding round in 2003. All were based on renewable energy and are:

- Te Rere Hau Windfarm, New Zealand Windfarms - a proposed 50 megawatt windfarm in Manawatu.

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- Toronui Mini-Hydro Power Scheme, Esk Hydro Power - a proposed mini-hydro scheme on the Pask family's Toronui station in northern Hawkes Bay.
- Awapuni Landfill – a proposed landfill-gas scheme in Palmerston North.
- Wainui Windfarm, Wainui Hills Wind Farm – a proposed 30 megawatt windfarm on a ridge between Wainuiomata and Wellington.
- Hau Nui Windfarm extension – 5 MW extension to the existing windfarm.
- Awhitu Windfarm – 19 MW windfarm proposed for coastal Waikato.
- New Zealand Refinery Company Co-Generation Plant – 80 MW at Marsden Point
- Southern Paprika Bioenergy Plant – Warkworth.
- Enhancements to TrustPower's Mangorei, Motukawa and Waipori hydroelectric power schemes. Hydro scheme enhancement on the Tongariro Power Development, Genesis Power Ltd
- Fire-Logs (NZ) Ltd – Manufacture and sale of wood pellets
- Rotokawa geothermal electricity generation project – Mighty River Power Ltd
- Watercare Services Ltd – Mini hydro generation projects
- Landfill gas to electricity project – TrustPower Ltd (This agreement is no longer in place.)

Two earlier projects also received emission units

- Te Apiti Windfarm, Meridian Energy – a 90 megawatt windfarm in Manawatu.
- Tararua Windfarm, TrustPower – 36 MW windfarm extension.

In the second bidding round seven projects received emission units. These are:

- Eastland Networks – Mokairau windfarm 9MW, 27 GWh
- Esk Hydro Power – 2.5 MW windfarm and 2 MW small hydro scheme
- Christchurch City Council – Burwood landfill gas project
- Kawatiri Ltd – to refurbish Buller Electric Power Station (Lake Rochfort)
- Meridian – White Hill windfarm
- Meridian Solution – York Valley landfill gas to Nelson Hospital
- TrustPower – Ashburton Hydro scheme

Detailed information on elements of climate change policy affecting the energy sector is cited in Appendix A.

4.6.4 National Energy Strategy

In the 2005 speech from the throne it was announced that the Government would prepare a National Energy Strategy to set the broader policy agenda across the entire energy sector. It will provide long-term direction and leadership to put New Zealand on the path to an energy system that supports economic development, while being environmentally responsible. The full terms of reference for this strategy are expected to be made public soon. It has already been announced that the replacement NEECS will come under the umbrella of - and be a subset of - the wider energy strategy..

5 Hydro Energy

5.1 Technology Overview

New Zealand has a range of large, medium and small hydro schemes, all of which are characterised as having only small amounts of storage by international standards. Electricity is generated from water by impounding or diversion through a canal type schemes and passing the water through a turbine to realise the benefit of both the height (head) and flow of this water.

Impoundment schemes have been a traditional form of construction but impediment of fish passage and inundation of large areas of land make large impoundment schemes difficult to obtain resource consents for.

Diversion schemes are undertaken in order to increase flows (by diverting water from other rivers and streams), increase the head (compared with a dam on its own), or significantly reduce the effects on the surrounding land and other uses of the water by not requiring an impounding dam. Diversion schemes are generally characterised by less flexibility of operation as they do not in themselves have the advantages of storage, but may rely on upstream natural storage which at times can be variable. Residual river flows have become a key determining factor on scheme size for diversion schemes.

Low head schemes using bulb turbines, while possible, are very rarely used in New Zealand (because they are relatively expensive) yet are very common overseas, where power prices are higher and there are opportunities associated with weirs and locks needed for river transport.

Hydroelectric generation technology is a proven and mature technology. However, compared with most other energy sources, hydro schemes can have a greater affect on surrounding communities. The technology is however being continually refined, with better techniques for site selection, plant design and construction; innovative civil works, improved generating plant and controls, and standardisation of equipment.

Improvements in turbines, draft tubes, and reductions in headrace and tailrace head losses and automation and remote control have revitalised obsolete stations and increased their power and energy output.

Today’s environment for hydroelectric development is very different from that which applied during the 1960s to 1980s when most investigations of the currently undeveloped hydro energy potential in New Zealand were undertaken or updated. These investigations were largely undertaken by (or for) state owned agencies whose brief was to “meet demand”. This regime no longer applies. Opportunities are now being investigated by investors who are commercially driven and need to recover their investment in a relatively short time. In addition, many of the best storage opportunities have been developed so new conceptual thinking is required in order to justify development of less attractive storage or diversion schemes. Owners are continually focusing on enhancing output from existing assets and many are investigating new hydro opportunities which have a risk associated with any new development.

Public acceptance of a potential hydroelectric development is more difficult today due to society’s changing environmental and conservation attitudes. In general there are a number of competing interests and values associated with rivers and lakes and these need to be considered when assessing opportunities. The statutory approval requirements for hydro schemes are by their nature time consuming, expensive, stringent and have no certainty of success. However, this should by no means preclude hydroelectric development from consideration as a future energy source. There are many opportunities that should be able to be consented if a robust consenting process is followed.

Many schemes previously considered not to be feasible for economic or environmental reasons may now be viable by the adoption of a different technical and commercial approach, e.g. using modern technology for civil structures and generating plant, or diverting part of the flow using a weir or a river side intake rather than river impoundment by a large dam. Generating electricity from the flow of water is a non-consumptive use as the water is returned to rivers and lakes. Therefore, future projects are likely to be multipurpose, e.g. hydropower combined with irrigation may make projects viable.

The change of focus from a damming approach for storage, to a water harvesting approach philosophy has provided new opportunities for existing concept hydro schemes and provided a number of new opportunities. The division of the Electricity Corporation of New Zealand (ECNZ) hydro schemes into new ownerships has also created a number of competitors who all have a focus on optimising the use of their assets. The practice of ECNZ of continuous enhancement has continued with many enhancements being undertaken.

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Small hydro schemes are generally less economic than a large scheme, however because the effects of a small hydro and the amount of land affected by inundation are less, small schemes are potentially easier to obtain consents for. Integrating an hydro scheme to an existing water take consent is currently being investigated and developed in many parts of the country. This is particularly the case with existing irrigation schemes which have a consented take, and often useable available generation heads. Consenting these schemes is easier as water take consents are already in place and often the community who are the scheme farmers have a direct financial interest for an integrated scheme. The financial, environmental and societal risk of a small scheme is often less and investigations costs are lower as a detailed refined analysis is not required. These types of small schemes are also able to be embedded into a local network providing all the benefits of distributed generation.

Micro hydro schemes are of relevance for isolated small rural communities or individual farms. A micro hydro scheme has minimal environmental impact and the risk of failure of water retaining structures is low. With similarly low capital costs such schemes can be attractive to small land owner investors. Micro hydro has particular relevance where local electricity supply networks have capacity or quality of electricity supply problems.

5.2 Current Utilisation and Emerging Development

The current capacity of the hydroelectric systems in New Zealand is assessed as 5345 MW (as at March 2005). This capacity provided approximately 25,975 GWh (93.5 PJ) in the year ending June 2005. This supply, along with that for the four previous years, is shown in Figure 9.

Only a small amount of greenfield capacity has been added in the last four years. The focus has been on gaining more energy from existing power stations with the Manapouri Power Station second tailrace tunnel and re-runnering dominating increases in capacity (230 MW) and energy output (710 GWh, 2.6 PJ) during that time.

Since December 2000 hydro plant investments providing an additional 2.68 PJ of energy were installed or are under construction.

New hydroelectric generation installations identified since December 2000 which are important to achieving the Renewable Energy Target are listed below:

Additional generation installed or under construction from 1 January 2001 to 31 December 2005:

• Manapouri Second Tailrace Tunnel	125 MW	640 GWh	
• Falls Dam Power Station	1.2 MW	9.5 GWh	
• Onekaka Power Station	1 MW	4 GWh	
• Mangahao mini-hydro	4 MW	22 GWh	
• Manapouri half-life refurbishment	145 MW	75 GWh	
	276.2 MW	750.4 GWh	2.7 PJ

Additional generation committed to construction:

Nil

Resource consents sought or carbon credits allotted and project announced:

• Arnold (new)	46 MW	220 GWh
• Ashburton Irrigation (TrustPower)	6 MW	34 GWh
• Fairdown/Kawatiri (Mt Rochfort)	4 MW	16 GWh
• Gowan [t]	14 MW	60 GWh
• Hawea	16 MW	70 GWh*

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Mangorei/Motukawa enhancements		3.5 GWh	
Mokau	10 MW	43 GWh	
Toronui Mini-hydro	1 MW*	4.3 GWh	
Waipori enhancements		35 GWh	
Wairau Valley		70.5 MW	415 GWh
	167.5 MW	900.8 GWh	3.24 PJ

[t] Variation to National Water Conservation Order sought – not granted

Projects publicly announced as being under serious investigation:

Kaituna (Mighty River Power)		Not known	
Lower Waitaki (North Bank tunnel)	200 MW	1100 GWh	
Mohaka		Not known	
	200 MW	1100 GWh	3.96 PJ

* 50% plant factor assumed

During the latter period covered by this report there have been a few announced investigations of other small hydro schemes which have not yet proceeded to firm proposals.

Appendix C lists all operational hydro plant, generally of MW scale or greater.

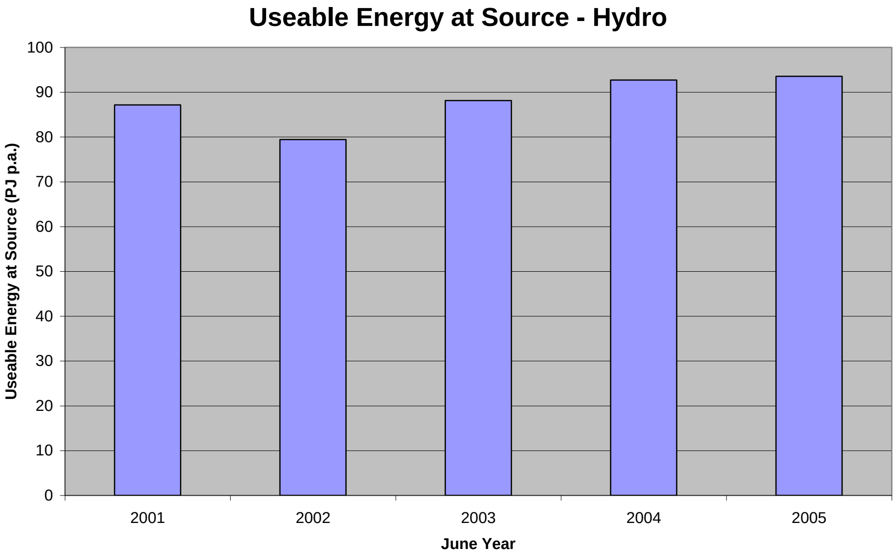

Figure 9 **Energy Contribution of Hydroelectricity Generation to New Zealand.**

Source: MED-7 2005, MED-7-2003, MED-7-2002.

5.3 Opportunities

There is a significant amount of hydro potential that is technically feasible within New Zealand. However much of the uptake will be limited because of economics and difficulty of consentability.

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There is an estimated 755 MW (4260 GWh, 15.3 PJ)[15] of undeveloped hydro potential at high/medium confidence levels available for future generation at costs up to 10c/kWh.

Hydropower opportunities can be divided into three broad categories:

- large hydro developments, generally over 30 MW, that attract existing well capitalised generation companies
- small-size developments of 1000 kW to 30 MW that are of interest to smaller generation companies, lines companies and private corporate investors and
- mini or micro-size developments of less than 50 kW to more than 1000 kW that are generally only of interest to individuals and community groups intending to use the electricity output for their own use.

Regardless of size most future large opportunities are likely to be in areas which have been previously investigated. Many medium and small schemes have previously been identified, however, water harvesting as a design concept has really only taken hold since the 90's and many new opportunities are being identified as stand alone projects or integrated with other uses such as irrigation. With the prospect of higher electricity prices combined with modern technology, and the possibility of providing other community benefits, many previously uneconomic and new schemes will become economically attractive.

Some lines company networks are being fully utilised with the changing irrigation demands of farmers for irrigation water. This has changed the pricing and load structure for electricity, where in some regions the demand and cost for electricity is greater in summer than winter. This issue is unlikely to diminish. Developing schemes that are embedded in electricity networks have significant financial advantages from higher generation prices, reduced transmission losses and forgoing the costs of line upgrades. This opportunity is being recognised by lines companies and as a result they are investigating medium to small sized embedded schemes. These lines companies are often community owned, therefore there are significant consenting advantages.

There are large numbers of mini and micro sized opportunities in rural areas, many of which have not been considered previously for hydro generation because of small stream flows. These can be expected to be of greater interest over the next few years as electricity costs increase, the capacity of many line companies networks are heavily utilised, and the need for embedded generation to avoid significant lines upgrades becomes financially significant.

Mini and micro hydro schemes are likely to be investigated by landowners rather than energy companies because of their attractiveness for embedding.

5.4 Geographic Distribution of Resource

The majority of the potential hydro resources are located in the South Island with almost 60% being in the West Coast, Canterbury and Otago regions. Table 8 indicates where the opportunities are located.

5.5 Hydro Industry

5.5.1 Industry Participants

The hydro electricity industry in New Zealand comprises the relevant activities of the five major generating companies (retailers) Contact Energy, Genesis Power, Meridian Energy, Mighty River Power,

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[15] EHMS 2004

Field Code Changed

and TrustPower along with a number of smaller generation companies e.g. King Country Energy, Pioneer Generation. Line companies are now entering the market as a result of the increased allowance of owned generation. Private or groups of investors are financing several medium size (30MW) schemes. Communities that are interested in large irrigation schemes are investigating hydro power as a by-product of the irrigation process.

A range of New Zealand and international consultants and contractors provide services as required to support the hydro-electric operations of these companies.

There are two main industry related organisations that are associated with hydropower in New Zealand. The first is the International Hydropower Association (NZ) which has an active New Zealand membership. The other is the New Zealand Society of Large Dams (NZSOLD), a technical group of the Institution of Professional Engineers New Zealand. NZSOLD is focused on the design, operation and monitoring of dams and is affiliated to the International Committee on Large Dams (ICOLD), noting that over the past few years many conferences and technical groups have focused on environmental and consenting issues.

5.5.2 Industry Capacity

With the significant downturn in the construction of large hydroelectric schemes in New Zealand in the early 1990s the design capability and the construction expertise has fallen away and may not be sufficient to pick up the challenge should a number of large new projects be undertaken. Several small-scale projects have been designed and constructed by New Zealand designers and contractors.

While there is a resource of hydropower design capability internationally it is important to involve local expertise in association with any international resource. In particular the nature of the geology in New Zealand makes it very important to have local expertise.

While local contractors may well have the skills and capacity to carry out some of the larger schemes providing they have little or no other work on at the time and have sufficient access to the required resources, joint venturing with offshore contractors has always been one way of effectively utilising local resources while ensuring that the project's overall resource requirements are met.

Micro and mini schemes are likely to be undertaken by landowners with minimal engineering input. To ensure appropriate capability for such projects it will be necessary to increase access to information and good practice guides suitable for non engineers.

5.6 Current and Projected Cost Profiles

Costs are project specific and have a range of drivers. Location as well as the head, flow, geological conditions, etc. affect the cost per MW of installed capacity. Flow, storage and capacity choice affect capacity factor, or degree of utilisation, the other key economic element. Opportunities for generation as a by-product of irrigation scheme development in the South island is being used to develop marginally economic irrigation projects. The development cost of projects includes all civil works, plant and equipment, transmission line, infrastructure, resource consent, and mitigation costs.

Where there is little storage associated with existing hydro schemes the price received for generation will generally be related to current river flows and spot market prices. Such schemes will therefore be price followers with little opportunity to increase revenue by generating at full power when the spot price is high. The exception will be if the schemes are able to be embedded into an industrial user's electricity demand management system. Controlled storage allows the water to be retained and used at times of higher electricity prices.

Table 8 provides a summary of undeveloped hydro resources available for future investment. The table shows that most of the high/medium confidence remaining small/large scale hydro resources are located

Field Code Changed

in the South Island with almost 75% being in the West Coast, Canterbury and Otago regions. Schemes in the southern part of the South Island may involve additional transmission costs, as well as schemes on the West Coast (noting that some West Coast generation may assist in resolving some key transmission issues).

In this table confidence levels based largely estimated on ability to gain consents have been assigned to the "Potential for Development". Schemes where there are likely to be significant geotechnical related risks leading to cost uncertainty have not been included.

High Confidence	Attractive, with few apparent issues
Medium Confidence	Attractive, but with some significant issues
Low Confidence	Possible, but with many issues

The cost of future hydro has been analysed for the range of opportunities available and shown in Table 9

An estimate by the authors of the cost of microhydro is that a 1kW scheme can produce electricity for approximately 30-40c/kWh.

Table 8 New Zealand Hydro Resources up to 16c/kWh,[16] 10% WACC.

Region	**No. of Potential Schemes**	**Potential for Development (MW)**			**Potential Energy Output GWh/y**
		High Confidence	**Medium Confidence**	**Low Confidence**	
Northland	-	-	-	-	-
Auckland	-	-	-	-	-
Waikato	8	8	24	44	252
Bay of Plenty	13	25	108	258	1,196
Gisborne	3	12	37	37	163
Hawkes Bay	7	51	154	154	779
Taranaki	4	-	22	48	230
Manawatu-Wanganui	8	53	144	144	704
Wellington	1	-	6	6	25
Nelson-Marlborough	6	35	48	83	408
West Coast	24	-	373	758	3,414
Canterbury	13	349	349	477	2,555
Otago	13	-	364	869	4,335
Southland	2	-	-	85	370
Total New Zealand	**102**	**533**	**1,629**	**2,962**	**14,431**

Source: EHMS-2004.

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[16] These costs are based on escalating costs based on studies done 20 or more years ago. Original data has been modified adjusted to take Project Aqua cancellation into account.

Field Code Changed

Table 9 **Hydroelectric Supply Costs, 10% WACC.**

Supply Cost Data	c/kWh	MW	GWh p.a.
High Confidence	2-4	-	-
	4-6	-	-
	6-8	130	630
	8-10	200	1,095
	10-12	100	500
	12-14	40	185
	14-15	65	325
Medium Confidence	2-4	-	-
	4-6	-	-
	6-8	500	2,785
	8-10	670	2,995
	10-12	155	755
	12-14	140	640
	14-15	205	990
Low Confidence	2-4	-	-
	4-6	5	65
	6-8	1,015	5,250
	8-10	875	3,905
	10-12	200	1,100
	12-14	370	1,750
	14-16	575	2,715

Source: EHMS-2004.

6 Geothermal Energy

6.1 Technology

New Zealand geothermal energy is accessed from earth heat through a water medium, frequently in a staged manner. The energy at indicative field temperature and use is:

30-69ºC	thermoculture, bathing;
70-110ºC	space and water heating, drying;
110-220ºC	drying, process heat, binary electrical plant;
220+ºC	steam turbine and binary electricity or process steam.

The stages of processing of geothermal energy are:

- *Extraction:* Water is channelled from a natural spring or from a drilled well. It is generally flow-controlled by piping, orifice plates and valves.
- *Treatment*: Steam and water are separated and other impurities are possibly removed.
- *Heat exchange/use*: Steam can drive a turbine or supply process heat. Hot water can be put through a heat exchanger for space or water heating, or to energise binary cycle power plant (uses low boiling point fluid), or used directly (e.g. bathing). Ground source heat pumps require lengths of buried pipes to exchange heat with the ground/ground water.
- *Disposal:* Used fluids are usually re-injected via wells into the field or (rarely) discharged to land or waterways. These fluids may need treatment (e.g. anti-scalant) prior to discharge. Gas is dispersed into the air and in some cases into waterways as dissolved gasses which are released to

Field Code Changed

the atmosphere further downstream. Where reinjection is used the gasses remain dissolved in the reinjection liquid.

A cascade system is one where fluids used for a high heat purpose may still have enough energy for lower-grade purposes. With a high temperature field, steam can go to a turbine and the separated hot water to binary plant for electricity production, then to direct heat for other uses within the limitations imposed by silica content.

As an alternative to cascade applications, process heat can be extracted prior to, or in parallel with, the electrical plant.

There are advantages in large-scale development, but small-scale plant is often viable where there are existing wells. Staged development of a field is useful for initial proving – it reduces risks but can negatively impact on economics.

There are potential improvements to the efficiency of the conversion of geothermal energy into electricity from existing plant, as follows:

- improvements in steam turbine and binary plant design, permitting higher inlet and lower exhaust pressures/temperatures by equipment manufacturers. High energy prices being paid for renewable resources in Europe are rapidly leading to improved technology and economics of small/scale/low temperature generation plants,
- retro-fitting of binary plant to existing condensing plants, and
- managing the deposition of mineral scale in geothermal plant. One significant constraint to improving plant efficiency is silica deposition - the further one drops the temperature of separated geothermal water, the more likely it is that silica will deposit in the pipework, heat exchangers or re-injection wells. Suppression of this tendency will allow lower rejection temperatures, allowing more heat to be directed to energy conversion. Some technologies that are routinely used overseas have not yet been applied in New Zealand.

Matters worth pursuing that could increase the uptake and effectiveness of the use of geothermal energy, particularly for new developments, are:

- application of advanced geophysical techniques to better identify field boundaries and most productive zones, e.g. active seismic and passive micro-seismic techniques (subject to cost considerations), collection and interpretation of aeromagnetic and gravity data.
- more refined reservoir resource assessment and modelling during operation (this requires greater attention to input data),
- economic extraction of some dissolved minerals,
- inhibiting silica or calcite deposition,
- optimised steam-field and station design,
- application of better drilling techniques to deal with lost circulation and to maximise well production,
- understanding and mitigating environmental effects,
- improved data on potential environmental impacts, and
- additional investigation of perceived financial risk.

Technologies for directly tapping magma for extraction of heat are at the conceptual stage. Hot dry rock extraction using very hot deep rock (by making hydraulic fractures and passing water between wells) is at the development stage although demonstration projects are under way in Australia. Both are unlikely to have commercial application in New Zealand within the next 20 years but may have increased importance beyond that as other sources of energy become more expensive.

Geothermal is a mature technology with a successful track record of fifty years. While fields may have degraded in output no geothermal field has ever been run to exhaustion, and operating costs are low. Active re-engineering of developments may be required over the years, but fields will ultimately reach a

Field Code Changed

point where operations are sustainable. Re-injection, if properly managed, and in the right circumstances, may assist sustainability goals.

Geothermal generation is unaffected by weather and can provide long-term reliable base load electricity generation (e.g. Wairakei plant load factor of greater than 95% for a considerable part of its almost 50 year operating life). Stations can run in load-following mode if required, but there may be a number of constraints on steamfield flexibility.

Geothermal extraction can affect surrounding land through subsidence. Monitoring of this effect provides information necessary for identification of appropriate fluid extraction rates. In rural areas subsidence may be an acceptable effect whereas it may not be acceptable in an urban area.

6.2 Current Utilisation and Emerging Development

The installed capacity of geothermal electricity generation in New Zealand is currently 450 MW, or about 5% of total capacity. Not all of the existing geothermal plant is fully utilised: actual production is limited to the equivalent of about 375 MW. It is regarded as a renewable resource that can be operated at a very high load factor, so geothermal in an average year produces about 6 – 7% of the total electricity supply. The supply for the year ending September 2005 was approximately 2,645 GWh (9.52 PJ).

New geothermal electricity generation installations identified since December 2000 which contribute (useable energy at source) to achieving the Renewable Energy Target are listed below:

Additional generation installed from 1 January 2001 to 31 December 2005:

• Rotokawa plant expansion	6 MW	55 GWh*	0.20 PJ
• Wairakei binary plant	14 MW	115 GWh*	0.41 PJ
• Mokai plant expansion	39 MW	310 GWh*	1.11 PJ
	59MW	480 GWh	1.72 PJ

Additional generation committed to construction (in these cases consents have been granted and some wells have been drilled but consents are under appeal):

• Geotherm	55 MW	458 GWh*	1.65 PJ
• Kawerau (PT/MRP)	70 MW	582 GWh*	2.10 PJ
	124 MW	1040 GWh	3.75 PJ

Resource consents sought or carbon credits allotted and project announced:

• Tauhara plant	15 MW	125 GWh*	0.45 PJ
• Ngawha expansion	15 MW	125 GWh*	0.45 PJ
	30 MW	250 GWh	0.90 PJ

Projects publicly announced as being under serious investigation:

• Rotokawa Expansion	67 MW	558 GWh*	2.00 PJ
• Other unspecified projects[17]	220 MW	1830 GWh*	6.59 PJ
	287 MW	2388 GWh	8.59 PJ

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[17] Mighty River Power (MRP) has indicated in media releases that they expect around 400MW of geothermal projects in coming years. These projects will include Mokai and Rotokawa expansions, Kawerau developments and other projects implemented by others.

Field Code Changed

In addition to new projects, Contact Energy has committed resources to making greater use of its existing assets at Poihipi, Wairakei and Ohaaki (while generation in terms of MWs is shown below, new generation plant is not being installed but under-utilised plant is being more fully loaded):

• Te Mihi drilling	18 MW	150 GWh	0.54 PJ
• Ohaaki drilling	18 MW	150 GWh	0.54 PJ
	36 MW	300 GWh	1.08 PJ

* 90% plant factor assumed

Countering this trend, in this period, Ohaaki power station has been formally derated by 38 MW such that it has a nominal potential of 66 MW. It current achieves around 27 MW but the drilling indicated above will see a further increase.

Table 10 shows the contributions to geothermal primary and useable energy since 2001. There has been a decline in primary energy since then while useable energy has remained almost constant. Usable efficiency has increased from 44.7% to 46.9%.

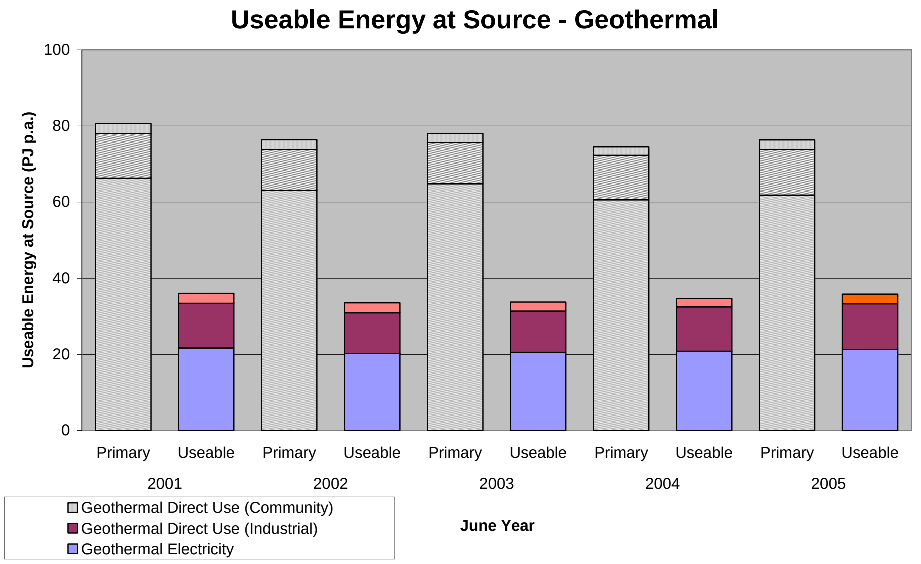

Figure 10 Contribution of Geothermal Energy to Useable Energy at Source.
Source: MED-STAT.

Since December 2000 geothermal plant investments providing an additional 0.2 PJ of energy were installed. 2.94 PJ are committed to construction and 3.25 PJ are seeking resource consents or have carbon credits allocated. Additional but not significant heat has been obtained for the Mokai greenhouses (6ha). It is planned that the Mokai greenhouses will expand to 20ha. There have been few substantive new community and recreational geothermal applications installed over the last five years.

There is currently (May 2006) estimated to be 11.8 PJ of heat derived from geothermal energy for industrial uses. This includes about 40 MW of electrical equivalent in direct heat at Kawerau. There have been little new industrial heat initiatives installed over the last five years.

Appendix D lists all operational geothermal electricity plant.

Field Code Changed

Residential applications using heat from geothermal sources are estimated to be about 2.41 PJ. Although information is not available on the energy used in many communities, district heating, residential and recreational uses are shown in Table 10.

Field Code Changed

Table 10 Community Direct Use of Geothermal Energy.

Locality	Type	Annual Utilisation	
		Capacity MWth	Energy (PJ/yr)
Ngawha	B		
Waiwera	B		
Waingaro	B		
Te Puia Springs	B		
Morere	B		
Te Aroha	B		
Kawerau	I	16	0.25
	G	>0.08	<0.01
Tikitere	B		
Rotorua	H	>22	0.69
	I		
	A		
	G		
Waiotapu	B		
Reporoa	A	9.14	<0.15
	A	4.14	<0.07
Wairakei	F	18.6	0.36
Taupo	G	0.055	
	I		
	A		
	H		
Mokai	G		
Tokaanu	B		
Hanmer Springs	B		
(Mariua) Springs Junction	B		
− Parakai	B		
− Miranda	B		
− Okauia	B		
− Okoroire	B		
− Tauranaga	B		
− Taupo	B		
− Waikite	B		
− Ohaki	I		

Source: Modified from Dunstall[18](TP-2005) and Luketina (EW 2002) [19]

Key:

A	Agricultural
B	Bathing and swimming (including balneology)
F	Fish and animal farming
G	Greenhouse and soil heating

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[18] This table does not include all community direct use applications but is the only source available.

[19] This table is not exhaustive but uses the best currently available information.

Field Code Changed

H	Space heating and district heating (other than heat pumps)
I	Industrial process heat

6.3 Opportunities

New Zealand has abundant geothermal resources and most remain untapped. A median estimate of New Zealand's technically available high temperature geothermal resource base [EHMS-2005[20]], using only current technology and considering a realistic economic drilling depth, is 2,200 MW of electrical equivalent. Other estimates may increase this to 3,600 MW.

There is an opportunity through residential/light industrial applications in conjunction with electricity generation to make more efficient use of fluid already being extracted.

Geothermal electricity generation has low greenhouse gas emissions compared to fossil fuel alternatives. The average CO_2 emissions from current geothermal plants in New Zealand per GWh are around 25% of those of combined cycle gas turbine plant (representing the most efficient form of fossil fuel generation readily available), or less than 10% of that of a modern coal-fired plant. In practice, this data may be skewed by the fact that two of the current developments, Ngawha and Ohaaki, tap unusually high-gas fields. The average CO_2 emissions for new developments can be expected to be somewhat lower.

Geothermal plants are built where the resource is found. These sites are reasonably close to the electricity transmission system so the emphasis has been on electricity production as there is generally no industrial heat user nearby.

Maori ownership and access to most geothermal resources is delivering support for Iwi development. Three out of four of the recent geothermal developments in this country have been wholly or partially in Maori ownership.

Surveys indicate that, of New Zealand's 129 geothermal areas, fourteen are in the 70-110ºC range, seven in the 110-220ºC range and fifteen in the >220ºC range. A recent reassessment of geophysical evidence by one company is claimed to have identified another 22 areas of possible geothermal potential.

All of the high temperature fields (which offer the most energy potential) are found in the Rotorua/Taupo region with the exception of Ngawha in Northland. Almost all the present use of geothermal resources occurs in these regions. However there are low temperature surface manifestations which indicate that geothermal heat is near the earth surface at other locations throughout New Zealand. These could be the subject of future deep heat exploration. Recently there have been media reports on geothermal energy accessible from abandoned oil wells. The background work shows that there will be useful geothermal resources at almost any location in New Zealand, though only niche developments might be feasible.

There is insufficient data to estimate the energy potential-supply costs of the fields with temperatures below 220ºC. The potential for the high temperature fields to be used for electricity production is shown in Table 11. Availability for energy/non electricity uses is large.

There are large areas of New Zealand where the geothermal resource has not been explored. This is in deeper reservoirs and in areas outside those with traditional surface features. Deep geothermal drilling and extraction technology has the potential to extend the uptake of geothermal energy using resources from cool to the near magmatic conditions in deep geothermal systems. Modern exploration technologies are available to allow these areas to be investigated.

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[20] Table G4, with Mangakino and Ngatamariki fields "available for further development".

Field Code Changed

In practice, this does not occur because of the inability of exploration companies to be able to secure development rights through licensing prior to exploration and significant uncertainties related to the technology and economics associated with the use of deep geothermal resources. Exploration of deep resources, or resources without surface features could result in new developments being located away from urban areas, plus they are unlikely to have undesirable effects such as subsidence.

Table 11 Estimated Additional Energy Available from High Temperature Geothermal Fields.

Area	**Year 2015**					
	High Confidence			**Medium Confidence**		
	MWe	**GWh p.a.**	**PJ pa**	**MWe**	**GWh p.a.**	**PJ pa**
Taupo Volcanic Zone	365	2,900	10.4	434	3440	12.4
Northland	0	0	0	0	0	0
Total	**365**	**2,900**	**10.4**	**434**	**3440**	**12.4**

Source: EHMS-2005.

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6.4 Geographic Distribution of Resource

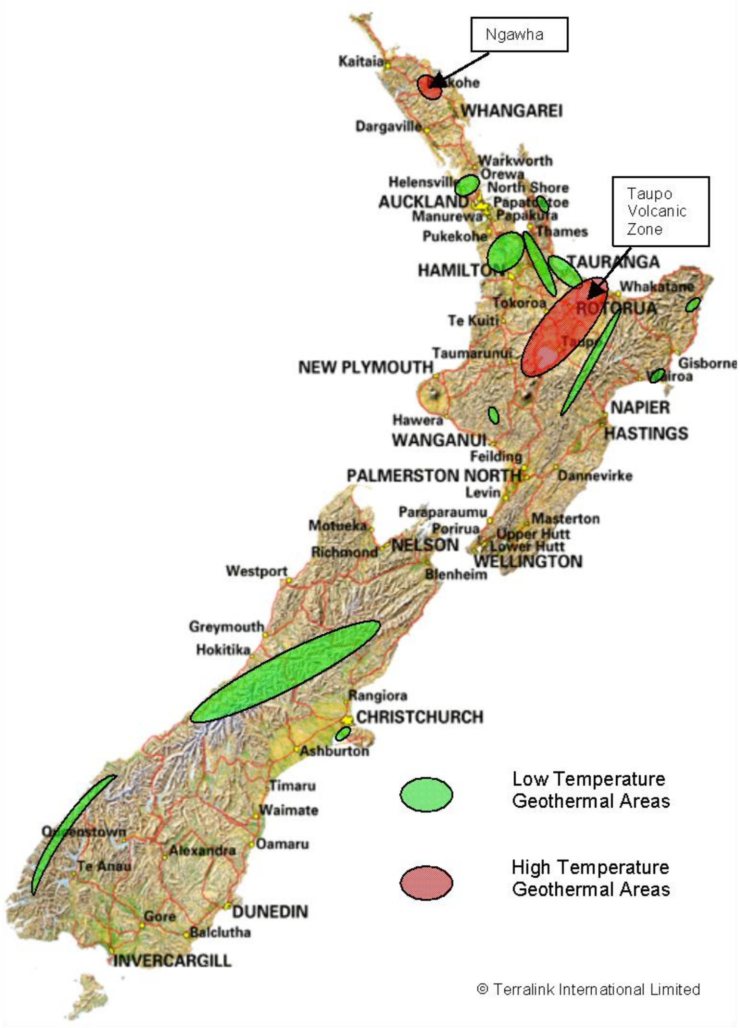

Figure 11: Location of Geothermal Resources in New Zealand

Source:EHMS 2002

6.5 Geothermal Industry

6.5.1 Industry Participants

The geothermal industry in New Zealand comprises a wide range of participants. For uses relating to industrial heat and electricity generation the relevant parties include Contact Energy, Mighty River

Field Code Changed

Power, Bay of Plenty Electricity, Top Energy & Tai Tokerau Trust, Tuaropaki Power Company, Norske Skog Tasman and Ngati Tuwharetoa Geothermal Assets along with a number of other organisations, including the Crown. Note that some Crown-owned assets at Kawerau were transferred through Mighty River Power to Tuwharetoa interests in 2005.

A range of New Zealand consultants and contractors provide services to support the geothermal aspects of these companies.

There are two main industry-related organisations that are associated with geothermal use in New Zealand. The first is the New Zealand Geothermal Association whose membership is diverse including the owners of geothermal developments, consultants, consenting authorities, central government, Maori interests etc. The other is the Auckland University Geothermal Institute. While this training institute has largely been in abeyance in recent years, Auckland University has announced that it will be resuming formal courses in 2007. Information on these organisations is given in Appendix B.

New Zealand also provided the secretariat for the International Geothermal Association and the Western Pacific regional Branch of the International Geothermal Association.

As well as the benefit to the geothermal industry within New Zealand, the country has a proven track record in exporting geothermal technology ($30 million by one estimate), mainly as expertise rather than hardware.

One organisation that is crucial to the status and ongoing benefit of the geothermal industry is the Waikato Regional Council (Environment Waikato) which is the regulatory authority for the “Take” and “Discharge” of many of the major geothermal resources in the Central North Island. Its role in the future use of the geothermal resource is crucial for setting the rules for access to geothermal resources. The Bay of Plenty Regional Council covers the Kawerau geothermal field and others, and the Northland Regional Council the Ngawha field.

6.5.2 Industry Capacity

There is a cadre of expertise and experience within the geothermal industry. The industry provides a level of service that meets the ongoing requirements of the asset owners and developers and has a strong export focus. However, while New Zealand was once a world-leader in this technology and associated research, it has been moving towards a follower status, there being insufficient domestic industry base or government funding to support much leading-edge research.

While there was a significant downturn in the construction of large electricity generating schemes in New Zealand over 10 years ago, the geothermal area continued to have some, albeit reduced, level of activity. This was also associated with the advent of reliable and economic small-scale modular plant, and staged development on new fields at Mokai and Rotokawa. The imported modular units require far less time for design, construction and commission and provide greater cost certainty.

A recent industry survey showed that the industry seemed to have a sufficient consulting base to support a major upturn. However, there are competing demands for service from international clients, and there are already cases where international consultancies have been brought in to support domestic consent applications because of conflicted or over-committed local resources.

6.6 Current and Projected Cost Profiles

Geothermal electricity generation development, at $2,600/kW-$3,800/kW, generally has lower capital requirements than a lot of hydropower opportunities. While there are economies of scale, these can be reduced by the lower cost of modular developments and the use of existing wells. Further economies are possible with the use of second-hand/refurbished equipment. In the long term, price is expected to stay around this level due to counteracting influences of plant improvement but increased cost of new wells. Significant operation and maintenance (O&M) costs are involved due to well replacement to maintain production, and ancillary plant such as waste treatment. These costs are offset by a high capacity factor >90% giving relatively competitive electricity prices.

For a greenfield process heat development, high load factors and large thermal loads are required to ensure profitable steam supply to counter the high cost of new well drilling.

An estimate of the unused geothermal resource that is available and considered to be consentable is given in Table 12.

Table 12 Estimated Supply Cost Data for Geothermal Electricity Generation.

Supply Cost Data	**c/kWh**	**Year 2012 WACC = 10%**	
		MW	**GWh pa**
High Confidence	2-4	25	200
	4-6	210	1660-
	6-8	120	950
	8-10	10	80
	10-12	-	-
Medium Confidence	2-4	25	200
	4-6	210	1660-
	6-8	185	1460
	8-10	14	110
	10-12	-	-
Low Confidence	2-4	25	200
	4-6	150	1180
	6-8	1550	12200
	8-10	20	160
	10-12	-	-

Source: EHMS-2005

7 Wind Energy

7.1 Technology

Wind turbine generators (wind turbines) can produce alternating current (AC) or direct current (DC) electricity as required by the application, e.g. DC for small remote electricity generation or water pumping systems, or AC for electricity grid connections. Windmills are also used for direct pumping of water.

Wind turbines can be located on land, or at sea with towers fixed to the seabed. Normally the wind at sea is stronger, more consistent, and less turbulent and offshore installations are occurring extensively throughout Europe. However, capital costs for offshore installations are greater, even more so in New Zealand as the seabed near the coast is likely to be more inhospitable than for European sites (e.g. depth, seabed conditions and wave heights), and the economy of scale economy benefits do not exist in New Zealand.

In the past decade, the configuration of wind turbines has almost exclusively standardised on three-bladed horizontal axis machines with upwind rotors, with some two-bladed machines also being built. However, it is not possible to rule out alternatives, such as vertical axis turbines being installed in the future. This type of wind turbine is most unlikely, particularly at the current large scale of wind turbine. Other technology advances such as the torque-limiting gearbox developed by Windflow Technology in Christchurch are also occurring.

The average sized wind turbine installed internationally has increased over time with 2.5 – 3 MW machines now being installed. In New Zealand, Meridian Energy has installed 1.65 MW turbines at its Te Apiti wind farm and resource consent applications are being lodged for developments that intend using 3 MW wind turbines.

A typical grid-connected machine stands 40-100 metres tall with rotor diameter of 40-90m. Towers are almost all tubular steel, with a small number being lattice steel. The bottom of tubular towers can accommodate electrical control and switchgear equipment.

Wind power technology is a proven technology with many commercial turbines being available. Currently 50% of the market internationally for large turbines is met by three companies. As with most mechanical plant, operating and maintenance costs tend to increase through the life of a wind turbine.

Overall wind turbine life is between 15 to 25 years with the possibility of a major overhaul after 10 years. To increase reliability and availability major manufacturers are now offering long-term maintenance contracts with guarantees on performance.

With the installation of the Brooklyn wind turbine 12 years ago and, more recently several commercial wind farms, New Zealand is now gaining real experience of various wind turbines. It is evident that there is significantly increased interest in New Zealand by major wind turbine manufacturers.

The timing of purchases, with large wind farms and manufacturing facilities being developed in Australia, as well as some local production, may assist in reducing costs.

Small wind turbine technology is well developed for rural area power supply schemes and for boats. The technology is very robust and able to handle harsh weather conditions. The economics of small turbines is such that they are mainly economic for niche applications and not grid connected applications.

7.2 Current Utilisation and Emerging Development

For the year ended June 2005, 556 GWh [21]of electricity was generated from wind energy. The generation of electricity from wind energy for the five years 2001–2005 is shown in Figure 12.

While there had been active investigation, consenting and placing of orders for additional wind farm capacity in the three years to December 2003, the only addition to the existing capacity during that period was the installation of WindFlow Technology Ltd's prototype 500 kW wind turbine at Gebbies Pass near Christchurch. However, in 2004 a significant increase (more than 350%) in wind energy capacity occurred, with a continuing trend for more capacity to be investigated and resource consents applied for.

There was an installed base of 168.3 MW as at December 2005[22]:

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[21] MED 2006

[22] (Note that a range of plant factors between 40% and 47% have been used to arrive at the assumed GWh figures)

Field Code Changed

Note: in compiling the following information, where no GWh figures have been publicised for the opportunities listed, a range of plant factors between 40% and 47% has been used to arrive at the estimated GWh figures

Additional generation installed between 1 January 2001 and 31 December 2005:

Gebbies Pass	500 kW	2 GWh	
Hau Nui extension	4.8 MW	19 GWh	
Southbridge	100 kW	0.35 GWh	
Tararua Stage II	36.3 MW	135 GWh	
Te Apiti	90.75 MW	370 GWh	
	132.4 MW	526 GWh	1.89 PJ

Additional generation projects with confirmed resource consents (some are presently under construction):

Awhitu	18 MW	63 GWh	
Tararua Stage III	93 MW	335 GWh	
Te Rere Hau	48.5 MW	182 GWh	
White Hill	58 MW	240 GWh	
	217.5 MW	820 GWh	2.95 PJ

Note: where no GWh figures have been publicised, a range of plant factors between 40% and 47% have been used to arrive at the (estimated) GWh figures

Resource consents under appeal to the Environment Court:

Hawkes Bay Wind Farm	225 MW	800 GWh	
Unison/Roaring 40s-Titiokura	45 MW	160 GWh	
Project West Wind	210MW	880 GWh	
	480 MW	1840 GWh	6.62 PJ

Resource consents sought or carbon credits allotted and project announced:

Awakino	27.2 MW	105 GWh	
Esk Hydro Power	2.5 MW	10 GWh	
Mokairau	9 MW	27 GWh	
Taumatatotara/Taharoa	44 MW	150 GWh	
Unison/Roaring 40s-Te Waka	111 MW	400 GWh	
Wainui Hills	30 MW	125 GWh	
	223.7 MW	817 GWh	2.94 PJ

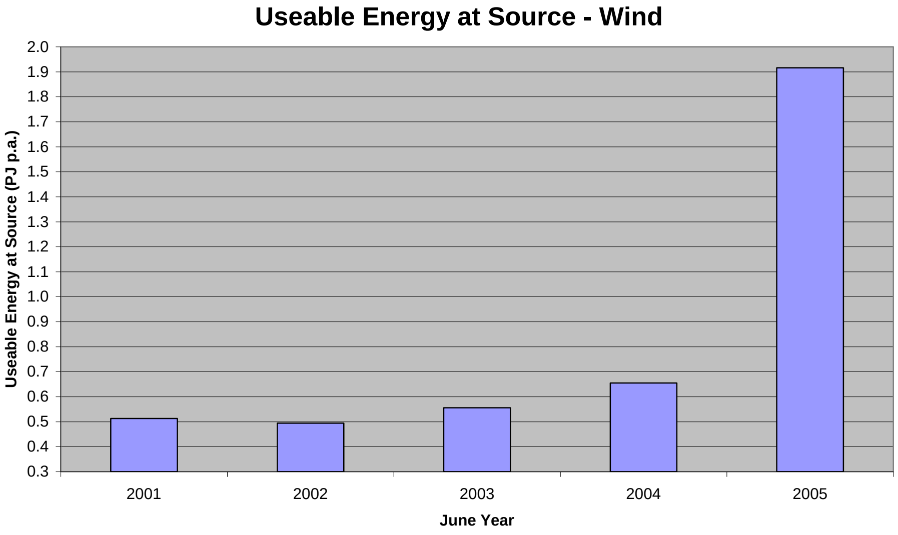
Projects publicly announced as being under serious investigation:

Ahipara	50 MW	180 GWh
Belmont (Wellington)	80 MW	300 GWh
Horehore Station (East Coast)	-	-
Lake Mahinerangi	300 MW	1000 GWh
Long Gully (Wellington)	-	-
Pigeon Bush (Wairarapa)	50 MW	190 GWh
Pouto (Kaipara - Meridian)	300 MW	1050 GWh
Pouto (Kaipara – Mighty River)	250 MW	875 GWh
Puketiro	26 MW	95 GWh
Rocklands (East Otago)	650 MW	2250 GWh
Rock & Pillar	25 MW	85 GWh

Field Code Changed

Scotts Road (Manawatu)	103 MW	400 GWh	
Te Uku (Waikato)	72 MW	250 GWh	
Tenergy (Taranaki)	10 MW	35 GWh	
Turitea (Palm Nth)	120 MW	450 GWh	
	2036 MW	7160GWh	25.78 PJ

Appendix E lists all network connected operational electricity generating wind turbine plant of 100 kW or greater.



Source. **Source: MED-7 2005, MED-7-2003, MED-7-2002.**

Figure 12 Contribution of Wind Electricity Generation to New Zealand Useable Energy at

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7.3 Geographic Distribution of Resource

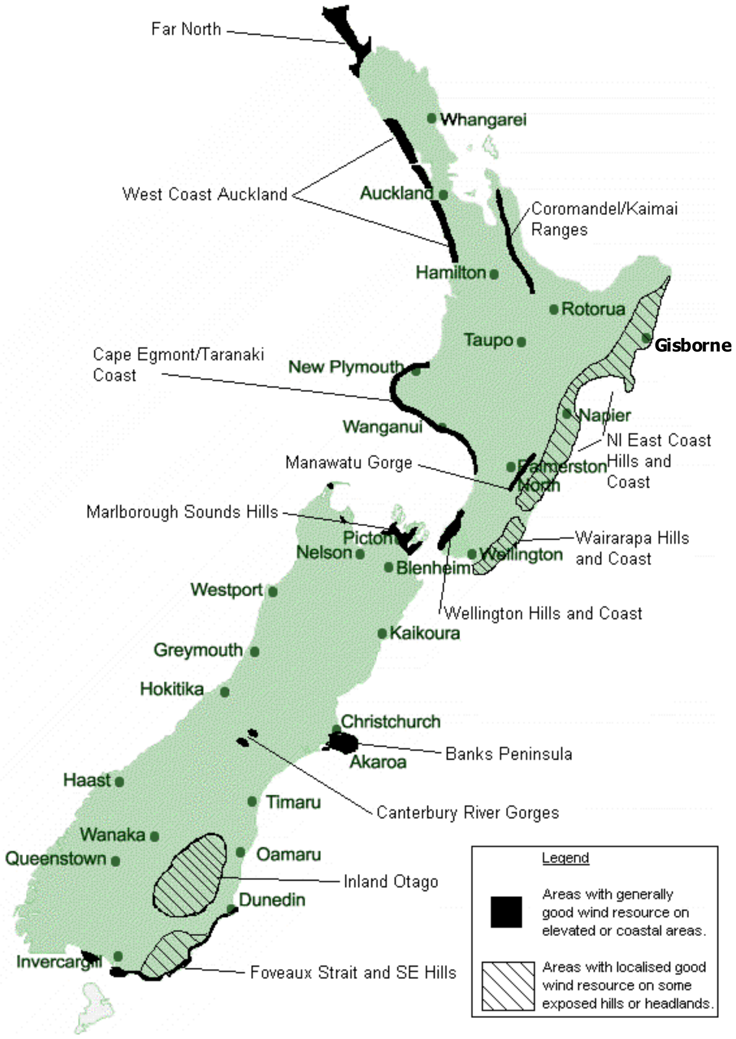

Figure 13: Location Most Suitable for Wind Energy Development

7.4 Opportunities

It has been assessed[23] that there is 9,370 GWh p.a. (approximately 34 PJ) of large-scale wind potential in New Zealand from locations that mostly have good wind resource and existing infrastructure

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[23] EECA-2001w

Field Code Changed

(transmission lines, roads, etc.) at costs up to 10c/kWh. Current installed capacity utilises about 700 GWh p.a. of that resource.

As noted above, New Zealand has an excellent wind resource. In addition to this, with the release of the 'Wind Integration Report' commissioned by EECA and MED,[24] as the first phase of a project to investigate the extent to which wind-generated electricity can be integrated into New Zealand's electricity system, there is also shown to be considerable ability to capture and integrate this resource. The Wind Integration report finds that (based on an initial application of a methodology to quantify the potential for the integration of wind-generated electricity), up to 35% of peak electricity demand (and 20% of annual electricity consumption) could potentially be met by wind generation in future. The report focused on technical as opposed to economic issues for wind power, but highlighted that wind generation was likely to be a key technology that would contribute to meeting the demand growth in electricity.

In addition to large-scale opportunities there is immense potential for small wind turbines in the rural areas and in industrial applications for embedded use. The economics of small size turbines are currently not adequate to justify investment except in niche applications, but as energy costs and rural line costs increase the smaller-scale opportunities will be worth pursuing.

Embedded wind energy can displace a base amount of electricity in industry with top up from the network connection. There are some areas where the network might benefit from embedded generation.

Previously direct pumping of water by windmills was extensively used in many areas throughout New Zealand but the number still operational has decreased significantly [25]. This is an area currently poorly promoted.

The value of uncontrolled wind energy can be improved if wind energy is coupled with storage such as can be provided by hydro - the water storage can be released when required, acting as a battery.

7.5 Wind Energy Industry

The wind energy industry in New Zealand associated with grid-connected wind turbines (at either the national grid or local network level) comprises of some major generating companies (gentailers) Meridian Energy, Genesis Power, TrustPower along with a number of smaller companies (e.g. Unison, Eastland Networks, Windflow Technology, Windfarm Developments). International wind farm operators such as Roaring 40's and Energreen Wind are also active.

Along with wind turbine manufacturers, a range of New Zealand and international consultants and contractors provide services to support the wind energy industry in New Zealand.

The main industry related organisation is the New Zealand Wind Energy Association (NZWEA).

The combination of asset owners, operators, equipment suppliers, consultants and contractors drawing on both local and international capacity provides an appropriate industry capability for the current level of wind energy activity in New Zealand.

The height and weight of turbines is increasing to the extent that cranes used to erect them are having to be specifically sourced from overseas.

Wind energy's contribution to renewable energy in New Zealand is increasing significantly (a 350% increase in installed capacity of wind turbines in 2004) and the industry is able to provide the necessary

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[24] Wind Energy Integration in New Zealand, Prepared by Energy Link and MWH NZ May 2005

[25] East Harbour, Southland Regional Energy Assessment, Report for Venture Southland, EHMS-2003

Field Code Changed

resources to provide, install and operate to meet this increase (assuming that access, resource consents and economics are in place). The wind turbine size has increased from 0.225 MW in 1992 (through 0.5 MW then 0.66 MW) to 1.65 MW in 2004, with 3 MW machines already being chosen for future developments, thus providing advantages of scale associated with installing each turbine.

As well as the emerging local manufacture of a 0.5 MW wind turbine by Windflow Technology, Vestas, a Danish company that is very active in the New Zealand wind energy industry (particularly following its merger with NEG Micon, the supplier of Te Apiti's turbines) has established manufacturing capability in Australia for wind turbine components.

There is a strong link with wind energy initiatives in Australia with at least two companies (Meridian Energy and TrustPower) also involved in developments in Australia, and Hydro Tasmania involved in wind farm activity in New Zealand through its involvement in Roaring 40's.

7.6 Current and Projected Cost Profiles

The economics of wind energy are very much determined by wind speed. This is such that even within a site variable energy outputs from different turbines are likely to occur because of where they are located on the site. Overall capacity factor for a wind farm could vary by up to around 25% on a monthly basis.

Capital costs currently applicable to New Zealand are in the $1,900/kW to $2,100/kW range. O&M costs could be higher than overseas, possibly 2.5% of capital cost per annum ($40-$50/kW installed) at very high wind speed sites (an average wind speed of 10-11 metres/second).

Lifecycle costs depend critically on average wind speed and distribution. At a very good site (10-11 m/s) costs could be around 7-8c (10% discount rate) per kWh. The cost of generation (up until turbine procurement) is very sensitive to exchange rate fluctuations which in effect change the capital cost/MW for wind turbines.

Small Wind Costs

Wind energy can be utilised on agricultural farms for both generation of electricity or direct pumping of water. Wind energy for agricultural farm scale use is disadvantaged by the generally small size of wind turbines and therefore their lower efficiency, lower wind speeds at lower hub height above the ground, and lower average wind speeds on the available sites when compared to the best national sites. With the cost of generation of electricity from such turbines at around 35c/kWh, they are unlikely to be economic for a number of years, except in remote and stand alone applications.

Direct pumping of water is more attractive and estimates are that the cost of energy could be around 22 to 30c/kWh where a turbine is separate from the water bore (e.g. on a nearby windy hill), or for direct pumping above the water bore. If the alternative is running a power line to a pump at the bore, then the cost of the line, monthly connection cost, and energy cost may result in the windmill being more financially attractive.

7.7 Sources of Information

The main source of information on New Zealand wind opportunities is available from the EECA website, and the New Zealand Wind Energy Association (NZWEA) http://www.windenergy.org.nz.,

Field Code Changed

8 Bioenergy

8.1 Bioenergy from Woody Biomass

8.1.1 Technology

Woody biomass for use as an energy feedstock comes from a number of sources:

- **Forestry residue** - slash, tops and unmerchantable stemwood from trees harvested for saw or pulp logs. Forest residue may include the cutover (those left at the stump) depending on location of harvest or material brought to the landing during the harvest operations.
- **Wood processing residues** - bark, sawdust, shavings, offcuts, etc. from processed wood for pulp, panel board, construction timber, furniture, etc. and black liquor from pulp plant residues.
- **Woody crop plantations** - short rotation crops grown specifically for energy purposes, possibly in association with land disposal of sewage and industrial effluent.
- **Firewood** - from dead trees, prunings, tree removal and a range of other sources used as firewood.

Cutover remains on the forest floor where cut or trimmed, and has to be collected. Forest residues produced at the landing with whole tree harvesting require preparation and loading for transport. A range of preparation and transport arrangements are possible with resulting cost differences.

Various management regimes are possible for short rotation tree crops. Short rotation woody crops grown intensively under a coppice regime are a means of sustaining biomass supply. Tree crops can also be grown in association with land-based wastewater treatment, the trees taking up nutrients in the course of treating the effluent. There has been some research into species selection and breeding programmes, and into hydraulic loading rates of effluent onto various energy crops and soil types.

Forest harvesting systems, have been developed overseas and some plant is in operation within New Zealand. The plant is generally used to scavenge harvest landings for material to produce woodchips but can also be used for extracting cutover, or possible for short rotation plantations.

Techniques for drying, handling and storage of the material have been developed for a number of local applications. Wider development will occur once the relative economics improve.

Wood residues and woodchips (or wood comminuted into smaller chunks) can be mechanically fed into suitable heating plant. The resultant heat can be used directly or to raise steam for process needs or for electricity production via a steam turbine. The mechanical handling and burning of wood is a proven technology.

A diverse range of technologies exists to convert woody biomass to useful energy, including combustion, gasification, pyrolysis and hydrolysis/fermentation systems.

- Combustion processes for heat applications consume most of the biomass for energy in New Zealand. Combustion can be in sloping grate or fluidised bed boilers. Although combustion is a mature technology, refinements relating to emissions control and efficiency continue. Most biomass combustion systems installed in New Zealand use grate technology and are available for a wide range of applications, however plant with improved efficiencies and able to handle fuel with higher moisture contents such as fluidised bed combustion plants have recently been introduced.

- Gasification technologies have reached the commercial evaluation phase with several plants overseas undergoing detailed evaluation and monitoring. Gasification, as a technology, has been proven for coal applications (though is still not widespread) and is currently being adapted for biomass. The gas produced ("syngas") is a mixture of carbon monoxide and hydrogen, with a low to medium heating value. Gas cleaning issues (particularly related to silica content and tars) are now being addressed in MW-scale demonstration plant. The technology is progressing to full large-scale commercial uptake, and is expected to take a more dominant position as a future means of large-scale energy conversion once clean-up problems are overcome.

Cogeneration of heat and power is particularly efficient where there is a demand for the heat.

Co-firing of biomass with coal presents an effective means of displacing a small portion of fossil fuels (3 -8 %) at minimal cost for heat generation.

8.1.2 Current Utilisation

It has been assessed that in December 2005 there was 1007 MW_{th} of energy plant producing 470 GWh (1.7 PJ) of electricity and 9,410 GWh (33.9 PJ) of heat. Table 13 shows the assessed energy from the various biomass sources. This includes the 13 PJ of energy that is used by the black liquor boilers in the pulp and paper industry. The black liquor derives from the wood processing activities. The Panpac cogen plant was commissioned in September 2005 so the energy contribution from that plant to the end of the year would be small.

A survey by the Bioenergy Association shows that most of the bioenergy plant based on woody biomass is of the 1-10 MW_{th} range. However because of a few large applications the average size is 19 MW. Figure 14 shows the distribution of heat plant. The survey showed that 44% of wood processors have a woody biomass heat plant greater than 1 $MW_{th,}$ 26% used fossil fuels some of which were co-fired, and 17% had no heat plant.

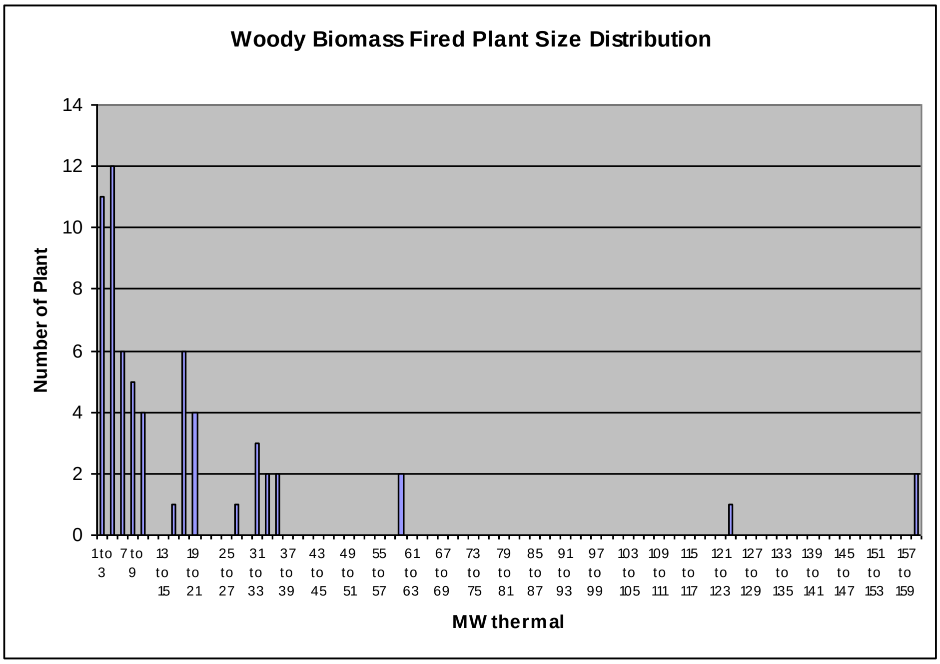
Where surplus heat is available, electricity production may be feasible for use on-site or for export to the grid but this is currently only undertaken in five plants producing 335 GWh of electricity. Those cogeneration facilities also produce 505 GWh of heat.

The only known heat plant in other sectors burning woody biomass is at Golden Bay Cement near Whangarei which burns wood waste from the Carter Holt Harvey LVL plant at Marsden Point.

Table 13 Sources of Useable Energy from Woody Biomass.

	Electricity PJ	Heat PJ
Forest residue	0	0
Wood processing residue	1.7	25.8
Woody crop plantation	0	0
Firewood	0	8.1
TOTAL	**1.7**	**33.9**

Field Code Changed



Source: BANZ Survey

Figure 14 **Size of Plant using Woody Biomass as a Fuel.**

Table 14 **Wood Processing Industry Heat Plant**

Plant Type	Share
Biomass heat plant >1 MW_{th}	44%
Fossil fuel heat plant >1 MW_{th}	23%
Heat plant <1 MW_{th}	13%
No heat plant	17%
Other heat plant	3%

Source: BANZ Survey.

There has been interest shown by territorial councils in developing schemes for disposal of effluent/sludge onto forest areas as a form of treatment. Christchurch and Rotorua already use the effluent to assist tree growth. It is possible that in future this could be used as a means of ensuring secure fuel supply to bioenergy plant.

On a smaller scale, biomass in the form of "firewood" is a significant domestic fuel (8.1 PJ[26]) used for space heating, water heating and cooking, particularly in areas where natural gas is not reticulated. Low emissions, high efficiency wood pellet heating is also becoming established with a range of appliances available nationally for residential and small commercial applications from Nature's Flame (Solid Energy Renewable Fuels Ltd) in Christchurch. Increased use of firewood or wood pellets for heating is likely to occur if greater promotion of efficient low emission wood burners is undertaken.

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[26] MED-1-2006

Field Code Changed

8.1.3 Activities and Trends Over the Last Five Years

There has been a little growth of bioenergy use from woody biomass used at source over the period from 2001-2005 (Figure 15). During that period 201MW$_{th}$ of new bioenergy plant was installed. Table 15 shows the growth in installed capacity that has occurred from January 2001 to December 2005.

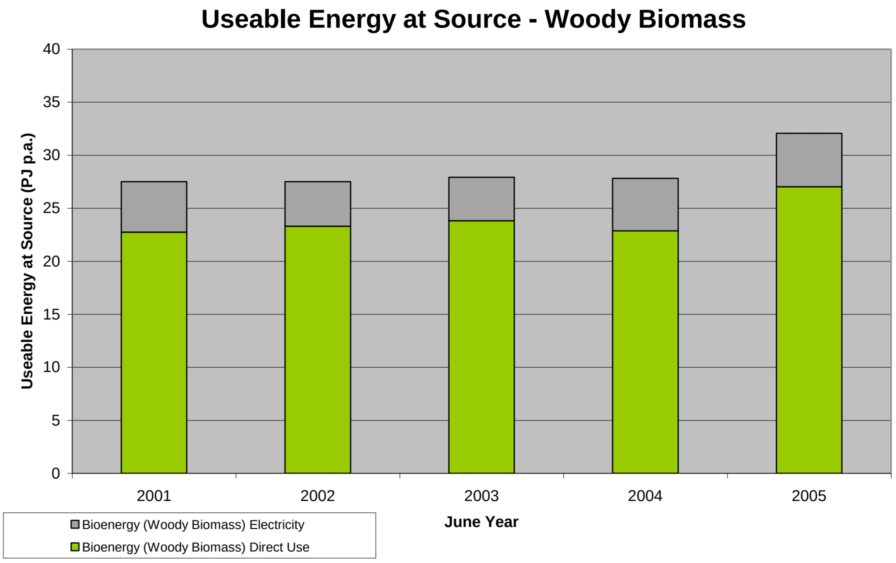

Figure 15 Contribution of Woody Biomass to New Zealand Useable Energy at Source.

Source: MED-7-2005, MED-7-2003, MED-7-2002.

Table 15 Heating Plant Installed Between 2001 and 2005.

Year	Capacity Installed MW$_{th}$	Estimated Output PJ
2001	79	1.8
2002	54	1.4
2003	37	0.9
2004	12	0.3
2005	19	0.5
Total	201	4.9

Source: BANZ Survey.

There is no additional plant currently under construction but 0.1 PJ, is under serious investigation. Appendix F lists major operational bioenergy plant.

8.1.4 Opportunities

The opportunities for bioenergy from woody biomass are based on the following:

Field Code Changed

- New Zealand has a significant amount of waste woody biomass that is available for conversion to energy.
- World-wide there is an increasing acknowledgement that the production of biomass for fuels and chemicals has a fundamental role in realising a sustainable future.
- The New Zealand Government adopted the National Energy Efficiency & Conservation Strategy (NEECS) which places a strong emphasis on sustainability issues and forms of renewable energy.
- The Government has adopted a Renewable Energy Policy and set a target of achieving an additional 30 PJ of consumer energy from renewable sources by 2012 and identifies bioenergy as a key source for achieving that target. This initiative is under review at present.
- The Government has ratified the Kyoto Protocol on Climate Change
- There is a well established and historical use of bioenergy from woody biomass throughout New Zealand that provides a sound base for continued growth with experienced consultants, manufacturers, and other parties who can implement cost-effective investment projects.
- The wood processing industry will be investing in substantial additional processing plant aimed at adding value prior to export. Additional wood processing requires additional heat and electricity, which can be provided most cost-effectively from bioenergy.
- The heat market is slowly expanding and a continual expanding forest processing industry provides opportunities for growth.
- The anticipated increase in gas prices due to the reduction of output from the Maui gas field will make the cost of producing heat and electricity from woody biomass very cost-effective relative to use of fossil fuels. The improving relative economics are already occurring for heat production and will progressively occur for electricity generation over the decade.

- The Government through the Forest Industry Development Accord has made $5.8 million of funding available for Bioenergy research Programme. EECA administers the fund and has a pan industry Advisory Group. Three workstreams are proposed; information, engineering and feasibility studies.

The bioenergy from woody biomass industry has a sound footing on which to build. There are experienced suppliers with proven products already very active and they have the capacity to extend the market to its full potential.

8.1.5 Projected Utilisation by 2010

The MED analysis (MED 2003) indicates that growth of energy supply from woody biomass could be at about 1.9% p.a. for the next decade. This amount of increase will depend on the growth of investment in new wood processing plant. If the current trend towards greater on-shore processing of wood continues as indicated by scenarios from the Wood Processing Strategy Steering Group, then significant new investment will be required. A key aspect will be the amount of heat required for timber drying.

It is expected that as other energy prices rise forest residues will become an economic source of fuel for heat plant. Already forest residues are being economically collected and processed into fuel for the Kinleith cogeneration facility. It is understood that there are four mobile wood chippers working on forest residues in the Rotorua/Taupo/Tauranga area capable of producing fuel from forest residues.

While it is economic to use wood processing residues and some forest residues as fuel for heat plant it is currently uneconomic to invest in electricity generation from bioenergy. However, development of future wood processing facilities is expected to have provision for cogeneration plant to be part of their energy plant as the return on investment costs will improve for embedded or distributed generation opportunities. The integration of heat and electricity along with fuel from coal, and on-site and forest residue sources, will provide a range of risk management strategies.

The construction of plant solely for the generation of electricity is not expected to become economic until the end of the decade.

Field Code Changed

8.1.6 Geographic Distribution of Woody Biomass Resource

Figure 16: Map of New Zealand Woody Biomass Resource

Source: EHMS 2002

8.1.7 Current and Projected Cost Profiles

The bioenergy cost ($/GJ of useful energy output) from woody biomass is particularly sensitive to:

Field Code Changed

- fuel feedstock production costs,
- harvesting costs,
- moisture content,
- fuel quality (including contamination issues),
- transport distance,
- capital cost of equipment (especially fuel handling equipment),
- labour requirements,
- conversion efficiencies,
- load characteristics and
- opportunity cost

Input feedstock costs range from a negative cost for disposal of wastes, through $30/tonne wet for residues used on site, to $50/tonne wet for processed biomass transported some distance to the point of use. Green biomass has a relatively low energy content (7-10 MJ/kg), which gives problems of transport, storage and handling and hence increased costs/GJ. Often biomass is difficult to recover, is poorly distributed, and is produced some distance from the markets. The exceptions are wood processing residues used on site and energy plantations grown near to areas of demand.

Currently only process residues are considered to be competitive with coal for industrial heating. Biomass forest residue material is too expensive mainly because of transport costs. However with greater experience of waste collection and processing forest residue costs have been recently decreasing and the economics will thus improve. Cost of forest residue in the Kinleith area is reported to be about $31/tonne delivered to a heat plant.

Biomass will not be affected by any carbon dioxide charge. Overall heating costs assuming increases in national energy costs and internalising a carbon benefit of $15 per tonne are shown in Figure 18.

Heating using biomass process residue will have an economic advantage over coal but biomass forest residue material will only just be competitive with coal in some locations.

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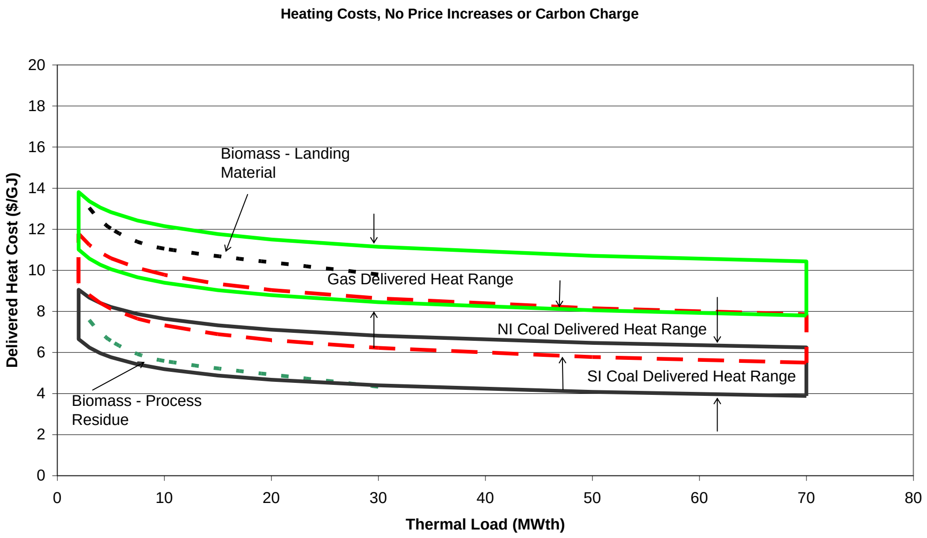

Figure 17 **Heating Costs From Various Fuel Types.** Source: EHMS-2005.

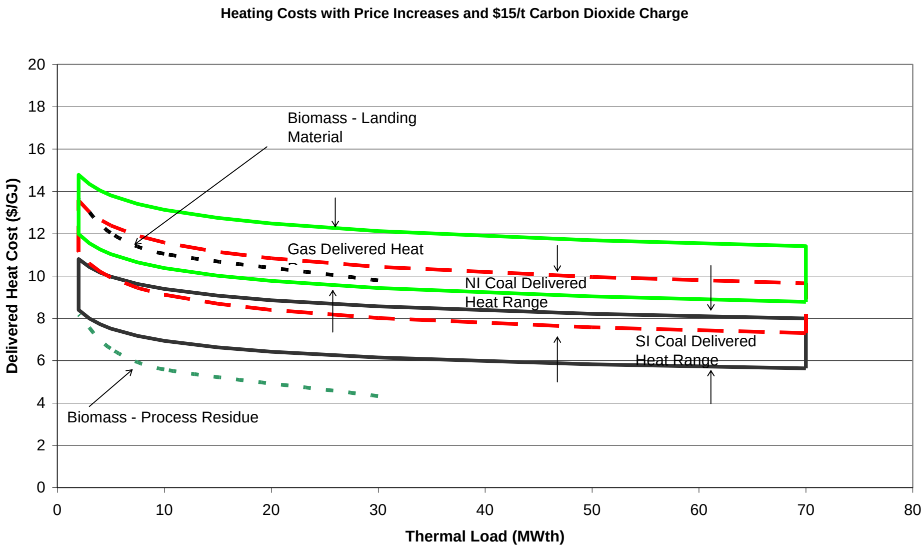

Figure 18 **Industrial Heating Costs Assuming Gas Price Increases and a Carbon Charge.** Source: EHMS-2005.

The economics of large-scale generation of electricity from bioenergy are such that while currently uneconomic, the introduction of any future carbon dioxide charge may make electricity generation from woody based sources to become economic. Development will commence with investment in cogeneration facilities, and then embedded electricity production, leading to larger-scale electricity production post 2010. Panpac in September 2005 commenced operation of their new 13 MW cogen plant to provide electricity as well as heat to their kilns.

Electricity production from a 40 MWe bioenergy facility is assumed to be 9–15c/kWh (dependent on the cost of fuel). However, a facility that size would require 850 to 2,300 tonnes of wood waste each day which would be difficult to achieve in many areas. Such a facility would also need to be built near a 110 kV transmission line in order to reduce transmission costs.

It is estimated that a sawmill processing 250 m^3/day of logs, 160 tonne/day of woody biomass waste available as a fuel into a 10 MW_{th} boiler with a 2.6 MWe second hand steam turbine generator could result in electricity being produced at a cost of 9-11c/kWh. To produce more electricity than this would require fuel to be brought in which would be at significantly increased cost thus increasing the cost of electricity produced by about 5c/kWh. Use of a new steam turbine generator would increase the cost of electricity very significantly.

New bioenergy facilities are likely to be around 2-3 MWe embedded into a wood processor site. With the probable shortage of on-site wood waste it is likely that the biomass will have to be supplemented by coal/lignite or forest residue. If this were the case, the cost of electricity would rise to 14-16c/kWh because of the increased cost of the supplementary fuel.

For the same plant using wood pellets with the current price of $450/t and discounted by 75%, the cost of electricity is 20-35c/kWh. Wood pellets are suited to smaller commercial heat raising applications and are competitive with liquid petroleum gas (LPG), natural gas and oil at this scale. At this price there is likely to be minimal uptake of this fuel.

8.2 Bioenergy from Municipal / Food Processing / Agricultural Residues

Bioenergy derived from food processing and agricultural activities can be from waste, by-products or from purpose grown crops. The biomass may be in solid or liquid form and each can be a source of biogas for electricity or heat, or used as a feedstock for direct combustion and production of heat.

Municipal waste can come in solid, liquid, and gaseous form. Municipal solid waste is derived from domestic or industrial sources and used as a feedstock for combustion to heat or, as commonly occurs in New Zealand, taken to landfills where it produces methane which can be used as an energy source.

Liquid biomass at municipal and industrial sewage works can be turned into biogas and used as an energy source.

8.2.1 Technology

Anaerobic Digestion

Biogas is commonly produced by anaerobic digestion as part of the treatment of wet organic waste. This occurs in municipal wastewater and sewage treatment plants, industrial operations that have liquid wastes containing organic material, and on types of farms where animals are kept or held in a small area, such as pig or poultry farms.

Biogas is a mixture of mainly methane and carbon dioxide with very small amounts of hydrogen sulphide and other impurities. The methane content can range from 50% to 80% (on a volumetric basis).

The high amounts of carbon dioxide in biogas typically reduce the heating value to between 18 and 26 MJ/m^3 (GCV) compared with natural gas typically around 40 MJ/m^3 (GCV).

Field Code Changed

Sewage treatment plants are methane generators by the nature of the process. The gas can be used on site to produce electricity for local consumption or exported from the site. Plants at Christchurch and Auckland are good examples where both methane and natural gas supplies are used in generators at each site.

In many industrial and farming cases treatment of the waste to produce biogas is not economical in itself but is carried out for other reasons such as waste management. Also, small-scale generation of biogas is rarely economic because of the high labour requirements and dilute nature of the effluent being treated.

Biogas from anaerobic digestion can be used to produce heat for the digestion process itself, or for process heat and electricity in other parts of the plant. It can be upgraded to “natural gas” quality and fed into a local utility network. It can also be used directly as a fuel in a number of different types of plant such as reciprocating gas engines, mini-gas turbines, Stirling engines, and fuel cells or by direct combustion in boilers or other CHP heat plant.

Anaerobic digestion is a mature technology and is used worldwide, particularly for municipal waste water treatment. Here the scale of treatment can justify the costs of installing and operating the equipment needed. If the organic content of wet waste stream is too dilute, recovery of the energy content will be made more expensive. Excess moisture may cause handling problems for gasification processes.

Anaerobic digestion is essentially a continuous process so it requires a reliable continuous feed of material.

Municipal Solid Waste (Combustion)

Bioenergy can be derived by combustion of municipal waste and agricultural residues.

Mixed municipal solid waste (MSW) consists of refuse from households and commercial premises, processing and industrial wastes, and material from demolition and construction. Typically between 60% and 70% of this material is organic in nature; mostly paper, but also wood, garden wastes and food scraps. In New Zealand, landfilling is the dominant method of MSW disposal, with about 2.46 kg/person/day being generated.[27]

With current MSW collection and processing in New Zealand there is only limited on-site processing and source separation, limited recycling, and even less materials recovery, and no energy recovery prior to landfilling. However, waste minimisation projects through recycling and materials recovery are being promoted in many of the cities and towns throughout the country and these are likely to lead to a reduction in the potential for bioenergy from MSW.

Combustion of MSW involves the removal of inorganic material and the shredding of the residue. This can be combusted in a grate or fluidised boiler for the production of heat.

Municipal Solid Waste (Landfill Gas)

Landfill gas is a by-product of the bacterial decomposition of organic components in municipal landfills. It is an extremely inefficient way of recovering energy from MSW.

The technology required to extract landfill gas, treat and utilise it to produce heat or electricity has been commercially applied since the 1970s. Ability to accurately predict the rate, variability and duration of gas supply from existing landfills is still being developed. Improved understanding requires further empirical information gained through experience.

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[27] EHMS-2002

Field Code Changed

A typical landfill gas mix will range from 40:60 to 60:40 methane to carbon dioxide. In theory, yields of 150-200 m^3 of gas/tonne of wastes collected should be achievable, the gas mixture having a heat value[28] of 19-22 MJ/m^3. In practice, over the lifetime of the site, the yields are a lot less than this, between 25% and 50%.

Due to concerns about landfill gas emissions, the mandatory capture of landfill gas from large landfill sites is required by The National Environment Standard. The Standard came into force on 8th Oct 2004 for large current operational (or future) landfills requiring all gas to be destroyed (flared or used for heating or electricity generation). Such a change in operating requirements will see greater utilisation of landfill gas for energy, such as burning it in a gas turbine onsite to generate electricity, or reticulating the gas for direct use in nearby households and industry.

Rate of decomposition can be accelerated by high temperature and moisture and increased presence of bacteria (for example from inclusion of sewage sludge).

8.2.2 Current Utilisation

Agricultural Crops

While agricultural residues such as straw and maize cutover commonly exist throughout New Zealand they are not processed into energy. The cost of baling, collection, storage transport and conversion for use as a fuel is too high compared with natural gas and coal.

Animal Effluents

Only a few on-farm digesters producing biogas have been installed to use animal wastes and green crops as feedstocks. Most small-scale plants that have previously operated have closed down in recent years, but a few large-scale industrial plants processing food wastes continue to operate successfully.

Food Processing

Other than at the Fonterra Tirau dairy factory there are no known food processing plants that have installed an anaerobic digesters to deal with the waste product. The Tirau plant has had an anaerobic digester treating liquid effluent since 1984.

Municipal Landfill

In 2004 an estimated 85 GWh (0.31 PJ) of electricity was produced from the landfill gas plants (15.7 MW) at Greenmount, Rosedale and Silverstream. 70 GWh (0.25 PJ) of electricity was produced from the sewage works (11.5MW) at Auckland, Christchurch and Hamilton. Biogas is supplemented by natural gas at the Pukete plant in Hamilton. Nelson Hospital is now using landfill gas to fuel a 1.7 MW boiler.

8.2.3 Activities and Trends Over Last Five Years

There has been a small increase in interest in anaerobic digestion and the Bioenergy Association held a seminar on the topic in 2004, the first since 1985.

Figure 19 shows the electricity generated from municipal biomass over the last five years. The 1.7 MW Nelson Hospital landfill gas extraction project (14 GWh, 0.05 PJ) and the 1 MW Awapuni landfill gas are the only projects that have occurred during the last year.

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[28] BAINES-1993

Field Code Changed

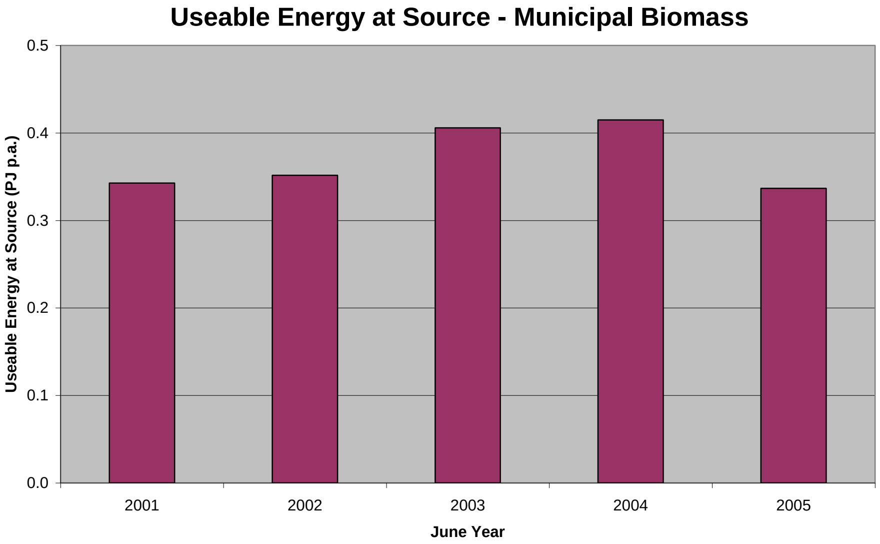

Figure 19 Contribution of Municipal Waste to New Zealand Useable Energy at Source. Source:MED-7 2005 MED-7-2003, MED-7-2002.

8.2.4 Opportunities

Agricultural Crops

The use of agricultural biomass as a source of energy provides significant opportunities for New Zealand. Not only does it deal with disposal of a waste but provides potential for increasing revenues from agricultural by-products.

Residue from agricultural crops can be a good source of energy as was shown by the use of husks in the Gore Flemings factory before it closed. However, a purpose-grown agricultural crops as an energy source is uneconomic in New Zealand and that is unlikely to change in the next two decades.

Piggeries

There are nearly 370,000 pigs in New Zealand, of which 177,000 are in the North Island and 192,000 in the South Island. They are spread over 4,200 farms.

In the North Island, about 55% of the pigs are on 48 farms, each with herds of 1,000 or more. In the South Island, herds with 1,000 or more pigs represent 52% of the pig population spread over 45 farms. Canterbury has the largest number of pigs, over 148,000 or 40% of New Zealand's total.

Total potential methane resource generated from piggery waste from all farms with more than 1,000 pigs per farm could provide 0.05 PJ pa.

Poultry

In the calendar year 2002 over 130,000 tonnes of broiler chicken meat was produced. Three companies produce more than 90% of the broiler chickens in six processing plants. Concentrated chicken litter can be used as an energy source.

Field Code Changed

Dairy Farms

Within New Zealand the majority of livestock are fenced as opposed to housed so effluent collection opportunities are limited to the time that cows occupy the milking sheds.

The potential energy available from processing manure in an anaerobic digester is relatively low; however costs are offset by avoidance of waste disposal costs. If 5% of the manure from 30% of dairy farms throughout New Zealand was collected and processed the total amount of energy could be approximately 90 GWh (0.32 PJ). However, the cost of electricity produced would be in the 20 to 30c/kWh range.

Dairy and Food Processing

Many food processing industries produce large amounts of organic waste that could be used as a source of energy, however the quantities are generally not large enough to provide the economies of scale for investing in on-site waste-to-energy plant unless they can cluster with neighbours. The waste is often not homogeneous and thus increased costs of handling are incurred if it is to be converted into energy.

The main synergy for biogas is between waste management and environmental controls. There are significant environmental benefits from waste digestion. These include reduced impacts of the effluents and solid waste disposal. Sludge from the digesters can be returned to the soil as fertiliser.

Climate change legislation may increase uptake of anaerobic digestion of wet wastes to reduce greenhouse gas emissions. However, the effect in overall energy terms is likely to be very small.

Effluent from the meat industry processing plants can be treated in a digester as a source of biogas. In a typical meat processing plant the digestion of liquid waste can produce around 0.6 MW of electricity at a cost of around 7c/kWh. The potential for electricity from biogas is however, small, amounting to an estimated 40 GWh/year. Leather and skin processing plants would have the potential for a further 20 GWh/year.

Municipal Waste

Opportunities for installing waste-to-energy landfill plant will depend on the future design of landfills and how waste is processed. The National Environment Standard came into force on 8th Oct 2004 for large current operational (or future) landfills requiring all gas to be destroyed (flared or used for heating or electricity generation). This will increase the gas collection from all major landfills not currently collecting the gas and any new large landfills in the future. There may be a flow on effect to smaller landfills as costs come down and communities desire landfill gas collection.

Production of landfill gas is possible from large, well managed landfills in the vicinity of major cities. Given that some of the cities already have successful utilisation projects, maximum electricity generation from landfill gas is likely to be 330-410 GWh/year per year. Subtracting current generation at 120 GWh/y implies a potential for new generation of around 210 to 290 GWh/y 0.75-1.04 PJ.

Combustion of solid municipal waste is a proven technology and more efficient than landfills for converting waste to energy however the costs associated with processing the waste for combustion is high. The largest barrier to greater adoption of this technology is generally the lack of certainty of waste supply arising from the short term contracts for waste available from Councils.

Production of electricity from sewage plants has proved economic, but it is assumed that new opportunities will only be considered when existing plants are upgraded or replaced.

8.2.5 Current and Projected Cost Profiles

The economics of extracting energy from agricultural crops are poor unless the offset costs of waste disposal are taken into account. As energy crops would need to yield an attractive return for the farmer, a delivered energy cost in excess of $11/GJ will be required. This is too expensive for heat and electricity generation applications.

Two critical factors affecting the economics of landfill gas-based power schemes are the gas yield per tonne of waste and the total collectable quantity of gas. Both of these can be affected by future waste management strategies and affect collection costs. Trends towards paper recycling, composting, the mulching and reuse of yard wastes, etc. may reduce landfill gas production.

Analysis of possible sites gives the cost supply curve in Table 16.

Table 16 Landfill Cost Supply Curve.

Confidence Levels	c/kWh	Year 2015 GWh/y	
		WACC=5%	WACC=10%
High Confidence	2-4	-	-
	4-6	50	50
	6-8	-	-
Medium Confidence[29]	2-4	-	-
	4-6	100	100
	6-8	-	-
Low Confidence	2-4	-	-
	4-6	200	200
	6-8	-	-

Source: EHMS-2005.

8.3 Transport Biofuels

8.3.1 Technology

Fermentation

Ethanol is currently produced from starch and sugar based products which are fermented to form a dilute alcohol. Various grades of industrial, beverage and fuel grade ethanol are then distilled from the initial dilute solution.

Transesterifiaction

Biodiesel can be produced from any non mineral oil or fat through transesterification, a reaction with alcohol and a catalyst. The products of the reaction are ester (biodiesel) and glycerol. A variation of the transesterification reaction has been used for centuries to produce soap but modern **biodiesel** production plants use a very fast, high pressure and temperature continuous process.

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[29] Medium and low confidence level resources are not additional to the high confidence level resources but represent the opportunity if collection costs are netted off the total capital cost.

Field Code Changed

Gasification

Interest is currently growing in the use of biomass gasification products to produce Fischer-Tropsch liquids (FTLs). These liquids may eventually be produced at similar prices to petroleum-based diesel. FTL formulations tend to be cleaner burning than petroleum-based diesel.

Pyrolysis

Pyrolysis processes provide greater flexibility and higher conversion efficiencies compared to combustion, but capital costs are also currently excessive and technology is in the early stages of development. The product, pyrolysis oil, which can be used in turbines and other heat plant, can be easily transported and thus allows separation of the resource location from the site of use.

Hydrolysis/Fermentation

Advances in the hydrolysis/fermentation of ligno-cellulose to produce ethanol/methanol and lignin are promising, with future cost reductions claimed. The alcohol fuels can be used in present designs of internal combustion engines, new micro-turbines, or as a source of hydrogen for fuel cells.

Refining

BP has announced it will be adding tallow to its inputs to one refinery to produce a diesel which is partially renewable.

8.3.2 Current Utilisation

There is an evolving transport biofuel market in New Zealand. The Government is currently investigating ways to introduce a sales obligation of biofuels into the transport market.

Ethanol

Ethanol from milk by-products is a mature technology. Three New Zealand plants exist representing both batch and continuous fermentation technology. The ethanol produced in New Zealand is used as a solvent or as a beverage additive, however with the recent changes in regulations can be used up to a 10% additive to petrol as a transport fuel. As an energy source, ethanol via dairy whey products is a very efficient energy conversion route.

Biodiesel

There has been an upsurge of interest in the last three years with Meridian Energy having looked at the feasibility of producing biodiesel on the South Island, a facility in Auckland producing biodiesel from tallow, and a similar plant in Christchurch utilising used vegetable oil, both for research and quality testing purposes. There has also been recent domestic and overseas interest in investment in large scale commercial biodiesel production facilities in New Zealand.

8.3.3 Activities and Trends Over the Last Five Years

Current production of ethanol from whey, a by-product of casein manufacturing, is around 20 million litres per year (equivalent to 0.4 PJ/year) of which about half is exported. Its potential is 0.5 PJ/year in 2006/07.

Recent activities in this sector have focused on the market barriers to biofuel production. The Government has changed the regulations so that blending of ethanol with petrol can occur. There are no restrictions on blending biodiesel with diesel provided the finished blend meets existing regulations. A New Zealand Standard has been developed for biodiesel quality, although this is currently still voluntary.

Field Code Changed

Government has also been very active in trying to facilitate uptake of biofuels by working closely with the petroleum and automotive industries.

8.3.4 Opportunities

Biodiesel and bioethanol are the only currently feasible options when it comes to renewable transport fuels. With the Government target for renewable energy transport fuel of 2 PJ by 2012 this is an area where research and development should be focused.

Tallow production by the New Zealand meat industry is around 150,000t/y. After conversion to esters this equates to approximately 5.5% of the national transport diesel demand.

Production of bioethanol from whey is likely to be insignificant in terms of the New Zealand energy mix (less than 0.5% of transport energy).

Once market barriers are reduced and demand for biofuels increases it can be expected that this will provide the incentive for investigation of production of biofuel from other domestically available feedstocks and/or for biofuel imports.

8.3.5 Projected Utilisation by 2010

The Government has indicated that it is developing and introducing a biofuels sales obligation. If the obligation is introduced it is likely that the use of biofuels will be between 2 and 8 PJ or more by 2012 depending on the target set.

8.3.6 Geographic Distribution of Resource

The geographic distribution of feedstock for biofuels is currently where tallow and whey are produced. While other feedstock are available and can be grown throughout New Zealand the value of the land for other crops and the costs involved in harvesting and processing is such that it is expected to be some years before purpose grown crops for biofuel would be economic. Emerging cellulose to ethanol technology is likely to become available before crops. Also purpose grown crops not likely, but rather crops with multiple end uses, one of which may be biofuels.

Imports of biofuels are also possible.

8.3.7 Current and Projected Cost Profiles

EECA has undertaken evaluations of the current and projected cost profiles of both biodiesel and ethanol including:

- Blending ethanol into petrol - an overview
- Biodiesel from Tallow
- Costs of biodiesel production
- Feasibility of producing diesel fuels from Biomass in New Zealand.

These reports are available from the EECA website [30]. However there has been no laboratory research since the 1970s on ethanol or biodiesel production from agricultural crops.

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[30] http://www.eeca.co.nz/eeca-library/libsearch.html

Field Code Changed

8.4 Bioenergy Industry Capability

8.4.1 Industry Organisation

The bioenergy industry is organised around the Bioenergy Association of New Zealand (BANZ). The Association is set up to:

- assist industry participants to realise commercial opportunities based on the wide range of biomass resources, particularly woody biomass in the first instance,
- assist Government to develop policies which will support and encourage the implementation of bioenergy projects and to provide export business opportunities,
- advocate policy issues to local, regional and central government officials and elected representatives, as well as to regulatory bodies, industry groups and other interested organisations in order to raise the awareness of the benefits of the use of bioenergy,
- promote widespread recognition of biomass as a sustainable energy resource,
- encourage and support research activities concerning the development of bioenergy technologies, biomass utilisation and the gathering of relevant industry data and statistics and to disseminate the results as appropriate,
- facilitate synergies that link bioenergy projects with the Kyoto Protocol mechanisms and carbon trading,
- identify, evaluate and, where appropriate, promote the development of markets for liquid and gaseous biofuels for the transport sector,
- encourage further uptake of waste-to-energy processes, in particular utilising landfill gases, biogas and municipal green waste,
- support the use of biomass as a renewable source of hydrogen, and
- promote the economic, environmental and social benefits of biomass use (including employment opportunities particularly in rural communities).

The strength of the association has been based on production of bioenergy from woody biomass. This has recently been broadened to include all sources of bioenergy. Membership is also broadening to cover these other energy conversion technologies.

8.4.2 Industry Participants

Bioenergy from Woody Biomass

The industry has a wide range of participants with experience gained from many years of installation and operation of woody biomass fuelled heat plant. The competence of New Zealand consultants and equipment suppliers is such that any projects can be undertaken using New Zealand-based companies and individuals.

Scion (previously Forest Research) has a research programme covering the full value chain from tree planting, fuel collection and energy conversion. Similarly, bioenergy research is led by Massey University’s Centre for Energy Research, an internationally respected advisor on renewable energy.

There are adequate suppliers of biomass handling equipment and combustion boilers in New Zealand although with the low level of investment that has been occurring they have moved their focus more towards Australia.

Investors in bioenergy plant are principally wood processors who use the plant for their own heat production. However, while most plant is wood processor owned and operated there is some plant owned by others, e.g. Meridian Solutions, who then contract for the supply of heat.

Field Code Changed

Agricultural / Municipal Waste

There is very little work being undertaken on the use of biomass from agricultural and food processing sources as a source of energy. The Bioenergy Association includes it in its work programme but there has been little activity to date.

Transport Biofuels

The key area for transport biofuels is the introduction of biofuel blends for use by the public. The Government is developing a biofuels sales obligation. The oil and motor industries are very active in considering practical issues of introducing biofuels into the New Zealand fuel market. There are a number of private companies, both domestic and international, that have publicly announced their interest in interesting in biodiesel production in New Zealand. Biofuels are also subject to ongoing research at a number of Universities around the country.

9 Solar Energy

9.1 Solar Thermal (Water Heating)

9.1.1 Technology

Heating water from solar energy[31] is currently cost competitive relative to some retail electricity tariffs throughout New Zealand, and increased investment in solar water heating (SWH) systems is principally limited by the public's (home owners, builders, architects, and plumbers) perception of the value of the investment, the cost, access to information and product performance. The lack of marketing experience and financial capabilities of the system suppliers and installers to undertake wider promotion also limits market expansion.

Solar hot water systems available in New Zealand are modular in design and have several variants:

- Glazed flat plate collector.
- Evacuated glass tube collector.

Of these systems, there are also variations of heat flow design:

- Passive (thermosiphon). (40% of sales)
- Active (pumped flow). (60% of sales)

Flow may be either in an open or closed loop heat transfer configuration.

Glazed flat plate systems are the most common collector available, although most new entrants to the industry are offering imported evacuated glass tube collectors. Installation of unglazed collectors for swimming pools is not monitored by the industry.

Most SWH systems are available as standard package units for installation for residential applications. Systems are installed with provision for electricity or gas energy boosting during periods of low solar input. There are currently 14 different products available from suppliers of equipment that have been accredited by the trade association, the Solar Industries Association. A number of other products are available from non-Accredited Suppliers.

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[31] References SIA-2003, EHMS-2002, EHMS-2003.

Field Code Changed

The pumped system can be connected to existing hot water storage cylinders and is often installed by retrofitting onto an existing house, motel, rest-home, etc. Hot water cylinders for pumped systems can be located anywhere in or outside a building.

Either a pumped or thermosiphon system may be used when a new structure is being built or an existing hot water cylinder requires replacement.

Specific commercial or industrial applications generally involve more complex design and have so far not been widely adopted, despite technical and economic feasibility. In industrial applications solar energy will often be a pre-heater for other conventional heat plant. The solar components may be arrays of conventional domestic systems or specific designed arrays of collectors to large volume hot water tanks.

9.1.2 Current Utilisation and Emerging Developments

As at 31 December 2005 there were an assessed 28,400 SWH systems installed throughout New Zealand. This is the equivalent of 59 GWh (0.21 PJ) per annum of avoided electricity generation, and a saving of 36,600 tonnes of carbon dioxide per annum compared to using electricity to heat the water.

During 2005, 3,200 (6.7 GWh) additional systems were installed by accredited members of the SIA[32]. The majority of systems being installed are in domestic homes. However, the economics of installation in commercial/industrial/institutional applications such as motels, rest-homes, hospitals, prisons, manufacturing are now being realised and systems in excess of 100m^2 of collector area are being installed in some of these applications. In addition there are probably around another 500 systems installed each year by non-accredited SIA members and non members.

In 2003 sales of SWH systems increased by around 68% over the previous year, and in 2004 by around 55% and in 2005 by 35%. This is an overall increase of 920% (19.7 GWh pa) increase since the year 2000. This trend is expected to continue as the public becomes more familiar with SWH.

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[32] Statistics referred to in this section are collected monthly from accredited SIA members. It is assessed that there may be another 500 systems installed by others.

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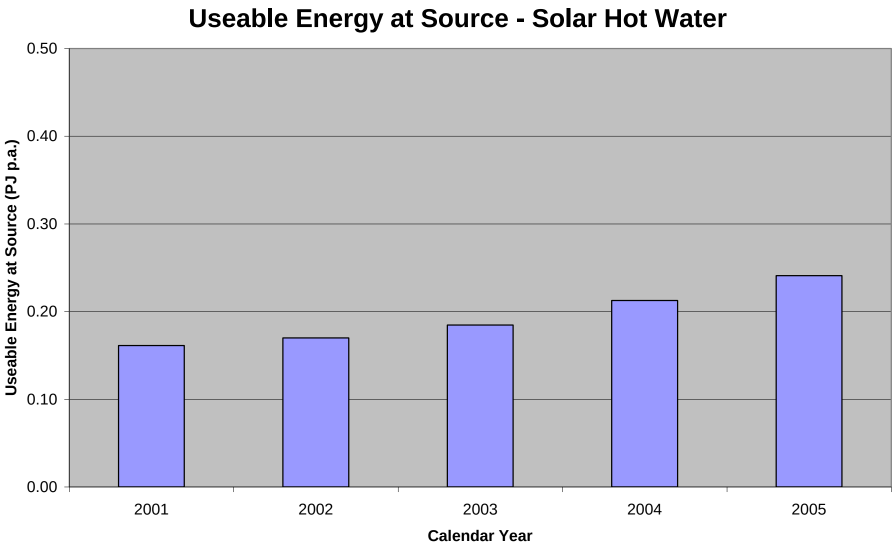

Figure 20 **Contribution of Solar Water Heating to New Zealand Useable Energy at Source.**

Source: Solar Industries Association, 2004

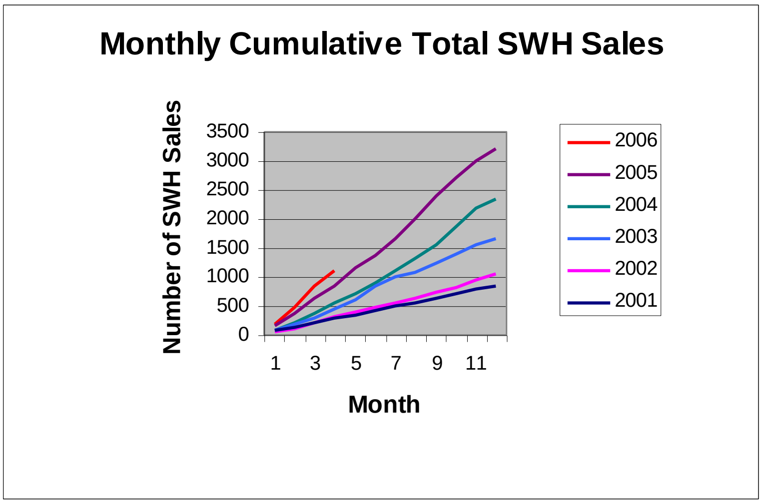

Figure 21 **Monthly Sales Of Solar Water Heating Installations.**

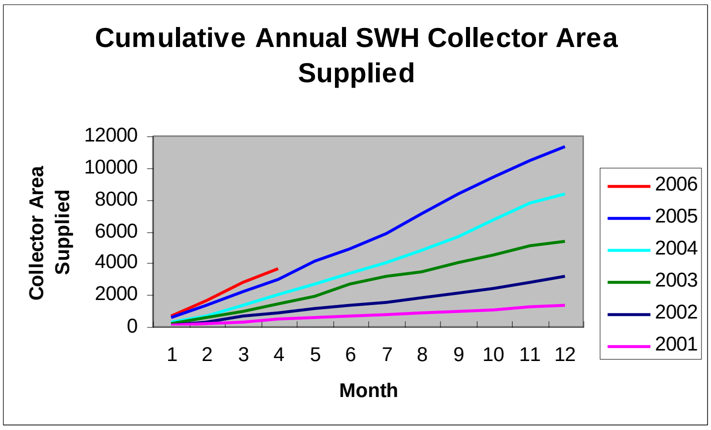

Figure 22 Annual Area of Solar Collector Area Installer.

Table 17 **Regional Distribution of SWH Installations**

	2002	2003	2004	2005
Auckland, Northland, Waikato, Bay of Plenty	58%	58%	45%	47%
Taranaki, Central NI, Hawke's Bay	21%	16%	19%	16%
Southern NI	5%	6%	9%	9%
South Island	16%	20%	27%	28%

Table 18 **Type of System Installed**

	2002	2003	2004	2005
Thermosiphon	49%	48%	40%	33%
Pumped	51%	52%	60%	67%

Since 2003 EECA has made funding available to assist with the purchase of solar water heating systems. This has been in the way of interest free or reduced-interest loans.

The increased activity in the industry has also encouraged the installation of solar water heating systems in commercial applications such as rest homes and food takeaway outlets. This has resulted in the average size of the collector area of an installation increasing as shown in Table 19.

Field Code Changed

Table 19 Average Size per System

2002	3.04 m^2
2003	3.25 m^2
2004	3.59 m^2
2005	3.50 m^2

9.1.3 Opportunities

The main immediate market for solar water heating in New Zealand is the residential mass market which will assist the industry to consolidate its capability leading to greater energy savings available from industrial and commercial building opportunities.

The solar water heating industry believes it is capable of achieving the industry's objective of installing 30,000 m^2 per year due to the following, and is working with EECA to identify how to achieve the Government's target of 500,000m^2 of collector area.

- Manufacturers/suppliers have proven reliable products.
- Manufacturers/suppliers have the capacity to meet greatly increased growth in demand.
- The economics of installing solar hot water systems are based on hedging future water heating costs at today's prices.
- Government has targeted solar water heating as a significant component of the National Energy Efficiency and Conservation Strategy Energy Supply, and Buildings and Appliances Programmes
- The Government has noted in the Speech from the Throne the objective of investigating a Home Energy Rating Scheme which includes solar water heating.
- SWH systems can be an effective investment in most parts of New Zealand.
- Members of SIA have agreed to work collectively on a market transformation programme of activities.
- The increasing cost of gas and electricity may make SWH a sound commercial decision in many residential, commercial and industrial applications,
- The Government has an opportunity through its ownership of a wide range of facilities using hot water (housing, prisons, hospitals, etc.) to provide role models at an economic cost while achieving other Government objectives.

Residential installations of solar hot water systems are expected to be 10,000 a year by the end of 2008 with the potential to ramp up to an assessed 40,000 installations a year by 2015. The equivalent electricity savings from this would amount to over 88 GWh p.a. (0.32 PJ). This would take the total installed capacity to 480 GWh p.a. (1.7 PJ) by 2015.

Potentially, the most significant energy gain from SWH would occur when systems are installed in commercial and industrial applications with the result that the quantities above could be doubled.

The Government has indicated that it will be investigating bulk purchase policies that it expects to increase the uptake of installations. Some government agencies such as the Department of Corrections have already installed a number of systems in prisons and this can be expected to continue. If other central and local government agencies increase their installation of SWH this can be expected to provide substantial expansion opportunity for the SWH industry.

Field Code Changed

The Government has also indicated that it would like to see a Home Energy Rating Scheme introduced and operational as soon as possible. If such a rating became mandatory for new homes, and used by the real estate sellers as a measure of energy efficiency of the house, this would provide a significant value to home owners and provide a significant push to the SWH industry.

9.1.4 Solar Water Heating Industry

Industry Organisation

The solar water heating industry is cohesive with all significant suppliers working within the framework agreed through the Solar Industries Association (SIA).

The SIA represents manufacturers, importers and installers of (SWH) systems.

The SIA has the objective of increasing the public perception of solar water heating as an essential component of every house and commercial buildings, and developing the market so that 10,000 solar water heaters (30,000m^2) per annum are installed by mid 2008.

There are a number of smaller suppliers and installers operating outside of the SIA.

Industry Participants

The SIA has 70 members, 16 of which are accredited suppliers supplying 14 complying products.

There are three New Zealand-based manufacturers with the remainder of accredited suppliers importing their product from overseas, mainly from Australia. Many of the accredited suppliers have been in the industry for a number of years and have an in-depth experience of SWH.

Those SIA members who are not accredited are generally installers or small suppliers who are in the process of developing their business.

There are 260 Approved Installers with most being dedicated agents/distributors for the longer established suppliers. Expansion of the industry has until recently been constrained by the lack of availability of experienced installers. The increased activity and potential for an increased number of installations is however encouraging more plumbers to see SWH as a business opportunity. The priority is now to increase their experience so that they can handle the increased number of installations, but more significantly ensure that quality installations occur.

There are few independent designers/consultants who have experience in SWH.

9.1.5 Industry Capacity

The number of systems that can be supplied by either importers/suppliers or local manufacturers is adequate to match demand at present. All suppliers are small businesses with limited staff and financial resources to undertake the promotion and market development necessary.

The SIA has established criteria and procedures for establishing complying products, and accreditation of SWH suppliers and designers for installation and design.

The Waikato Institute of Technology introduced in February 2005 courses for SWH Installation and SWH Installation Management. Courses are run approximately every month with part by distance learning and part a weekend hands-on practical workshop.

SIA has facilitated the SWH industry establishing a “Code of Practice for the Manufacture and Installation of SWH in New Zealand”. The Code of Practice covers product manufacture and installation and is essentially a good practice guide. The industry and EECA are also active on the joint

Field Code Changed

Australian/New Zealand standards committee responsible for solar water heating technical standards. The continual revision of AS/NZ 2712 and the hot water installation standards AS/NZS3500.4 have resulted in a standards based quality system applying to all systems installed. The industry is currently commencing to work with Council Building Inspectors to improve processing of building consents and reduction in consent costs. The Department of Building and Housing is funding the writing of an Acceptable Solution to the Approved Document G12 of the Building Code.

The New Zealand and Australian solar water heating industries work closely together through the standards committee.

The Standards Committee is working to make the standard AS 4234 for the calculation of the energy performance of SWH systems a joint standard.

A Nelson based testing laboratory, Applied Research Services is setting up a facility for testing systems to the standard AS/NZS 2712.

The New Zealand Master Plumbers, Gasfitters and Drainlayers Association have set up a SWH special interest group for plumber members who wish to specialise in SWH installation.

Building Research and EECA are jointly funding the monitoring of actual performance of installations on a range of houses in each of Dunedin, Christchurch, Wellington and Auckland.

The Department of Energy Studies at the University of Otago are undertaking a Foundation for Research Science and Technology funded project into the comparative performance of SWH systems in Dunedin. The University wants to establish this as an on-going SWH research programme.

9.1.6 Current and Projected Cost Profiles

In a residential application hot water can be delivered at around 15-17 c/kWh, in a large commercial / industrial application around 13-15 c/kWh.

Over the last few years and despite an increased number of installations happening each year costs have increased. This is assessed to be because of the increased standards expected and the need for Building Consents. The cost of installation has also become a big cost component particularly for retrofit installations as plumbing costs have increased because of the shortage of plumbers.

Product prices have been under pressure because of the very competitive market with 14 complying product and a large number of fringe sellers importing cheap units particularly from China.

Many of the new entrants now entering the market not only have different products but have different retail structures with the result that traditional plumber / agent networks are having to become more market focused. The suppliers who have responded to the necessity of establishing effective sales and installation networks have remained dominant in the market.

The product has a potential for cost reduction in the near future due to increased efficiency of installation and economies of scale leading to price reductions based on substantial market expansion. Currently, market initiatives are focused on creating a market. With an expanded market solar system suppliers would be undertaking promotion within a market with consequential cost effectiveness of promotion expenditure. Based on overseas trends it has been assessed that with a larger market costs could drop around 20% within ten years.

Field Code Changed

9.2 Solar Electric (Photovoltaic)

9.2.1 Technology

Direct solar to electricity conversion can be carried out with photovoltaic cells. These are usually solid-state semiconductors that generate an electrical potential when exposed to light. There are a number of different cell production techniques, with differing performance resulting. Only a small number of cell designs have reached industrial production, however this is one of the fastest developing technologies and over the period to 2012 it can be expected that a number of new designs will eventuate.

Photovoltaic cells are made from a variety of semiconducting materials either in:

- single crystal form (silicon, gallium arsenide (GaAs), indium phosphide),
- multicrystalline and polycrystalline form (silicon, cadmium telluride (CdTe), copper indium gallium diselenide (CIGS)), or
- amorphous form (silicon, silicon-germanium alloys).

About 60% of current production is based on single crystal flat plate technology, 25% on polycrystalline silicon technology, and 11% on amorphous silicon technology.

Most industrially produced cells are silicon with efficiencies of around 15% (versus lab efficiencies of up to 24.5%). However, Sunpower Corp has recently built a high-volume manufacturing plant producing commercial solar cells with 21.5% efficiency.

PV has been commercialised in small-scale niche applications since the 1970s. First trials of MW-sized utility systems were installed in the 1980s. Several countries have large-scale MW-sized demonstration/commercial plants, but the bulk of capacity is still at the domestic and commercial system size, with an increasing proportion being grid-connected.

Solar technologies are easily integrated into new or existing buildings, they can be unobtrusive, can enhance the aesthetics and architectural appeal of buildings, and can be considered a positive asset due to their green image.

Systems are reliable such that PV modules generally carry a manufacturer’s guarantee of 20 to 25 years to 80% or better of nameplate output.

Several laboratory technologies are currently being transferred to industry (e.g. laser grooved buried contact patterning, single crystal silicon, production of large thin films) with consequent efficiency gains or reduced cost due to less material and lower production costs.

It is likely that PV technology will continue to enjoy spin-off benefits from developments in the microelectronic industries generally. The current worldwide investment in new materials and devices by these industries is very large and technological breakthroughs applicable to PV systems are likely.

9.2.2 Current Utilisation

The Photovoltaic Association has recently undertaken a survey of the number of installed PV systems in New Zealand. They advise that there is an estimated 1 MWp of installed PV capacity in general use in New Zealand as at December 2004. In addition there is about 400 kWp of capacity on BP petrol station canopies. Thus, a rough estimate of total installed PV in New Zealand at 31 December 2004 is 1.4 MWp. This is up from 0.75 MWp in 2001.

An estimate of energy output is that as at December 2004, 2.5 GWh (0.01 PJ) of electricity is generated by PV in New Zealand annually. There is no breakdown of the split between grid-connected and off-grid installations.

9.2.3 Activities and Trends Over Last Five Years

While no information is available as yet for any change in the number of installations that has occurred over the last four years, the NZPVA advises that the current growth rate in installed capacity is about 35% annually. The majority of installations are for off-grid applications.

A trend in the PV industry worldwide has been the involvement of major petroleum companies (Shell, BP) and other large companies (GE Energy, Sharp, Sanyo) in the ownership, direct production and promotion of solar energy, especially PV electricity production. This has seen recent company amalgamations, and the establishment of larger-scale PV production plants (10 to 100 MWp/year) in Australia, Europe and the USA which may realise substantial economies of scale. These large plants have been developed as a result of an international increase in demand in the near-term estimated in the range 30 to 45% per year for an indefinite period. There are packaged PV and PV/diesel hybrid systems, grid-connected and stand alone, in the kW load range available from a number of Australian and New Zealand suppliers.

The international PV industry appears to have reached a critical level of economies of scale such that large-scale manufacture is leading to associated price reduction. This in turn is boosting demand. This international trend is starting to occur in New Zealand for off-grid applications.

The New Zealand oil companies Shell and BP, and more recently Canon, have published their intention to import and supply PV modules and systems in New Zealand. BP already has PV systems installed on 11 petrol service stations throughout New Zealand.

9.2.4 Expected Growth Trend

Solar energy can currently be converted into electricity at a cost suitable for small niche uses and is already well established in stand alone off-grid applications in remote areas throughout New Zealand. Overseas PV has experienced growth in the presence of financial and legislative incentives (e.g. Germany, Japan, Australia and most of the States in the US). The economics currently make PV much less attractive for grid-connected applications where sale of electricity is an objective.

However, the technology is rapidly advancing and an increasing proportion will be taken up for other applications over the next two decades.

PV power systems are versatile as to their size and power output, from microwatts for calculators to megawatts and larger for central grid-connected power stations. System availability should be quite high (85-95%) and maintenance needs will be modest.

Uptake of PV on the international scene has been on an exponential basis, with similar trends evident domestically. New Zealand's uptake will be assisted by the expanding international sales forcing down prices generally. However, New Zealand's uptake path may be somewhat different because of the following:

- Daily load curves. New Zealand's electricity peaks are early morning and evening when solar contribution is minimal, the exception being greater Auckland, while places such as Australia and California have strong air-conditioning loads timed during the day when solar can relieve the peaks. (In the Auckland area PV could contribute over time to a reduction of peak energy demand to a small degree.)
- Current low price of retail electricity. This sets the target for grid-connected PV lower than other countries. This does not apply off-grid.

- Increasing concerns about the continuity of grid electricity supply has resulted in an increase in uptake in PV systems, with battery facility, being installed for the “insurance value”.
- Solar Global Energy levels. New Zealand receives 1300-1500 kWh/m^2/year of solar global energy, while parts of the USA (such as California - a major region of PV uptake) works on 1800-2300 kWh/m^2/year. The low insolation values compared to the USA reduce the system capacity factor reducing the number of kWh over which the capital investment can be spread. On the other hand New Zealand generally has higher insolation levels than many parts of Europe where substantial PV is being installed.
- Absence of a PV manufacturing base. New Zealand does not have a PV manufacturing base, so has no need to provide a nurturing ground for its development over and above other renewables. If a proposal to install a high-grade silicon plant proceeds, this situation may change. The US, to encourage its industry, has a *Million Solar Roof Initiative* which aims for one million roofs with solar panels by 2010. Other manufacturing countries have government-based incentive packages.

PV is expected to follow the technology development trend already demonstrated by wind turbine costs where costs have reduced significantly each year as demand has increased and results of research and development have been transferred to commercial application. With such large potential cost changes it is very difficult to predict future electricity production costs.

By 2015, the unit cost (without tax) is expected to be in the 35-50c/kWh range for on-grid PV and more for off-grid applications involving inverters and batteries. While this would appear to be excessive, a large number of farmers and other potential users will be favourably comparing this price with that of diesel generation or the need for further network connection. Any upward movement in retail electricity price will increase benefits and may see an increased uptake of opportunities.

9.2.5 Opportunities

PV is the energy source of choice for off-grid signage lighting, isolated navigation lights, telecom sites and remote area applications where reliability and low maintenance are of the utmost importance.

The main applications can be divided into four broad sectors (including two distinct types of grid-connected systems).

Consumer Products

These (after space applications) were the first commercial applications of PV, e.g. calculators, watches, toys. They also included individual power supplies (caravans, mobile homes, boats) and individual supplies for novelty products (home security, garden lighting, car sunroofs, fans and battery chargers).

Industry Applications

PV systems can be sold to a service industry, especially “professional systems” provided by companies active in the communication industry and the cathodic protection industry. New Zealand’s electric fence industry is a substantial and good example.

Standalone Power System (SAPS) Applications

These are applications in the watts to kilowatt size range located at sites remote from the main distribution grid. This will be a pivotal growth area in a number of areas throughout New Zealand for applications like water pumping, water treatment, and communications links.

The Department of Conservation and various tourist lodges have installed PV systems to provide reliable electricity.

Grid-Connected Distributed Supply System Applications

These systems are simpler than SAPS as they require only PV panels and inverter to provide AC voltage and connect to the local distribution grid. The main electricity supply acts as a storage facility, receiving electricity at times of PV surplus and supplying it at times of PV deficiency, hence there is no need for a battery system. The level of battery storage and cost is dependent upon the application. Telecommunications installations require high reliability and redundancy, with batteries contributing up to 50% of the capital cost, while in other less critical applications batteries may contribute up to 35% of the project’s capital requirement. The corresponding change in cost per kWh is directly proportional to the change in capital cost of the project, assuming negligible cost for battery maintenance and inverter/battery inspection. Agreements and standards for electricity transfer in both directions on and off the site are usually required. These systems provide electricity at the consumer end of the distribution chain and compete with the retail price of electricity.

The Government is establishing a regulatory regime to facilitate the connection of small systems like PV to allow for export of electricity to the local network.

Grid-Connected Power Plant Applications

These have been trialled overseas to a size of >1 MW. These include both full-scale central PV stations feeding power to the distribution grid, and embedded generation PV systems used to correct either overloads or degraded power quality at critical points (thus deferring substantial capital and maintenance expenditures on transformers, lines, etc.) A very successful illustration of this embedded application is found in the Kalbarri 20 kW PV system in Western Australia. (These applications include utility-scale, flat-plate thin film PV and concentrating reflectors.)

New Zealand has the opportunity to develop the infrastructure and the technical and commercial capacity to capitalise on the many opportunities that are being created as the PV industry grows worldwide. Specific opportunities include:

- development of cost-effective procedures for production of high purity silicon in New Zealand
- innovation in traditional areas of the industry including interface electronics and other systems such as inverters, wiring and installation technologies
- development of integrated grid-connected embedded/distributed generation services to support rural electricity networks, and

To maintain the present growth rate of the worldwide PV industry requires massive scale-up of present PV cell and module manufacturing and associated facilities. Major energy companies which are already involved in the New Zealand energy market (e.g., BP and Shell) are vigorously promoting and developing PV production facilities internationally. Such developments are already creating new opportunities for innovative countries and enterprises in core and a variety of ancillary industries.

New Zealand is strategically located in the Asia/Pacific region and has close trading ties with Australia, the South Pacific and much of Asia. New Zealand is thus well placed to export products and services for PV into these markets if its PV industry can become established quickly enough. In reality Australia and other countries in the region with more extensive and already developed supplier networks are likely to capture this market.

Given the costs associated with supplying renewable electricity from a PV source and the lack of strong drivers in the short to medium term for other than niche off-grid installations, PV will make little contribution to meeting the 30 PJ Renewable Energy Target. However with the expected significant decrease in capital costs, and an increase in uptake for other applications post 2012, it is expected that PV will become a more common source of energy. It is also expected to become more common after 2013 in remote areas when the network companies do not have to maintain their remote lines.

9.2.6 Solar Photovoltaic Industry

The photovoltaic industry has organised itself under the New Zealand Photovoltaic Association (NZPVA). The Association currently has approximately 60 members of whom 40 are supplier/installers. The remainder are individuals or companies interested in the promotion of PV systems.

The PV industry in New Zealand comprises mainly distributors of imported modules and a network of equipment installers. Inverters, battery chargers and ancillary equipment are made locally. There is no PV cell or panel manufacturing capability in New Zealand, but should the development of a silicon metals refinery in Southland eventuate there may be the opportunity to supply a worldwide market with feedstock and eventually establish a manufacturing facility nearby.

The small size of the NZ PV industry limits its ability to undertake additional promotion of PV. The Association relies on voluntary input from members as it is under-resourced with respect to significant employment of executive staff who can undertake positive proactive action. EECA funds some of the executive and some of the promotion, standards and training work that the Association does.

Research into aspects of the photovoltaic industry is undertaken by Industrial Research Ltd (IRL) and some New Zealand universities.

Industrial Research Ltd
IRL has an extensive research programme into distributed energy systems. The work specifically considers integration of PV with other energy sources, technology aspects, and economic drivers.

Otago University
The Otago Energy Studies Programme undertakes research into the potential for use of renewable energy (including PV) for household applications in remote Pacific islands. This research has included Fiji and Papua New Guinea.

Massey University
The Massey University Nanomaterials Research Centre (NRC) is a member of the MacDiarmid Centre of Advanced Materials and Nanotechnology Centre of Research Excellence. The NRC researches the development and use of materials to inter alia improve the electrical conductivity of materials used and hence the efficiency of, PV modules.

9.2.7 Current and Projected Cost Profiles

Current costs of on-grid generation of electricity from PV are estimated to be around 100 to 120c/kWh (80 to 95c/kWh excluding tax), and it is estimated that they will reduce but remain high for the foreseeable future (Table 20). At 5% WACC they will be competitive with diesel generation by 2025. These costs are for electricity generation at source and do not include allowance for avoided costs such as electricity lines which would otherwise be needed if the energy was supplied from a grid connection.

In an off-grid application the cost could be increased by around 15% to 35% depending on the need for electricity storage.

Private use of non-commercial applications would generally not be for a taxable application so would be costed excluding tax.

The value of photovoltaic installations may be much higher than just the cost of the equipment and installation if it avoids a significantly more costly alternative cost such as installation of a transmission line, or other form of electricity source such as batteries or on-site diesel generator. In an on-grid application PV-generated electricity may allow a reduction in the quantity of electricity imported to a site

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and thus a reduction in the variable cost of electricity otherwise purchased. The value of PV can only be calculated when the alternative options are known.

Current projections of the cost of generating electricity from medium PV arrays (10 kWp) are given in Table 20, while Table 21 gives current predictions for off-grid medium PV array (10 kWp). The estimated costs (including tax) are given also at the 5% WACC as this is considered to represent the investment criteria for domestic investors. Table 21 electricity costs include the premium for storage required for an off-grid application.

Table 20 Cost Supply Medium-Sized, On-Grid (Unit Costs c/kWh).

	Year 2015 c/kWh		**Year 2025 c/kWh**	
	WACC=5%	**WACC=10%**	**WACC=5%**	**WACC=10%**
Insolation Value =1,300 kWh/m^2/y	40	60	35	50
Insolation Value =1,500 kWh/m^2/y	35	50	30	40

Analysis was based on a 15% increase in insolation value due to favourable panel orientation

Table 21 Cost Supply Medium-Sized, Off-Grid (Unit Costs c/kWh).

	Year 2015 c/kWh		**Year 2025 c/kWh**	
	WACC=5%	**WACC=10%**	**WACC=5%**	**WACC=10%**
Insolation Value =1,300 kWh/m^2/y	45	70	40	55
Insolation Value =1,500 kWh/m^2/y	40	60	35	50

9.3 Solar Space Heating (Passive Solar Design)

9.3.1 Technology

Passive solar design (PSD) can markedly reduce energy use in buildings. It entails careful consideration of the site, building placement and orientation, and building design features so that maximum solar energy is captured, stored and released in the building. Passive solar design typically offsets energy purchased for space heating and cooling, lighting and ventilation. In addition, research suggests that PSD buildings are more pleasant to occupy.

Solar space heating involves the collection, storage, distribution of thermal energy to provide warmth to the inside of buildings. Good passive solar design also includes making maximum use of natural light.

The application of passive solar design principles will result in significant improvements in comfort as well as energy savings. The principles can be applied to new buildings and to a lesser extent to renovations.

The benefits of passive solar design can often be obtained with little (or no) additional cost; however, effective application of these principles does require attention to details of design and construction.

Solar combisystems are solar heating installations providing space heating as well as domestic hot water for the inhabitants of the building.

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9.3.2 Current Utilisation

It is difficult to quantify the energy saving benefits achievable as the savings are created as an integral part of the building design.

9.3.3 Activities and Trends Over Last Four Years

The building industry has a number of projects underway that contribute to improved inclusion of solar energy collection and distribution in buildings. These include:

Building Research Association of New Zealand (BRANZ)

- Household Energy End-Use project (HEEP) – research project to obtain information on actual energy use in New Zealand houses.
- Zero And Low Energy House project – research project to evaluate suitable energy saving technologies that will lead towards zero energy houses.
- ALF – Annual Loss Factor software is an aid to the thermal design of houses.

Cement and Concrete Association (CCA)

- Cement and Concrete Association and EECA have sponsored publications on Designing Comfortable Homes.

Universities

- University Architecture Schools each have significant solar design components in their teaching programmes.
- Victoria University hosts the IEA Solar, Heating and Cooling programme website.
- Victoria University is the New Zealand representative on the IEA Solar, Heating and Cooling programme. Some of the IEA programme tasks include:
    - Task 23 - Optimization of Solar Energy Use in Large Buildings (Finished)
    - Task 22 - Analyzing Solar And Low-Energy Buildings (Finished)
    - Task 24 - Active Solar Procurement
    - Task 26 - Solar Combisystems
    - Task 27 - Performance of solar façade components
    - Task 28 - Sustainable solar housing
    - Task 31 - Daylighting buildings in the 21st Century

Sustainable demonstration homes

- Demonstration homes continue to be constructed and marketed locally. These each provide a strong focus on the use of passive solar energy but do not seem to contribute to a national picture of solar acceptability.

- The NOW Home is a collaborative, live research project undertaken by Beacon Pathway Ltd. Beacon is a research consortium committed to improving the sustainability of New Zealand's residential built environment. Beacon's shareholders are Scion, Building Research, Fletcher Building, NZ Steel and Waitakere City Council. Shareholder contributions are matched, dollar for dollar, by funding from the Foundation for Research, Science and Technology. Through the design, construction and monitoring of the NOW Home Beacon is testing ways to achieve affordable, desirable, and environmentally sustainable homes for all New Zealanders. Designed to meet future needs, the NOW Home uses materials and technology available now. The NOW Home is located at Olympic Place, New Lynn, Auckland

- Despite education of architects in PSD over the last few decades, very few buildings are constructed to PSD principles today. There are thought to be many reasons for this including (but not limited to): the building industry is comfortable with traditional forms of construction; the

> Building industry has limited expertise of PSD; agents in the construction of commercial buildings face particular drivers that do not support PSD (e.g. incentive structures, penalty payments); residential construction is not generally designed by skilled PSD practitioners (e.g. architects design only around 5% of new houses); and consumer demand for PSD has traditionally been very low.

Territorial council policies
Councils such as Waitakere City have introduced policies and promotion activities that have a strong focus on passive solar energy in buildings.

9.3.4 Expected Growth Trend

There is a growing awareness of the value of considering passive solar energy when designing buildings but the actual growth in the contribution of passive solar energy to heating and lighting in buildings is difficult to quantify.

The Building Code is currently being reviewed to respond to the expanded purposes and principles of the new Building Act 2004. The Act requires consideration of "the need to facilitate the efficient use of energy and energy conservation and the use of renewable sources of energy in buildings". Specific project are expected to include work to improve the efficiency of the building envelop (i.e. insulation levels and double glazing), water heating and space heating.

Introduction of a Home Energy Rating Scheme (HERS) as proposed by the Government would provide a significant incentive for new home builders to put more attention to the incorporation of solar energy capture into building design.

9.3.5 Opportunities

The promotion of solar space heating and the demonstration of suitable examples of designs and technologies can have a significant influence on uptake.

9.3.6 Solar Space Heating and Lighting Industry

Solar space heating and lighting are major consideration for architects. However the biggest breakthrough is likely to be with "spec" building companies and builders (and designers somewhat) who draw up most housing designs. The industry generally needs to upskill on passive solar design and consumer demand would then drive things along.

9.3.7 Current and Projected Cost Profiles

The value of having good passive design in a building can be intangibly recognised in the building resale value. Other benefits include reduced moisture and condensation, improved sound insulation and building interiors that are naturally for longer within the range of comfort temperatures without the need for external heating or cooling.

9.4 Geographic Distribution of Resource

Solar energy is distributed throughout New Zealand as shown in figure 23. Figure 24 shows how the solar energy distribution changes throughout the year for some representative locations.

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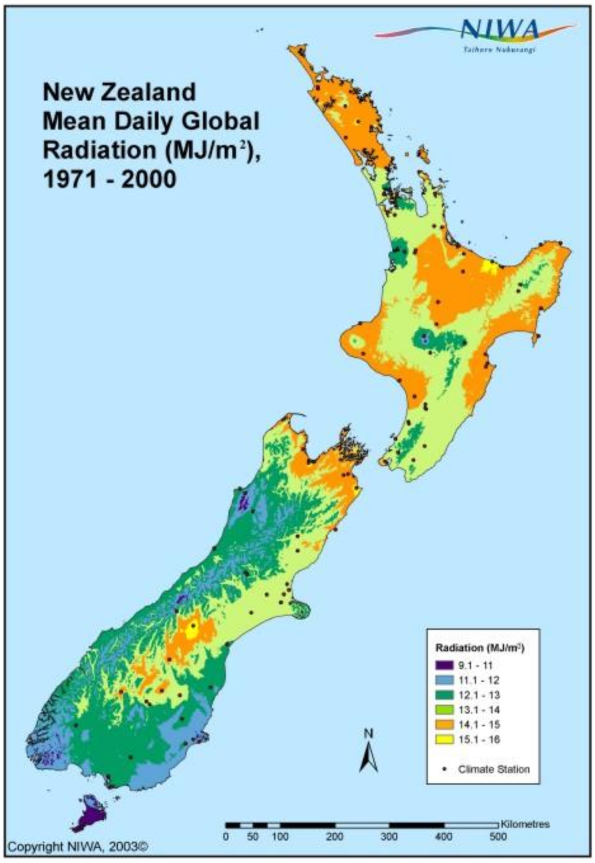

Figure 23: Solar Radiance in New Zealand

This map of mean daily solar radiation for New Zealand is based on an interpolation of climate station data collected during the period 1971–2000. Contact NIWA's National Climate Centre for more information. NIWA makes no representations or warranties regarding the accuracy of the information shown on this map, the use to which the map may be put, or the results to be obtained from the use of the map.

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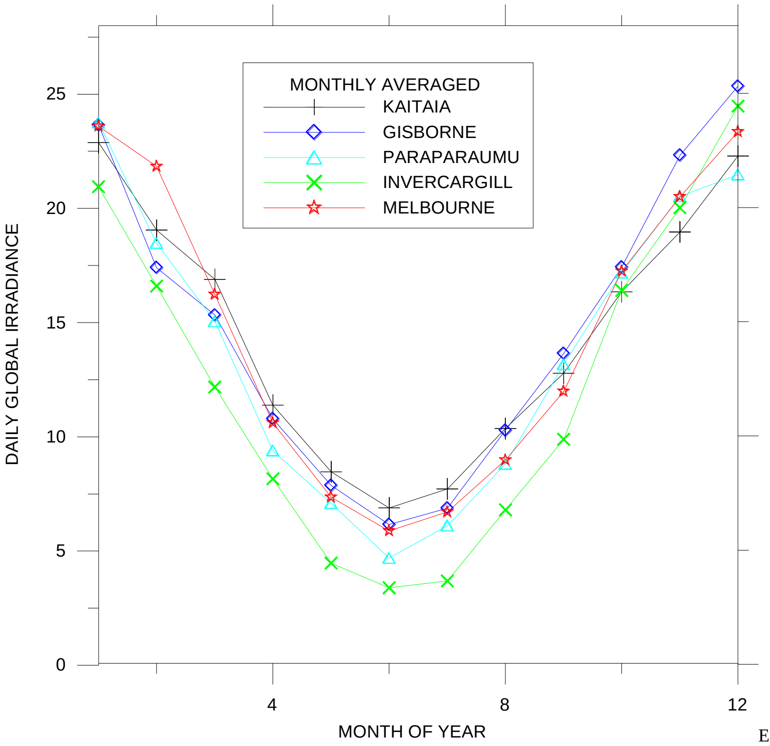

EECA 2001s

Figure 24 Solar Radiance in New Zealand

10 Marine Energy

10.1 Introduction

New Zealand is surrounded by ocean and our coastal environment has world-class wave energy and a useful tidal energy resource. Internationally, significant research and development efforts are underway to devise technologies to extract energy from waves and tides. Such technologies could play a significant part in New Zealand's future energy supply portfolio.

10.2 Wave Energy Converter Technology

10.2.1 Device distance from shore

The physical size of a device determines the depths that are required for siting .Each opportunity should be used to take advantage of areas of intensified wave energy ("hotspots" section 2.1.2), thus reducing the distance a device is required to be from shore.

Shoreline

Until recently shoreline devices were the most developed of wave energy converter technologies. The LIMPET device on the island of Islay and the Pico Plant in the Azores were the most publicised.

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Shoreline devices require extensive civil works and create coastal armament similar to a breakwater. Once a device is constructed expansion of capacity requires duplicating the armaments and civil works. It remains to be seen if such structures on the foreshore will be acceptable to New Zealanders. Devices could be incorporated into new or retrofitting into existing breakwaters.

Shallow water (<50m)

A wave that has a wavelength (crest to crest) of 100 metres is typical of New Zealand conditions. The energy of this wave will descend to a depth of 50 metres. If the depth of the water is less than 50 metres, this energy will interact with the sea bed transforming the speed and shape of the wave and reducing the wave's energy. Therefore wavelength determines the boundary between deep and shallow water (100 metre wavelength results in a boundary at 50 metres depth).

In travelling from deep water to the shoreline waves lose nearly all of their energy – only a small amount is reflected back out to sea. Processes that can affect a wave as it propagates from deep into shallow water include:

- shoaling, refraction, and diffraction;
- dissipation due to friction and percolation;
- breaking;
- additional growth due to the wind;
- wave-current interaction; and
- wave-wave interactions.

Complex bathymetry complicates these transformations and may result in wave energy focusing at some locations (Figure 1). Locations of intensified wave energy are referred to as "hotspots", and may be useful for locating wave energy converter devices in future. Eventually all energy (apart from a very small amount that is reflected) is dissipated completely over the often relatively short distance from approximately 50 metres depth, to dry land.

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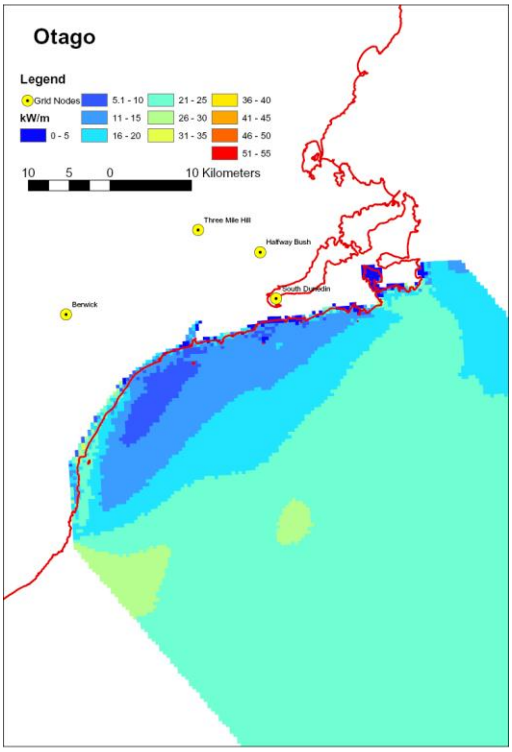

Figure 25. Hotspot map for Otago shows hotspots of wave energy close to shore in the north and south. **(Frazerhurst 2005, Courtesy of ASR Ltd)**

Devices requiring shallow water often do so because of their mooring systems, and may require a solid reference to the seabed. Devices that are able to operate at these depths are able to take advantage of seabed topography intensifying wave energy in the form of hotspots. However if no hotspot wave focusing is occurring, then the wave energy in shallow water will be significantly reduced due to friction.

Deep water (>50m)

Deep water waves do not interact with the sea bed and thus dos not suffer the potential energy losses of shallow water. The distance to deep water from shore varies significantly in New Zealand and may require significant submarine cabling with subsequent electricity losses. The physical superstructure of some devices means that deep water is the only location that can be utilised. Some devices can operate in deep and shallow water through the use of differing mooring systems. This adaptability allows device location to be optimised.

10.2.2 Power Take Off

There are a wide range of solutions to the problem of harnessing energy from passing or breaking waves. The majority of wave energy devices seek to absorb some of the energy from waves, whilst being robust enough to resist the destructive power of the waves.

About 35 alternative wave device designs have been proposed and a smaller number of these have been built. These devices seek to extract energy using a limited number of different general power take-off methods. The following examples are actively being developed at present and demonstrate the current range of different power take off methods. The details of individual devices are complex.

Resistance

Resistance power takeoff is the application of resisting forces to the wave induced articulation, rotation, or oscillation of masses. The resisting forces are either magnetic in the form of rotational or linear generators, or hydraulic rams pressurising a fluid to drive a turbine. Devices that utilise this power take off are.

- Pelamis - through the use of resistance hydraulics to the articulation of its joints as it spans wavelengths.
- The Archimedes Wave Swing (AWS) - through the use of a linear generator to magnetically resist the oscillation induced by buoyancy forces
- The Aquabuoy - through the use of a novel “hose pump” to resist the oscillation of its buoyancy relative to a damper plate.
- INRI Sea Dog - through the use of pumping mechanisms resisting the oscillations of heaving floats.

Oscillating Water Column (OWC)

The basic principle is that the device traps air in a fixed volume chamber, into which waves rise and fall. With each rising wave, air is expelled through a port in the chamber and the passing air turns a turbine. As the wave recedes, air is sucked back into the chamber and, with the correct turbine configuration, the turbine continues to rotate. Energy is thus extracted from both the rising and falling wave. The chamber cannot oscillate and therefore is either fixed to the seabed or is of such a large mass that its resonance is different from the oscillation the waves, moving air across the turbine.

Examples of OWC power take of devices in development are:

- Energetech - Port Kembla Wave Energy Converter;
- WaveGen LIMPET ; and
- OreCon MRC1000;

Overtopping

Overtopping power take-off systems use the wave motion to elevate water (overtopping) then extract energy from the gravitational potential of the water descending through low head (Kaplan) hydro turbines. Like OWC devices overtopping device are also often fixed to the sea bed or of such mass that their resonance is different from the oscillation of the overtopping waves. An example of an overtopping power take off device in development is the Wave Dragon

10.2.3 Wave energy commercial development

After a period of inactivity in the 1980s, interest in wave energy devices has been re-awakened with devices being developed to full-scale prototype level. Globally research and development has resumed. Full scale pre-commercial devices have been developed for the;

- Ocean Power Delivery Pelamis;
- Energetech OWC device;

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- WaveGen LIMPET;
- The Archimedes Wave Swing ; and
- Wave Dragon

Other devices are approaching this level of development including

- AquaEnergy Aquabuoy;
- INRI Sea Dog;
- OreCon MRC1000 ; and
- WaveBob.

The industry is evolving towards commercial viability. The first commercial wave farm to be built, 5 km off Portugal's northern coast, near to Póvoa de Varzim was announced in May 2005. The initial 2.25 MW wave farm will consist of three 750 kW Pelamis devices, the first of which has been delivered. A letter of intent has also been issued to order a further thirty Pelamis machines (20 MW) before the end of 2006, subject to satisfactory performance in the initial phase.

Systems-level designs have also be made by the Electric Power Research Institute (EPRI) for a 1,500 MWh demonstration plant and a 300,000 MWh wave farm for the states of Hawaii, California, Oregon, Washington, Massachusetts and Maine. The Pelamis device was chosen for each of these studies as it was determined to be the most developed device for this project. Comparison of the expected outputs for these proposed wave farms with comparable wind farms has shown the wave farms to have a potentially lower cost of electricity. The Energetech OWC device was also evaluated for California and also proved to have significant potential.

In New Zealand two projects are in development. A consortium of IRL, NIWA and energy consultancy Power Projects Limited to developing a prototype wave energy device. Power Generation Projects is attempting to develop a Pelamis wave farm for New Zealand.

The predictability of the wave resource also provides a significant advantage over less predictable renewable energy resources such as wind and solar energy resources.

It seems likely that there will be commercial wave farms in the next few years. It is difficult to assess at this time when wave farms might become a reality for New Zealand.

10.3 Wave Resource

Energy is transferred from the sun which in part creates climatic conditions in the atmosphere with concentrated areas of high winds (storms). When passing over the ocean, these storm systems interact with the ocean surface. Wind moving across a smooth sea surface will produce ripples; a persistent wind will produce waves. The longer and harder the wind blows, the greater the height of the waves, until a dynamic equilibrium of height is met. Waves then propagate across the ocean away from the areas of generation. Only a small amount of wave energy is expelled through several processes in deep water and then in shallow water through frictional contact with the seabed. Any remaining energy is finally exchanged through the act of waves breaking in the nearshore.

10.3.1 Global

Ocean locations that often have storm events will produce waves on adjacent coastlines. Waves can travel vast distances with little energy loss so the nearest coastline may be many thousands of kilometres away. There are seasonal variations of storm events (less in summer, more in winter) and hence there are seasonal variations of wave climate. These seasonal variations are more pronounced in the Northern Hemisphere's oceans than the Southern hemisphere. The Southern Ocean with its year long westward

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procession of low pressure systems contrasts with the Northern Pacific and Atlantic Ocean, where storms encounter the seasonally variable thermal inertia of the land masses of Eurasia and North America (Figure 2).

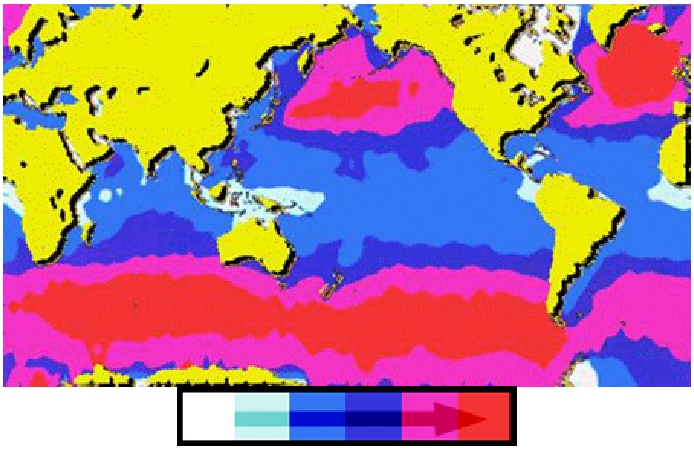

Figure 26.Global wave energy average

(Source: The Renewable Energy Information Network)

10.3.2 New Zealand

New Zealand has a large wave energy resource with waves generated by the winds of the "Southern Ocean" hitting the western and southern coasts of the main islands (Figure 3) Average wave power can exceed 55 kilowatts per metre of wavefront arriving on southwest-facing coasts. The wave energy of Southern Ocean can clearly be seen in Figure 2 encircling the globe.

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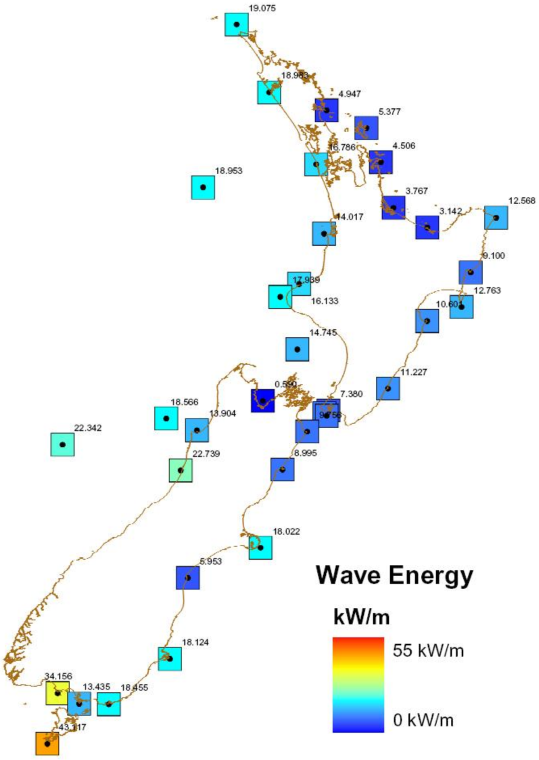

Figure 27. New Zealand wave energy averages

(Source Frazerhurst, data courtesy of NIWA)

The predictability of the wave resource emanating from the Southern Ocean is such that a potential output of a wave farm could be known with a high degree of certainty two days out from their arrival at a wave device, and their conversion to electricity.

10.4 Tidal Technology

Tidal energy devices seek to harness potential energy generated by either the rising or falling of the tides or the kinetic energy derived from the movement of the tides. Devices for utilizing both potential and kinetic energy from tides have been developed.

10.4.1 Tidal Range

Capturing the energy from rising and falling tides requires passive devices which trap water as the tide levels change. There are two principal passive devices: tidal barrages and tidal impoundments.

Tidal Barrages

Tidal barrages are the simplest of tidal energy devices. A barrage comprises a series of gates, which are open during the flood tide and close at high water. During the ebb, the water is then allowed to flow out from the barrage across a series of turbines, which generate electricity. The best existing example is the La Rance River barrage near St. Malo in northern France. This 13-metre high barrage has a capacity of

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240 MW and generates electricity on both the flood and ebb tides. Other smaller tidal barrages are in operation in the Bay of Fundy in eastern Canada, and have been proposed for northern Western Australia.

The low tidal range in New Zealand (2 - 3 m) is too small to make tidal barrages an attractive option. Whilst barrages are expensive to build, they are cheap to operate, as there are no fuel costs and relatively little maintenance. There may be problems with silting behind the barrage, which has to be periodically cleared. Also, such barrages may interrupt the movements of migratory fish.

Tidal Impoundments

Tidal impoundments are structures which entrap rising tidal waters, restrict their exit during ebb tides and use the differential hydraulic head created to generate electricity. These impoundments require relatively flat shallow water coastlines with reasonable tidal heads so they may have limited applications in New Zealand. A tidal impoundment scheme has been proposed off the coast of North Wales but has yet to be built.

10.4.2 Tidal Currents

There are a number of devices, in various stages of development, which seek to harness the kinetic energy in tidal currents. These devices operate in similar ways to the now-familiar wind turbines. However, the energy density in moving seawater is much higher than in moving air (approximately 600 times), so tidal energy devices must be more robust than wind turbines but do not need to be so large. Devices can be classified according to whether they harness power by using a turbine that rotates around a horizontal or a vertical axis. An alternative, reciprocating device has also been developed

Horizontal Turbines

These devices are perhaps the simplest to understand as they are principally submarine “windmills”. Methods of mooring such devices vary:

- Monopole (Marine Current Turbines (MCT))
- Tripod (Hammerfest StrØm)
- Swing (TidEL)

These devices have been designed to prototype scale with the following descriptions of the work to data;

Marine Current Turbines (MCT) - has been testing a single horizontal axis submarine turbine and is now planning to build a twin-turbine version. Each marine turbine should generate about 500 – 1,000 kW. A small single-turbine experimental device (300 kW) has been demonstrated off the coast of Devon and “farms” of larger devices are planned to form marine power stations in 30 – 50 m water depth.

Hammerfest StrØm this Norwegian company has trialled a 300 kW device in Kvalsundet fiord near Hammerfest in northern Norway in 2002 - 2003 and supplied electricity into the national grid. Despite this early success development is currently halted. It is not clear when further development will take place.

A novel horizontal axis device has been developed by a British company, called SMD Hydrovision, a manufacturer of submarine devices for North Sea oil and gas companies. SMD has tested a 1:10 scale version of this device and its development is continuing.

Lunar Energy is a Scottish company, which has developed the concept of a submarine turbine located at the centre of a venturi-shaped duct, which focuses and accelerates passing submarine currents

Lunar Energy’s device rests on the seafloor and responds to both current directions. Mathematical modelling has shown that the device extracts more energy from currents, which are not aligned with the

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device axis, so precise orientation with respect to the predominant tidal direction is not necessary. A prototype is currently in development.

Vertical Turbines

Perhaps the most advanced vertical axis turbine is the Canadian Blue Energy Ocean Turbine proposal. The Ocean Turbine concept has been proposed on a variety of scales (from micro-generation – 25 kW – to major tidal fences, which could generate 100s of MW of electricity. No commercial version has yet been built.

At least two groups in New Zealand are developing vertical axis tidal energy devices.

Reciprocators

The Stingray tidal energy device was designed by a United Kingdom company, called the Engineering Business. Stingray is radically different from other tidal energy devices in that it extracts energy from tidal streams using a reciprocating hydrofoil, rather than a rotating turbine. The next stage was to be a full scale 5MW demonstration plant but the project has been put on hold.

10.4.3 Tidal energy commercial developments

The only use of tidal energy to date has been tidal barrages in Europe. These have significant environmental issues halting further development of this type of device.

Although the development of scale and full size prototypes has been significant in number compared to wave energy, commercial demonstration projects have not been built.

10.5 Tidal Resource

The moon has a gravitational pull on the oceans as it orbits the earth. This pull causes the water to bulge toward the Moon. Because the earth is spinning there will be a bulge on the opposite side of the Earth as well.

As the Earth rotates on its axis, each location on the earth will experience both tidal bulges. The areas of high water levels are high tides and the areas of low levels are low tides.

Tides vary from day to day. As the Earth, Moon, and Sun orbit, their positions constantly shift, causing slightly different gravitational effects. Since the Earth and the Moon rotate around the Sun, there is an added modifying factor. When the Sun and Moon are aligned, there are exceptionally strong gravitational forces, causing very high and very low tides which are called “spring” tides, though they have nothing to do with the season. When the Sun and Moon are not aligned, the gravitational forces cancel each other out, and the tides are not as dramatically high and low. These are called “neap” tides.

Because the earth is not completely covered with uniformly deep water the tidal bulge moves around the earth moves through the seas, oceans, and straits undulating in circular paths about nodal points. This movement can be very complex but has been studied for centuries and can be modelled in great detail so that even in very complex situations where the tides along a coastline vary from place to place by metres in height these variations are expected.

10.5.1 Tidal Range

Tidal range is the difference in height between the low and high tides for a location. Range only refers to the vertical distance the water is displaced. Tidal rage can be increased by certain types of embayment.

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10.5.2 Tidal Currents

Tidal currents are the motions of the tidal bulge undulating about nodal points in the ocean basins. Every drop of water in the oceans is part of tidal current but for energy extraction it is the currents that are focused though straits and between bathymetric features that are useful. The velocity and direction of the water through the tidal cycle will vary, being fastest in the mid points between high and low, and low and high, slowest during high and low peaks.

10.5.3 New Zealand

The tide rotates anticlockwise around New Zealand's islands meaning that it is always high tide at one location around the country, and low tide elsewhere.

New Zealand's tidal range is 2 - 3 m and no significant intensifying embayment exists. This range is low compared to the global ranges so the tidal energy resource exploitable from tidal range devices is limited. However there are a number of locations where the tidal currents are significant particularly through sections of Cook Strait (Fig 5) as well as the 'narrows' at the exits of some harbours, providing opportunities for tidal current devices .

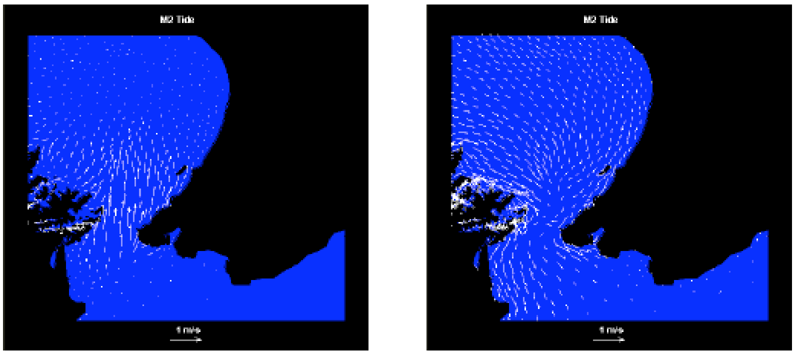

Figure 28. Tidal currents in Cook Strait (Courtesy of NIWA)

10.6 New Zealand industry participants in marine energy

Marine energy is currently under-developed but concerted efforts, both international and domestic, will enable New Zealand to realize the benefits of its energetic near shore environments. Investment in marine energy will also help New Zealand meet its renewable energy targets under the National Energy Efficiency and Conservation Strategy (NEECS) and to meet its emissions reductions targets under the Kyoto Protocol.

In New Zealand two projects are in development. One project seeks to develop a New Zealand – designed device whilst the other is seeking to import an overseas device. A consortium effort of IRL, NIWA and energy consultancy Power Projects Limited is developing a prototype wave energy device. Meanwhile, Power Generation Projects is planning to import a Pelamis wave energy converter.

The benefits for New Zealand of an active industry in marine energy will be an additional, renewable energy to complement the existing energy supply portfolio and the opportunity for a technology export industry.

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The New Zealand industry has established an industry association, Aotearoa Wave and Tidal Energy Association (AWATEA).

10.7 New Zealand marine energy industry capacity

New Zealand is well-placed with abundant potential wave and tidal resources to meet some of its future energy requirements from marine energy generation. The capacity of New Zealand’s marine energy resource is immense. The resource that could be captured and utilized is increasing with developments in both wave and tidal energy.

Locations for utilisation of tidal currents have been identified and await device development. A number of projects have been proposed.

New Zealand industry is well positioned to take advantage of the developments of the next few years, if New Zealand wishes to utilise its vast natural resource. Horizontal transfer of knowledge and experience from the marine construction, cable laying and engineering industries will mean a fast uptake from the demonstration projects currently underway and proposed for several US states, the UK and Portugal.

10.8 Marine energy costs profiles

Marine energy devices have high capital costs but lower operating costs, because the fuel – moving water – is free. The challenge for marine energy developments is to extend operational life of devices, minimize maintenance requirements and simplify operating procedures.

Tidal energy could potentially be a cost effective energy source. Although there is a daily variation in tidal energy, the variation is completely predictable. However, managing energy demand with this variable supply will require the availability of other energy sources.

A recent study of a hypothetical 300,000 MWh wave farm based on the Pelamis device, for each of five coastal US states, using experience curves for installed capacity, postulated that Pelamis-produced electricity will cost less from equivalent wind farms in four of these states when the cumulative production capacity is around 15000 MW or more.

10.8.1 Limitations

Tidal plant cannot take advantage of any economically advantageous peak demand periods because the direction of the tides changes every 12 hours 25 minutes and the power generation will not always be synchronised with a daily power demand curve.

The biggest obstacle in the development of the tidal power system is the relatively high capital cost for low utilization. Tidal power stations can only be built where there are large tidal flows, maximum high/low tidal ranges and where natural submarine features allow construction at lowest costs.

The key issues include the need for backup electricity supplies and satisfactory integration with the national grid. These issues are similar for all electricity generating stations, but have a particular focus due to the variable nature of wave energy.

As wave power is variable it has some of the characteristics of wind generation and needs to work with other sources of electricity generation that can cover any shortfall, and can be integrated up to a limit with a national grid system. Wave energy is intermittent but relatively predictable, tidal current energy is intermittent but largely predictable. Tides are highly predictable.

The hydro domination of New Zealand's grid means the integration of wind and wave power is less of an issue than with thermal dominated systems

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10.8.2 Environmental Issues

These include:

- Reductions in wave energy after passing by the "wave farm"
- Interactions with sea life and sea birds
- Atmospheric and oceanic emissions
- Visual appearance
- Conflicts with other users of sea space
- Installation and decommissioning.

10.8.3 Information Sources

Information on the wave resource around New Zealand is not widely available. NIWA has some information on their website, http://www.niwa.co.nz/ncces/cem/2004-06/wave.

1 "New Zealand Wave Energy Potential:Riding the Crest of a Wave or Gone with the Wind?" By Iain Sanders and Alister Gardiner of Industrial Research Limited; and, Guy Penny and Richard Gorman of the National Institute for Water and Atmospheric Research

2 EPRI Report E21 Global WP009-US Rev1, by Roger Bedard et al. January 2005

3 NIWA website http://www.niwa.co.nz/ncces/cem/2004-06/wave.

11 New and Emerging Technologies

11.1 Renewable Energy Storage

As many renewable energy sources are uncontrolled or intermittent, energy storage is essential to maximise the utilisation of these resources. Ideally the stored energy should be able to be recovered when needed. Traditionally variants of commonly available batteries have been to store renewably generated electricity. Recent research and development has seen the emergence of new battery technologies more suited to the energy storage and discharge requirements of large scale installations.

11.2 Hydrogen from Renewable Energy

A major issue for the increased uptake of renewable energy is that it is often not storable. The use of hydrogen as a storage mechanism may be one way of increasing the value of renewable energy.

One potential partial alternative to fossil fuels is hydrogen. Hydrogen does not occur in nature as the fuel H_2. Rather, it occurs in chemical compounds like water or hydrocarbons that must be chemically transformed to yield H_2. Hydrogen, like electricity, is a carrier of energy, and like electricity, it must be produced from a natural resource. Through its reaction with oxygen, hydrogen releases energy explosively in heat engines or quietly in fuel cells, in both cases water is the only by-product produced.

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The hydrogen economy is a network of three functions, production, storage and use. The gap between the present state of the art in hydrogen production, storage, and use and that needed for a competitive hydrogen economy is very wide and fundamental research breakthroughs are required.

To achieve widespread use of hydrogen, especially as a fuel for automobiles, it must be produced cost-effectively either in large plants or in smaller facilities at or near vehicle fuelling stations. If the hydrogen is produced in large plants, infrastructure must be put in place to distribute it to fuelling stations. Hydrogen storage technologies must be developed for vehicles that will give consumers the range between refuelling that they expect.

Production

Renewable electricity is the only reasonable alternative for making zero carbon hydrogen. Other sources of energy are more efficiently used directly. International development of hydrogen production is usually reliant on having access to large amounts of low cost electricity. This is often supplied from nuclear or geothermal generation.

Hydrogen is a widely used industrial gas, and is produced in large quantities (globally about 50 million tonnes), almost all of it by reforming natural gas, oil or coal. Electrolysis accounts for only about 4% of the production. The challenge in the development of hydrogen fuelled energy systems is to find inexpensive and efficient routes to create hydrogen in sufficient quantities from non−fossil resources.

The most promising route is splitting water, which is a natural carrier of hydrogen. It takes energy to split the water molecule and release hydrogen, but that energy is later recovered during oxidation to produce water. To eliminate fossil fuels from this cycle, the energy to split water must come from non−carbon sources.

Electrolysis of water can be accomplished by using electricity from photovoltaic cells. This two step process has been combined into a single nanoscale process called photolysis in the laboratory. Currently research is continuing to improve the efficiency of the process.

Water can be split in thermochemical cycles operating at elevated temperatures to facilitate the reaction kinetics. Heat sources include solar collectors operating up to 3000°C or nuclear reactors designed to operate between 500°C and 900°C. More than 100 types of chemical cycles have been proposed. At high temperatures, thermochemical cycles must deal with the tradeoff between favourable reaction kinetics and aggressive chemical corrosion of containment vessels. Separating the reaction products at high temperature is a second challenge.

There is considerable research directed at finding suitable catalysts to reduce the temperatures needed or improve the reaction kinetic for the hydrogen conversion.

Plants use photosynthesis to convert CO_2, water, and sunlight into hydrogen and oxygen. The hydrogen is used to manufacture the carbohydrates in their leaves and stalks. Single−cell organisms such as algae and many microbes produce hydrogen efficiently at ambient temperatures. Research is looking at ways to understand these mechanisms and imitate them using artificial materials.

Gasifiers using biomass can also produce hydrogen. However the conversion of hydrogen to biomass is an inefficient process. The land, water and other resources needed to produce the large quantities of biomass that will be required, will limit production of energy crops to small geographic areas. The cost of the hydrogen produced is not likely to be competitive with other methods of producing hydrogen.

Storage

Effective and efficient storage of hydrogen from renewable energy sources is key to its widespread introduction and use and is one area where progress has been slow, particularly for transport applications. Hydrogen gas has good energy density per weight, but poor energy density per volume.

Traditional methods of storing hydrogen are in high pressure cylinders or as a liquid. Liquid hydrogen boils at -253 deg C and liquefaction requires a large amount of energy (up to 40% of its energy content) and the tank must be well insulated to prevent boil off. Even liquid hydrogen has significantly lower energy density per volume than hydrocarbon fuels such as petrol.

Hydrogen can be stored in the form of metal and chemical hydrides. The two challenges for on−vehicle hydrogen storage and use are capacity and cycling performance. Hydrides that have low−temperature capture and release behaviour, have low hydrogen content and are thus heavy to carry. In comparison other hydrides contain high volumetric hydrogen densities but require temperatures of 300°C or more at one bar to release their H_2.

Nanostructured materials offer a host of promising routes for storing hydrogen at high capacity in compounds that have fast recycling, but such technologies are considered to be several decades away from commercial introduction.

Use

The underlying premise of a hydrogen economy is that fuel cells will replace internal combustion engines and turbines as the primary way to convert chemical power into motive and electrical power. The benefit to this changeover is that fuel cells, being electrochemical, can be more efficient than heat engines. Currently, fuel cells are very expensive, but there is active research to bring down fuel cell prices.

Internal combustion engines can be easily modified to burn hydrogen, but efficiencies are significantly lower than fuel cells.

11.2.1 Vanadium Redox Battery

The Vanadium Redox Battery (VRB) is an electrochemical energy storage device, whereby energy (electricity) can be stored indefinitely in a liquid and can be recovered instantaneously. The VRB will be used for emergency standby power in the telecommunications industry, as the backup unit in Uninterruptible Power Supply (UPS) systems, a load levelling device in a power station, the energy storage device in a solar or wind generated remote power system or to power an electric car.

The VRB has been referred to as “The Green Battery” due to the materials used in it’s construction and for it’s ability to integrate with natural power sources such as wind and solar.

Hydro Tasmania have installed a Vandium Redox battery at their 2.5MW King Island installation. It has storage capacity of around 800kW.

11.3 Quality of Renewable Energy

11.3.1 Capacitors for Storage

Capacitors store energy in the form of an electric field by accumulating electric charge. For a given capacitor, the more charge it stores, the higher the voltage across the capacitor. To increase the amount of stored energy in a capacitor bank, either its voltage or its capacitance must be increased.

Present day capacitors have relatively low energy densities. High energy density capacitors are in development. Ultracapacitors, also referred to as supercapacitors or high energy density (HED)

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capacitors, have higher specific energy and power densities. They are being developed as primary energy devices for power assistance in hybrid vehicles during acceleration and hill climbing, as well as recovery of braking energy. They are also potentially useful as secondary energy storage devices in the same vehicles.

Uninterruptible power supply units using high density capacitors instead of batteries are commercially available in sizes from 5kVA to 3MVA.

11.3.2 Flywheel storage

Beacon Power Corporation have a contract with the California Energy Commission to demonstrate the potential benefits of using flywheel energy storage to provide frequency regulation of the grid particularly where renewable energy is involved. The demonstration plant is being installed in 2005.

A flywheel energy storage system typically consists of a rotor, a shaft, housing, bearings, and a generator/motor. Low speed (less than 10,000 rpm) steel-rotor flywheel systems are a mature technology and are currently available from a number of manufacturers. Other more advanced, though less developed systems employ high-speed high strength (fibre-reinforced) composite-rotors supported by magnetic or mechanical bearings (sometimes in a vacuum or near vacuum containment to reduce windage losses). The control system directs energy in and out of the flywheel storage by accelerating or decelerating the rotor using the integrated motor/generator energy conversion system.

11.3.3 Fuel Cells

The fuel cell may in future be part of integrated energy systems taking non firm renewable energy, storing it as methane or hydrogen, and using it to generate electricity via a fuel cell when needed.

There is a range of types of Fuel Cells including:

- Phosphoric Acid
- Proton Exchange Membrane or Solid Polymer
- Molten Carbonate
- Solid Oxide
- Alkaline
- Direct Methanol Fuel Cells
- Regenerative Fuel Cells
- Zinc Air Fuel Cells
- Protonic Ceramic Fuel Cell

Fuel Cells have many applications:

- Stationary
- Residential
- Transportation
- Portable Power

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Appendix A – Government Renewable Energy Policies

Overview of Government Energy Policy

The government's approach to renewable energy policy forms an integral part of its wider commitment to a sustainable energy future for New Zealand – which, in turn, largely derives from the "Sustainable Development for New Zealand: Programme of Action (SDPOA) which was published in January 2003 – see following section.

A recent articulation of government's position on sustainable energy is in the Ministry of Economic Development's discussion document "Sustainable Energy: Creating a Sustainable Energy System", October 2004. In chapter 2 this document provides a concise overview of the current sustainable energy policy framework. It includes a statement of the three objectives of sustainable energy policy as being to foster an energy system which is reliable and resilient; to ensure that energy production and use is environmentally responsible; and ensure that energy prices are efficient and fair.

The discussion document also includes reference to:

- 2003/04 reforms of the gas wholesaling, transmission, distribution and retailing to cope with more diverse sources of supply and increased trading arising from the decline of the Maui gas field;
- incentives for gas exploration;
- transport reform based on sustainable transport principles – including efficient and renewable energy use;
- resource management reform;
- the climate change policy package; and
- the reform of local government – affecting transport, landuse and urban form, as well as implications for the development of new energy supplies.

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The current policy position on renewable energy owes much to the government's Energy Policy Framework, released in October 2000 - covering energy efficiency and renewable energy, climate change, electricity reforms, the gas sector, and transport. The renewable energy work programmes required in each of these areas have been detailed in subsequent Government policy documents; most notably the National Energy Efficiency and Conservation Strategy (NEECS) - a replacement for which is currently under development; the current and emerging climate change policies; the New Zealand Transport Strategy and the government Policy Statement: Further Development of New Zealand's Electricity Industry.

The 2002 the government revised its policy on electricity to include a requirement that the industry arrangements be consistent with sustainable development. The principles also required that "market rules were to ensure that the use of new electricity technologies and renewables, and distributed generation, is facilitated and that generators using these approaches do not face barriers."

In 2003 the government introduced policy establishing the Electricity Commission and requiring it to secure reserves within the electricity system to reduce the risk of electricity shortfalls in periods of very low hydro inflows. These reserves include a range of measures including generation, energy efficiency, demand exchange etc. The Electricity Commission has a strong focus on security of supply including that from renewable energy. Renewable technologies are seen to enhance the security of supply by diversifying the energy supply mix.

Government Sustainable Development Programme of Action

In January 2003 the Government released its Sustainable Development Programme of Action. The programme cites energy as one of four priority areas for action under an overarching goal:

> To ensure the delivery of energy services to all classes of consumer in a fair, reliable and sustainable manner.

It is subsequently focused on achievement of the following outcomes:

- energy use in New Zealand becomes progressively more efficient and less wasteful,
- our renewable sources of energy are developed and maximised, and
- New Zealand consumers have a secure supply of electricity

National Energy Strategy

Arising out of the Sustainable Development Programme of Action the Government is currently developing a national energy strategy to provide long-term direction and leadership to put New Zealand on the path to an energy system that supports economic development, while being environmentally responsible. The Government also emphasised renewed commitment to promoting energy efficiency and renewable sources of energy.

National Energy Efficiency and Conservation Strategy (NEECS)

In September 2001, the Government released the National Energy Efficiency and Conservation Strategy (NEECS). This was developed as a requirement of the Energy Efficiency and Conservation Act (2000). Preparation of the current NEECS was lead jointly by the Energy Efficiency and Conservation Authority and Ministry for the Environment.

The purpose of NEECS is to promote energy efficiency, energy conservation and renewable energy within the context of a sustainable energy future. It does so by setting up a strategically directed sectorally based programmes of policy and operational actions. Responsibility for driving implementation of the Strategy lies with a wide range of public sector agencies, while overall oversight of the NEECS – including its monitoring – is the responsibility of EECA

The NEECS sets two overarching national targets: one of these is to achieve at least a 20% improvement in economy wide energy efficiency by 2012. The other target, relating to renewable energy, is discussed in the following section.

The goals of NEECS are to:

- reduce CO_2 emissions,
- reduce local environmental impacts,
- improve economic productivity,
- promote industry development,
- improve economic resilience, and
- improve health and welfare.

In 2005 EECA released the 3 year on report, which documents progress towards the goals in the NEECS over the first 3 years. Over this period a 1% improvement over business as usual energy efficiency has occurred.

The government has recently announced that it will develop a replacement NEECS – which is expected to be published in the first half of 2007.

Renewable Energy Target

A Renewable Energy Target is set within the framework of NEECS. The target is to increase renewable energy supply to provide a further 30 PJ of consumer energy by 2012. The Government intends that the target will be achieved by a combination of measure to break down the barriers to uptake of renewable energy supplies. This includes facilitation of the renewables industry, addressing regulatory and planning barriers, encouraging market driven private sector investments, as well as the provision of financial incentives. Government policies and programmes operated by EECA are designed to complement those administered as part of wider work government programmes – particularly those in climate change and transport.

In the analysis leading up to the setting of the 30 PJ of consumer renewable energy target it was assumed that the energy would come from a mix of resources, although an indicative target for transport fuel (2 PJ) was specifically set within the target.

Crown loans – change in policy to consider renewable energy projects with a longer payback period up to 5 years. Since renewable energy projects typically have longer paybacks this could be another option available to fund renewable energy projects for local and central government organisations.

Specific EECA renewable energy programmes are covered in the relevant sections.

Review of the NEECS

A review of the current NEECS had been completed by EECA, for the Minister of Energy, with oversight from an interdepartmental steering group. The replacement NEECS will sit within the National Energy Strategy when developed.

The review found that the Strategy’s action plans have generally been implemented as intended and are contributing to the social, economic and environmental goals, but need to be strengthened. The original Strategy laid the foundations, and removed barriers to the uptake of energy efficiency and renewable energy. New Zealand is now in a good position to build on these foundations. So far, there have been only very modest improvements in energy efficiency. To reach the existing national target would require an improvement of 2.5 percent per year, which is greater than international best practice at 2 percent. New Zealand is currently tracking at a rate of improvement of between 0.5 percent and 1 percent per year.

In light of these findings, and because New Zealand’s energy situation has changed during the last four years, EECA concluded a replacement Strategy was both necessary and timely. This recommendation was made to the Minister of Energy.

Climate Change Policy

Under the Kyoto Protocol, New Zealand is committed to reducing its emissions to 1990 levels or take responsibility for any excess emissions. The Climate Change Office of the Ministry for the Environment (MfE) has developed policies to this effect.

Projects to Reduce Emissions

The Projects to Reduce Emissions Programme (PRE) facilitated near-commercial renewable energy projects that would otherwise not be viable. The PRE programme is on hold at present with no round this year. When proposals are called for near-commercial renewable energy projects will be able to bid-in for financial support to bridge a funding gap that would otherwise prevent such projects proceeding.

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The Projects Programme is designed to reduce New Zealand's greenhouse gas emissions by supporting projects that:

- provide emission reductions in the Kyoto Protocol's first commitment period (2008-2012) beyond the reductions that would have occurred without the project, and
- are not viable without the tendered emission units.

Projects must result in a measurable reduction in greenhouse gases and go beyond business as usual. They must also take place in New Zealand and reduce greenhouse gas emissions that are counted in New Zealand's greenhouse gas inventory.

The 24 projects that have been successful to date in being awarded carbon credits are listed in section 4.6.

Review of Climate Change Policy

The Government is currently reviewing the Climate Change Policy to identify a new policy replacing the previous one put on hold in 2005. The carbon charge, due to be introduced in 2007, was withdrawn late in 2005.

Negotiated Greenhouse Agreements (NGAs)

During the first Kyoto Protocol commitment period (2008 to 2012), it is recognised that the international competitiveness of some New Zealand firms or industry groupings could be at risk because of the emissions charge. For firms that are prepared to undertake meeting world's best practice targets in the management of their greenhouse gas emissions, the Government is prepared to negotiate a full or partial exemption from the emissions charge. This is called a Negotiated Greenhouse Agreement (NGA).

While renewable energy is not the focus of NGAs, it is considered as a future opportunity for the development of renewables.

Electricity Network Company Regulation

Until 1998 local electricity network companies had built and operated a number of small hydro power stations. With the introduction of competition to the electricity industry, the Electricity Industry Reform (EIR) Act (1998), through requirements for separation of generation and network asset ownership forced Network companies to divest their generation assets. In 2004 parliament passed the Electricity and Gas Industries Bill which modified the 1992 Electricity Act to allow network companies to manage periods of peak demand with their own limited generation capacity and in particular their own renewable energy generation (this had been allowed since 2001). This was undertaken as an exemption to the separation rules.

The Electricity and Gas Industries Act (2004) introduced a further amendment to the EIR Act which is:

> [46A. Exemption for new distributed generation from new renewable energy source—
> (1) The following activities do not cause any person to breach the ownership separation rules:
> (a) generating electricity from new distributed generation using only—
> (i) a new renewable energy source; or
> (ii) a new renewable energy source and fossil fuels if fossil fuels provide no more than 20% of the total fuel energy input for the generator or generators comprising the generation plant in any 12-month period or any larger amount approved by the Minister under subsection (3):
> (b) selling electricity referred to in paragraph (a):
> (c) owning or operating, directly or indirectly, new distributed generation, or any other core generation assets used in connection with new distributed generation that is capable of generating electricity referred to in paragraph (a).

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(2) Subsection (1) applies only if and as long as sections 24 and 25 are complied with (corporate separation and arms length rules).
(3) The Minister may increase the thresholds in subsection (1)(a)(ii) or in paragraph (b) of the definition of “new renewable energy source” to approve a particular activity for the purposes of subsection (1) (on the conditions, if any, he or she thinks fit) after first taking into account whether or not the generation uses new or advanced technology.
(4) in this section,—

> “New distributed generation” means distributed generation that does not exist on the date on which this section comes into force
> “New renewable energy source”—
>
> > (a) means an energy source that occurs naturally and the use of which will not permanently deplete New Zealand's energy sources of that kind, because those sources are generally expected to be replenished by natural processes within 50 years or less of being used; but
> > (b) does not include hydro or geothermal energy sources at a generator or generators comprising a generation plant that has an aggregate generating capacity (determined according to nameplate or nameplates) of more than 5 MW, unless approved by the Minister under subsection (3).

(5) This section does not limit section 5(2)(e) (exclusion from definition of electricity supply business).]

The Electricity Industry Reform Act (1998) removes any obligation for network companies to supply electricity after 2013. This provides an opportunity for local renewable energy projects to provide electricity supply from distributed generation.

Resource Management (Energy and Climate Change) Amendment Act 2004

The Resource Management (Energy and Climate Change) Amendment Act 2004 introduced three new matters which those who exercise powers and functions under the Act must consider. These are the efficiency of the end use of energy efficiency, the effects of climate change, and the benefits to be derived from the use and development of renewable energy. These matters form new clauses in section 7 of the principle Act. The means by which these matters can be considered include changes to policy statements and plans that are prepared in accordance with the Resource Management Act, and through consideration of resource consent applications for energy projects.

Ideally, both regional councils and territorial authorities should review their planning documents to see how the new section 7 matters can best be incorporated into revised versions of regional policy statements and regional and district plans. In practice, this is likely to take place over a period of years, although at least one territorial authority has already initiated a plan change as a result of the Amendment. Wellington City Council has resolved to change to its District Plan, with new chapters on renewable energy including specific district rules for wind farms and wind speed measuring equipment. The plan change also discusses other renewable energy installations, but does not provide specific rules for them as it is considered that, in Wellington's case, wind is the only energy resource for which planning proposals are likely to come forward during the life of the current District Plan. Elsewhere, other renewable energy resources might be more important.

Elsewhere, the silence of planning documents in regard to renewable energy installations may have led, in the absence of the new RMA section 7 matters, to other local policies and rules carrying more weight in the decision-making process than the more general requirement for sustainable development, which is the stated purpose of the Act. Matters such as protection of landscapes and visual amenity will continue to be considered by local authorities when they are determining planning applications, but incorporating

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specific policies and rules into planning documents may lead to a more balanced consideration of the potential impacts of a development.

Some Councils may choose to introduce some renewable energy development into their plans as "permitted activities", in which case resource consent would not be required. Some small-scale renewables, such as installation of photovoltaic panels on roofs of existing buildings, are already likely to be permitted activities in many areas, as long as they do not increase the overall height of the building to more than provided for by existing permitted activity rules. (In such instances, applicants can seek a certificate of compliance to confirm that the proposed development would be lawful without resource consent.)

Until plans and policy statements are changed to provide specifically for renewables, planning authorities will need to take into account the new section 7 matters in determining resource consent applications. People making applications should therefore seek to demonstrate how their proposals contribute to meeting these matters, along with all the other matters dealt with by the relevant plan.

These recent amendments to the RMA include:

- The introduction of a reduced notification process
- Specific emphasis on the national value of energy efficiency and renewable energy
- Reductions in Environment Court delays
- Development of national environmental standards

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These changes to the RMA are all considered to be favourable to the increased uptake of renewable energy.

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, Regional 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.

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However, historic resource consent decisions still stand.[33]

In 2005 the Act was further amended by giving additional powers to Regional 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
(ii) does not use them to generate any electricity for supply to any other person:
These powers will 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 now District Plans are required to give effect to a Regional Policy Statement. This gives Regional Policy Statements more power 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.

Air Quality

The National Environmental Standard for Air Quality recently came into force. As part of this standard there are proposed limits, monitoring periods, and number of exceedances per year for a number of pollutants. The pollutants covered by the standard are fine particles (PM10), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) carbon monoxide (CO), and ozone (O_3).

Monitoring results indicate that the proposed National Standard for fine particles is exceeded at 36 locations throughout New Zealand. It is estimated that 5 centres are likely to exceed the proposed standard more than 50 times per year: Alexandra, Christchurch, Nelson, Richmond and Timaru. In most cases the main source of particulate emissions is home heating (either open fires or solid fuel burners) 34.

In both Christchurch and Nelson programmes have been but in place to reduce air pollution from home heating. These initiatives often result in an improvement in the energy efficiency of homes as a result of improvements in insulation, but also often result in the replacement of a solid fuel burner or open fire with electrical heat pumps. This means a reduction in the use of renewable energy for home heating and additional infrastructure stress on the electricity system. At present because of the scale of these initiatives it is not a major concern; however given the scale of the air quality problem in cities and towns throughout New Zealand this has the potential to have a significant impact on acceptable energy choices for home heating in the future.

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[33] A Private Members Bill is currently before Parliament that will have the effect of reversing these particular provisions.
[34] Ministry for the Environment - http://www.mfe.govt.nz/publications/air/nes-air-standards-analysis/html/table2.html

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As air quality becomes more important we should expect to see a reduction in the use of renewable energy sources for home heating such as solid fuel burners and open fires and more reliance on electricity and gas for home heating.

Air quality issues also have the potential to reduce the use of biomass for production of bioenergy in or near urban areas with air quality problems.

In areas with air quality issues the use of bio-diesel as a transport fuel is expected to become more desirable than the use of conventional diesel, due to the reduced PM_{10} emissions from bio-diesel.

Transport

In 2002 the government introduced the New Zealand Transport Strategy. There are several policy initiatives and changes in the transport sector; however it is difficult to determine the impact these changes are likely to have on renewable energy, if any. The single biggest opportunity is expected to be where government policy influences fuel choices i.e. climate change policy and/or national air quality standards.

In August 2005, the Government confirmed that it would develop and introduce a mandatory biofuels sales target (CAB Min(05) 29/4). This policy recognised benefits to climate change, air quality and security of energy supply. The sales target of biofuels in transport fuels will have a significant effect on the production and use of ethanol and biodiesel.

Appendix B – Market Participants

Industry Associations

12.1.1 Solar Industries Association

The Solar Industries Association (SIA) represents manufacturers, importers and installers of solar water heating (SWH) systems.

The SIA has the objective of increasing the public perception of solar water heating as an essential component of every house and commercial building, and developing the market so that 30,000m^2 (10,000 systems) of solar water heaters per annum are installed by mid 2007.

SIA has an effective management structure and action programme and employs a part-time Executive Officer. The action programme is based around market transformation objectives. Funding comes partly from a levy imposed on each solar water heating system installed.

The Association has 14 Full Members and 70 Associate Members. There are 14 products that comply with the technical standards and 16 Accredited Suppliers. Accreditation is managed on behalf of the industry by the Association. The Accredited Suppliers have 260 Approved Installers. Installers are approved by the suppliers for installation of their products.

The Association, in partnership with EECA, has been working through a 3-5 year programme which has focused on quality and now is moving more into promotion.

Work programmes have been primarily focused on establishing;

- Code of Practice
- Technical standards
- Installer training course
- Supplier accreditation
- Complaints procedures

The focus of current activities is to work with suppliers and their approved installers to ensure that they have good installation practices. The Association works closely with the national Master Plumbers Association.

12.1.2 Bioenergy Association of New Zealand

The Bioenergy Association of New Zealand (BANZ) is an industry association formed to represent the bioenergy interests of commercial companies, research and development groups, and individuals. It also provides a single point of contact on the bioenergy market.

Members include anyone with a commercial interest in bioenergy – sawmillers, wood processors, energy researchers, energy suppliers, consultants, manufacturers and investors.

BANZ has adopted a strategy to increase the uptake of bioenergy by:

- improving the knowledge and experience base for potential and existing bioenergy plant investments by collectively sharing the cost,
- undertaking collective market research, identifying barriers to growth and assisting members overcome these barriers, and
- supporting the capacity building of New Zealand-based manufacturers and suppliers.

BANZ has a key performance target of raising the contribution of bioenergy to 5% (50 PJ) of New Zealand's total consumer energy by 2010.

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BANZ has a contracted (limited hours) part-time Executive Officer.

The Association has work programmes based on;

- Woody biomass
    - Process residues
    - Forest residues
    - Short rotation crops
- Transport biofuels
    - Ethanol
    - Biodiesel
- Biogas
    - Agricultural residues
    - Food processing residues
    - Municipal waste

12.1.3 New Zealand Photovoltaic Association

The New Zealand Photovoltaic Association (NZPVA) represents manufacturers, researchers, importers, installers, and energy sector participants with an interest in photovoltaic systems.

NZPVA's mission is to promote and support the increased use of energy from the sun as a reliable, sustainable and clean energy source for the direct production of electricity for the benefit of New Zealand.

The overall objectives (or activities) of the Association are to:

- increase public perception of the potential for photovoltaic (solar electric) systems,
- develop and implement training and accreditation schemes to ensure the quality of installations in New Zealand meets appropriate world best-practice standards,
- increase the number of installed photovoltaic systems in New Zealand, and the capacity of the domestic industry to meet the demand in products and services,
- develop, promote, and provide leadership for a partnership programme between the PV industry and Government to implement PV/diesel replacement or new community electrification projects within the Asia-Pacific region,
- promote PV and assist Government with initiatives leading to the reduction of greenhouse gases from the energy sector and with the transition to a more sustainable energy system for New Zealand, and
- to develop and manage the Association for the benefit of the photovoltaic industry, the Association's members, and the public in New Zealand.

NZPVA has a contracted (limited hours) part-time Executive Officer.

Association work activities are based principally around increasing grid connected PV systems.

12.1.4 New Zealand Geothermal Association

The New Zealand Geothermal Association (NZGA) is a scientific, educational and cultural organisation established to operate in New Zealand. It is affiliated to the International Geothermal Association. Its aim is to encourage, facilitate, and, when appropriate, promote coordination of activities related to worldwide and national research, development and application of geothermal resources.

The Association has an interest in the following markets:

1. Large and small-scale electricity generation from geothermal sources.

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2. Large and small-scale direct use of heat from geothermal sources. The Association acknowledges that this may be more thermodynamically and commercially efficient where a good match between sources and use exists.
3. Development of minerals and biota associated with geothermal environments.
4. Non-extractive uses, such as tourism.

The aims of the Association also include education, scientific investigation and conservation of geothermal systems. The Association takes an active role in regulatory issues to do with geothermal matters.

NZGA is an Incorporated Society and has a part-time executive officer.

12.1.5 International Hydropower Association (NZ)

The International Hydropower Association (IHA) was formed in 1995, with the support of UNESCO, for the purposes of exchanging and enhancing knowledge on various aspects of hydropower, and to encourage research and good engineering practice in this field.

IHA’s mission is to assess and promote good practice within its membership, and to increase general awareness of the integrated role of hydropower in the sustainable supply of electricity and water.

The IHA:

- is an international multidisciplinary body,
- exists to increase awareness of the role hydropower can play in sustainable development, as the most important source of renewable energy,
- provides an open forum for its members to exchange and enhance knowledge,
- promotes hydro development that is planned and implemented in an environmentally and socially acceptable way,
- advances knowledge on various aspects of hydropower,
- promotes good practice and international standards in hydro development and operation, and encourages innovation,
- tackles technical, administrative, social, environmental, economic and financial problems that are preventing or slowing down the development of the world's hydro resources,
- develops and disseminates information for the public and policy-makers on hydropower,
- provides educational material on hydropower, such as lectures, special publications and computer-aided learning, for various levels of education,
- selects and recommends key issues for research, and
- identifies priorities for future IHA work.

IHA’s New Zealand membership is represented by a number of generating companies as well as companies and individuals that have an interest in hydropower.

IHA(NZ) has a voluntary executive.

The New Zealand Society of Large Dams (NZSOLD) is a technical group of the Institution of Professional Engineers New Zealand. NZSOLD is focused on the design, operation and monitoring of dams and is affiliated to the International Committee on Large Dams (ICOLD).

12.1.6 New Zealand Wind Energy Association

The New Zealand Wind Energy Association Inc (NZWEA) is an industry association representing many of New Zealand’s major energy sector participants, network companies, turbine manufacturers, consultants, and individuals that have been involved in this area for a number of years.

The mission of the Association is to promote the uptake of New Zealand's abundant wind energy resource as a realistic, sustainable and clean energy source.

NZWEA has a full-time Chief Executive and offices in Wellington.

12.1.7 Aotearoa Wave and Tidal Energy Association (AWATEA)

The New Zealand industry has established an industry association, Aotearoa Wave and Tidal Energy Association (AWATEA). The association has a part time executive officer.

Government Agencies

12.1.8 EECA

The Energy Efficiency and Conservation Authority (EECA) was established under the Energy Efficiency and Conservation Act 2000 as an independent Crown entity and has responsibilities to encourage, promote and support renewable energy, energy efficiency and energy conservation. EECA undertakes renewable energy activities under its Energy Supply and FIDA/biomass Programmes. Within each programme there are specific activities relating to renewable energy.

EECA also publishes hydro and wind guidelines and an ongoing series of factsheets. Funding options are set out on their December 2003 report "Funding Options for Renewable Energy Projects".

EECA works to deliver renewable energy outcomes through the renewable energy industry associations and targeted stakeholders by implementing the activities in the NEECS and addressing market barriers. EECA works through partnerships with private and public sector stakeholders to facilitate the delivery of the 30 PJ target of additional renewable energy by 2012.

12.1.9 Ministry of Agriculture and Forestry

The Ministry of Agriculture and Forestry (MAF) is a Government ministry which has an interest in primary sector industry. It has recently increased its focus on renewable energy activities with a particular interest in geothermal and bioenergy. Bioenergy is included in the Forest Industry Development Accord, which is the responsibility of MAF, and has been negotiated with the forest industry under the Climate Change policies framework. (EECA is responsible for leading the bioenergy component of the Accord)

12.1.10 Ministry of Economic Development

The Ministry of Economic Development (MED) is the Government ministry that oversees Electricity Market Policy. MED also compiles statistical information on, and prepares projections of, energy supply and demand and greenhouse gas emissions from the energy sector, in order to fulfil New Zealand's international reporting obligations and to aid domestic policy development.

MED has previously commissioned reports on renewable energy costs and availability[35] to assist its energy demand/supply modelling.

MED has responsibility for the use of natural resources for national economic development. It undertakes studies into the use of resources and provides assistance to regional councils on the national interest of resource use.

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[35] EHMS-2002

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MED manages New Zealand’s involvement with the OECD and IEA and APEC energy activities. These include specific programmes on bioenergy and solar heating.

12.1.11 New Zealand Trade and Enterprise

New Zealand Trade and Enterprise (NZTE) are the Government’s trade and economic development agency, formed from the merger of Trade New Zealand and Industry New Zealand. The agency has a number of regional development programmes and specific business programmes that can cover renewable energy investigations and developments.

NZTE is a principal supporter of the New Zealand Clean Energy Centre at Taupo which proposes to be an innovation centre for energy technologies.

12.1.12 Foundation for Research, Science and Technology

The Foundation for Research, Science & Technology (FRST) is a Crown entity that invests in research, science and technology on behalf of the New Zealand Government to enhance the wealth and well-being of New Zealanders. FRST manages a pool of contestable research funding for renewable energy research projects from the Research for Industry Output Class. Appendix G details the currently funded research. Energy research aligns to two of FRST’s portfolios *Optimising Use of Resources* and *High Performance & Efficient Networks, Structures & Utilities.* These portfolios provide the overall objectives and directions for the Foundation's investment in this area.

Recent requests for proposals have focused on research to develop or adapt international technologies to produce energy from wind, marine or biomass resources.

RFI research is primarily assessed against the following criteria:
- Benefit Factors:
  - *Science Merit*
  - *Benefit to New Zealand through Innovation*
  - *Users’ Capacity to Innovate*
  - *Future Human/Provider Capability*

- Critical Success Factors:
  - *User Connections and Partnerships*
  - *Pathway to Implementation*
  - *Existing Delivery Capacity*

The Foundation has committed funding on renewable energy projects of:

2002/3	$6.3 million
2003/4	$5.6 million

12.1.13 Ministry for the Environment

The Ministry for the Environment (MfE) works with others to identify New Zealand’s environmental issues and get action on solutions. MfE advises the Government on environmental laws, policies, standards and guidelines, monitors how they are working in practice, and takes action to improve them. MfE reports on the state of the environment and on local government performance on environmental matters. These roles and responsibilities can include policy work on renewable energy.

MfE funds specific waste minimisation programmes that are relevant to renewable energy.

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MfE is the agency responsible for the administration of the Resource Management Act and its effectiveness in operation. This can include issues of relevance to renewable energy.

Climate change programmes and policy development are led by the Climate Change team. Other government departments are responsible for specific areas of the policy programme. The New Zealand Climate Change Office is a business unit within the Ministry for the Environment. It is responsible for leading the development, coordination and implementation of whole-of-government climate change policy.

New Zealand's target from 2008 to 2012 is to reduce its emissions to the level they were in 1990.

12.1.14 Ministry of Transport

As the government's principal transport policy adviser, the Ministry both leads and generates policy. The government's New Zealand Transport Strategy (NZTS) provides the framework within which transport policy is developed.

The Ministry of Transport acts as the Minister of Transport's agent for managing the interface with the transport Crown entities, the Aviation Security Service, and the National Rescue Co-ordination Centre.

12.1.15 Electricity Commission

The Electricity Commission is a Crown entity set up under the Electricity Act to oversee New Zealand's electricity industry and markets.

The Commission regulates the operation of the electricity industry and markets, to ensure electricity is produced and delivered to all consumers in an efficient, fair, reliable and environmentally sustainable manner.

The Commission also promotes and facilitates the efficient use of electricity.

Energy User Groups

Few energy users other than large energy using wood processing companies have a specific interest in renewable energy. The exception is solar water heating which is of interest to domestic users. Some isolated rural farmers are starting to take an interest in how renewable energy can reduce their electricity network costs.

There are a number of industrial companies that already have on-site electricity generation, however the bulk of industrial renewable energy plant is for heat production.

Some sector groups such as Federated Farmers, Major Energy Users Group, Sustainable Energy Forum, Business New Zealand, and regional Chambers of Commerce take a strong interest in specific aspects of renewable energy within their wider interest in energy. These groups generally actively submit to Government on energy policy issues and engage consultants to advise on specific questions.

Energy Companies

12.1.16 Gentailers

There are five large generator companies, three of which are Government owned, Genesis Power, Meridian Energy and Mighty River Power. The other two are Contact Energy and TrustPower. These companies also have significant retail customer bases and hence are described as “gentailers”. They each have a range of renewable energy based plant including enhancements in varying stages of investigation, consenting or construction. These companies are also the most active investors investigating opportunities, the key aspects being the cost of electricity supply and how such investments would affect their risk portfolio.

12.1.17 Independent Electricity Generators

There are a number of smaller independent electricity generators (with 10 MW or more) supplying local areas. Among them are Bay of Plenty Electricity, Duke Energy, Genesis/CHH, Genesis/Anchor Dairy, Mangahao JV, NGC, Tai Tokerau Trust, Tuaropaki Power Company, and Whareroa Kiwi Dairy Plant.

12.1.18 Lines (Network) Companies

There are 24[36] lines companies that own electricity distribution networks. A small number are in private ownership with the majority in trust ownership.

The 2001 amendment to the Electricity Industry Reform (EIR) Act (1998) gives lines companies the opportunity to construct/own renewable generation. There are some signs of uptake of renewable generation by line companies, including the consenting of two windfarms proposed by Unison. Another example is the Centralines Tukituki hydro project.

12.1.19 Oil Companies

Four major oil companies BP, Caltex, Mobil and Shell and the smaller company Gull supply petroleum based products to New Zealand customers. The four major companies also have more than a 70% share in the New Zealand Refining Company’s oil refinery at Marsden Point.

Oil and oil products make up over 35% of New Zealand’s primary energy supply and nearly 50% of its consumer energy.

Research and Development Organisations

12.1.20 Crown Research Institutes

Industrial Research Ltd

Industrial Research Ltd (IRL) is a Crown Research Institute (CRI). The IRL Electrotec team researches issues such as renewable energy systems (including wave energy in conjunction with NIWA), as well as hydrogen storage for renewable energy.

The Electrotec Renewable Distributed Generation programme focuses on the promotion of local renewable resources as a sustainable energy supply.

IRL undertakes geothermal reservoir modelling and holds data from numerous geothermal fields in New Zealand. Their work is used to help manage the sustainability of deep geothermal reservoirs by building a better understanding of changes to the resource over time, after exploitation, and field management.

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[36] Source: Electricity Network Association, 2004.

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National Institute of Water and Atmospheric Research

The National Institute for Water and Atmospheric Research (NIWA) is a CRI that provides a scientific basis for the sustainable management and development of New Zealand's atmospheric, marine and freshwater systems and associated resources.

NIWA often works in collaboration with other research organisations to investigate renewable energy systems.

NIWA maintains the Nationally Significant Database: Water Resources and Climate. This programme provides comprehensive and accessible data to support research on New Zealand's climate and freshwater resources. Data from national monitoring networks are collected, stored, and disseminated as two core nationally significant databases:

- the Climate Database, and
- the Water Resources Archive.

The data include air temperature, barometric pressure, wind direction, rainfall, lake and river water levels, river flows and sediment loads, and river water quality variables. Quality control procedures ensure national consistency and provide assurance that data can be confidently used for scientific and planning purposes.

NIWA provides consultancy services to assist renewable energy project developers meet the requirements of the Resource Management Act.

The National Climate Database is operated by NIWA in concert with the National Cooperative Climate Network, which contributes the ongoing stream of data needed to maintain the data series, from over 105 climate stations, 800 rainfall stations, and other sources such as weather balloons. The National Climate Database is New Zealand's national repository of climate data. Information on temperature, rainfall, wind, solar radiation, and other climate elements is available at various time intervals from minutes up to years for a wide range of locations. The maintenance of the database and the climate network is funded under contract with the Foundation for Research, Science and Technology (FRST).

Forest Research Institute

The Forest Research Institute is a Crown Research Institute which has a number of research programmes to commercialise bioenergy in the following areas:

- advanced bioenergy supply chain technologies,
- thermochemical biomass conversion technologies,
- biomass based distributed energy systems, and
- the environmental and socio-economic implications of bioenergy.

Manaaki Whenua - Landcare Research

Manaaki Whenua - Landcare Research is an environmental CRI specialising in sustainable management of land resources, optimising primary production, increasing the resource efficiency of businesses, and has a waste reduction research programme.

Institute of Geological & Nuclear Sciences Ltd

The Institute of Geological and Nuclear Sciences (GNS) is a CRI. Amongst other research programmes, the GNS researches sustainable management of geothermal and mineral resources as well as the understanding and protection of groundwater resources.

The integrated and multidisciplinary geothermal research undertaken by GNS seeks to improve the cost-effectiveness of geothermal energy extraction and utilisation, and so to help remove the barriers for development.

Research is in four major tasks:

- *Enhanced Energy Production from Deep Geothermal Environments.* This research provides the necessary knowledge to optimise the target areas for a deep production bore to be drilled.
- *Increased Utilisation of Geothermal Fluids for Power Production and Direct Heat.* The chemical behaviour of contaminants (principally arsenic, mercury and hydrogen sulphide) within power station pipes and effluent streams is investigated as well as the design and testing of novel methods for their mitigation (e.g. use of extremophile bacteria).
- *Enhanced Utilisation of Low-enthalpy Hydrothermal Systems.* Research into low-enthalpy geothermal systems is being carried out with a major focus of developing a GIS database of low enthalpy resources for developers to use.
- *Environmental Effects of Geothermal Development.* The aim of this task is to reduce the uncertainties that currently constrain efficient management and sustainable development of New Zealand's geothermal resources under the RMA process.

12.1.21 Universities

University of Canterbury

The University of Canterbury's commercialisation arm (Canterprise Ltd) is presently involved in research into the acoustic properties of wind turbines.

The University of Canterbury's Electric Power Engineering Centre is involved in research into the following renewable energy related projects:

- Design a renewable energy, integrated electrical supply and distribution system for scientific field facilities at Cape Bird and in the McMurdo Dry Valleys.
- To use and further develop a state space Harmonic Transfer Function modelling method to model doubly-fed induction machine generators, and propose and implement controls that ensure reliable operation of a group of similarly designed wind generators.

The Civil Engineering Department has an active small hydro turbine development programme and has run a short course on anaerobic digestion.

The Department of Chemical and Process Engineering has FoRST funding to research biomass gasification. As part of the project the University of Canterbury represents NZ as a member of IEA Bioenergy Group Task 33: Thermal Gasification of Biomass.

The Centre for Advanced Engineering (CAE) has been involved with research projects into national distributed energy applications.

Massey University

The Centre for Energy Research at Massey University was established in 1997 to enhance knowledge in the field of sustainable energy supply, utilisation, efficient management and policy advice through research and development of particular relevance to New Zealand, and to facilitate technology transfer by establishing an interface with industry.

Current research topics include:

- Biodiesel production,
- Ocean energy opportunities for New Zealand,
- All year round harvest and feedstock supply of woody biomass,
- Wind technology developments and
- Distributed energy Systems and development
- Assessment of renewable energy resources
- Carbon sequestration in soils under energy crops

Papers taught include:

- Sustainable Energy Systems,
- Renewable Energy Resource Engineering,
- Sustainable Energy Policies in Planning,
- Case Studies of Renewable Energy Systems,
- Renewable Energy Conversion Devices,
- Renewable Energy Resources,
- Renewable Energy Systems Design, and
- Greenhouse Science and Policy

University of Auckland

“The Centre of Excellence in Energy”, based within the University of Auckland Business School, is being established to foster and promote interdisciplinary research into energy-related topics, encouraging collaboration among academia, industry and government, as well as linking with leading energy sector organisations overseas.

An Advisory Board drawn largely from the energy sector will oversee the Centre’s development, and further partnerships with industry players will be sought. Issues to be investigated include the impact of new technologies, and the viability of alternative fuels, including solar, wind, tidal and hydrogen.

The University of Auckland School of Engineering undertakes research from time to time on aspects of renewable energy.

The internationally recognised Geothermal Diploma Course, taught by the Geothermal Institute at Auckland University for 24 years was closed in 2003 due to lack of funding. The Geothermal Institute was a strong focus for the industry, particularly through the annual Geothermal Workshops, which may now be lost. Auckland University has now announced that geothermal courses will be offered again in 2007.

Lincoln University

Lincoln University specialises in research into the agricultural sector and undertakes research on resource use and energy economics.

The Natural Resources Engineering Group (NRE) aims to facilitate the sustainable development and use of natural resources through integrated and advanced engineering practices including that of water resources and renewable energy.

Victoria University of Wellington

The MacDiarmid Institute for Advanced Materials and Nanotechnology is concerned with research in materials science and nanotechnology. Victoria University, through the School of Chemical and Physical Sciences, is the host organisation. The University of Canterbury and Industrial Research Ltd are the major partner organisations. Staff from Massey University, the University of Otago and the Institute for Geological and Nuclear Sciences also contribute.

Recent work on surface texturing for solar cells has resulted in the fabrication of cells by the Canterbury team of the MacDiarmid Institute with efficiency exceeding 15%. This project is funded by NERF[37] and in collaboration with the PVSC[38] of the University of New South Wales in Australia.

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[37] New Economy Research Fund

[38] Photovoltaic Specialists Conference

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The School of Architecture specialises in passive solar energy design for buildings. The School is the New Zealand representative on the IEA Solar, Heating and Cooling Task programme. The IEA SHC website is hosted from Victoria University.

Otago University

The Otago Energy Studies Programme undertakes research into the potential for use of renewable energy (including PV) for household applications in remote Pacific islands. This research has included Fiji and Papua New Guinea. The Energy Studies Department is undertaken research into the performance of solar water heaters.

12.1.22 Independent Organisations

CRL Energy

CRL Energy (Coal Research Ltd) is an independent commercial research organisation providing science and technology services to New Zealand energy production and utilisation industries. CRL Energy provides analytical, R&D, consulting, testing, surveying and information services to the energy industries. It has a core staff of 26 and an annual turnover of over $2,000,000.

CRL Energy has developed an Energy Efficiency Resource Assessment (EERA) model and database. The EERA highlights energy efficiency opportunities by quantifying and comparing the energy and GHG savings of efficiency improvements and their economic viability. It has undertaken research in recent years on co-firing coal and biomass, coal gasification.

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Appendix C – Operational Hydro Generation Plant

Table 24 Hydro Generation Plant in Use (December 2005).[39]

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[39] GENDATA – see References.

Field Code Changed

Owner	Name of Power Station	Capacity (MW)
Bay of Plenty Electricity Ltd	Aniwhenua	25
	Bay of Plenty Electricity Ltd Total	*25*
Onekaka Energy Ltd	Onekaka Energy	1
	Onekaka Energy Ltd Total	*1*
Carter Holt Harvey	Mataura	0.8
	Carter Holt Harvey Total	*0.8*
Contact Energy	Clyde	432
	Roxburgh	320
	Contact Energy Total	*752*
Eastland Network	Waihi	5
	Eastland Network Total	*5*
Genesis Power	Kourarau A + B	1
	Tongariro Scheme	*360*
	Rangipo	120
	Tokaanu	240
	Waikaremoana Hydro Scheme	*138*
	Kaitawa	36
	Piripaua	42
	Tuai	60
	Genesis Power Total	*499*
King Country Energy	Kuratau	6
	Mokauiti	1.92
	Piriaka	1.55
	Wairere Falls	4.56
	King Country Energy Total	*14.03*
Meridian Energy	Tekapo A	25
	Tekapo B	160
	Ohau A	264
	Ohau B	212
	Ohau C	212
	Benmore	540
	Aviemore	220
	Waitaki	105
	Manapouri	710
	Meridian Energy Total	*2448*
Mighty River Power	Aratiatia	84
	Ohakuri	104
	Atiamuri	84
	Whakamaru	100
	Maraetai (A & B)	360
	Waipapa	58
	Arapuni	197
	Karapiro	90
	Mighty River Power Total	*1077*
Northpower	Wairua	3
	Northpower Total	*3*
Opuha Dam Ltd & Alpine Energy	Opuha	7
	Opuha Dam Ltd & Alpine Energy Total	*7*

Continued overleaf.

Field Code Changed

Owner	Name of Power Station	Capacity (MW)
Pioneer Generation	Falls Dam	1.2
	Fraser River	2.4
	Glenorchy Hydro Scheme	
	Glenorchy 1	0.4
	Glenorchy 2	0.08
	Meg Hydro Scheme	
	Lower Meg 4	1
	Upper Meg 1	0.51
	Upper Meg 2	0.75
	Upper Meg 3	2
	Monowai	6
	Teviot (6 Stations)	10.53
	Wye Creek	1.5
Pioneer Generation Total		*26.37*
Todd Energy/King Country Energy JV	Mangahao	38
Todd Energy/ King Country Energy Total		*38*
TrustPower	*Branch Hydro Scheme*	
	Argyle	3.8
	Wairau	7.2
	Arnold	3
	Cobb	32
	Coleridge	45
	Dillmans Hydro Scheme	
	Dillmans	3.5
	Duffers	0.5
	Kumara	6.5
	Highbank	25.2
	Hinemaiaia Hydro Scheme	
	Hinemaiaia A	2.4
	Hinemaiaia B	1.35
	Hinemaiaia C	2.85
	Kaniere Forks	0.43
	Kaimai Hydro Scheme	
	Lloyd Mandeno	15.6
	Lower Mangapapa	6
	Ruahihi	20
	Kaimai 5	0.35
	Mangorei	4.5
	Matahina	72
	McKays Creek	1.1
	Montalto	1.8
	Motukawa	4.8
	Paerau/Patearoa Hydro Scheme	
	Paerau	10
	Patearoa	2.25
	Patea	30.7
	Wahapo (formerly Okarito Forks)	3.1
	Waihopai	2.5
	Waipori Hydro Scheme	
	Waipori 1A	10.88
	Waipori 2A	56
	Waipori 3	9
	Waipori 4	9
	Wheao/Flaxy	26.2
TrustPower Total		*419.51*
Watercare	Mangatangi Dam	0.6
	Waitakere Dam Water Treatment Plant	0.075
Watercare Total		*0.675*

Field Code Changed

Grand Total	**5316**

Field Code Changed

Appendix D – Operational Geothermal Plant

Table 25 Geothermal Electricity Generation Plant in Use (December 2005). [40],[41]

Owner/Operator	Name of Power Station	Capacity (MW)
Bay of Plenty Electricity	*Tarawera Geothermal Scheme*	
	Tarawera Geo 1	2.6
	Tarawera Geo 2	3.8
	Bay of Plenty Energy Total	*6.4*
Contact Energy	Ohaaki	66
	Poihipi Road	55
	Wairakei	179.4
	Contact Energy Total	*300*
EnergyCo	Tasman Geothermal	8
	EnergyCo Total	*8*
Tuaropaki Power Company/Mighty River Power	Mokai	94
Tauhara North No. 2 Trust/Mighty River Power	Rotokawa	28
	Mighty River Power Total	*122*
Top Energy	Ngawha	11.6
	Top Energy Total	*11.6*
	Grand Total	**448**

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[40] Review of Current and Future Personnel Capability Requirements of the NZ Geothermal Industry, Sinclair Knight Merz, October 2005

[41] MED-7-2003

Field Code Changed

Appendix E – Operational Wind Generation Plant

Table 26 Network Connected Wind Generation Plant in Use (December 2005).

Owner	Name of Power Station	Capacity (MW)
Genesis Power	Hau Nui	8.65
	Genesis Power Total	*8.65*
Meridian Energy	Brooklyn Wind Turbine	0.225
	Te Apiti	90.8
	Meridian Energy Total	*91.025*
TrustPower	Tararua - Stage I	31.68
	Tararua - Stage II	36.3
	TrustPower Total	*67.98*
Windflow Technology	Gebbies Pass	0.50
	Windflow Technology Total	*0.5*
Energy3	*Southbridge*	*0.1*
	Energy3 Total	*0.1*
	Grand Total	**168.3**

Field Code Changed

Appendix F – Operational Bioenergy Plant

Woody Biomass

Table 27 Woody Biomass Energy Plant.

Plant	MW (Thermal) *
Blue Mountain Lumber Tapanui	10
Niagara Sawmilling	10
Carter Holt Harvey Ecopine Putaruru	12
CHH Ecopine Nelson	15
Fletcher Wood Panels Taupo	17
Carter Holt Harvey Futurebuild LVL	18
Carter Holt Harvey Pine Panels Ashley	18
Fletcher Wood Panels Kumeu	20
Redstag Timber (Waipa Sawmill)	20
Juken Nissho Masterton	28
Carter Holt Harvey Pulp & Paper Whakatane Mill	31
Juken Nissho Gisborne	34
Rayonier MDF	34
Juken Nissho Kaitaia	36
Pan Pac Forest Products Ltd	60
Carter Holt Harvey Kinleith	90
Nelson Pine Industries	95
Carter Holt Harvey & Norske Skog JV	110
Carter Holt Harvey Kinleith (Black Liquor recovery boilers)	284
TOTAL	942

* Plant less than 10 MW_{th} has not been included. There is another 1213 MW of bioenergy or co-fired plant sized between 1-10 MW_{th} .

Field Code Changed

Municipal Solid Waste

Table 28 Municipal Solid Waste Energy Plant.

Plant	MWe
Rosedale	3.6
Greenmount	5.4
Redvale	2
Whitford Landfill, east of Manukau City	2
Hutt Valley Silverstream	2.7
Awapuni (Palmerston North)	1
Christchurch (Burwood,	1
Kay Road Balefill, Auckland (closed landfill, flaring only)	
Horotiu Landfill, Hamilton	0.9
Southern Landfill, Wellington	
Southgate Landfill, Wellington (Closed landfill, flaring only on a part-time basis)	
York Valley Landfill, Nelson (Operating landfill)	

Source: Ministry for the Environment, “Assessment of Greenhouse Gas Emissions from Waste Disposal as a Result of Implementation of the Proposed New Zealand Waste Strategy 19518”, April 2002.

Liquid Waste

Meat Processors

Richmond Ltd Dargaville (Collect methane off treatment pond to burn as part of odour control)

Richmond Ltd Tirau (Methane collected and piped to nearby dairy factory)

Sewage Works

Christchurch Wastewater Treatment Plant (Bromley)

Hamilton City Council (Pukete Cogen plant) (1.84 MW)

North Shore Rosedale Wastewater Treatment Plant (0.9 MW)

Watercare Manakau (6.8 MW)

Invercargill (Clifton Wastewater Treatment Plant)

Appendix G – Foundation for Research, Science and Technology Investments in Renewable Energy Research

Table 29 Summary of FRST Investment in Renewable Energy Research. Source: FRST Database.

Renewable Resource	Title	Organisation	Portfolio	2004/05	2005/06
Bio Fuels	Pond-based anaerobic energy recovery systems	National Institute of Water and Atmospheric Research Ltd	Optimising Use of Physical Resources	$205,000	
	Energy from algal biomass	National Institute of Water and Atmospheric Research Ltd	Optimising Use of Physical Resources	$58,000	
	Supply Chain Technologies and Systems	New Zealand Forest Research Institute Ltd	Optimising Use of Physical Resources	$96,000	
	Energy Demand Analysis	New Zealand Forest Research Institute Ltd	Optimising Use of Physical Resources	$86,000	
	Social, Economic, Environmental and Cultural Aspects of Biomass Energy	New Zealand Forest Research Institute Ltd	Optimising Use of Physical Resources	$78,000	
	Evaluation of BIGCC technologies developed overseas	University of Canterbury	Optimising Use of Physical Resources	$129,668	
	Transfer and development if BIGCC system to suit NZ situation	University of Canterbury	Optimising Use of Physical Resources	$141,297	
	Mapping of woody biomass feedstock supply and energy demand	University of Canterbury	Optimising Use of Physical Resources	$112,541	
	Design and modelling of woody BIGCC systems	University of Canterbury	Optimising Use of Physical Resources	$100,585	

Renewable Resource	Title	Organisation	Portfolio	2004/05	2005/06
Distributed Generation	Local Energy Resource Analysis	Innovation, Industrial Research Limited	Efficient Networks, Structures and Utilities	$120,000	$50,000
	Community End Use Energy Solutions	Innovation, Industrial Research Limited	Efficient Networks, Structures and Utilities	$130,000	$200,000
	Turbine design	Unitec Institute of Technology	Optimising Use of Physical Resources	$70,000	$60,000
	System development and testing	Unitec Institute of Technology	Optimising Use of Physical Resources	$5,000	$15,000
General	Linking New Zealand climate and hydrology to renewable resource availability and energy demand	National Institute of Water and Atmospheric Research Ltd	Efficient Networks, Structures and Utilities	$68,000	$80,000
Geothermal	Enhanced energy production from deep geothermal environments	Institute of Geological & Nuclear Sciences Limited	Optimising Use of Physical Resources	$393,030	$393,030
	Increased Utilisation of Geothermal Fluids For Power Production and Direct Heat	Institute of Geological & Nuclear Sciences Limited	Optimising Use of Physical Resources	$302,315	$302,315
	Enhanced utilisation of low-enthalpy hydrothermal systems	Institute of Geological & Nuclear Sciences Limited	Optimising Use of Physical Resources	$269,853	$269,853
	Environmental effects of Geothermal development	Institute of Geological & Nuclear Sciences Limited	Optimising Use of Physical Resources	$134,802	$134,802
Hydro	New Zealand rainfall simulation tools	National Institute of Water and Atmospheric Research Ltd	Efficient Networks, Structures and Utilities	$142,000	$130,000
	Nationally Significant Database:	National Institute of Water and	Maintaining Environmental	$1,769,000	$1,769,000

Renewable Resource	Title	Organisation	Portfolio	2004/05	2005/06
	Water Resources and Climate (1)	**Atmospheric Research Ltd**	**Integrity for Sustainable Resource Use**		
	Nationally Significant Database: Water Resources and Climate (2)	**National Institute of Water and Atmospheric Research Ltd**	**Maintaining Environmental Integrity for Sustainable Resource Use**	**$1,769,000**	**$1,769,000**
	Minimum water and flow requirements to maintain aquatic ecosystems function and values	**National Institute of Water and Atmospheric Research Ltd**	**Resilient, Functioning and Restored Natural Ecosystems**	**$418,000**	**$418,000**
	The duration of minimum water before instream values are threatened	**National Institute of Water and Atmospheric Research Ltd**	**Resilient, Functioning and Restored Natural Ecosystems**	**$211,000**	**$211,000**
	Requirements for Hydrological Variability	**National Institute of Water and Atmospheric Research Ltd**	**Resilient, Functioning and Restored Natural Ecosystems**	**$340,000**	**$340,000**
Hydro continued	**Effects of water harvesting and hydro-storage on channel stability, morphology, and substrate**	**National Institute of Water and Atmospheric Research Ltd**	**Resilient, Functioning and Restored Natural Ecosystems**	**$195,000**	**$195,000**
	Effects of changes in flow regimes on low gradient/lowland streams and rivers.	**National Institute of Water and Atmospheric Research Ltd**	**Resilient, Functioning and Restored Natural Ecosystems**	**$286,000**	**$286,000**
Solar	**Light Harvesting Dye Synthesis**	**Massey University**	**Optimising Use of Physical Resources**	**$105,000**	**$105,000**
	Conducting Polymer Production and Assessment	**Massey University**	**Optimising Use of Physical Resources**	**$100,000**	**$100,000**
	Spectroscopic Characterisation of Dyes and Polymers	**Massey University**	**Optimising Use of Physical Resources**	**$80,000**	**$80,000**

Renewable Resource	Title	Organisation	Portfolio	2004/05	2005/06
	Developing Polymer Solar Cells	**Massey University**	**Optimising Use of Physical Resources**	**$125,000**	**$125,000**
	Nickel-Zinc Batteries	**Massey University**	**Optimising Use of Physical Resources**	**$180,000**	**$180,000**
	Conducting Polymer Electrodes For Rechargeable Batteries	**Massey University**	**Optimising Use of Physical Resources**	**$55,000**	**$55,000**
	Developing Titanium Dioxide (TiO2) Solar Cells	**Massey University**	**Optimising Use of Physical Resources**	**$165,000**	**$165,000**
Wind	**Turbine design**	**Unitec Institute of Technology**	**Optimising Use of Physical Resources**	**$70,000**	**$60,000**
	System development and testing	**Unitec Institute of Technology**	**Optimising Use of Physical Resources**	**$5,000**	**$15,000**
Total Investment in Renewable Energy Research by the Foundation for Research Science and Technology				$8,515,091	$7,508,000