The Renewable Energy and Energy Efficiency Potential of Waitakere City

A thesis presented in partial fulfilment of the requirements for the degree

of

Masters of Technology
in
Energy Management

at Massey University,
New Zealand.

Lloyd D. Grooby

2005

Abstract

Electricity restrictions and blackouts have occurred in Waitakere City in the past and are likely to occur again in the future unless the city can become more self reliant by meeting, at least in part, the increasing energy requirements for what is one of the fastest growing cities in New Zealand. In this study the potentials for energy conservation, energy efficiency and renewable energy resources have been broadly quantified and assessed using desktop analysis of publicly available data for stationary final use energy systems (i.e. excluding transportation) within the geographical area of Waitakere City and adjoining waters.

It was found that energy efficiency and energy conservation measures can consistently and predictably achieve overall energy savings and reduce daily and seasonal peak demand.

The best renewable energy resource potential exists with solar and geothermal for heating applications and wave, offshore and inshore wind and tidal currents for electricity generation. There is very limited potential for hydro and bioenergy systems beyond what already exists. PV solar and land based wind power generation are currently only feasible for limited off-grid applications.

This scoping study confirms the achievability of the vision expressed in Waitakere City Council's "Long Term Council Community Plan" (LTCCP) that by 2020 "*Waitakere City will be an energy cell, not an energy sink. Air quality supports good health*". A range of flagship projects have been identified to progress the achievement of this vision. Waitakere City Council can use this report as part of the development of a comprehensive energy management plan.

Acknowledgements

The following people and institutions are acknowledged for their contribution to the development of this thesis.

Professor Ralph Sims (Massey University) – Study supervisor, editorial and initial concept

Waitakere City Council (Katja Lietz, Brent Bielby) – Study supervisor, benefactor of study, generic Waitakere data.

Philip Mladenov (EECA) – Editorial

EECA – Energy end user database for Waitakere City

Transpower – Data and information on Transpower network

Vector Energy – Waitakere network data and network maps.

James Frazerhurst – Wave power bathymetric studies and analysis

Rob Funnell (Institute of geological and nuclear sciences) – Geothermal data

Nigel Isaacs (BRANZ) – HEEP study

Murray Kennedy (Greater Wellington Regional Council) – Wellington renewable energy study and wind assessment

Dr Andrew Tait (NIWA) – Wind analysis using thin plate smoothing spline interpolation

Table of Contents

Table of figures

List of Tables

1 Introduction

Waitakere City has a geographical area of 367 km^2 with no major energy resources such as coal, oil, gas, geothermal, large hydro or even cogeneration opportunities. It has a population of 170,000 (4.5% of NZ) and an electricity consumption of 2.1 TWh per annum (7.5PJ). The renewable resources (solar, wind, small hydro and biomass) at face value are also not that outstanding.

Could Waitakere City:

1. use its renewable energy resources to meet its per capita share of the National Energy Efficiency and Conservation Strategy additional 30PJ per year of renewable energy production national target which would mean achieving a local target of 1.35 PJ per year (375 GWh/yr);
2. generate enough electricity to sustain itself (currently the annual demand of 2100GWh is growing by approximately 2% per annum, which is greater than the national average growth rate of 1.7%);
3. produce enough electricity to both sustain itself and also become a net energy exporter?

Waitakere City is facing the challenge of achieving all of the above points in its Long Term Council Community Plan (LTCCP) which states:

Vision 2020 "Waitakere City will be an energy cell, not an energy sink. Air quality supports good health"

(Waitakere City Council, 2004)

The problem must be solved in a sustainable way, which implies using a mix of energy production (sustainable and renewable), energy efficiency and energy conservation.

If the answer to any of the above questions is YES then a new set of questions need also be addressed, such as:

- How?
- Along what timeline?
- Who will do it?
- At what cost?

- At what social impact? and
- What is stopping this happening now?

To address these questions, this independent project was instigated with the aim of investigating and analysing the renewable energy potential within the Waitakere City geographical area.

1.1 Background

Following the Rio Earth summit in 1992, Waitakere City adopted the principles of Agenda 21 in 1993 and has been working towards becoming an Eco City since then. In 2003 this vision was confirmed through the process of establishing a Long Term Council Community Plan (LTCCP) (a requirement under the Local Government Act), which involved extensive community consultation.

As part of the Sustainable Energy and Clean Air platform within the LTCCP, Waitakere City has the vision of becoming an "Energy Cell" rather than an "Energy Sink" by 2020.

Over the next 10 years the Council aims to encourage renewable energy generation and energy efficiency within the city. Specifically the Council would like to see some renewable generation in the Northern Strategic Growth Area (NSGA).

Because Council has no direct control over the energy sector, it convened a workshop in February 2004 to discuss options for a more sustainable energy future for Waitakere City with key industry players.

One of the recommendations by the workshop participants was to undertake a scoping study of renewable energy opportunities in Waitakere City. This recommendation was subsequently endorsed by Council's Environmental Management Committee.

1.2 Project objectives

- Identify and quantify the renewable energy resources in Waitakere City.
- Identify and assess restrictions and barriers to the exploitation of these resources and provide recommendations on overcoming barriers.

- Analyse renewable energy conversion technologies for suitability and feasibility to exploit local renewable energy resources.
- Identify potential renewable energy producers/investors and how they could be encouraged to start/invest in renewable energy initiatives.
- Compare supply side (renewable energy production) and demand side (energy efficiency) initiatives to define and prioritise based on $per unit produced/saved.
- Provide information and data for informed future policy and decision making.
- Understand the potential of renewable energy in Waitakere City as a resource, and as a means to reduce greenhouse gas emissions.
- Create greater public awareness within the City of renewable energy, energy efficiency and greenhouse gas emission reductions using locally tailored factual information and real world data.
- Assist in meeting the National Energy Efficiency and Conservation Strategy (NEECS) targets which are to both improve energy efficiency by 20% and to increase renewable energy production by 30PJ per year by 2012.
- Move Waitakere City closer to achieving its 2020 vision of being a net energy supplier, while simultaneously reducing greenhouse gas emissions.

1.3 Project scope

- Assess current and future energy demands in Waitakere City (excluding transport fuels) including:
  - type of demand (residential, commercial, industrial);
  - usage of electricity (water heating, space heating, appliances etc);
  - seasonal variations of demand; and
  - daily profiles of demand throughout seasons.
- Assess current and future energy supply opportunities (generation and transmission) including:
  - transmission network weaknesses; and
  - generation type and hierarchy (hydro, gas, geothermal, coal).
- Identify and assess renewable energy sources (solar, wind, hydro, wave, tidal, ocean currents, cogeneration and biomass).
- Review renewable energy conversion devices from a technical, economic, environmental and social impact perspective.
- Review barriers to introduction of renewable energy systems.

- Assess energy efficiency opportunities in terms of:
    - net cost, and
    - net benefits.
- Review enabling systems and their potential for introduction in Waitakere City (e.g. subsidies, green electricity purchasing, and carbon charges).
- Identify a flagship renewable energy project to create a greater public awareness with replication potential.

The study will **include** electricity production, heating, greenhouse gas emission reductions, waste-to-energy and energy conservation measures (stationary final use energy systems).

It will **exclude** analysis of transportation, and will cover only the Waitakere City geographical area.

2 Literature review

Three previous New Zealand geographical area energy potential studies were identified. These reports covered the Southland region (see 2.1), the Wellington region (see 2.2) and the Canterbury region (see 2.3). Each of these reports has taken a different approach to the topic due to the differing aims and target audience. The Southland study is relatively detailed and closely matches some of the intentions of this report. The Wellington and Canterbury reports provide high level overviews of the renewable energy potential within their respective regions. These reports also highlight the uniqueness of each geographical area, its available resources and end energy uses. This report can only utilise some of the more generic information from these studies, investigate referenced information sources and apply some of the structural elements.

Various national level reports were identified that either look at renewable energy from a high level or provide a level of detail on a specific topic.

EECA and CAE jointly produced a book in 1996 titled “New and emerging renewable energy opportunities in New Zealand”(EECA & CAE, 1996). While some of the information in this book is becoming dated and/or been superceded, the book provides an excellent reference of the potential of renewable energy in New Zealand.

Wind energy analysis utilizing metrological office data has been performed on a national scale by various people/groups. Vere Smyth developed a report (Smyth, 1987) in 1987, though also somewhat dated, provides a large amount of data and analysis of the general wind conditions that may be utilised in the wind analysis of Waitakere City.

Nigel Isaacs and the team at BRANZ are currently performing a major study of the energy use within New Zealand residences. The Household Energy End-use Project (HEEP) is a detailed study of a large sample of New Zealand houses and the energy use that occur within them. Several intermediary reports have been released which detail specific aspects of the study.

A number of overseas reports were also consulted in the formation o this report. The Australian study “National Framework for Energy Efficiency Background Report (V4.1) Preliminary Assessment of Demand-Side Energy Efficiency Improvement Potential and

Costs" (Armstrong & Sustainable Energy Authority of Victoria, 2003) was fundamental in developing the energy efficiency analysis for this study (see Chapter 5). A report titled "A clean energy future for Australia" (Saddler, Diesendorf, & Deniss, 2004) provided valuable background information of renewable energy options, and policy to create a sustainable energy future. The city of Portland, Oregon in the USA has been one of the standout leaders in the development and implementation of policies and initiatives to manage energy within a municipal environment. A Case study of Portland (The Climate Group) is detailed in Appendix E.

2.1 Southland study

(East Harbour Management Services, 2003)

In 2003 Venture Southland commissioned a report by East Harbour Management Services to provide an energy assessment of the availability and demand for energy in the Southland region. This study provided information on current and predicted future energy demands and constraints and gave an overview of Southland's energy development opportunities. The report encompassed both renewable energy and fossil fuel resources.

In terms of renewable energy and energy efficiency, this report identified:

- Southland's regional advantage in regard to renewable energy;
- the range of options and the possible viability of renewable energy types;
- energy efficiency opportunities.

The Southland region has some obvious energy supply opportunities (such as coal, hydro, gas), and a large agricultural and industrial base with significant energy consumers (e.g. Tiwai Point smelter). The analysis of the renewable potential was in the most part a generic survey of technologies, their environmental impact, economics and barriers to their uptake. The report for the most part (except hydro) did not focus on likely sites for renewable energy or site specific potential.

The report overlooked the significance of the wave resource around the Southland coast (Frazerhurst, 2005) and the future potential to extract this resource. Specific wind energy sites were not identified although such sites are in planning. The focus of the report was around the abundant fossil fuel potential of the region and promoting continued fossil fuel energy development.

The structure of the Southland report has been used as a guide in developing this Waitakere report. The different geographical location, lack of readily identifiable resource, different industry mix, and emphasis on the renewable energy potential within the Waitakere region provide a different level of detail and focus than the Southland study.

2.2 Wellington study

(Kennedy, 2003)

This study completed by the Greater Wellington Regional Council aimed to advise the council of recent developments on the need for renewable energy with particular reference to the Wellington Region and to seek Council approval to complete a feasibility study for a wind farm development at the Belmont Regional Park.

The report only provided a very cursory glance at the renewable energy opportunity outside of Wind generation in the Wellington region. It understated the potential of these technologies to provide energy for the region, and was for the most part a report emphasising the abundant wind generation opportunity within the region and supporting development of the Belmont Regional Park site. The report focus was very short term.

The report provided some valuable background information regarding wind assessment, which has been used in the development of the Waitakere study.

2.3 Renewable energy resources in Canterbury: Potential, barriers and Options

(Westergard, 2002)

This report aim was to summarise the available literature on renewable energy in the Canterbury region. It discussed the barriers to renewable energy development and use in Canterbury, and shows some ways in which these barriers may be overcome in the future.

This report summarises the available literature, only in such that is states the potential available resource found from each study. It does not give any indication of the amount of detail available in these reports, their methodologies or details of the potential resource in terms of seasonality, quality etc. The vast majority of the cited literatures are high level reports generated by Energy Efficiency and Conservation Authority (EECA).

The discussion of barriers to renewable energy development is useful and relevant to the Waitakere study. The majority of the analysis is at a national level and again citing EECA reports.

Canterbury is a large rural region with large and obvious renewable energy potential, especially from large scale hydro (e.g. Project Aqua - Waitaki river development) and from biomass (e.g. forestry or agricultural crops). Waitakere City does not have these obvious energy solutions. The aim of the Canterbury report is different to the aim of the Waitakere report in that the Canterbury report is a high level literature survey and the Waitakere report provides some level of detail, measurement and analysis that will further assist parties interested in pursuing renewable energy development within the region. It also will discuss the potential of energy efficiency which is an equally, if not more important means of managing energy supply and demand.

2.4 New and emerging renewable energy opportunities in New Zealand

(EECA & CAE, 1996)

EECA and CAE jointly produced this book in 1996 which draws many industry experts to write renewable energy subject specific sections. While some of the information in this book is becoming dated and/or been superceded by technological advancement, the book provides a valuable reference of the potential of renewable energy in New Zealand. The subject area experts that have written each chapter (topic area) have provided a valuable insight into the breadth and depth of the subject areas, the level of understanding available at the time, and have created a valuable reference point for further specific and/or more detailed studies on renewable energy.

The report provides a valuable starting point for this study both in terms of subject matter and the underlying structure of the report. It provides enough high level data on the available resources, such that areas of particular relevance and opportunity to Waitakere City can be identified and focused on. Conversely it also allows some areas of very limited potential to be quickly excluded from further detailed analysis.

2.5 *Wind energy resource survey of New Zealand. Phase 1: National survey using existing data*

(Smyth, 1987)

Wind energy analysis has been performed on a national scale by various people/groups. These analyses have generally used metrological data to determine the nature and potential of the New Zealand wind resource. Neil Cherry and Vere Smyth have developed several of these reports, which have been reviewed in the development of this report. Smyth's study in 1987 provides a large body of analysis with sufficient detail to be able to be used as part of the wind analysis in section 6.6. The resulting Weibull Distribution parameters (and mathematical probability distribution function used within wind engineering to describe the wind characteristics of a particular location/area allowed more detailed understanding of the wind conditions within Waitakere City beyond the average wind speed numbers available from other sources.

NIWA have developed some more sophisticated modeling using spline interpolation of data from available metrological data collection points. The graphical output from the NIWA analysis for Waitakere City is shown in Figure 30. This methodology allows the wind speed at points between Metrological stations (Data collection points) to be approximated with a reasonable level of accuracy.

Data from metrological stations does have some limitations in its accuracy and use for wind engineering. Such data is collection at a relatively low attitude (generally 10m above ground). Such wind conditions may be altered by such factors as local geography, turbulence, and buildings. The level of accuracy and maintenance of wind data collection equipment will also act to reduce the quality of results obtained. Discussions with various wind engineers and wind data collection equipment suppliers indicated that in general terms the wind speed will be underestimated by approximately $1ms^{-1}$. Local geography such as hills, valleys and vegetation interact to influence the wind conditions at a particular site, so while the broader mapping of wind conditions is valuable in identifying areas of good wind conditions, a more detail study is required to identify particular sites to place a wind turbine or wind farm.

2.6 *Energy use in New Zealand households: Reports on the analysis for the Household Energy End-use Project (HEEP)*

(Isaacs, 2003) and (Isaacs, 2002) and previous reports.

Nigel Isaacs and the team at BRANZ are currently performing a major study of the energy use within New Zealand residences. The Household Energy End-use Project (HEEP) is a detailed study of a large sample of New Zealand houses and the energy patterns that occur within them. While this study is ongoing, a number of intermediary reports have been released which detail specific aspects of the study. These preliminary findings provide an insight into the residential built environment and to some of the key areas where residential energy management that could be enhanced. Since Waitakere City has a large residential population, relatively large growth and residential energy consumption is proportionately high when compared with commercial and industrial consumption, these reports and the resulting final analysis will be particularly valuable for this region.

This study uses the reports published so far from the HEEP study to understand the extent of energy wastage within the residential sector of Waitakere City and to support arguments for radical changes to government policies, guidelines and regulation controlling residential building construction and residential energy management. The issues arising from these studies extend beyond energy to other areas such as health, education, economic performance and social well-being of the nation. The importance of the HEEP study cannot be understated.

2.7 *Australia - National framework for energy efficiency - background report (V4.1) Preliminary assessment of demand-side energy efficiency improvement potential and costs*

(Armstrong & Sustainable Energy Authority of Victoria, 2003)

The objective of the study was to provide, in a short time frame, a preliminary estimate of the potential for, and costs of, energy efficiency improvement (EEI), in the residential, commercial and industrial (stationary) energy end-use sectors in Australia.

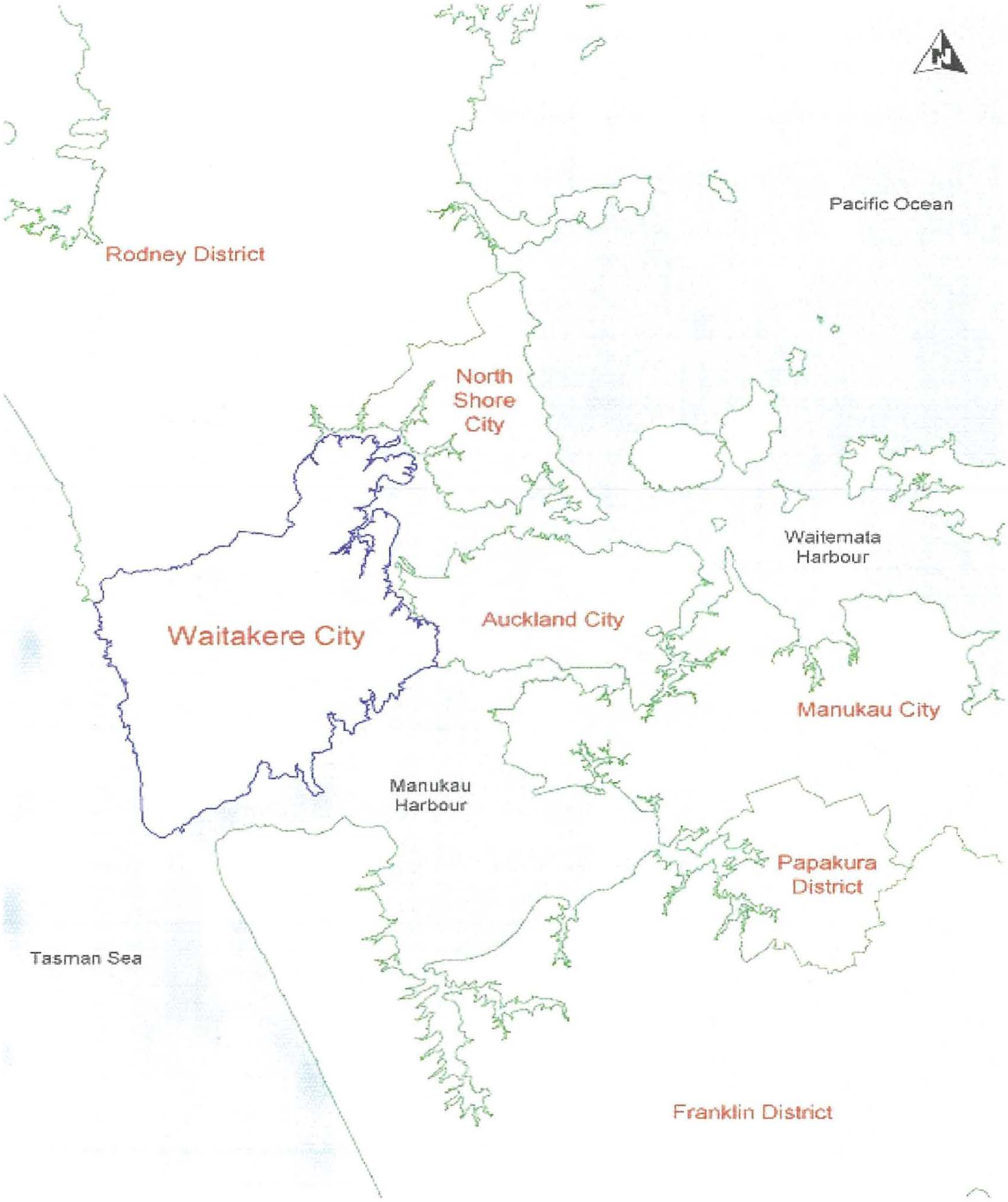
This report drew together a large body of available data and information to develop quite a comprehensive and relatively detailed analysis of the energy efficiency improvement potential across the residential, commercial and industrial sectors. The report segmented the commercial and industrial sectors using the ANZIC classification system.

From the information provided, it is possible to apply the methodologies employed and consolidation of information to provide a similar level of analysis for Waitakere City or indeed for any region of New Zealand or the country as a whole. The outcome could be a powerful indicator to stakeholders of the potential of energy efficiency and conservation as an energy management tool. The report provides sufficient referencing to allow some "do-it-yourself" energy management, auditing and implementation.

This report is used with the HEEP study reports (Isaacs, 2003) as the base resource for the energy efficiency and conservation analysis in this study (Chapter 5).

3 Waitakere City Profile

Figure 1: Map showing Waitakere City and greater Auckland region



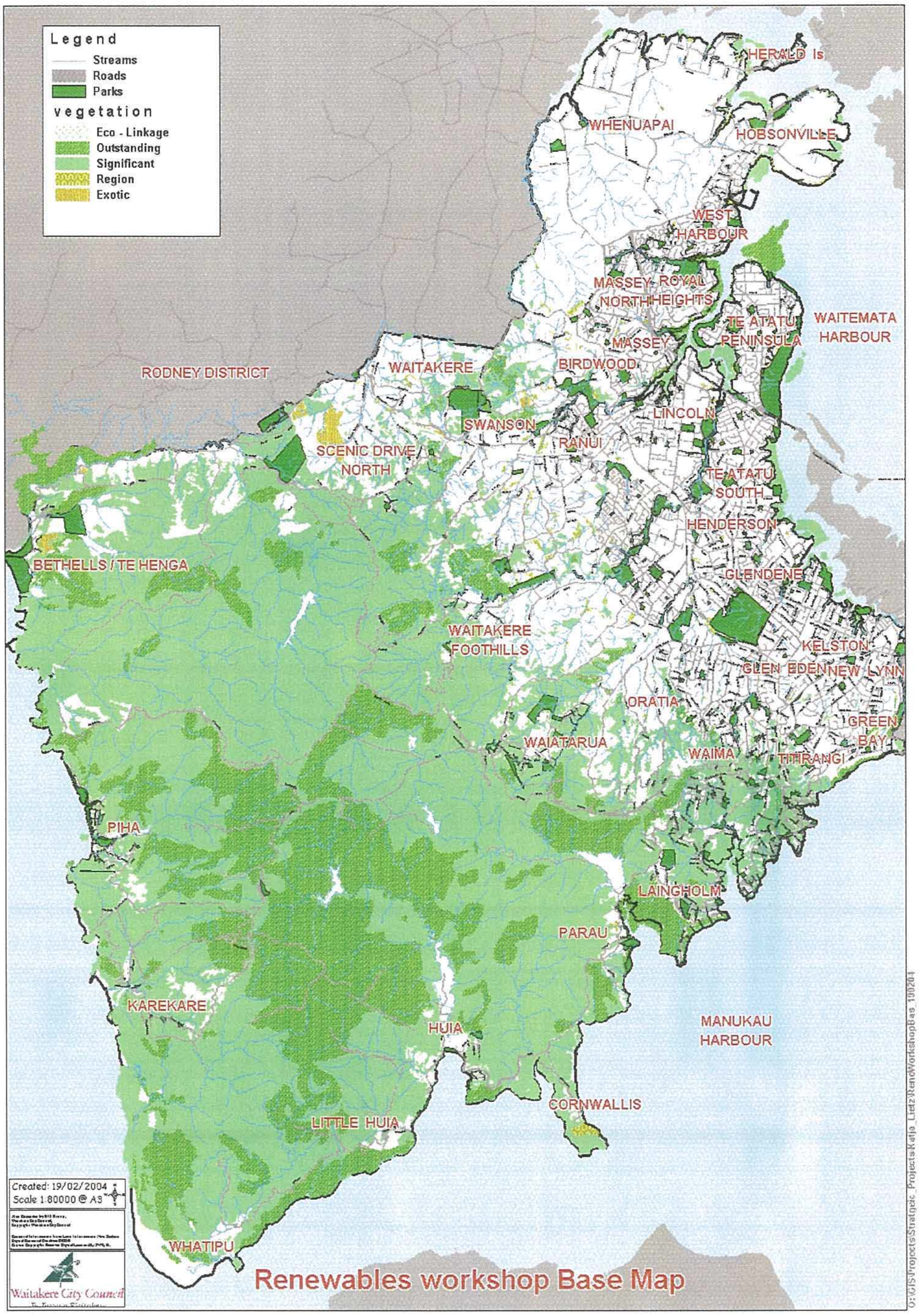
Source: (Lietz, 2004)

3.1 Geographical size of Waitakere City

- Total land area: 367 square km

- Total urban "living" area: 25.8 square km
- Metropolitan Urban Limit (MUL) area: 8192 hectares (23% of the total land area).

Figure 2: Map of Waitakere City showing urban and rural areas



Source: (Lietz, 2004)

3.2 *Waitakere climate*

The climate of Waitakere is an important determinant of both the energy consumed and the generation capability of renewable energy systems such as solar, wind and wave energy.

Using the Köppen System of climate classification developed by German climatologist and amateur botanist Wladimir Köppen in 1928, Waitakere is classed as Climate type Cfb:

"Marine climates that are found on the western coast of most continents. They have a humid climate with short dry summer. Heavy precipitation occurs during the mild winters because of continuous presence of mid-latitude cyclones."

Sub definitions are:

Major climate type - C = Mild mid latitude climate type – coldest month above 0 °C, but below 18°C, warmest month above 10 °C. This climate generally has warm humid summers with mild winters. It extends from 30 to 50 degrees of latitude mainly on the eastern and western borders of most continents.

Precipitation subtype - f - constantly moist: rainfall consistent throughout the year

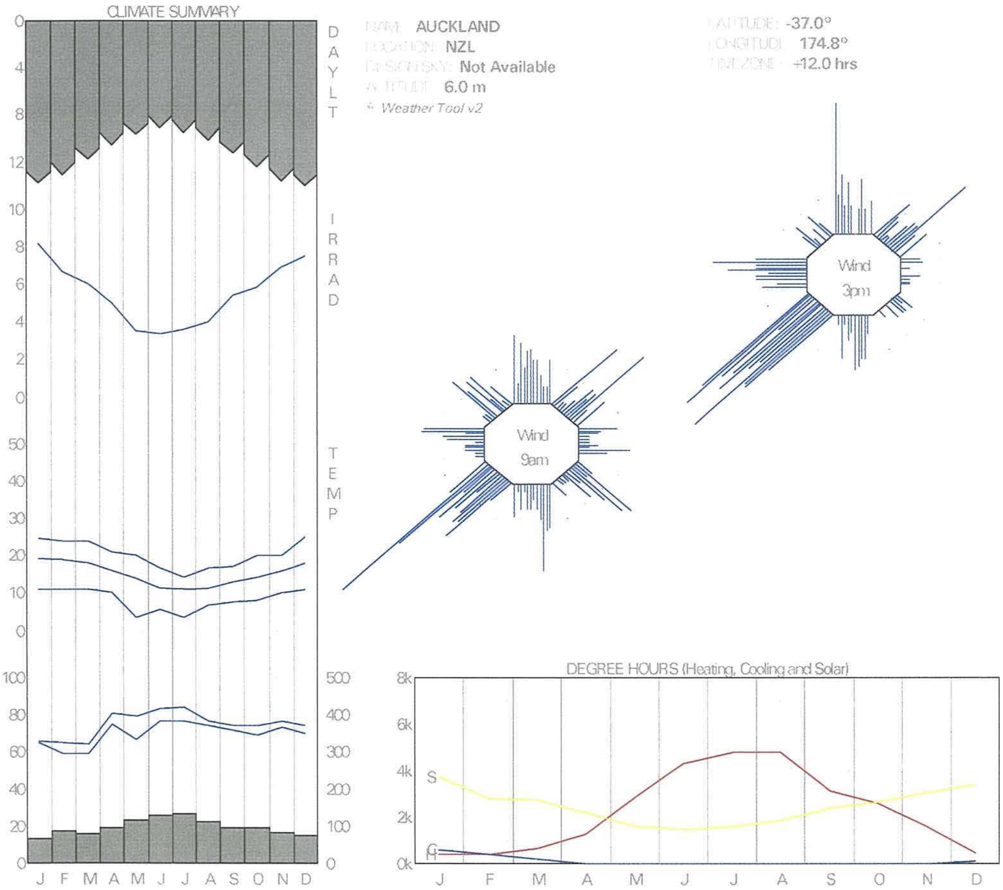
Temperature subtype - b - warmest month below 22 C

(Marsh, 2002)

A summary of the major weather indicators for Waitakere City is shown in Figure 3. The dominant wind is from the South West. Other indicators show seasonality typical of a mid latitude southern hemisphere location.

A more detailed view of the Waitakere Climatic resource showing measurements of parameters useful of renewable energy and energy management analysis is shown in Appendix A.

Figure 3: Waitakere City climate summary



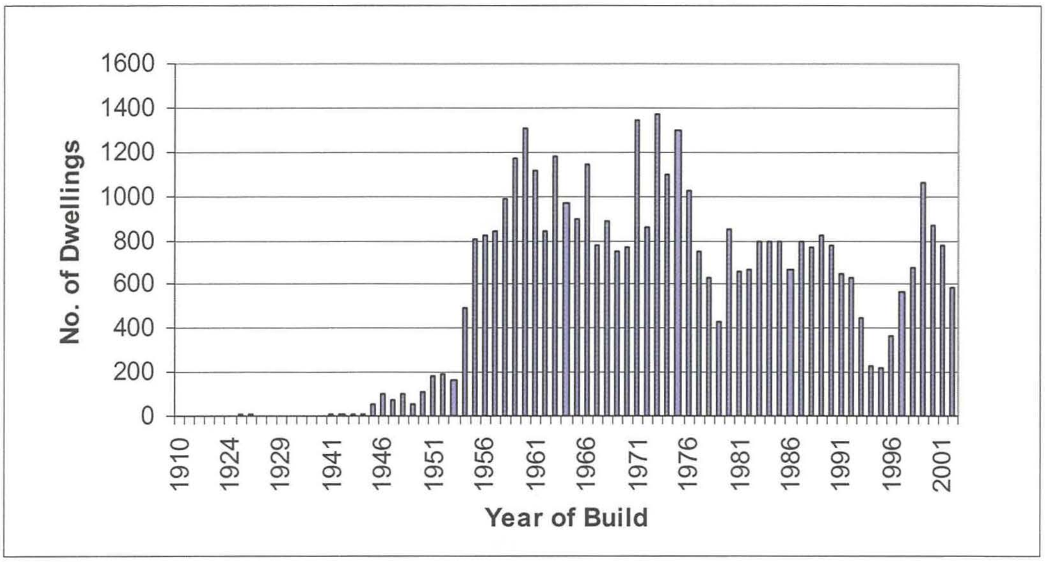
Data source: (ASHRAE, 2004)

3.3 Households

From the 2001 Census, the population of Waitakere is 168,750 and the number of households (occupied dwellings) in Waitakere City is 55,653 (Statistics NZ, 2001).

Approximately 40,000 of the dwellings in Waitakere City were built prior to 1978 when housing insulation standards became mandatory (Figure 4). Total of building consents (Figure 4) are 41,096 and thus underestimate total dwellings in City. The data after 1980 are likely to be reliable. This data was the best available data from Waitakere Council.

Figure 4: Approximate number of residential houses built in Waitakere City by year based on building consents issued

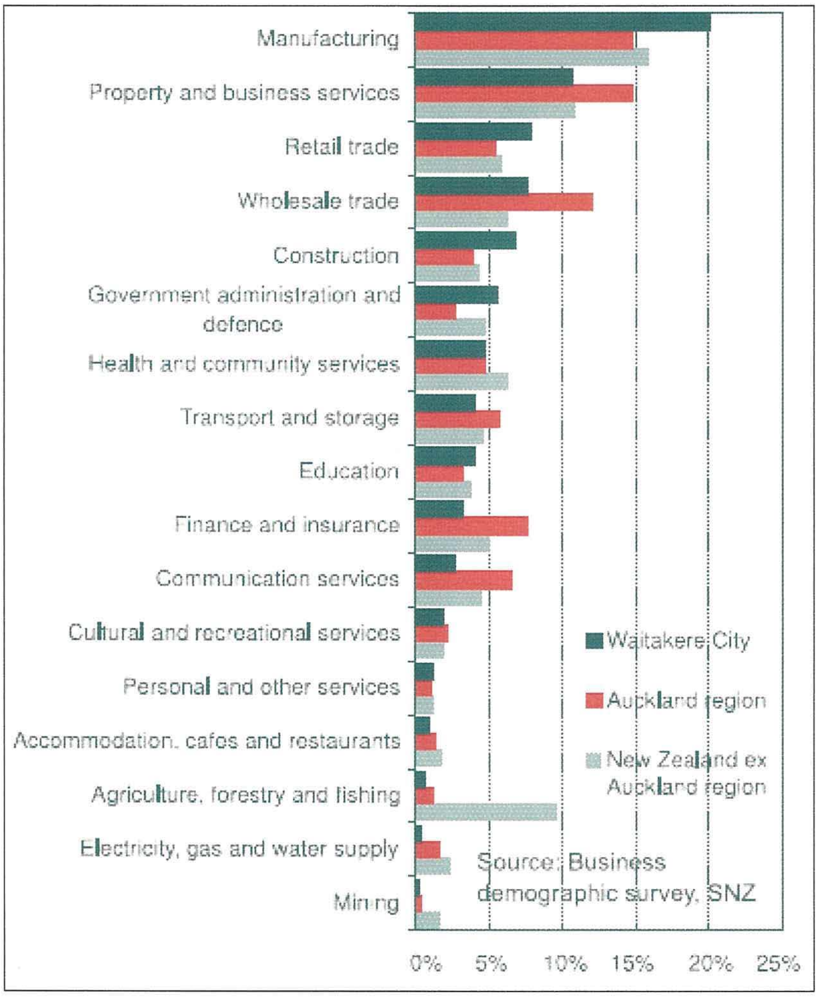


Source: (Waitakere City Council, 2004)

3.4 Business and economy

There were 10,962 business units in Waitakere city in 2002. Primary industries accounted for 1% of all production in Waitakere's economy. Secondary industries (manufacturing and construction) accounted for 27% of all production over the year to March 2003. Tertiary industries accounted for 55% of all production (Year to March 2003) with property and business services and retail trade being the city's largest tertiary industries. The various sectors of industry in Waitakere City and their contribution to the local economy are compared with similar data for the Auckland region and New Zealand (Figure 5).

Figure 5: Waitakere industry's share of the local economy as at February 2003



Source: (Waitakere City Council, 2003)

4 Current Energy Supply and Demand

4.1 Transpower transmission system

Source: (Transpower, 2002) and (Transpower, 2004)

Waitakere City is supplied from the Henderson and Hepburn road substations that are part of Transpower's Northern Isthmus Region covering the upper North Island (Figure 6). The North Isthmus Region is supplied from Otahuhu via the following 220 kV circuits:

- Otahuhu-Henderson double circuit line (with one circuit passing through Southdown); and
- Henderson-Marsden A double circuit line.

Limited supply from the core grid is also available from the Henderson-Maungatapere A 110 kV line.

Figure 6: Transpower Northern Isthmus region geographically

Source: (Transpower, 2002).

4.2 Electricity demand growth

Transpower (2004) made the following projections in determining the energy demand growth out till 2015 (**Error! Reference source not found.**):

- Population growth: 0.5% p.a.
- GDP growth: 2.2% p.a.
- Demand price elasticity: -0.07

- Peak demand growth rate is same as energy growth rate (2.3% per annum).
- Technology and energy efficiency to occur at current rate
- Distributed generation: 5%

For the North Isthmus regions, as shown in Table 1, Transpower forecasted that electricity demand in the Northern Isthmus will continue to grow at a steady rate of 2.3% per annum out to 2040, although over the next six years Transpower's forecast growth is 2.5% per annum. The high demand growth figure is 3.0% and the low growth figure 2.0%.

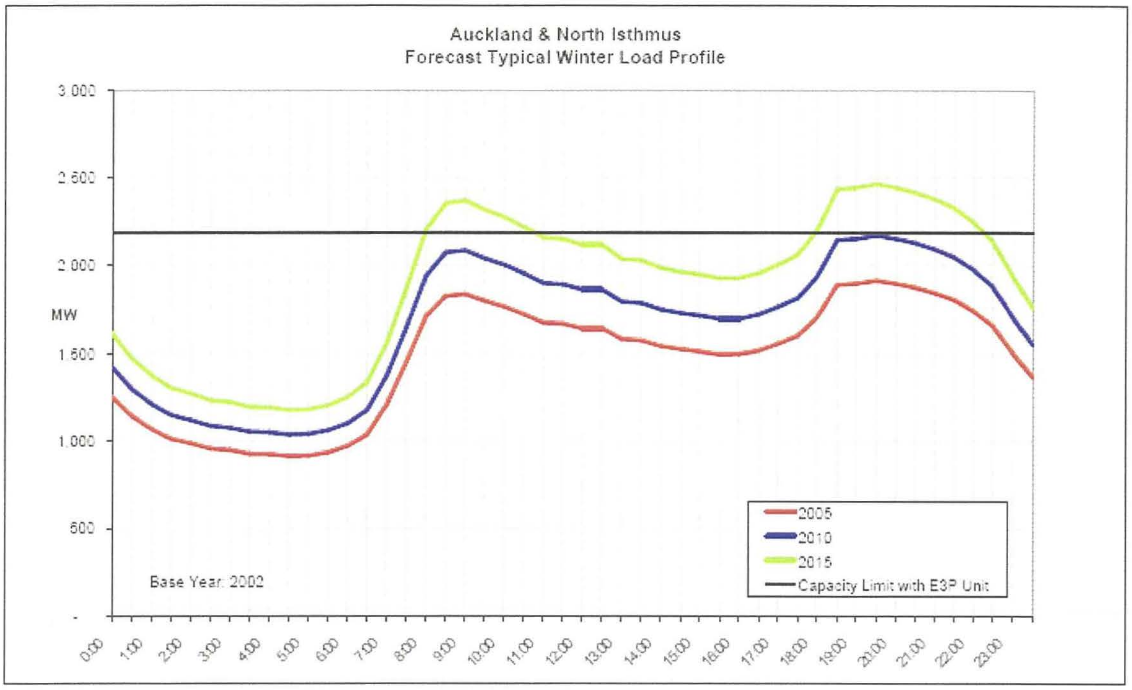
Given this forecast, the typical winter load, the evening peak (Figure 7) will meet the capacity limit by 2010 and both morning and evening peaks will exceed the capacity limit by 2015. This assumed that Genesis' new E3P gas fired CCGT units of 300MW will be installed at Huntly and come on line by 2007.

Table 1: Northern Isthmus and Auckland demand forecast.

Year	North Isthmus Demand (MW)	Auckland Demand (MW)	Combined Demand (MW)
2005	719	1203	1922
2006	737	1232	1970
2007	756	1263	2019
2008	776	1296	2072
2009	796	1330	2125
2010	817	1364	2181
2011	838	1399	2237
2012	859	1435	2294
2013	881	1472	2352
2014	903	1509	2412
2015	926	1550	2476

Source: (Transpower, 2004).

Figure 7: Auckland and Northern Isthmus region forecast typical winter load profile



Source: (Transpower, 2004).

4.3 Forecast transmission adequacy for transmission into North Isthmus (Otahuhu to Henderson)

Source: (Transpower, 2004).

Based on forecast demand and committed generation and transmission projects, supply problems into the North Isthmus are likely to be experienced from 2010 under a medium demand growth scenario and will increase in severity as demand continues to increase unless the peak load can be reduced by load shifting or energy efficiency

The critical contingency would be the loss of the Otahuhu B combined cycle gas turbine unit leading to voltage collapse in the area causing a partial or total loss of supply to the North Isthmus region. The loss of one Henderson-Otahuhu 220 kV circuit may also lead to voltage collapse in the area, but at a later date than the Otahuhu B outage scenario.

Table 2: Electricity shortfalls in Northern Isthmus region 2005-2015

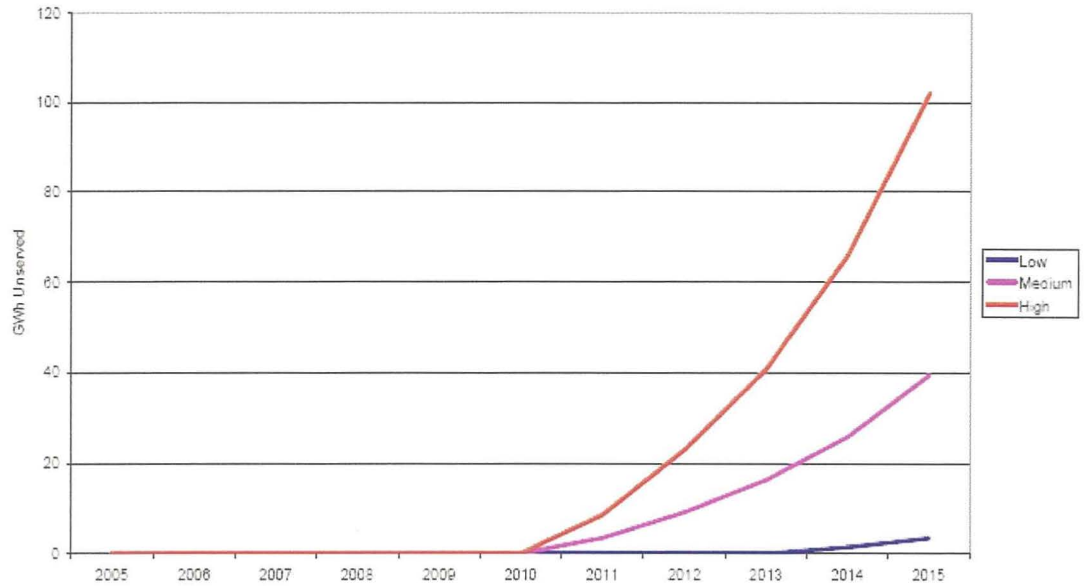
Year	Additional energy requirement range (from low to high demand) above the current maximum secure network capacity (GWh)	Additional peak demand requirement range (from low to high demand) above the current maximum secure network capacity. (MW)
2005	0	0
2006	0	0
2007	0	0
2008	0	0
2009	0	0
2010	0-3	0-12
2011	0-9	0-37
2012	0-23	0-62
2013	0-41	10-88
2014	1-66	28-114
2015	3-102	46-141

Source:(Transpower, 2004)

Table 2 assumed only committed generation plants will be built including the recently confirmed E3P generation project at Huntly by Genesis Energy. Figure 8 and Figure 9 show forecast projections for high, medium and low demand growth scenarios that were used to derive Table 2.

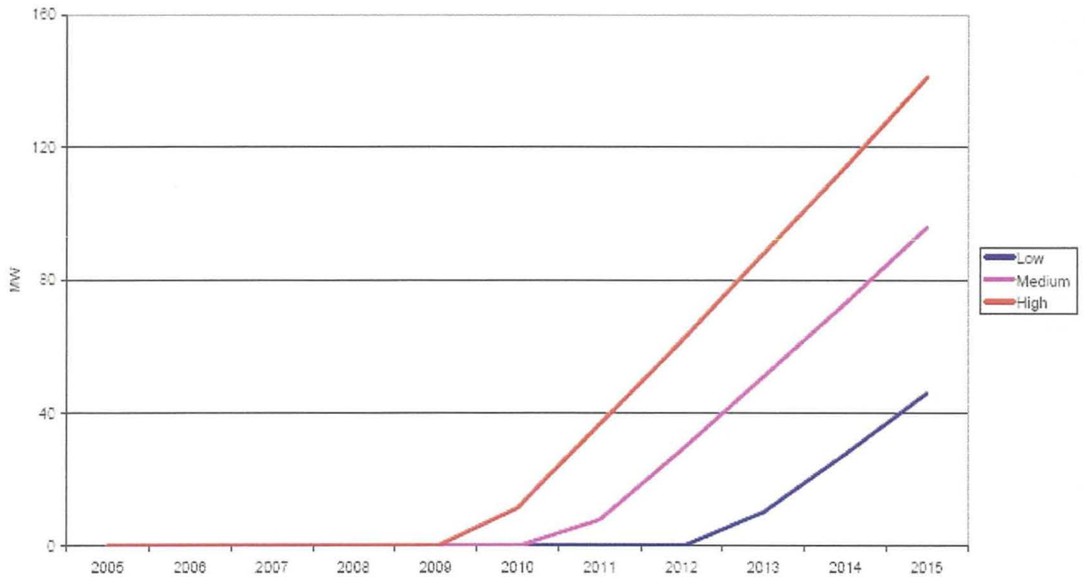
Transpower is planning to reinforce the supply from Otahuhu to the North Isthmus. Two broad options are being evaluated, namely an underground cable route between Penrose and Albany or a new 220 kV transmission line between Otahuhu and Henderson. High level cost-estimates place the costs of these solutions between $160-250 million + 30%. The critical line to be addressed in terms of reduced loading is the existing Otahuhu-Henderson 220 kV line.

Figure 8: Total GWh above limit for Northern Isthmus region for 2005 – 2015



Source: (Transpower, 2004).

Figure 9: Peak demand exceeding transmission capacity limit for Northern Isthmus region for 2005 - 2015



Source: (Transpower, 2004).

The forecasts in Table 2, Figure 8 and Figure 9 did not consider proposed generation within the region. The development of the 300-320MW Marsden B coal-fired plant proposal by Mighty River Power could generate approximately a third of future electricity requirements of the Northern Isthmus region and significantly alleviate the constraints in peak and overall supply to the Northern Isthmus and Auckland region.

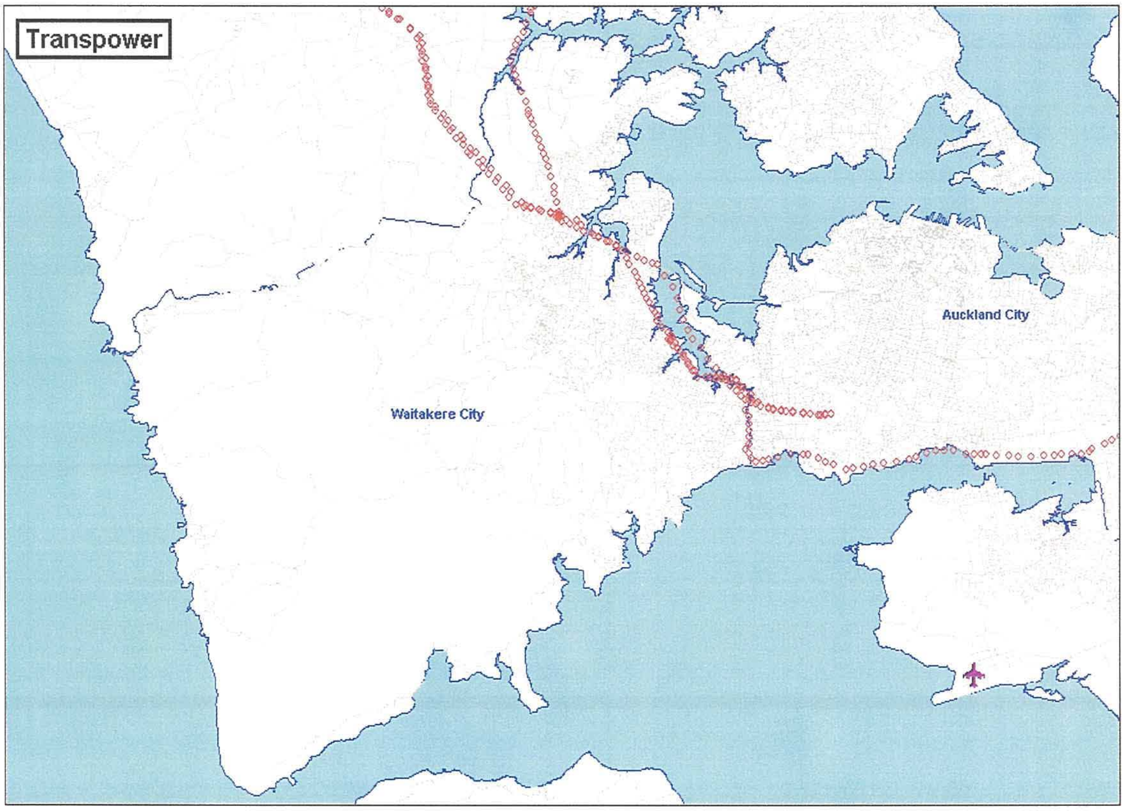
Clearly any other local generation would have a significant benefit to the region, alleviating the current and future network constraints.

4.4 Physical location of Transpower transmission lines within Waitakere City

The Transpower transmission network of pylons and lines feeding Waitakere City (Figure 10) follow the north eastern edge of the city, running in parallel with the North Western Motorway through Te Atatu North with a branch at Massey heading towards Albany.

Major electricity generation projects within Waitakere City (above 30MW) would require substantial investment to connect to the Transpower network, due to the distance to Transpower infrastructure. Generation that is able to be connected to the local network would be a more viable option.

Figure 10: Transpower transmission network within Waitakere City



Source: (Transpower, 2004)

4.5 Vector electricity distribution system.

The Vector electricity distribution system within Waitakere City (Figure 11) does not extend significantly into the Waitakere ranges. The run to Piha is over 100kms long and experiences frequent faults (mostly weather related) and is a weak grid. Houses within the Waitakere ranges and foothills tend to be either remote from power lines, have significant connection costs or are towards the end of the distribution lines. Homes within these areas, due to the cost of connection and reliability of supply, may have enhanced economic benefit from the consideration of renewable energy generation. The benefits obtained may extend to electricity suppliers if operational savings can be made.

The remote south west corner of the city (where wave, tidal and wind generation potential exists) has no power supply infrastructure. It may be more feasible to have generation in this area if transmission is connected to the grid on the south side of the harbour entrance, where other generation proposals are being developed (i.e. Genesis Energy's Awhitu wind farm).

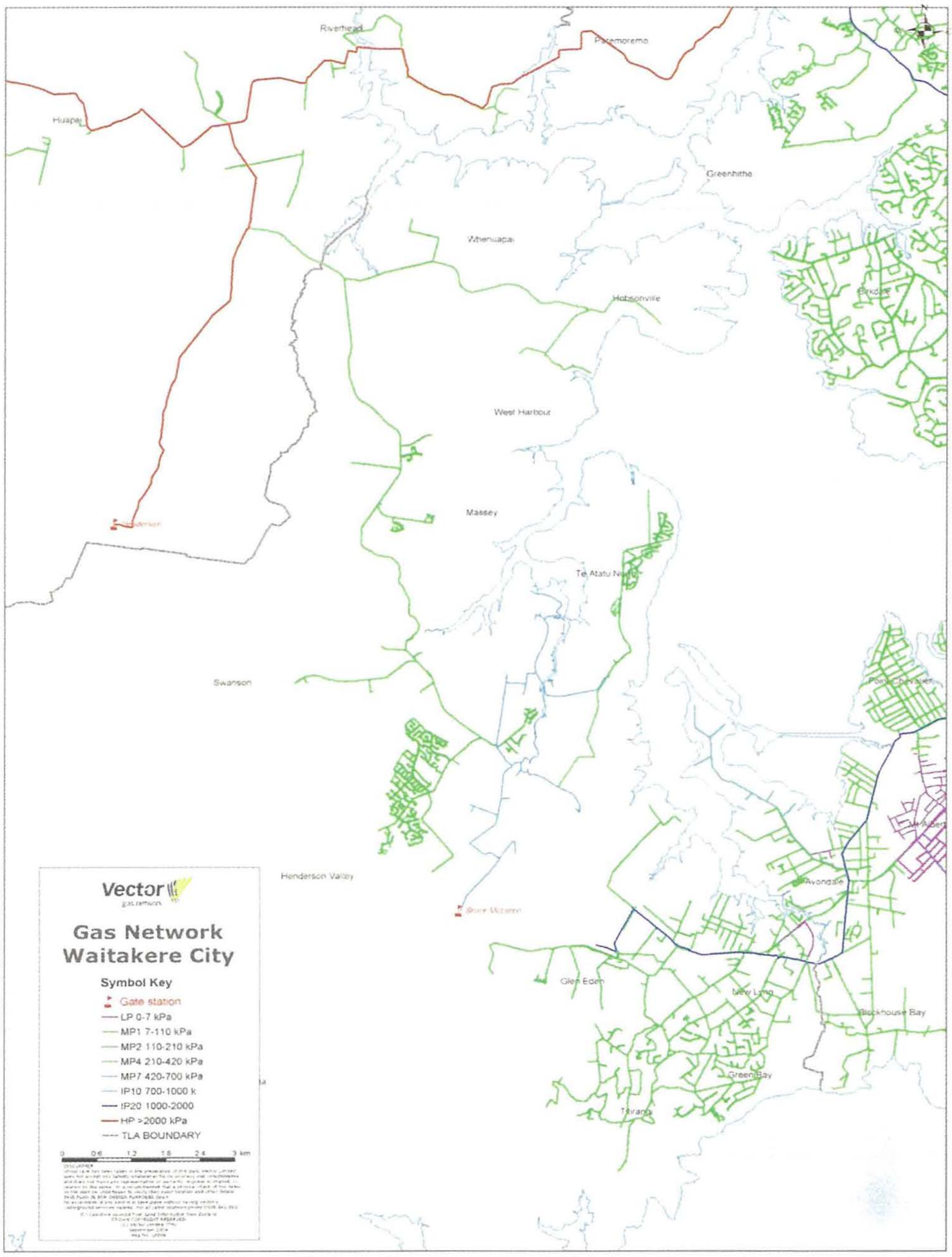
Figure 11: Vector network hierarchy, zone substation, grid exit points, HV network distribution system

Source: Vector Energy (2004)

4.6 Vector natural gas distribution system.

Piped gas is limited to the south east suburbs close to Auckland City and the new housing developments in Swanson and Te Atatu Peninsula (Figure 12). The lack of gas supply limits the ability to offset some of the electrical heating demand with gas consuming appliances, which may be more energy efficient. In the future leading edge hydrogen for fuel cell electricity production using the reformation of gas to produce the hydrogen will be limited due to this lack of piped gas supply.

Figure 12: Natural gas network in Waitakere City



Source: Vector Energy (2004).

4.7 *Energy consumption*

EECA has derived a breakdown of energy consumption by sector for Waitakere City (EECA, 2005) (Table 3). The data was carefully derived from national and sub-national data available from multiple sources and thus represents a good approximation of the energy consumption of Waitakere City.

Table 3: EECA energy end use database for Waitakere City (GJ) matching supply with demand

New Zealand Delivered Energy (GJ)	Aviation Fuel	Black Liquor	Coal	Diesel	Electricity	Fuel Oil	LPG	Natural Gas	Petrol	Wood	Total
Agriculture	954	0	47,481	89,120	8,830	191	0	132,629	17,113	0	296,317
Basic Metal Industries	123	0	0	1,078	30,826	3,388	485	11,944	41	0	47,885
Beverages, Tobacco, confectionery and sugar, and otherfood processing	175	0	0	4,393	39,173	0	1,840	112,167	13,019	0	170,768
Central Govemment Administration	0	0	102	964	12,800	42	0	8,634	886	0	23,429
Central Govemment Defence Services	463,784	0	24,696	159,849	52,566	1,167	0	40,771	8,811	0	751,664
Chemicals, Related Products and Plastics	252	0	10,149	83,878	104,875	6,474	2,309	177,764	1,296	0	386,998
Commercial Transport and Storage	12,036	0	339	1,163,565	25,565	17,203	73,440	1,891	227,479	0	1,521,517
Communication	0	0	0	8,261	11,540	0	82	170	2,969	0	23,021
Concrete, Clay, Glass and Related Minerals Manufacture	121	0	145,408	13,066	31,468	0	4,775	57,444	0	0	252,282
Construction	3,923	0	0	146,841	44,343	436	4,184	128	44,641	0	244,496
Dairy Products	0	0	0	0	0	0	0	0	0	0	0
Education Services: Pre-School, Primary and Secondary	0	0	17,860	0	32,325	289	0	40,043	0	0	90,517
Education Services: Tertiary Education	0	0	110	0	325	2	0	481	0	0	918
Fabricated Metal Products, Machinery and Equipment	166	0	1,647	114,424	59,980	1,626	3,625	77,494	2,801	0	261,763
Finance, Insurance, Real Estate and Business Services	0	0	15	0	52,107	0	0	45,231	0	0	97,353
Fishing and Hurting	41	0	0	19,085	1,276	6,402	0	0	8	0	26,812
Forestry and Logging	29	0	0	2,095	985	0	0	0	539	0	3,648
Health and Welfare Services	0	0	8,923	0	13,343	0	0	53,264	2,687	0	78,217
Household	0	0	23,136	0	1,780,656	0	76,648	445,744	0	253,713	2,579,897
Household (Private Transport)	0	0	0	535,166	0	0	22,320	3,353	3,892,236	0	4,453,076
Local Government Administration	0	0	1,745	7,929	27,741	0	0	20,544	8,368	0	66,328
Mining and Quarrying	0	0	3,991	23,868	9,315	4,005	0	264	1,599	0	43,043
Motels, Hotels, Guest Houses	0	0	2	362	4,705	4	90	11,369	394	0	16,925
Other Manufacturing Industries	0	0	0	744	6,308	4	109	1,682	840	0	9,688
Other Social and Related Community Services	0	0	1,377	0	62,532	374	0	7,385	0	0	71,668
Paper and Paper Products, Printing and Publishing	919	617,880	0	638	347,446	14,502	675	455,623	77	294,940	1,732,700
Retail Trade - Food	0	0	1,385	7,238	150,468	20	5,249	82,381	17,544	0	264,285
Sanitary and Cleaning Services	0	0	0	14,478	22,334	0	0	0	9,781	0	46,593
Slaughtering and Meat Rocessing	34	0	13,732	1,082	15,470	84	692	16,245	3,270	0	50,609
Textile, Apparel and Leathergoods	234	0	5,042	26,282	30,531	1,297	310	98,507	1,167	0	163,371
Water Works and Supply	0	0	0	0	9,755	0	0	0	0	0	9,755
Wholesale and Retal Trade - Non Food	0	0	20,184	33,976	89,720	143	7,260	76,326	129,705	7,931	365,245
Wholesale Trade - Food	0	0	0	3,836	7,285	0	26	1,560	4,984	0	17,692
Wood Processing and Wood Products	0	0	12,035	1,686	86,487	2,061	5,826	81,085	53	379,935	569,168
Total	482,791	617,880	339,359	2,463,903	3,173,084	59,735	209,945	2,062,121	4,392,306	936,520	14,737,646

Source: (EECA, 2005)

Electricity is the dominant non-transport fuel followed by natural gas. The household category dominated in electricity use and was a leader in natural gas consumption. Other major consuming categories were paper products and plastics due to large industrial plants located within the city. Coal and wood were also used, particularly in household heating, but were relatively minor energy fuels within Waitakere. The data from this table has been used as the basis for further analysis (Section 5).

Waitakere is a predominantly residential city with few major energy consuming industries or businesses and contains none of the top 300 electricity consumption sites that consume 90% of New Zealand's electricity. The major energy consumers in the city are shown in Table 4.

Table 4: Major energy consumers in Waitakere City

Retail	
	Westcity shopping centre
	Westfield Lynmall
Plastics manufacuture	
	Huhtamaki Van Leer NZ Ltd Henderson
	Huhtamaki Van Leer NZ Ltd New Lynn
	Alto Plastics
Paper Tissue	
	Svenska Cellulosa (Ex Carter Holt Harvery Tissues)
Services	
	Watercare Huia
	Waitakere Hospital
	Waitakere City Council (Multiple accounts)
Food	
	Tegel foods - Henderson
Pharmaceuticals	
	Douglas Pharmaceuticals
Defence	
	Whenuapai and Hobsonville Airbases

Source: (Vector Energy, 2004)

The demise of the airbases at Whenuapai and Hobsonville will result in an energy reduction that will eventually be exceeded by the planned replacement with residential housing, commercial development and a potential commercial airport at Whenuapai.

Watercare has significant plans underway to develop hydro generation that will meet all their own energy requirements and also export some electricity to the local grid.

Statistics NZ Household Expenditure Survey (HES) indicated that in 2001 the average household spent $23.90 per week ($1246.21 annually) on domestic fuel and power. When the data was updated to 2003 figures, the city's total residential sector spend was in the order of $73 million per year on electricity, gas, fuel wood etc, with the $68 million being spent on electricity. The total estimated electricity spend for Waitakere city sectors in 2003 is detailed in Table 5.

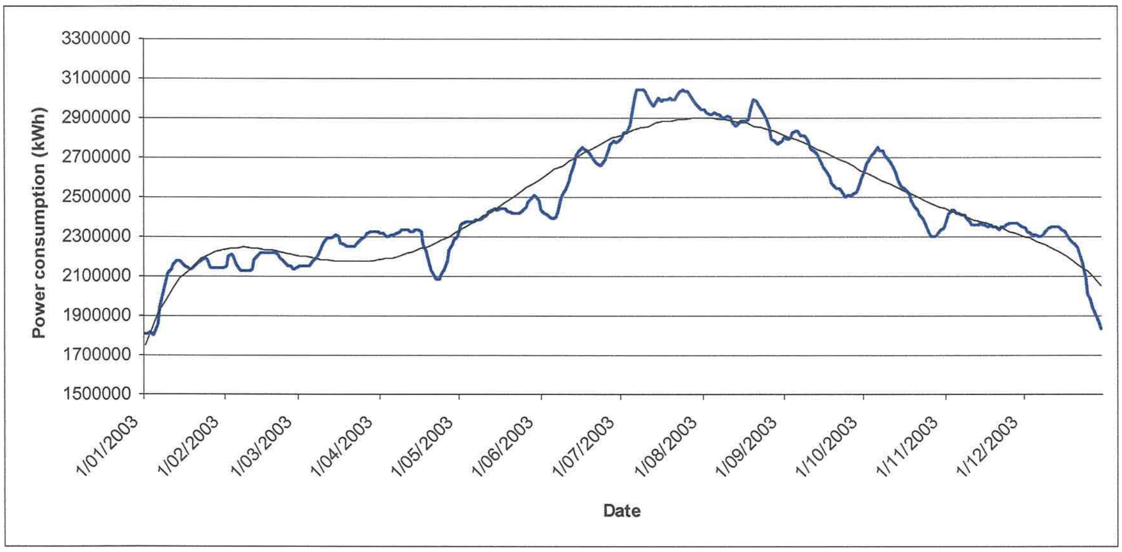
Table 5: Estimated spend on electricity in Waitakere City (2003) by industrial, commercial and residential sectors

Sector	Consumption (kWh)	$/kWh (MED to March 2003)	Total cost
Industrial	217,423,785	0.0723	$15,729,514
Commercial	149,942,064	0.1079	$16,173,734
Residential	494,627,062	0.1382	$68,345,046
Total	861,992,912		$100,248,295

Data Source: Ministry of Economic Development (MED)

The seasonal and daily profiles of electricity consumption in Waitakere City (Figure 13 and Figure 14) were consistent with the national profile having late winter peak consumption. Wind speed, and therefore wave energy offer similar seasonality to this consumption pattern and may be worthwhile considerations for energy production. Lighting and heating are likely to be the main drivers for this seasonality and thus efficiency measures for these would have greatest impact on annual peak demand.

Figure 13: Waitakere City seven day rolling average annual power profile with trend line

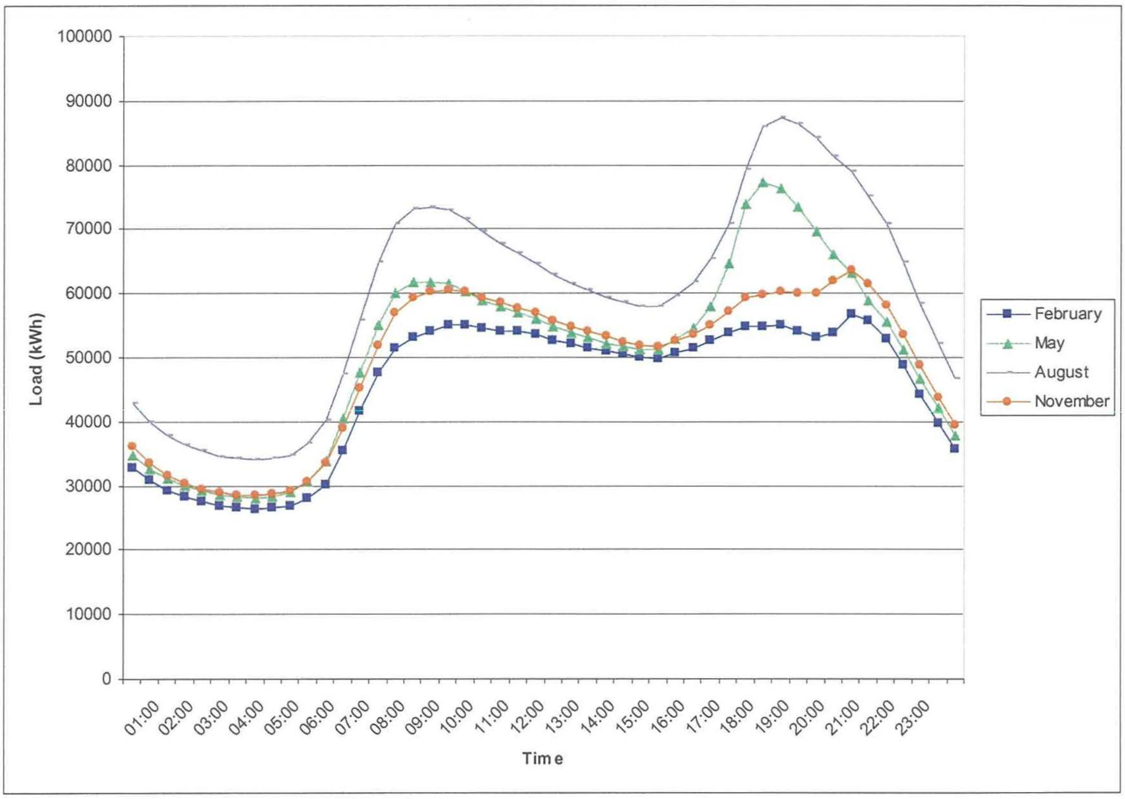


Data Source: Vector Energy Ltd

Energy reductions seen on Figure 13 align with major public holidays observed in Waitakere, while other irregularities align with observed weather patterns giving hot/cold spells.

The winter load profile has more prominent peaks than the overall Auckland and Northern Isthmus Region profiles (Transpower, 2004) highlighting the residential nature of Waitakere city. The dominant drivers of the daily profile are residential hot water heating, central heating and lighting. Hot water heating energy consumption follows hot water usage, showing morning and higher evening peaks (mostly determined by bathing time). Central heating is seasonal and largely confined to morning (wake up until depart for work) and evening (at home until bed time).

Figure 14: Waitakere monthly averaged daily load profile (2003)



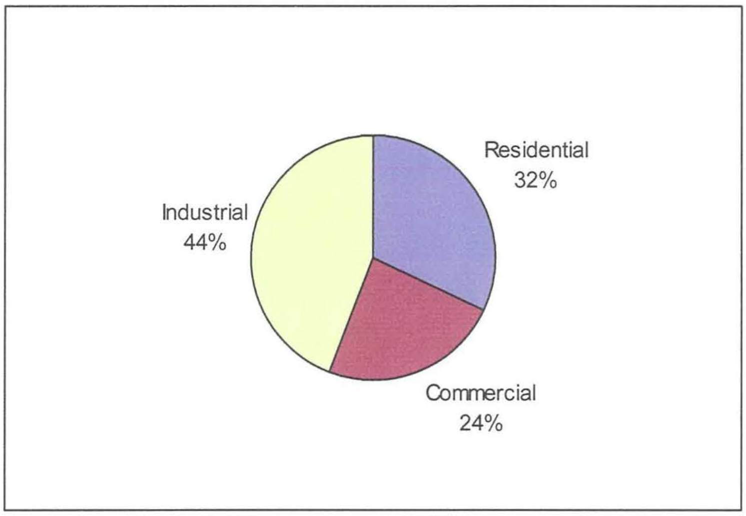
The data used for these daily and annual profiles (Figure 13 and Figure 14) are from Vector Network grid exit points at Henderson and Hepburn, thus the coverage area is slightly larger than Waitakere City though the profiles are expected to be consistent with Waitakere only data.

Reduction of the energy consumption within Waitakere City through targeted campaigns focusing on lighting, space conditioning and (non ripple controlled) hot water supply would be very beneficial in reducing the peak demand load for the region (and for Auckland as a whole). This reduction would reduce the likelihood of supply constraints within the network and could delay costly upgrading of network infrastructure. The question remaining is how the benefits of such initiatives can be aligned to those whom would bear the costs.

5 Energy Consumption and Efficiency Analysis by Sector

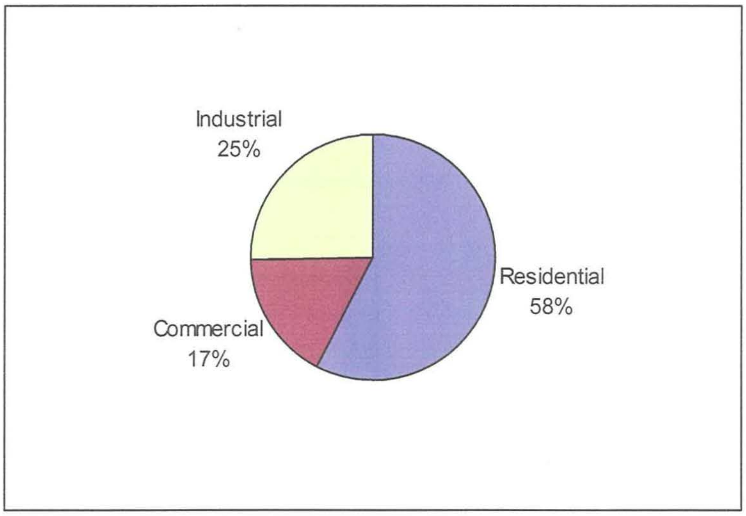
Figure 15 shows the proportions of Waitakere energy and electricity consumed by each sector. The industrial sector is the major consumer of energy in Waitakere mainly because of the use of large quantities of biomass from waste the products produced and used for fuel. The residential sector is the largest consumer of electricity.

Figure 15: Total energy consumption by sector (%)



Data Source: Ministry of Economic Development (MED) via EECA Energy End User database (EEUDB)

Figure 16: Total Electricity consumption by sector (%)



Data Source: Ministry of Economic Development (MED) via EECA EEUDB.

In November 2003 a report was prepared for the Sustainable Energy Authority Victoria, Australia as part of the development of the "National Framework for Energy Efficiency"(Armstrong & Sustainable Energy Authority of Victoria, 2003). Energy efficiency improvement (EEI) was defined in terms of the energy savings that could be achieved as a percentage of current energy use for a specific energy service. The objective of the study was to provide, in a short time frame, a ***preliminary estimate*** of the potential for, and costs of EEI, in the residential, commercial and industrial (stationary) energy end-use sectors, in order to: (i) provide inputs for economic modelling (reported on in a separate study) to give an *order of magnitude* estimate of the national costs and benefits of energy efficiency improvement, beyond the business-as-usual levels, over a 12-year period; (ii) stimulate discussion on the potential for, and means of achieving, significant energy efficiency improvements in Australian stationary end-use sectors.

An adaptation of some of the analysis of this report derived some preliminary estimation of the level of energy savings that could be achieved if similar energy saving initiatives were introduced within the Waitakere City residential, commercial and industrial sectors. While much of the analysis and techniques of obtaining energy efficiency are robust, the results of these analyses should be seen as **indicative of the potential savings** obtainable in each sector rather than as an accurate assessment based on rigorous research and analysis.

Two scenarios were envisaged.
A low energy efficiency improvement potential (EEIP) characterised by

- average economic payback of approximately 4 years, and
- data relatively robust.

And a high EEIP characterised by

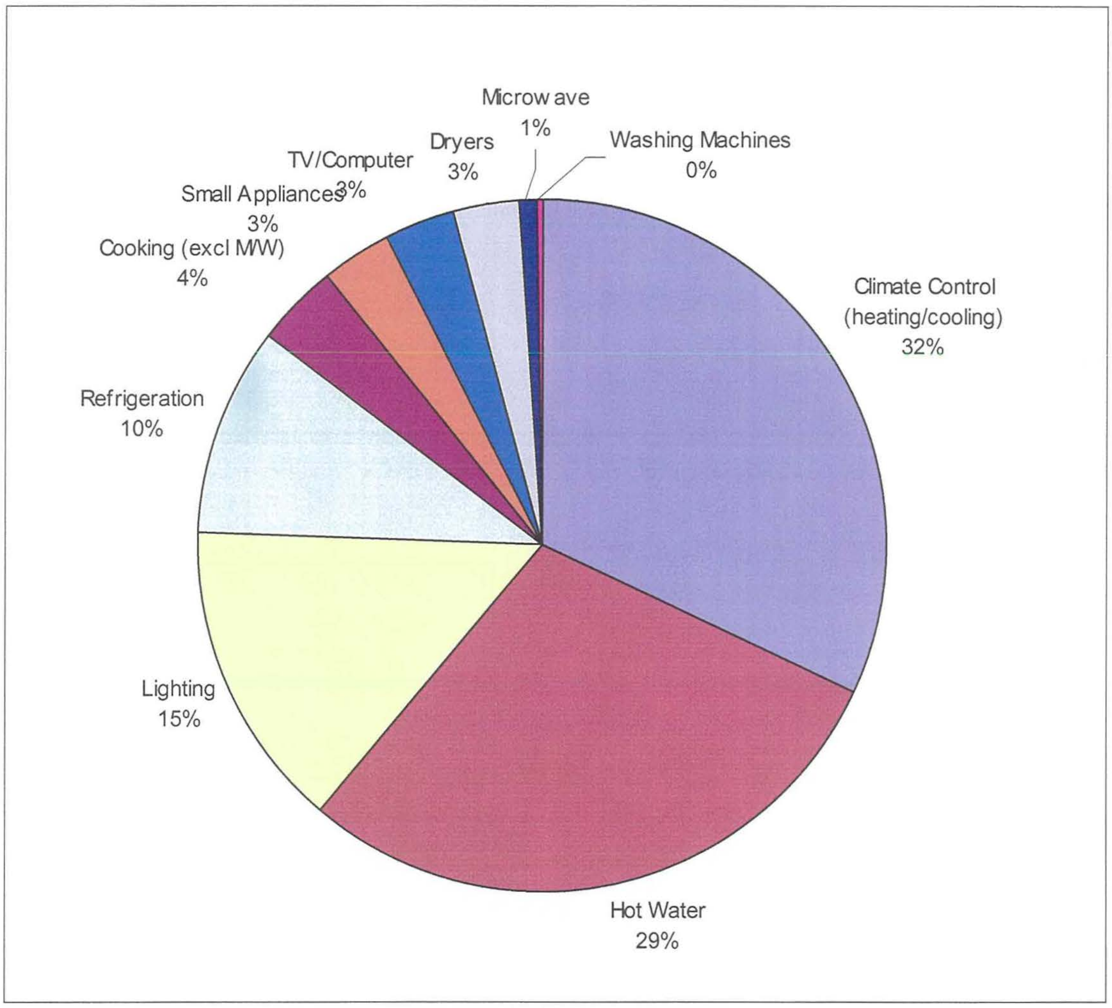
- average economic payback of approximately 8 years, and
- indicative of energy efficiency improvements that might become feasible over time.

Both these scenario definitions represent a simplification of the definitions provided by Armstrong (2003) which created definitions based on the mix and trade off between technical, economic and market potentials as defined in the Australian context. It is felt that the outcomes obtained are sufficient for this indicative view of the potential savings within Waitakere City and that the suggested energy efficiency improvements and categorisation align well with documents from EECA and BRANZ (including HEEP study reports(Isaacs, 2003)). Further detail of the energy efficiency improvement potential (EEIP) data used and initiatives used to reach these EEIP values is shown in Appendix B.

5.1 Residential sector

Analysis of the residential sector incorporated the breakdown of the residential electricity consumption by end use based on the preliminary reports from the HEEP study (Isaacs, 2003) with the EEIP savings from Armstrong(2003). The resulting energy saving potential aligns well with data from other studies.

Figure 17: Waitakere residential energy consumption based on HEEP study



Source:(Isaacs, 2002)

Potential energy savings in low and high EEIP scenarios are shown by end use within the residential environment (Table 6). Energy saving potentials were applied across the range of end uses (Table 7). Conclusions that can be drawn based on the results obtained, included:

- lighting offers the quickest and easiest savings ;
- insulation for building climate control offers the biggest direct saving and also has multiple spin-off savings through the well studied and documented health and welfare improvements; and
- various hot water energy saving initiatives are possible with many simple measures offering quick win, quick payback energy savings. Solar and air sourced heat pump hot water systems offer the greatest energy saving potential while still offering a positive economic payback. Capital cost and installation appear to be the biggest disincentive to these systems, despite EECA incentives.

Table 6: Waitakere residential high and low energy efficiency improvement potentials (EEIP)

	Climate control (heating/cooling)	Hot water	Lighting	Refrigeration	Cooking (excl microwave)	Small appliances	TV/computer	Dryers	Microwave	Washing machines
Electricity										
Low EEIP	25%	20%	40%	30%	20%	10%	40%	15%	0%	20%
High EEIP	80%	70%	75%	75%	40%	40%	75%	60%	0%	40%
Gas										
Low EEIP	20%	20%			10%					
High EEIP	80%	70%			30%					
Biomass										
Low EEIP	30%									
High EEIP	80%									

Table 7: Waitakere residential electricity cost saving potential by use

	Climate control (heating/ cooling)	Hot water	Lighting	Refrigeration	Cooking (excluding microwave)	Small appliances	TV/computer	Dryers	Microwave	Washing machines	Total
Estimated energy use percentage	31.82%	29.24%	14.55%	9.70%	3.86%	3.40%	3.26%	3.18%	0.68%	0.30%	100.00%
Energy cost per year	$5,004,845	$4,599,691	$2,287,929	$1,525,286	$607,731	$534,803	$512,401	$500,485	$107,247	$47,665	$15,728,084
Energy saving - low EEIP	$1,251,211	$919,938	$915,172	$457,586	$121,546	$53,480	$204,960	$75,073	$0	$9,533	$4,008,500
Low EEIP savings as a percentage of total energy cost	7.96%	5.85%	5.82%	2.91%	0.77%	0.34%	1.30%	0.48%	0.00%	0.06%	25.49%
Energy saving - high EEIP	$4,003,876	$3,219,784	$1,715,947	$1,143,965	$243,092	$213,921	$384,301	$300,291	$0	$19,066	$11,244,243
High EEIP savings as a percentage of total energy cost	25.46%	20.47%	10.91%	7.27%	1.55%	1.36%	2.44%	1.91%	0.00%	0.12%	71.49%

5.1.1 Lighting

Compact fluorescent lighting (CFL) is cheap, energy efficient and easy to install. The wide introduction of these light bulbs would be ideal for a quick-win energy saving of up to 11% of household energy consumption. These long-life, low energy consumption bulbs offer an excellent return on investment. The overall cost of less than $3M (10 bulbs per house x $5 x 55,000 houses) would be at a level where a public campaign could be developed to focus attention on energy efficiency with lighting as a good practical example of what can be achieved.

The main problem with CFL is the range of poor quality products available on the market at present that do not perform in a similar way to incandescent lamps. These lamps often have poor start up (slow to come to full strength light) and/or produce a blue/white colour light. Labelling does not give an indication of light characteristics. There is an over supply of Edison screw fitting and lack of bayonet fitting bulbs on market shelves.

The future may bring even more potential savings with the use of white light-emitting-diode (LED) lamps. These currently can produce approximately six times the light output per watt compared to incandescent lamps, and last up to 50,000 hours (being 50 times the life of an incandescent lamp). As the white light is generated from mixing red, green and blue LED's it is possible to mix any colour of the rainbow, and produce different colours for aesthetic effect. The current limitation of these lamps is price but that should be overcome with the next few years (Associated Press, 2005).

5.1.2 Insulation

In a relatively damp climate like Waitakere, insulation is just as important for moisture control as it is for reducing heat flow. While the World Health Organisation (WHO) recommends an indoor temperature of 18 °C (20 °C for the elderly, young children and those with disabilities) to ensure good respiratory health, the HEEP studies (Isaacs, 2003) indicated that in Waitakere these levels are not maintained with many people putting on extra clothing rather than heating their home sufficiently. Unfortunately, the breathing of cold air, often full of mould and mildew, is the major cause of respiratory, allergies, asthma, seasonal colds and flu within New Zealand. One study of New Zealand conditions found that adults living in un-insulated houses were 10 times more likely to be treated in hospital for respiratory illness than those living in insulated houses (Howden-Chapman, 2004). It also found children were twice as likely to suffer asthma symptoms and 3 times as likely to get colds or flu.

The estimated cost of $1800 per house ($72M for the estimated number of 40,000 houses older than 1978 in Waitakere City) to install ceiling and under-floor insulation, weather stripping as well as a ground moisture barrier, seems a small cost when compared to the net benefits of public health and a reduction in days off work and school. Energy savings through space conditioning improvements represented about 25% of the total household energy consumption. Estimates put the additional cost of insulation above the minimum building code R levels at approximately $300 per house. This level of insulation is required to meet the WHO recommended comfort levels and achieve reductions in the majority of the energy consumed for space conditioning. This additional cost would offer excellent return on investment and health benefits.

5.1.3 Hot water consumption and energy efficiency measures

Hot water production consumes approximately 29% of residential energy (Isaacs, 2002). There are a range of simple and economic measures available to reduce the amount of energy used in this process. Table 8 shows typical household hot water use and the effect of some simply applied water savings (which correspond to energy savings).

Table 8: Household hot water consumption

Normal Use (4 person household)			
Use	Quantity (litres)	Frequency	Average Daily use (litres)
Shower (9 l/min)	150	Daily	150
Dishwashing	30	Daily	30
General	40	Daily	40
Clothes washing	70	2 per week	20
Total (Normal use)			240

Low Use (4 person household)			
Use	Quantity (litres)	Frequency	Average Daily use (litres)
Shower (6 l/min)	100	Daily	100
Dishwashing	30	Daily	30
General	30	Daily	30
Clothes washing	70	2 per week	20
Total (Low use)			180

Sources: (Williamson & Clark, 2001) and (Isaacs, 2003)

The main energy losses in hot water systems are from standing losses (Table 9). The installation of an insulating blanket around older hot water cylinders can save 350-550 kWh/year. The installation of ultra efficiency A grade hot water systems could reduce losses even further. The lower capital cost and level of savings obtainable may make this option economically preferable over the more expensive solar based systems. Given the expected 25 year life of hot water systems it is appropriate to encourage the solar based solutions (preferably including ultra-efficiency cylinders) to achieve maximum energy efficiency rather than settling for the smaller gains from more efficient cylinders alone.

Table 9: Standing losses of electric storage hot water sysems

Type	kWh/year Losses
Pre 1976	1500 - 2000
1976-1986 - 'C' Grade	1300 - 1800
B' Grade open vented	1000 - 1400
B' Grade valve vented	850 - 1000
"A' Grade NZS 4605: 1996	600 - 800

Source: (Williamson & Clark, 2001)

Other losses result from:

- high shower flow rate, which can be overcome by the installation of low flow shower heads to reduce hot water electricity consumption by approximately a quarter;
- leaking taps and fittings, in that a hot water tap that drips at one drop per second will waste approximately 1500 litres of water per year and up to 100 kWh of electricity (Williamson & Clark, 2001); and
- heat loss in distribution pipes, where hot water pipe lagging will save approximately 120 kWh per year.

All of these losses can be rectified easily and readily and have an economic payback of 1 year or less.

There is also a subsequent saving in water pumping costs to be had from the Watercare dams and distribution systems within the city, due to any resulting decreased residential water demand. Water savings can be enhanced if general water conservation measures are practiced as well. One recommended idea, from the SEAV is to install a rainwater tank to capture water to use for toilet flushing.

The installation of solar hot water systems, air-sourced heat pump hot water systems or ground-sourced heat pump hot water systems (see section 6.9 Geothermal energy) can reduce the overall energy consumption for hot water by 60-70% (as discussed in section 6.1).

5.2 Commercial sector

The commercial sector consumed 24% of the non-vehicle energy and 17% of electricity in Waitakere City. Energy use varied by the size and type of business. The retail food trade followed by government administration and defence were the largest electricity consumers within the commercial sector (Figure 18). The estimated breakdown of electricity uses by business type is indicated in Table 10.

Figure 18: Electricity use by business type in commercial sector

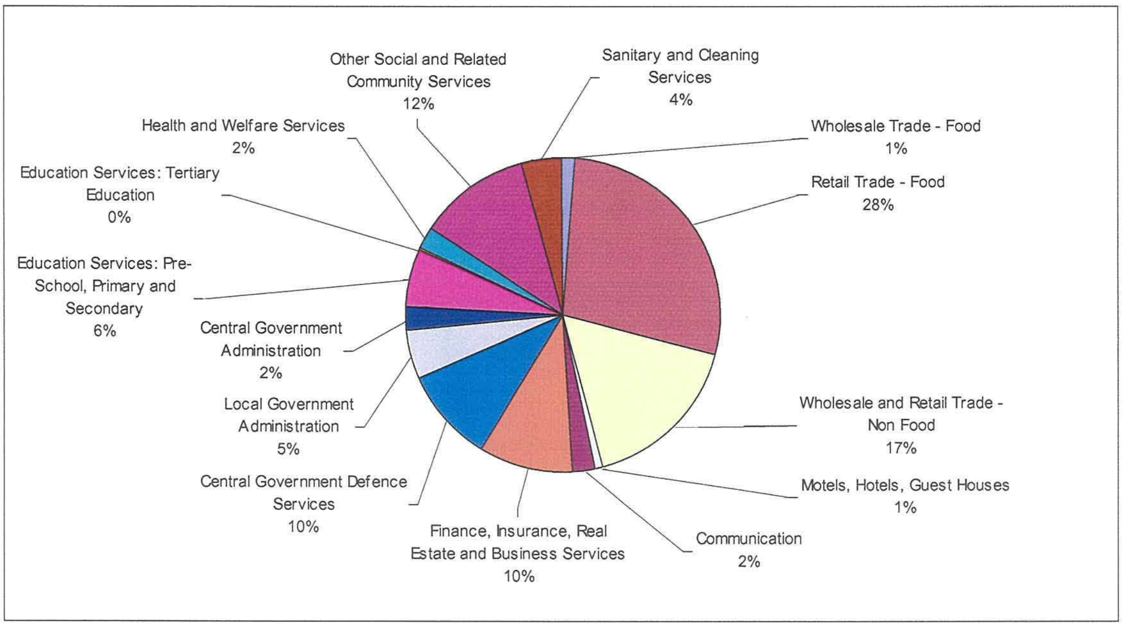


Table 10: Estimated percentage of total energy consumed by end use for each business type in commercial sector of Waitakere City

Delivered energy (GJ) Waitakere City	Heating (Elec)	Ventilation	Cooling/pump	Lighting	Hot water	Cooking	Refrigeration	Elevators	Office equipment	Other
Wholesale Trade - Food	28%	15%	12%	26%	2%	1%	8%	1%	3%	4%
Retail Trade - Food	28%	15%	12%	26%	2%	1%	8%	1%	3%	4%
Wholesale and Retail Trade - Non Food	28%	15%	12%	26%	2%	1%	8%	1%	3%	4%
Motels, Hotels, Guest Houses	30%	6%	20%	8%	13%	4%	16%	0%	1%	2%
Communication	25%	18%	25%	17%	3%	0%	4%	1%	5%	2%
Finance, Insurance, Real Estate and Business Services	25%	18%	25%	17%	3%	0%	4%	1%	5%	2%
Central Government Defence Services	25%	18%	25%	17%	3%	0%	4%	1%	5%	2%
Local Government Administration	25%	18%	25%	17%	3%	0%	4%	1%	5%	2%
Central Government Administration	25%	18%	25%	17%	3%	0%	4%	1%	5%	2%
Education Services: Pre-School, Primary and Secondary	33%	18%	17%	15%	10%	0%	2%	1%	2%	2%
Education Services: Tertiary Education	33%	18%	17%	15%	10%	0%	2%	1%	2%	2%
Health and Welfare Services	36%	6%	16%	8%	9%	4%	18%	0%	2%	1%
Other Social and Related Community Services	39%	11%	21%	9%	4%	2%	10%	0%	2%	2%
Sanitary and Cleaning Services	28%	15%	12%	26%	2%	1%	8%	1%	3%	4%
Overall	15%	8%	9%	11%	2%	0%	4%	0%	2%	2%

The analysis of the commercial sector based on the preliminary reports from the HEEP study (Isaacs, 2003) with the EEIP savings potential from Armstrong (2003) (Table 11) gave results for low and high EEIPs (Table 12 and Table 13)

Table 11: Estimated potential savings by energy type for each end use in commercial sector

	Heating	Ventilation	Cooling/pump	Lighting	Hot water	Cooking	Refrigeration	Elevators	Office equipment	Other
Electricity										
Low EEIP	20%	10%	35%	21%	35%	20%	25%	10%	30%	20%
High EEIP	60%	70%	85%	90%	95%	40%	50%	25%	80%	40%
Gas/Other										
Low EEIP	30%				35%	20%				
High EEIP	50%				95%	40%				
Broadrange										
Low EEIP	30%	10%	35%	21%	35%	20%	25%	10%	30%	20%
High EEIP	50%				95%	40%				

Table 12: Waitakere commercial sector low EEIP saving potential ($)

Low EEIP Savings	Heating	Ventilation	Cooling/pump	Lighting	Hot water	Cooking	Refrigeration	Elevators	Office equipment	Other	Sector Total
Wholesale Trade - Food	$12,224	$3,274	$9,168	$11,918	$1,528	$437	$4,366	$218	$1,965	$1,746	$46,843
Retail Trade - Food	$252,474	$67,627	$189,356	$246,162	$31,559	$9,017	$90,169	$4,508	$40,576	$36,068	$967,517
Wholesale and Retail Trade - Non Food	$150,543	$40,324	$112,908	$146,780	$18,818	$5,377	$53,766	$2,688	$24,194	$21,506	$576,904
Motels, Hotels, Guest Houses	$8,459	$846	$9,868	$2,368	$6,414	$1,128	$5,639	$0	$423	$564	$35,709
Communication	$17,289	$6,224	$30,255	$12,344	$3,631	$0	$3,458	$346	$5,187	$1,383	$80,115
Finance, Insurance, Real Estate and Business Services	$78,064	$28,103	$136,612	$55,738	$16,393	$0	$15,613	$1,561	$23,419	$6,245	$361,749
Central Government Defence Services	$78,752	$28,351	$137,815	$56,229	$16,538	$0	$15,750	$1,575	$23,625	$6,300	$364,935
Local Government Administration	$41,560	$14,962	$72,730	$29,674	$8,728	$0	$8,312	$831	$12,468	$3,325	$192,590
Central Government Administration	$19,176	$6,903	$33,559	$13,692	$4,027	$0	$3,835	$384	$5,753	$1,534	$88,863
Education Services: Pre-School, Primary and Secondary	$63,924	$17,434	$57,629	$30,509	$33,899	$0	$4,843	$969	$5,811	$3,874	$218,893
Education Services: Tertiary Education	$643	$175	$579	$307	$341	$0	$49	$10	$58	$39	$2,201
Health and Welfare Services	$28,785	$2,399	$22,389	$6,717	$12,594	$3,198	$17,991	$0	$2,399	$800	$97,270
Other Social and Related Community Services	$146,144	$20,610	$137,713	$35,412	$26,231	$7,495	$46,841	$0	$11,242	$7,495	$439,182
Sanitary and Cleaning Services	$37,475	$10,038	$28,106	$36,538	$4,684	$1,338	$13,384	$669	$6,023	$5,354	$143,609
Totals	$935,512	$247,270	$978,686	$684,387	$185,385	$27,989	$284,015	$13,759	$163,143	$96,232	$3,616,379

Table 13: Waitakere commercial sector high EEIP saving potential ($)

High EEIP Savings	Heating	Ventilation	Cooling/pump	Lighting	Hot water	Cooking	Refrigeration	Elevators	Office equipment	Other	Sector Total
Wholesale Trade - Food	$36,671	$22,919	$22,265	$51,078	$4,147	$873	$8,731	$546	$5,239	$3,492	$155,961
Retail Trade - Food	$757,422	$473,389	$459,864	$1,054,981	$85,661	$18,034	$180,339	$11,271	$108,203	$72,135	$3,221,299
Wholesale and Retail Trade - Non Food	$451,630	$282,269	$274,204	$629,057	$51,077	$10,753	$107,531	$6,721	$64,519	$43,012	$1,920,774
Motels, Hotels, Guest Houses	$25,376	$5,921	$23,966	$10,150	$17,411	$2,256	$11,278	$0	$1,128	$1,128	$98,613
Communication	$51,866	$43,567	$73,477	$52,903	$9,855	$0	$6,915	$864	$13,831	$2,766	$256,045
Finance, Insurance, Real Estate and Business Services	$234,192	$196,721	$331,772	$238,876	$44,496	$0	$31,226	$3,903	$62,451	$12,490	$1,156,128
Central Government Defence Services	$236,255	$198,454	$334,694	$240,980	$44,888	$0	$31,501	$3,938	$63,001	$12,600	$1,166,312
Local Government Administration	$124,680	$104,731	$176,631	$127,174	$23,689	$0	$16,624	$2,078	$33,248	$6,650	$615,505
Central Government Administration	$57,529	$48,324	$81,499	$58,679	$10,930	$0	$7,671	$959	$15,341	$3,068	$284,001
Education Services: Pre-School, Primary and Secondary	$191,773	$122,038	$139,956	$130,755	$92,012	$0	$9,686	$2,421	$15,497	$7,748	$711,886
Education Services: Tertiary Education	$1,928	$1,227	$1,407	$1,315	$925	$0	$97	$24	$156	$78	$7,157
Health and Welfare Services	$86,356	$16,791	$54,372	$28,785	$34,183	$6,397	$35,982	$0	$6,397	$1,599	$270,862
Other Social and Related Community Services	$438,433	$144,271	$334,445	$151,765	$71,198	$14,989	$93,682	$0	$29,978	$14,989	$1,293,751
Sanitary and Cleaning Services	$112,424	$70,265	$68,258	$156,591	$12,715	$2,677	$26,768	$1,673	$16,061	$10,707	$478,138
Totals	$2,806,536	$1,730,889	$2,376,809	$2,933,089	$503,188	$55,978	$568,030	$34,398	$435,049	$192,464	$11,636,431

Commercial businesses can save most energy by changes in space heating and cooling, provision of ventilation and lighting. Cost of energy to the businesses can be reduced by timing the operation of heating/cooling and ventilation plant away from peak tariff periods and intelligent use of the building thermal performance properties. Ice storage systems for cooling may also be appropriate to direct consumption away from peak tariff times. The reduction of lighting load would also impact the heating and cooling load and thus should be the first factor to address. It is usually the cheapest and easiest to implement and offers the quickest return on investment.

5.3 Industrial sector

In the industrial sector it is much more difficult to make broad generalisations of the way in which energy/electricity is used in each category. Energy use is dictated by the specific industrial equipment used rather than the general categories used within the residential and commercial sectors. Each category of business will also consist of very small to very large enterprises, making comparison more difficult. Thus the analysis of the energy savings available within this category should be treated with more caution. In particular it is obvious that the major industrial companies (SCA Hygiene Australasia (formerly Carter Holt Harvey), Huhtamaki (2 plants), Alto plastics and Douglas Pharmaceuticals) have disproportionate consumption to other businesses and potentially much larger savings. The analysis of electricity consumption within the industrial sector is shown in Table 14.

Table 14: Waitakere industrial sector electricity consumption

Delivered energy (GJ) Waitakere City	Electricity (GJ)	Cost	Percentage of total
Agriculture	8,830	$177,446	1.07%
Fishing and Hunting	1,276	$25,642	0.15%
Forestry and Logging	985	$19,794	0.12%
Mining and Quarrying	9,315	$187,193	1.13%
Paper and Paper Products, Printing and Publishing	347,446	$6,982,218	42.01%
Chemicals, Related Products and Plastics	104,875	$2,107,551	12.68%
Wood Processing and Wood Products	86,487	$1,738,029	10.46%
Fabricated Metal Products, Machinery and Equipment	59,980	$1,205,348	7.25%
Concrete, Clay, Glass and Related Minerals Manufacture	31,468	$632,376	3.80%
Basic Metal Industries	30,826	$619,474	3.73%
Textile, Apparel and Leathergoods	30,531	$613,546	3.69%
Slaughtering and Meat Processing	15,470	$310,883	1.87%
Other Manufacturing Industries	6,308	$126,765	0.76%
Dairy Products	0	$0	0.00%
Beverages, Tobacco, confectionery and sugar, and other food processing	39,173	$787,214	4.74%
Water Works and Supply	9,755	$196,035	1.18%
Construction	44,343	$891,110	5.36%
Totals	827,068	16,620,624	100.00%

The energy saving potential by industry type (Table 15) identifies that energy efficiency targeting should be aimed at the large organisations named above. Some of the potential gains may have already been realised from in house energy management initiatives (i.e. the EEIP rating for these business types could be optimistic). Large energy efficiency gains could be made from focused energy initiatives aimed at particular companies where these companies are willing to cooperate and implement solutions.

Table 15: Waitakere industrial sector potential energy savings by industry

Delivered Energy (GJ) Waitakere City	Low EEIP	High EEIP	Low EEIP saving potential	Low EEIP saving % of toal use	High EEIP saving potential	High EEIP saving % of toal use
Agriculture	20%	50%	$35,489	0.21%	$88,723	0.53%
Fishing and Hunting	20%	50%	$5,128	0.03%	$12,821	0.08%
Forestry and Logging	20%	50%	$3,959	0.02%	$9,897	0.06%
Mining and Quarrying	20%	50%	$37,439	0.23%	$93,596	0.56%
Paper and Paper Products, Printing and Publishing	20%	45%	$1,396,444	8.40%	$3,141,998	18.90%
Chemicals, Related Products and Plastics	25%	45%	$526,888	3.17%	$948,398	5.71%
Wood Processing and Wood Products	20%	45%	$347,606	2.09%	$782,113	4.71%
Fabricated Metal Products, Machinery and Equipment	25%	55%	$301,337	1.81%	$662,942	3.99%
Concrete, Clay, Glass and Related Minerals Manufacture	30%	50%	$189,713	1.14%	$316,188	1.90%
Basic Metal Industries	20%	42%	$123,895	0.75%	$260,179	1.57%
Textile, Apparel and Leathergoods	25%	45%	$153,387	0.92%	$276,096	1.66%
Slaughtering and Meat Processing	25%	55%	$77,721	0.47%	$170,985	1.03%
Other Manufacturing Industries	25%	50%	$31,691	0.19%	$63,382	0.38%
Dairy Products	25%	55%	$0	0.00%	$0	0.00%
Beverages, Tobacco, confectionery and sugar, and other food processing	25%	55%	$196,804	1.18%	$432,968	2.61%
Water Works and Supply	20%	50%	$39,207	0.24%	$98,017	0.59%
Construction	20%	40%	$178,222	1.07%	$356,444	2.14%
Totals			$3,644,928		$7,714,748	

5.4 Summary of direct energy efficiency potential

The potential electricity savings that could be made in Waitakere City given its unique mix of electricity consuming activities are shown in Table 16. The overall savings potential is harder to analyse given the lack of available detailed data for natural gas and fossil fuels. A high level indication (
Table 17) shows the economic benefits accruing from energy efficiency improvements are significant, even for low EEIP gains. A large proportion of this saved revenue would flow back into the local economy.

Table 16: Projected potential annual electricity savings in Waitakere City for low and high EEIP scenarios

	Low EEIP	High EEIP	Low EEIP $ Saved	High EEIP $ Saved
Residential	27%	71%	$4,172,036	$11,187,184
Commercial	22%	72%	$3,616,447	$11,637,002
Industrial	21%	46%	$14,352,460	$31,438,721
Total (across all categories)	23%	65%	$22,140,943	$54,262,907

Table 17: Projected potential annual energy (gas, electricity, fossil fuels) savings in Waitakere City for low and high EEIP scenarios)

	Low EEIP	High EEIP
Residential	25%	72%
Commercial	12%	32%
Industrial	20%	43%
Total (across all categories)	20%	50%

Once again lighting is the stand out end use to achieve fast and economically feasible energy saving gains. Residential sector gains can readily be made by homeowners whereas commercial and industrial gains would require electricians to change light fittings to more economical ones. A campaign focused on lighting efficiency alone would provide a good start to achieving some significant energy efficiency within the city.

Heating and ventilation is the second most important category due not only to the significant energy saving potential, but to the additional benefits to the city from health and welfare improvements and their flow on effects to employment and education. Residential sector improvements are simple to implement (ease of installation of insulation, room use, and draft exclusion for example). In the commercial and industrial sectors improvements require more specialised knowledge on the efficiency of equipment, usage patterns (e.g. use of thermal storage), and installation of new, more efficient, equipment.

Capital cost and prevalence of rental properties are major constraints to obtaining the potential improvements within the residential sector. This is one area where change requires mandating rather than persuasion. The Building code requires improvement to mandate higher R levels of insulation to a point where homes can readily achieve WHO prescribed comfort levels. An enforceable action plan is required to retrofit insulation to existing buildings, especially rental accommodation where owner inclination is low and likely low socio-economic status of the tenants means requirement is greatest.

Hot water is very important to obtain residential energy efficiency gains, and in certain areas of the commercial and industrial sector. The average life of a hot water system is 25 years and the most economic time to install energy efficient systems is when first installed or at the point of replacement. Therefore, again, some sort of mandating is required to achieve energy efficiency goals, as the capital cost is relatively high, economic return relatively long, window of opportunity is very small and as most economically it only occurs approximately every 25 years. Such mandating for new homes is now in force in Victoria, Australia, which is a good model of what is required in Waitakere.

In the commercial and industrial sectors, energy auditing is required to achieve most economically feasible gains. For these sectors the encouragement through education and demonstration would be most prudent. For smaller enterprises in particular, a city council sponsored energy inspection and education service may achieve results. Such an initiative would align well with the Building Act 2004 which states in Part 1, Subpart 1, section 4, "the principles to be applied by the council in performing functions or exercising powers under the Act that the council must take into account the principle of" "the need to facilitate the efficient use of energy and energy conservation and the use of renewable sources of energy in buildings" ("Building Act," 2004).

5.5 Indirect energy efficiency

5.5.1 Minimise use and waste

Every product or service provided to the city inhabitants consumes resource and energy. The choice not to use or continue to use certain products and services also constitutes an energy saving. The management of the processes of manufacture and distribution to minimise the use of materials and material wastage can significantly reduce the levels of embodied energy within the final goods and services.

The use of energy auditing alone is not sufficient to reduce the overall energy used in production as it does not fully consider embodied energy. An open competitive environment can lead to reductions in energy use where competing companies work to protect profit margins by increasing efficiency. The increased packaging and marketing to attract customers can erode some of these efficiencies.

The efficient use of public water supply (including prudent rainwater collection and use) is also included in the Building Act (2004). Waitakere City Council has produced a number of public documents encouraging the efficient use of water, particularly from an environmental perspective, but could also support their cause by showing the energy savings obtained through the reduction of water pumping around the city from water conservation measures.

5.5.2 Reuse and recycle

The reuse or recycling of goods after their primary purpose has expired significantly reduces the energy content needed to manufacture the goods. Some examples of potential savings from recycling are:

- recycling a tonne of aluminium may save the equivalent of 53,000 kWh

(Approximately equivalent to 5 times the annual electricity requirement for residential houses in New Zealand (10,500 kWh per year))

- recycling a tonne of textiles may save the equivalent of 15,000 kWh
- recycling a tonne of steel may save the equivalent of 4,700 kWh
- recycling a tonne of lead may save the equivalent of 7,500 kWh
- recycling a tonne of glass may save the equivalent of 900 kWh
- recycling a tonne of paper may save the equivalent of 4,077 kWh

(Greenpeace, 2003)

The amount of energy saved from continual reprocessing of recycled materials far exceeds the amount of energy obtainable from energy recovery processes such as combustion or anaerobic digestion.

5.5.3 Energy recovery

The recovery of energy from goods (usually at the waste stream) should only be considered efficient when waste minimisation, reuse and recycling options have been exhausted. The remaining waste is much lower in embedded energy, as the plastics within the main waste stream contain up to 80% of the energy content on combustion (Greenpeace, 2003). Landfill gas is one of the most cost efficient processes to obtain energy, though it is not the most energy efficient. This is the current practice with Waitakere City waste.

6 Renewable Energy Generation

Solar thermal hot water and closely related air sourced heat pumps are a viable and valuable source of energy production that should reduce hot water system electricity consumption by approximately 60-70%. There has been much technical discussion about which one of solar thermal or air sourced heat pumps is more energy efficient. The end result is that while they are roughly equally efficient over the year, each one has its own advantages and drawbacks.

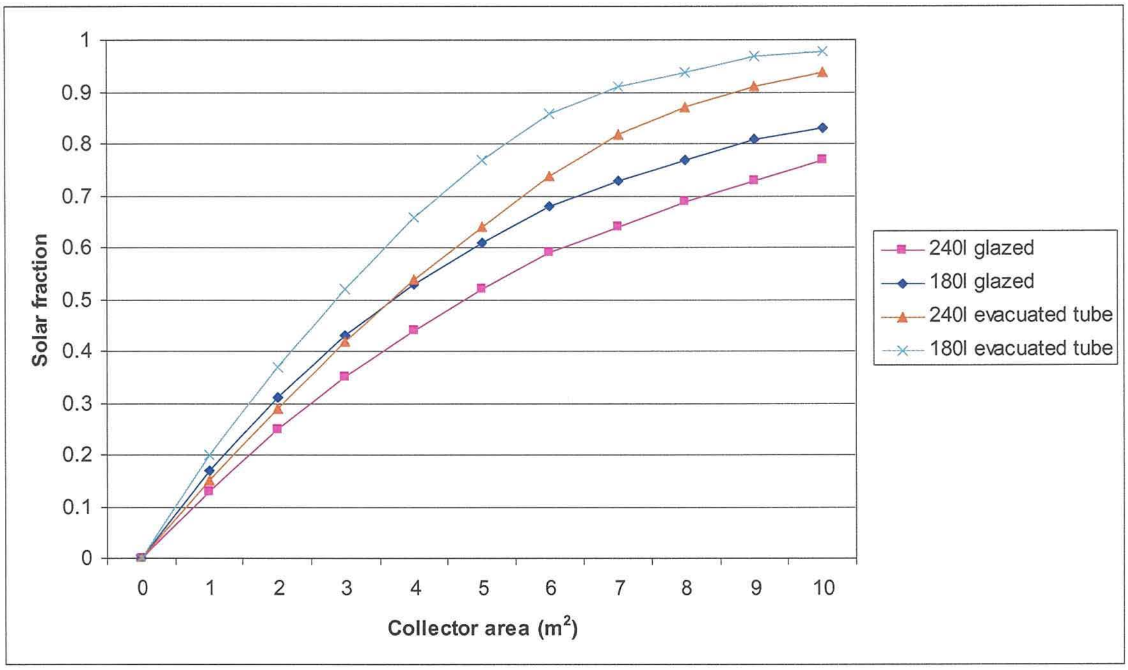
6.1 *Solar thermal hot water*

The solar thermal hot water system is the more typical system, where panels on a roof heat a fluid and feed it through a heat exchanger within an attached or separate water storage tank. Analysis has been performed using the f-chart method (Beckman, Klein, & Duffie, 1977), which provides a means of easily determining the thermal performance of active solar space heating systems (using either liquid or air as the working fluid) and solar domestic hot water (SDHW) systems. The method is essentially a correlation of results from hundreds of simulations of solar heating systems. The conditions of the resulting correlations give f, the fraction of the monthly heating load (for space heating and hot water) supplied by solar energy as a function of two dimensionless variables involving collector characteristics, heating loads, and local weather (AIT, 2005).

For purposes of evaluation two scenarios were used in the analysis; the normal consumption rate of 240l per day and a low use rate of 180l per day of hot water (Table 8). The key determinants of the solar fraction (proportion of hot water available from the solar panel) are design of the collector (glazed, special surface, evacuated tube), the surface area, the solar radiation input and ambient temperature (level of losses).

Figure 19 shows that the evacuated tube collector offers superior performance to the simple glazed collector and thus would require less collector area to achieve the same level of heat output. Due to the availability of cheap imported evacuated tube systems and their physical attractiveness these systems are proving a popular choice for those wanting a solar hot water system.

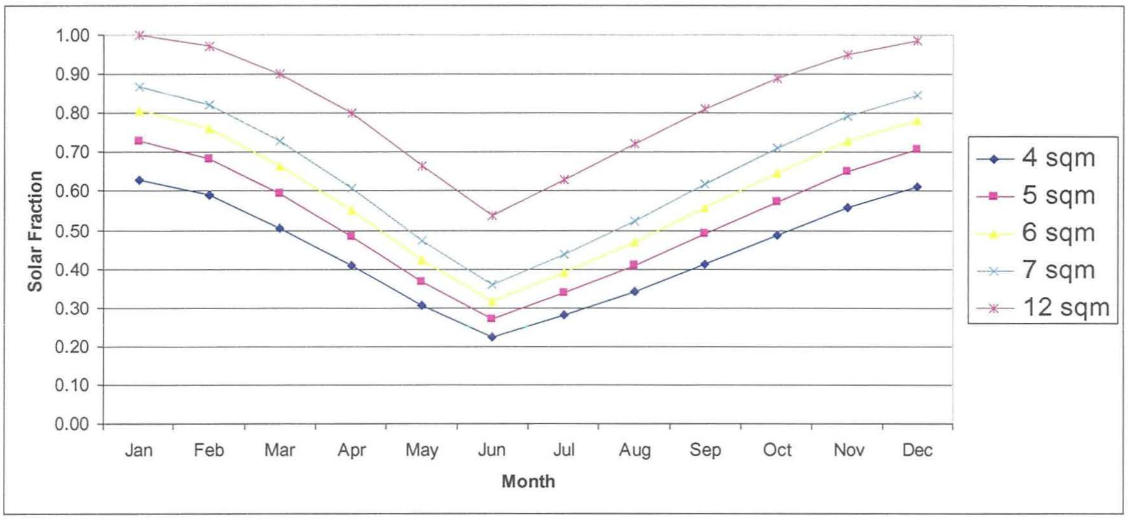
Figure 19: Solar domestic hot water annual solar fraction using f-chart method for typical household in Waitakere City



While advertising of solar hot water systems readily state that up to 100% of your hot water needs can be met with a solar hot water system, due to the variability of the Waitakere climate and high levels of cloudiness, a normal economically sized system (Figure 20) would on average meet 80% of summer hot water requirements reducing to only about 30% in winter. The same set up would provide about 10% more of the hot water requirement if energy efficiency measures were introduced reducing daily consumption from 240 l/day to 180 l/day. High seasonal variability does not alter the overall economic viability of a system. Collector size can be increased to increase the overall proportion of hot water provided from the solar collector (Figure 19 and Figure 21). Unfortunately the collector represents the major cost of the system and increased sizing can reduce payback and erode the economic feasibility of a solar hot water system.

Figure 20: Seasonal performance of solar domestic hot water system with a $6m^2$ glazed collector.

Figure 21: Monthly solar fraction for various sized glazed collectors to meet 240l/day demand for hot water.



The output of an individual system will vary slightly if the system is shaded for part of the day, its orientation is not to solar north or it is not tilted at latitude angle (36.9 degrees). Standards New Zealand produced a performance multiplier table (Table 18) that allows conversion of results to non-ideal tilt angles and angles away from solar North.

Table 18 : Factors for inclination and solar orientation

		Tilt Angle (degrees)					
		0	20	40	60	80	90
Direction	(degrees)						
West	270	0.85	0.85	0.80	0.72	0.60	0.53
	300	0.85	0.92	0.92	0.86	0.73	0.65
	330	0.85	0.98	0.99	0.93	0.80	0.71
North	0	0.85	0.97	1.00	0.94	0.80	0.70
	30	0.85	0.94	0.95	0.88	0.74	0.65
	60	0.85	0.88	0.86	0.77	0.65	0.57
East	90	0.85	0.80	0.73	0.64	0.52	0.46

Red	Best Orientation
Orange	Good orientation
Yellow	Moderate orientation
No Fill	Poor orientaion

Source: (Standards NZ, 1986)

To address the problems within the industry the Solar Industries Association (SIA) has developed some guidelines to assist in determining the economic and technical sizing of both solar collector panels and hot water cylinders. The following has been extracted from the Codes of Practice:

- Installations should be sized to give up to 70% of the normal annual hot water energy requirement of the household.
- The cylinder capacity should be not less than one day's expected use. Generally better overall solar performance can be obtained with a somewhat larger cylinder, up to 1.5-2 times the daily use. In particular if the system is used with off-peak (night rate) auxiliary electric heating then a cylinder capacity of at least 1.5 times the daily use is recommended.
- The ratio of cylinder volume to collector area should be in the range 40-90 litres per square metre of collector area. A given area of collector ratios at the lower end of the range will give quicker response to solar input. Those at the higher end will give better overall solar savings but generally slower recovery.
- Depending on the local ambient temperature and the local insolation 4 m^2 of collector will normally give between 50 and 70%of the normal household hot water energy required for a year.
- Where possible the manufacturers' recommendations should be taken ahead of these estimates.

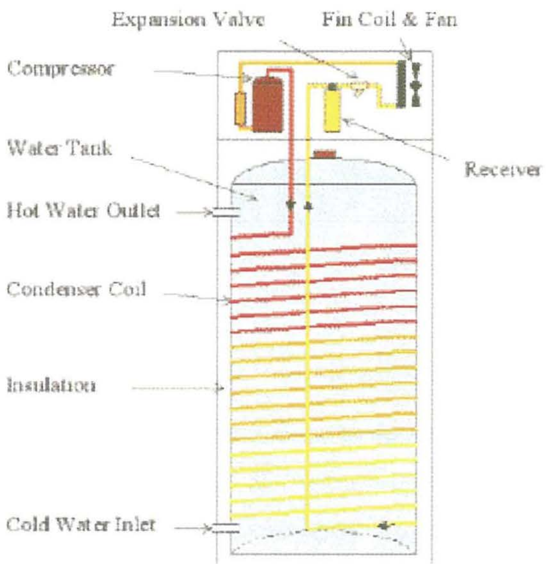
(Solar Industries Association, 2003)

The installed cost of an average system is around $5500 to $6000 (EECA) compared with approximately $1000 to $1500 for a standard hot water system. Some support is available through the EECA solar water heating financial assistance programme that provides loans with interest free periods currently available until June 2005 (though with an extension likely).

6.2 Air to water heat pump

The air source heat pump works on the principle of a refrigeration circuit, drawing heat out of one space and discharging it into another (Figure 22). The system consists basically of a compressor, an evaporator heat exchanger and a condenser heat exchanger. In operation, the evaporator absorbs whatever heat energy is available to it from the atmosphere (air) to vaporise the refrigerant. The vapour is then compressed raising its pressure and temperature. This high temperature vapour is passed through pipes inside or bonded around the outside of a water storage tank forming the condenser. As the refrigerant vapour condenses back to its liquid form, it gives off its heat to the stored water. As this happens, the condensed refrigerant liquid passes back to the evaporator panels through a receiver and expansion device where it is vaporised, and the cycle then repeated.

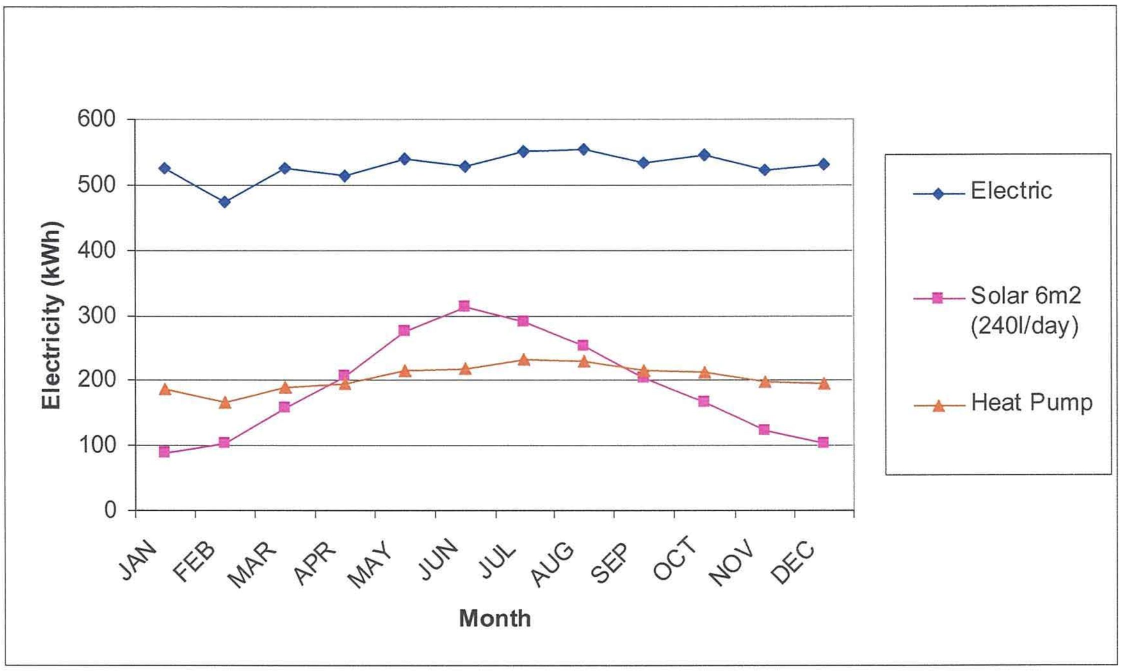
Figure 22: Air sourced heat pump hot water system schematic



Source: (Quantum, 2004)

The amount of electricity used by an air source heat pump hot water system is determined by the ambient air temperature. Thus the time of water usage affects the system recovery time and the overall system coefficient of performance. An example comparison of electricity consumption for various hot water systems for a typical Waitakere household with a hot water consumption of 240 l/day and typical usage pattern (moderate morning use, low through the day, high evening use), is shown in Figure 23. This example shows that the air source heat pump solution has lower electricity consumption than an equivalent solar system and much lower than a standard electric cylinder.

Figure 23: Example of comparative electricity consumption of domestic hot water systems processing 240 l/day in Waitakere City.



The heat pump performance is based on a Quantum compact cylinder coefficient of performance (COP). In the analysis the solar system provided 64% of annual demand and the heat pump 61% of annual demand. A further 10% reduction could be achieved by introducing energy efficiency measures that reduce consumption from 240 l/day to 180 l/day. (These energy efficiency measures alone would reduce the electricity consumption of a standard electric cylinder by 25%). Aside from the solar factors, monthly variance is due to the differing number of days in each month as well as the varying cold water input temperature throughout the year.

The heat pump offers greater seasonal performance than solar hot water systems. Importantly, the energy consumption is lower than alternative options through the key annual peak load months of June to October. From a network viewpoint, where peak demand dictates plant size and cost, heat pumps would be seen as a superior choice for hot water heating. The challenge is how these potential network gains can be shared among potential consumers to reduce product price and provide an incentive to move to these energy efficient products.

Capital cost, installation, noise (especially from the heat pump fan), cool air flow from the system (which can be used for ventilation or air conditioning if required), operation/maintenance and product availability are the determinants for market penetration of air sourced heat pump hot water systems. Rheem NZ has recently released a heat pump hot water cylinder in NZ for approximately $5200 + gst (March, 2005), the Quantum system was on sale at the recent EcoShow for $4760 (March, 2005) and there is a Dux Hot Water HeatPro split heat pump and tank system sold through major plumbing retailers for $4168 (rrp) plus tank cost of $1165 (rrp for 250l tank). The Carrier "Hot Shot" heat pump system that connected to an existing cylinder for approx $1800-$2000, offered excellent return on investment, but appears to be no longer available. A similar solar hot water system (evacuated tube collector with 300l tank) would cost approximately $5500 to $6000 installed (source: EnergyOptions Ltd).

6.3 Passive solar design in Waitakere City

Passive solar design is an approach that provides building heating and cooling using sunlight, shading and natural breezes, without the use of mechanical equipment. The orientation of the building, site selection, materials, and design features are combined to allow the building to collect, store and distribute the sun's warmth in winter, block the excess heat from the sun during the summer, and provide for natural air circulation and natural day lighting. Some of the architectural design principles to develop a passive solar solution in Waitakere City are detailed in Appendix C.

"With foresight, careful planning, knowledge, and common sense we can achieve comfort in virtually any climate naturally using sunlight, shading, earth sheltering, insulation and natural daylight" (Chiras, 2002).

"In Auckland it is possible to approach zero auxiliary heating with the passive solar house whose only thermal mass is a concrete slab floor" (Breuer, 1994).

For the purposes of building design, comfort is defined negatively as the absence of any form of thermal stress. It has been shown that bodily heat loss/gain is interdependently related to the following factors:

Environmental:

- Dry Bulb Temperature,

- Mean Radiant Temperature,
- Relative Humidity,
- Air Movement,

Physiological:

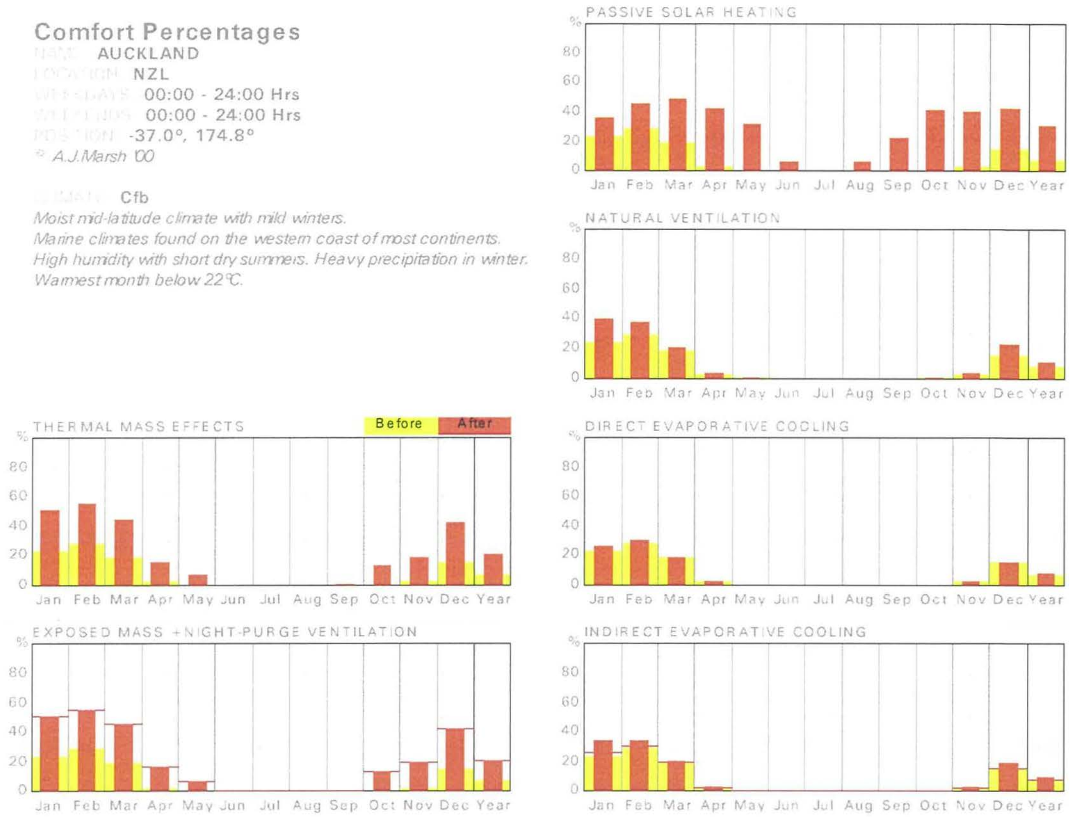
- Metabolic Rate and
- Clothing Level

The comfort zone as used in the "Weathertool" passive solar analysis software (Marsh, 2002), is based on these factors by using the Predicted Mean Vote equation(International Standards Organization, 1984). The International Standards Organization uses limits on PMV as an explicit definition of the comfort zone. By using these definitions within the psychrometric analysis of the Weathertool, the effects of a range of passive design systems were obtained (Figure 24):

Three primary systems to increase the comfort levels of buildings given Waitakere climate conditions are (in order of merit):

1. passive solar heating;
2. thermal mass effects; and
3. natural ventilation – (While this is not have a significant role in heat control, it does have a very significant role in moisture and condensation control).

Figure 24: Human comfort improvement in Waitakere City using various passive design techniques



Developed using Weathertool software:(Marsh, 2002)

6.3.1 Passive solar heating

Approximately 72% of houses in Waitakere were built prior to 1978 when housing insulation standards were introduced (Figure 4). While some of these houses would have been retrofitted with insulation (mostly in the ceiling) many would still lack adequate insulation, and the older housing stock would have poor levels of efficiency in construction (particularly high levels of air infiltration). The standard levels of insulation in post 1978 houses would be to the minimum specified in the Building Code which is still insufficient for good passive solar, energy efficient and human comfort design. Many house designs, even today, show inadequate respect to placement and sizing of glazing to make the most of the solar resource available. The result is a low energy efficient housing stock.

The principles of passive solar heating can be applied to new houses and, by renovation, to existing houses. Of suitable passive solar techniques, passive solar heating has the greatest potential to achieve energy benefit and is particularly valuable as it can be implemented across the whole housing stock.

To obtain benefit from solar heating a house must have:

- adequate glazing on the sun exposed walls;
- good insulation to trap the solar gains; and
- Good design and construction controlling air infiltration, ventilation, shading of glazed surfaces and colour/nature of materials used (termed as efficiency).

While these parameters can be readily incorporated into new buildings, there remains a large stock of existing houses that have poor thermal performance resulting in higher energy consumption.

The Psychrometric Chart provides a graphic representation of the full state of the air under any condition. It relates temperature on the horizontal scale to moisture on the vertical scale. If the temperature of a given volume of air is decreased to the point at which it can hold no more moisture, it becomes saturated. The corresponding temperature is called the dew point and is shown by a curved line which gives the chart it distinguishing shape(Marsh, 2002). Using psychrometric chart analysis of Waitakere conditions (Table 19 and Figure 25) it was demonstrated that as well as for new houses, all existing houses could have their human comfort levels improved by incorporating a combination of efficiency (as defined above), glazing and insulation.

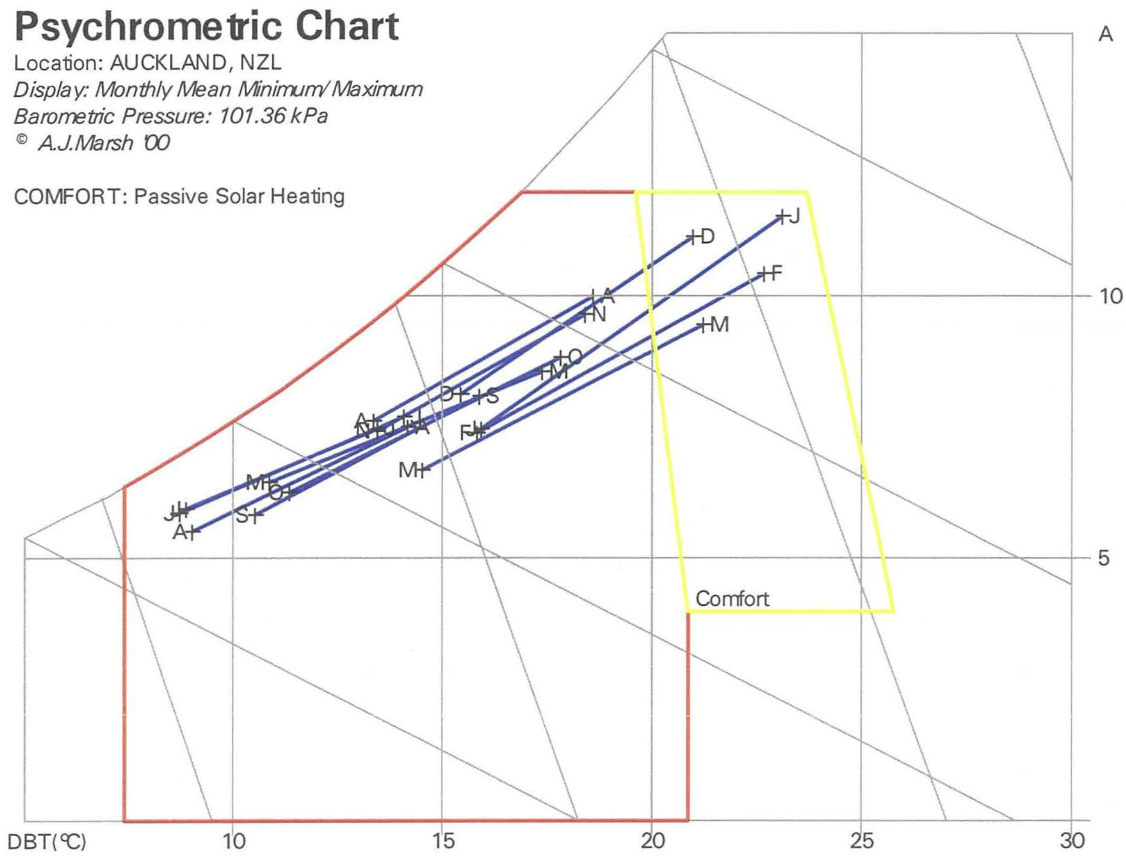
Table 19: Combinations of design element improvements to achieve acceptable psychrometric (human comfort) environment in Waitakere.

Efficiency (design/constructon quality)	Glazing (% of North facing wall)	Insulation level
Average	75	Low
	55	Medium
	35	High
	25	Very High
High	65	Low
	45	Medium
	35	High
	25	Very High
Very High	60	Low
	40	Medium
	30	High
	20	Very High

Notes:

1. *Glazing* is percentage of the area of the north facing wall (i.e. not related to floor area as per thermal mass calculations).
2. *Efficiency* refers to quality of design and construction controlling air infiltration, ventilation, shading of glazed surfaces and colour/nature of materials used).

Figure 25: Passive solar design - extended comfort zone (red) when house efficiency, glazing and insulation parameters altered



Developed using Weathertool software: (Marsh, 2002)

Notes:

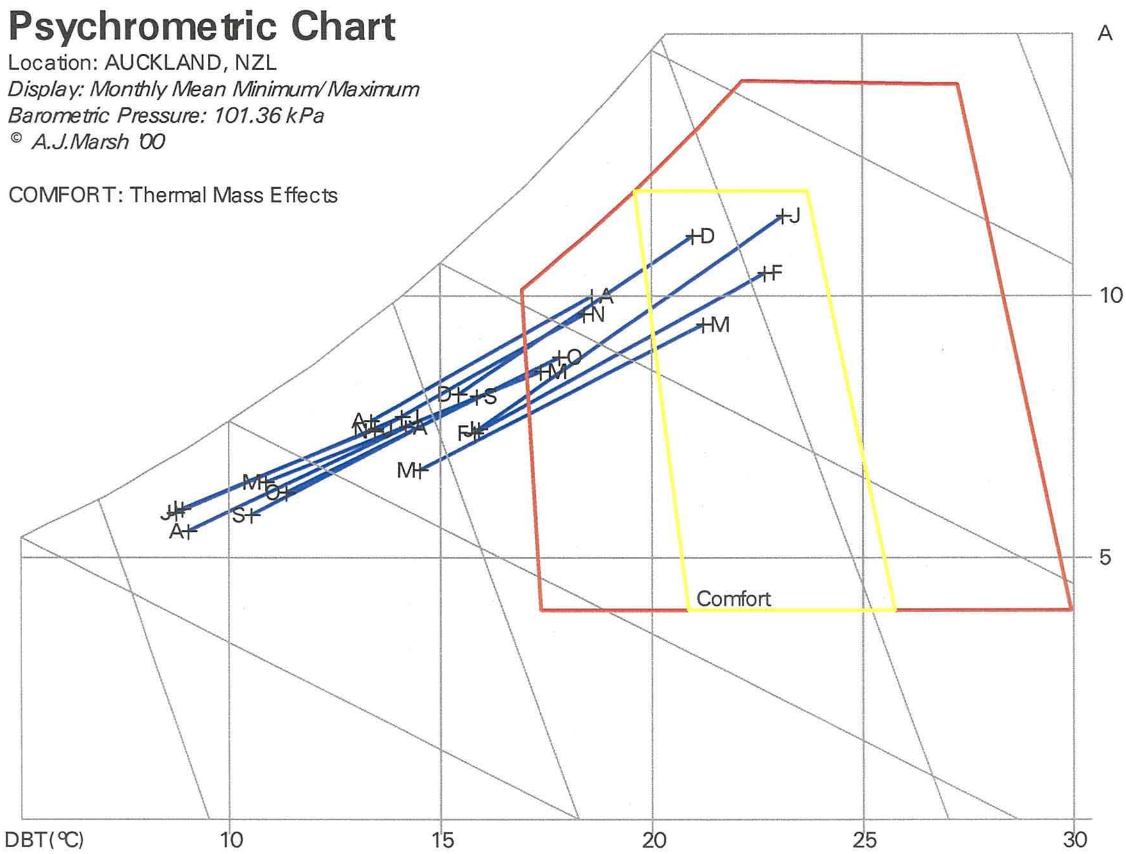
- Blue lines on chart represent monthly average temperature/humidity ranges.
- Yellow polygon with word comfort in bottom left corner represents the comfort zone within a standard building
- Red polygon represents the extension of the comfort zone if particular passive design elements were incorporated into building

The exact combination of efficiency, glazing and insulation to achieve acceptable comfort levels would be determined by technical and economic feasibility of an upgrade, as well as cosmetic appeal on a house by house basis. What is important is that combinations exist for all dwellings that are economic, especially when full costs of poor efficiency such as health, work, and educational costs, are considered.

6.3.2 Thermal mass

Thermal mass can be achieved by a number of measures which in most cases are restricted to new buildings or very extensive renovations. There is potential to expand the human comfort zone so that additional heating is not required for much of the year (Figure 26).

Figure 26: Passive solar design - improved thermal mass effect on psychrometry

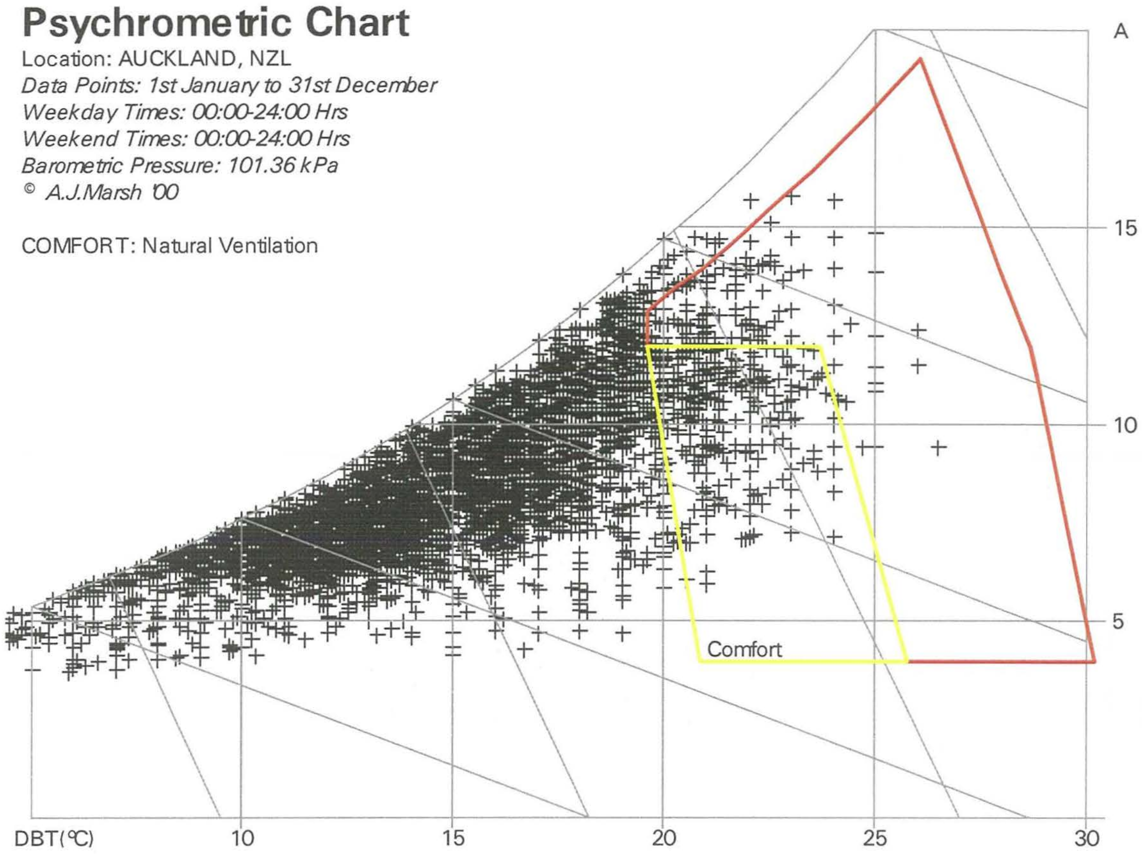


Developed using Weathertool software: (Marsh, 2002)

6.3.3 Natural ventilation

Natural ventilation has little effect on extending comfort to increase coverage of the monthly average temperature ranges but is adequate to cover the less frequent times when the summer psychometric conditions become uncomfortable (Figure 27). This would indicate that air conditioning is not required for Waitakere houses, especially if properly designed. However it is very important that adequate natural ventilation is provided in buildings to prevent condensation and moisture.

Figure 27: Passive solar design – impact of natural ventilation on psychrometry



Developed using Weathertool software: (Marsh, 2002)

Note that on Figure 27 hourly climate data points have been used as impact of natural ventilation is on climate conditions that occur infrequently and thus are outside range of average monthly climate condition ranges.

6.4 Solar photovoltaics

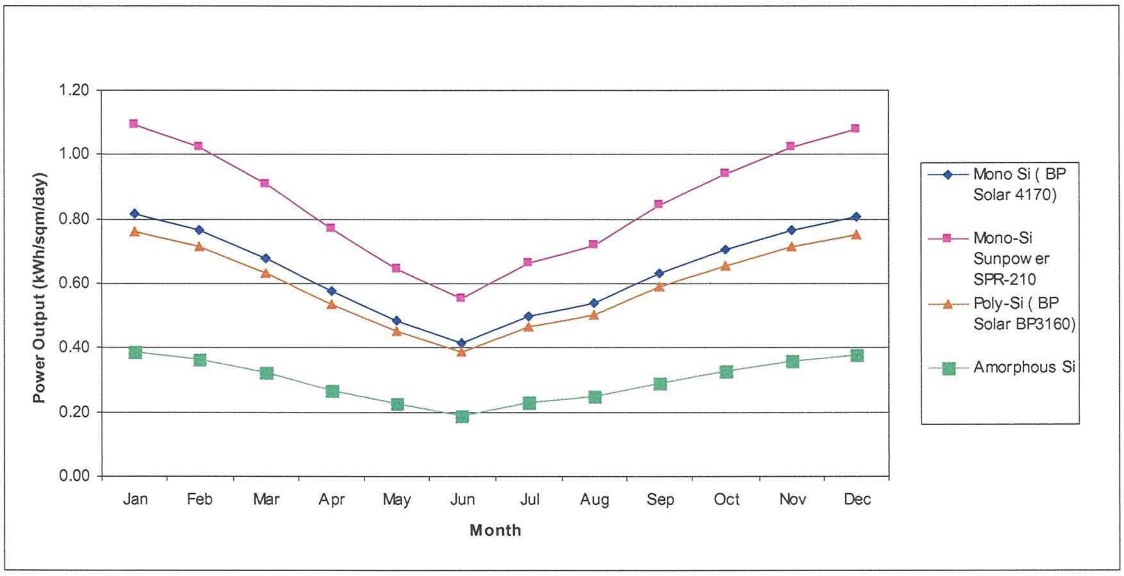
The nominal performance of various representative PV cell technologies which are available commercially (Table 20) are lower than laboratory results which have shown higher efficiency PV cells are possible but these have yet to be made commercially available.

Table 20: Output efficiency of selected commercially available PV cells.

	Nominal operating cell temperature (NOCT)	Power coefficient (%/degree)	Output efficiency at Standard conditions
Mono Si (BP Solar 4170)	45	0.4	15
Mono-Si Sunpower SPR-210	48.5	0.38	20
Poly-Si (BP Solar BP3160)	45	0.4	14
Amorphous Si	50	0.11	6.8

When the standard efficiency (under standard test conditions) characteristics of a PV cell are corrected for local temperature and multiplied by the local Waitakere solar conditions (given a surface at latitude angle (37 degrees)) the daily power output per square metre of PV module were obtained (Figure 28).

Figure 28: Power output of selected PV cells under Waitakere solar insolation conditions



The area of PV cells required depends on the configuration of the installation including grid connect, battery back up, AC /DC loads. Table 21 gives an indication of the area of PV panels required to provide the annual requirement for a standard and an energy efficient house. Each individual technology needs to be considered on the basis of available area, panel price and aesthetics. The amorphous silicon product for example requires a large collection area but is cheaper and can be purchased as a roofing tile thus negating the requirement for additional roofing in new house developments. (This technology is still developing and thus less tested in NZ conditions).

Table 21: Area of PV cells required to meet residential house annual electricity consumption

PV cell type	Annual Output ($kWhm^{-2}$)	Area of PV cells required (m^2)	
		Standard House (10500 kWh/year)	Energy efficient house (7500 kWh/year)
Mono Si (BP Solar 4170)	233	50	36
Mono-Si Sunpower SPR-210	312	37	27
Poly-Si (BP Solar BP3160)	218	54	38
Amorphous Si	109	107	76

The following were assumed:

- Grid connection (no batteries).
- No maximum power point tracker (MPPT) (if required, divide by 0.95).
- Inverter efficiency of 90%.
- For the inclusion of a battery bank divide figure by 0.8.
- Solar north facing panels at latitude angle (37 degrees). For differing slopes and azimuth angles, performance will be reduced. (Generally variations will be small and acceptable if variations are limited to +/- 30 degrees from North and slope +/- 15 degrees).
- No shading – generally require good sun exposure between 9am and 3pm (approximately +/- 45 degrees from north and clear above 17 degrees above bottom of panels).

As an indicative example using the Sunpower SPR210 PV cell, with MPPT and inverter efficiencies mentioned above, but ignoring network losses, would take approximately 3.3 km^2 of total PV area to meet the current average annual electricity requirement of Waitakere City. If the high EEIP savings were to be made, this figure could be reduced to approximately 1.2 km^2. Using the increased efficiency of future PV cells, the number of devices required will reduce even further.

The largest solar energy plant in the world opened in Muhlhausen, Germany in December 2004 covers 0.12 km^2. The German government's subsidy provided guaranteed revenue of 46 euro cents per kWh indicating the poor economics of PV (excluding remote off grid applications) at this time.

6.5 *Other solar conversion systems*

6.5.1 High temperature solar concentration systems

Concentration systems require high levels of direct sunlight as diffuse radiation will not be focused onto the collection point. Waitakere does not have sufficient direct sunlight for these systems to be viable for the foreseeable future (EECA & CAE, 1996).

6.5.2 Solar chimney

This system has been trialed in Spain and an operational unit reaching 1km high is proposed for Mildura, Victoria, Australia. Both these sites have very high amounts of sunshine and it is expected that New Zealand would have insufficient radiation to make this system viable in the near term.

6.5.3 Solar ponds

Due to the southerly latitudes of New Zealand, solar ponds systems are not viable (EECA & CAE, 1996).

6.5.4 Ocean thermal energy conversion (OTEC)

The small temperature difference in the temperate shallow waters around New Zealand restricts a viable OTEC project from being contemplated (EECA & CAE, 1996).

6.5.5 Photo-chemical energy conversion

Major advances have been made worldwide with respect to new non-silicon solar cells such as photoelectrochemical (PEC) solar cells and solid state organic or plastic solar cells. Aspects of both of these technologies are under development in the Nanomaterials Research Centre (NRC), Massey University (Officer, 2004). Professor Officer notes in his report that there is still a significant way to go before commercially viable solutions are available.

The development of non-silicon solar cells, artificial photosynthesis and Electroluminescent devices (such as low-energy light emitting diodes for lighting applications) are all areas that offer significant future prospects for energy conversion and/or energy savings.

6.6 Wind energy

A Wind energy resource survey of New Zealand using available meteorological information was published by (Smyth, 1987). This study summarised the characteristics of the local wind conditions using the Weibull parameters (where k is the shape factor, c a factor related to average wind speed and b the percentage of calms). These parameters for areas indicative of Waitakere City are shown in Table 22.

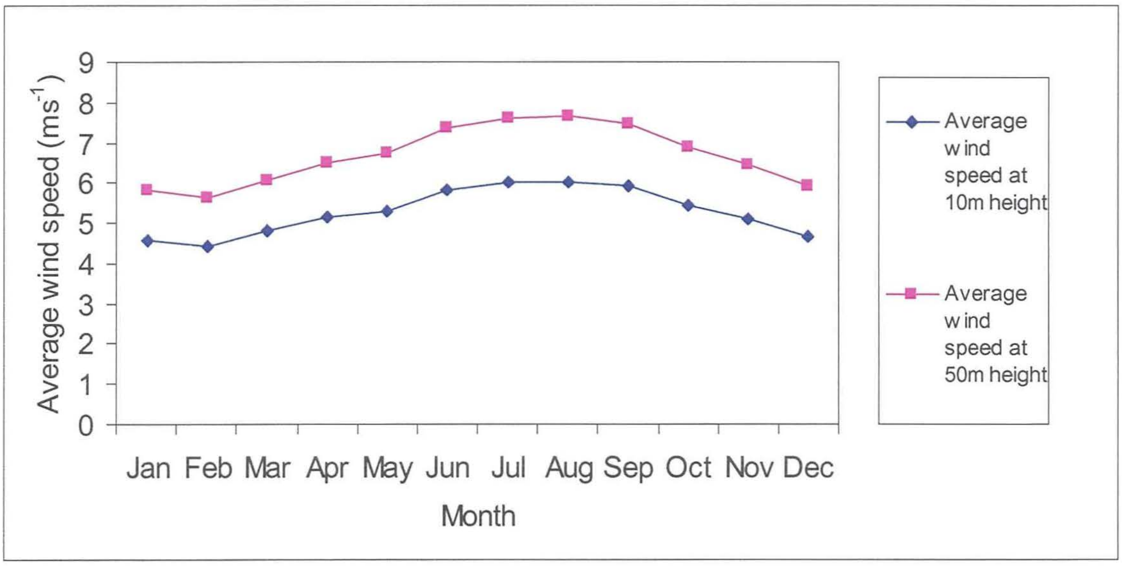
Table 22: Weibull parameters for Auckland region

Location	k	c ms^{-1}	b %
Whenuapai Aerodrome	1.85	5.5	25.3
Auckland City	1.94	6	12.9
Auckland Aerodrome	1.99	6.6	13.2

Source: (Smyth, 1987)

The wind resource seasonality matches well with the energy demand profile showing a winter/spring peak (Figure 29).

Figure 29: Auckland airport wind speed seasonality, measured at 10m and 50m heights



Source: (NASA, 2005)

Data were obtained from NIWA which provide an assessment of the mean annual wind velocity over Waitakere City. The NIWA data were developed using data obtained from climatic stations around the area and then interpolated from these stations to a regular grid with 500m spatial resolution using a thin plate smoothing spline. For further details, refer to Appendix D. The resulting map of Waitakere City (Figure 30) has an estimated accuracy of these data as +/-1 ms^{-1}. Local small-scale increases (e.g. speed-up over ridges and hills) are unlikely to be correctly identified due to the 500m spatial resolution. The value of data at these resolutions are in identifying locations where more detailed investigations involving models and/or anemometer measurements can and should be performed.

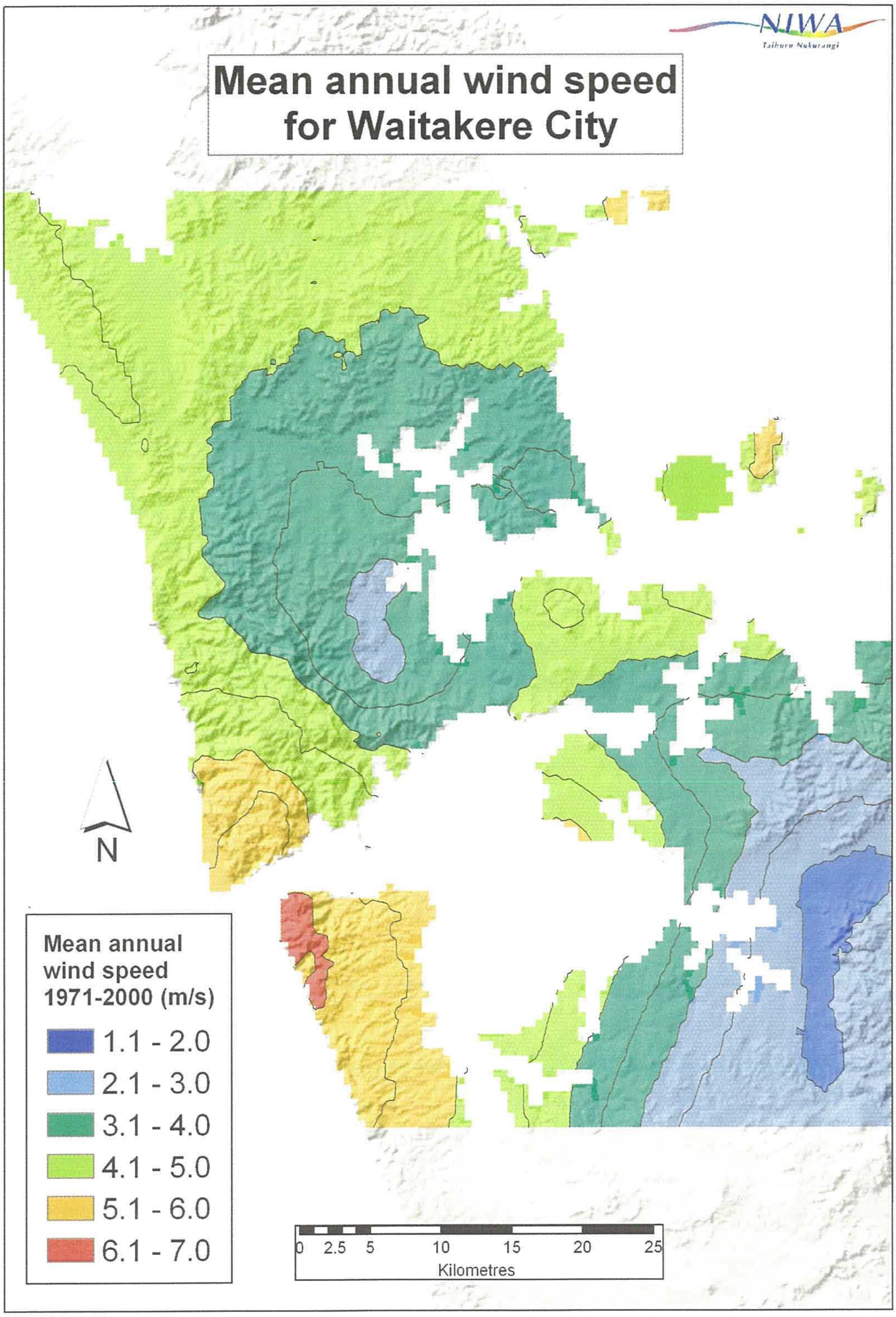
The south-west corner of Waitakere City shows the best potential for wind farm development. The area on the other side of the harbour at Awhitu was the site of a recent proposal for a wind farm, though the initial resource consent was declined. The south-west corner of Waitakere City is particularly remote from roading and transmission (though transmission could be taken across to Manukau Heads). It is also included in the Waitakere Ranges National Heritage Area, where a draft bill has been prepared to protect this area from further development. For these reasons it is very unlikely that this area will be feasible for wind farm development. The western area of the region has a lower wind potential and also sits within the proposed Waitakere Ranges National Heritage area, so is also technically, economically and environmentally unlikely to be used for wind generation.

6.6.1 Offshore (and inshore) wind energy

In the article "Hydrodynamics of Manukau Harbour, New Zealand, (Bell, Dumnov, Williams, & Greig, 1998) stated "prevailing surface-wind directions are from the south-west (average 26% of a year), north to northeast (24%), and west (10%), whereas it is calm for 13% of the time. The median wind speed is c. 6 m/s. Sustained winds >15 m/s are seldom experienced (0.2%), usually associated with cold, unstable south-west airstreams (original source: New Zealand Meteorological Service 1982)".

The Weibull probability distribution of the stated Manukau Harbour wind conditions at 10m is shown in Figure 31. This distribution can be used to determine the proportion of time that suitable wind speeds is available to power a wind turbine and the likely power output (and therefore economics) over time. Particularly important is the amount of time that usable wind speeds are available (Above starting/cut-in speeds (approximately

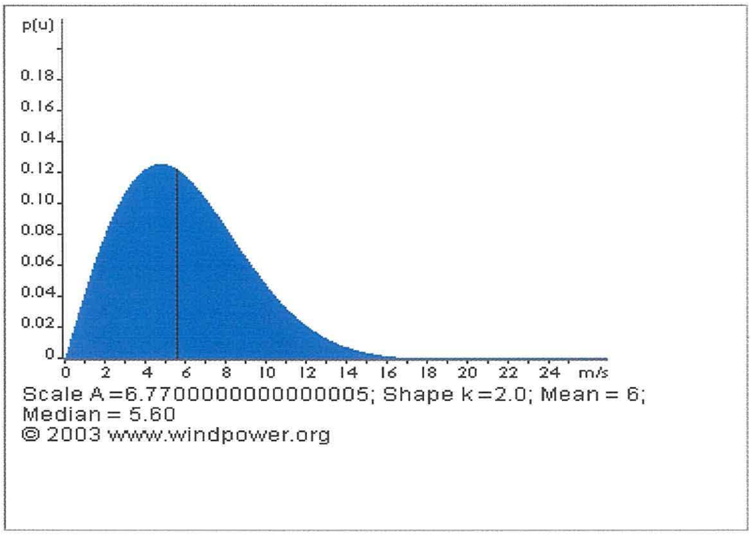
Figure 30: Spline interpolation of mean wind speed by NIWA



Source: NIWA (2004)

above 3 ms^{-1} and below stall/cut-out wind conditions (Turbine dependent). The Weibull parameters can be used in modelling to find the most appropriate wind turbine and turbine height for a particular application, and to assist the development of feasibility studies for a wind turbine site or wind farm.

Figure 31: Weibull distribution for Manukau Harbour (average wind speed of 6 ms^{-1} at 10m height)



Source: (Danish Wind Industry Association, 2005)

Further anecdotal evidence is described by New Zealand Windsurfer magazine in 1995:

"Note that the Manukau Heads make a nozzle which squirts wind all the way across Mangere Bridge, Howick and then into Tamaki Strait. So tryout Onehunga or Tamaki Strait for the strongest winds during a south-westerly."

(DeepFried.tv, 2005)

There is approximately 223 km^2 of land exposed in the Manukau Harbour between the low and high tide marks (therefore with less than 3m water depth in all tidal conditions), with large areas that could be suitable for turbines. With nominal wind turbine spacing of 700m apart, this represents a significant potential for power production. Other important factors exist:

- The harbour has the benefit of a shallow relatively calm surface with zero (water surface) to low (estuary exposed) roughness classes (i.e. low turbulence effect from interaction of terrain surface and wind allowing lower turbine tower heights and larger turbine sizes to achieve maximum economic power output).
- The ecological effects from wind farm establishment and interconnection to the grid are also much reduced in this marine environment, and in overseas

studies, proven to be beneficial to the environment (e.g. artificial reef effects around tower base increasing levels of marine life).

- Noise effect is reduced as there are no close neighbours. This also allows wind turbines to be optimised for power production.
- The harbour environment is a much more benign area than the open sea environment outside the harbour to establish wind generators and turbine life should exceed both the land based expected turbine life of 20 years and the offshore expected turbine life of 25 years.
- There could be some difficulty related to the building of suitable foundations for the turbine tower bases due to the sedimentary soil types, though several examples of foundation systems have been used and proven economic in water depths up to 15m. Furthermore the turbine tower foundation has a fifty year life expectancy reducing overall impact on payback.

Danish studies put their offshore wind power costs at 4 to 5 eurocents (approx 8-10 NZ cents) per kWh. With the rate of technology development and commercial experience offshore wind farms (100 MW and above) are rapidly becoming cost competitive with both land based wind farms and other technologies (Krohn, 2002).

As an indicative example of potential, using the wind turbine power calculator from the Danish Wind Industry Association website (Danish Wind Industry Association, 2005) it would take approximately 162 Vestas V66 2000/66 offshore (rated 2MW, 66m diameter rotor, 66m tower) to produce enough energy for the total Waitakere city average annual electricity demand (ignoring network losses). This figure could be reduced to as low as 57 devices if High EEIP savings were made. Larger turbines are also available between 3 MW and 5 MW rating.

The possibility of establishing New Zealand's first offshore (inshore) wind farm in the harbour would be worthy of greater study, given:

- the proximity to a major demand centre;
- the 6 ms^{-1} average wind speed is likely to be significantly under the true wind speed at 10m (anecdotally, by approximately 30%) and will not be representative of the whole harbour (ignoring wind channelling effects, and shadowing). A rough estimate using the empirical power law, given the boundary layer profile shows wind speeds at the nominal turbine height of 66m would be between 7.2ms^{-1} (given 6ms^{-1} at 10m) to 9.4 ms^{-1} (given 6m plus 30% at 10m). These winds speeds are around the average speeds quoted for some

overseas offshore wind farm developments though these are often subsidised; and

- the potential for this technology to compete economically with current generation technologies.

The resulting wind farm would look something like the Horns Rev wind farm off the coast of Denmark (Figure 32).

Figure 32: Horns Rev, 160MW offshore wind farm by Elsam A/S, Denmark

Source: (British Wind Energy Association, 2005)

There also exists the potential to combine both tidal stream power generation using, for example, a MCT Ltd monopole type system and a wind turbine mounted on top of the monopole structure, allowing increased generation at one particular site and therefore increased economic feasibility. The MCT monopole is discussed in more detail in the tidal stream section (6.7.4).

The open sea environment on the west coast of Waitakere City also has good wind resource but due to the lack of population and therefore transmission it is less likely to be economically feasible to develop when compared to other potential sites outside the city coastline.

6.7 Water energy

6.7.1 Hydro power

There are three major drinking water catchments within Waitakere City covering 31% of the land area of the city (Figure 33). All three are used by Watercare to provide drinking water to the Auckland region. There is a small hydro scheme attached to the Waitakere water treatment plant producing 0.075MW that is used to partially power the plant. There is also a proposal to build a hydro power plant on the Nihotupu bypass channel that will generate power for local use with excess provided to the grid.

There are a myriad of streams and waterways throughout the area and many of these may be technically feasible to develop small scale hydro plants. In reality though, it is unlikely that the vast majority of these potential sites would ever be developed due to economic and ecological feasibility.

6.7.2 Manukau Harbour

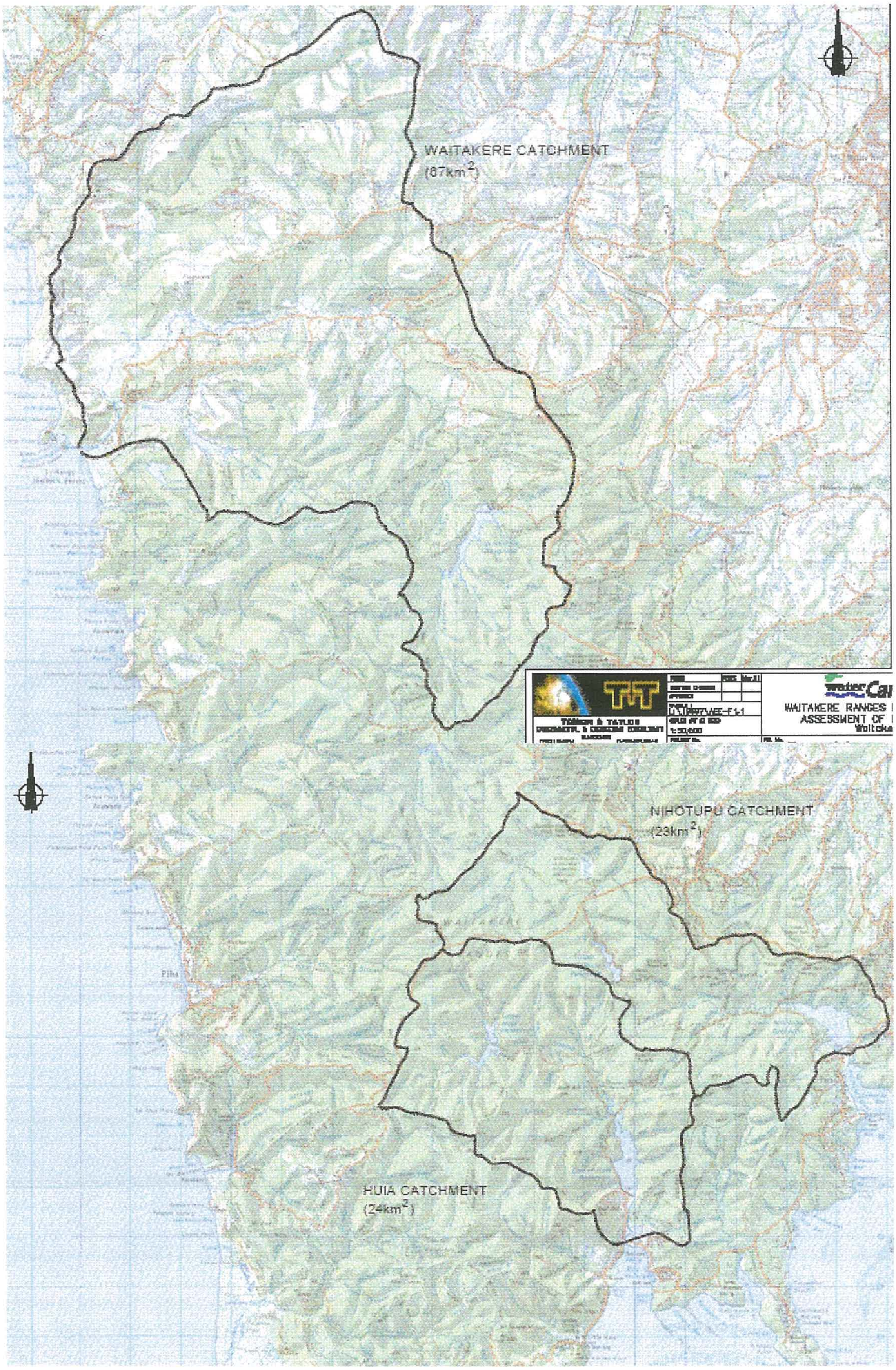
The Manukau Harbour is situated on the southern border of Waitakere City (Figure 34). It is a vast harbour with some interesting characteristics that may make it useful for a number of renewable energy systems, including wind, tidal flow and wave (outside harbour entrance).

After the Kaipara Harbour the Manukau has the second largest harbour shoreline in the Southern Hemisphere and is the eighth largest harbour in the world. The Manukau claims the largest volume in-fall and out-fall of water of any harbour in the world with a tidal range in the harbour from 0.0 metres up to 4.6 metres. (Manukau Volunteer Coastguard, 2005)

"Manukau Harbour is a large meso-tidal coastal lagoon. The surface area, which at mean high water spring tide (368 km^2), is reduced by 60% at low spring tide, with the exposure of broad low-gradient tidal flats and banks covering 145 km^2. Maximum depths across the entrance channel vary from 30 to 50 m in the deepest section off Paratutae Island. Inner-harbour channel depths vary from 30 m at Puponga Point to 5-10 m near the perimeter of the harbour. Minimum depths in the main shoaling sections are: Huia Banks in the entrance channel (5 m), Wairopa Channel (3 m), and Purakau Channel (2.5 m).

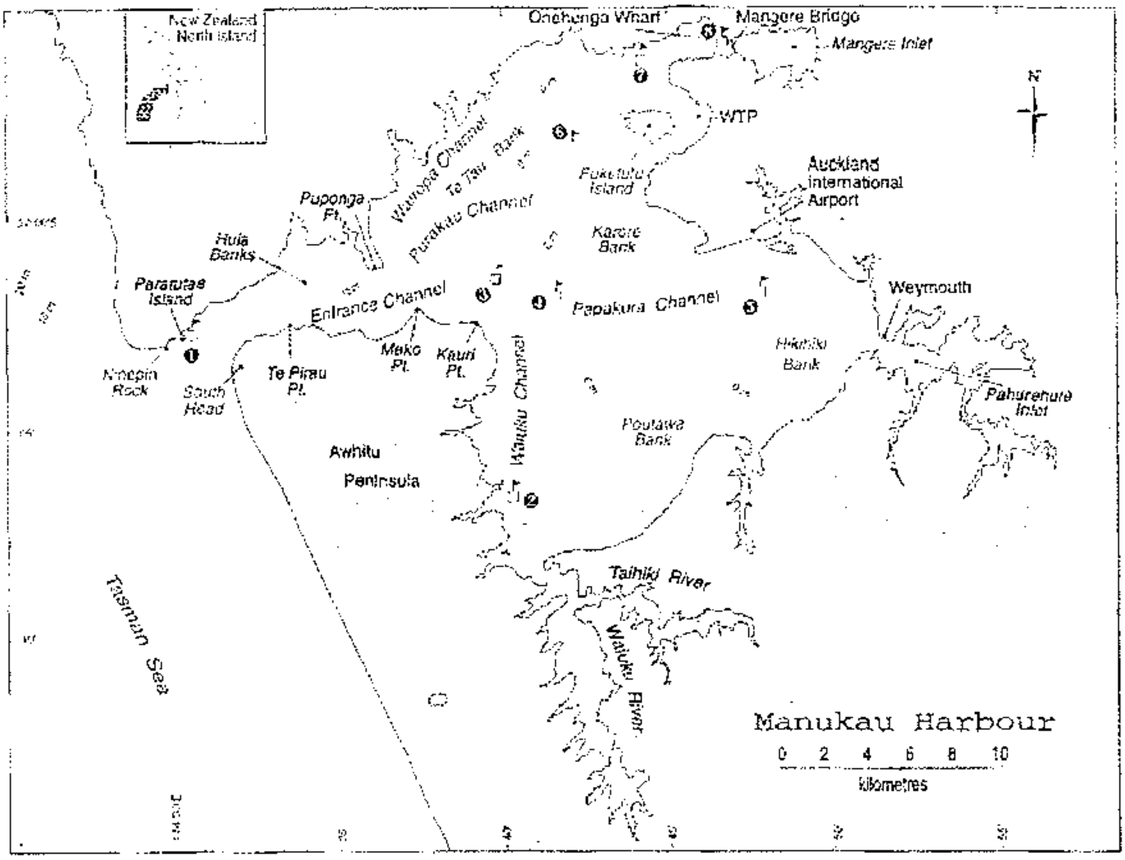
The catchment area (850 km^2) is only about twice that of the harbour itself, so the mean-annual freshwater inflow (including sewage) of 26.3 $m^3 s^{-1}$ is relatively small.

Figure 33: Waitakere (67 km²), Huia (24 km²) and Nihotupu (23 km²) catchments



Source: (WaterCare, 2001a2001b)

Figure 34: Location map of Manukau Harbour



Source: (Bell et al., 1998)

The tidal ranges in Manukau Harbour are among the highest in New Zealand. The mean spring (neap) tidal range is amplified inside the harbour, from 2.7 m (1.5 m) at the harbour entrance (near Paratutae Island) to 3.4 m (2.0 m) at Onehunga Wharf in Mangere Inlet. Measurements have shown that peak velocities of up to 1.8 ms^{-1} can occur in the entrance channel. Other regions where high velocities have been measured are in the mouths of the inland tidal inlets: Mangere Inlet, 1.0 ms^{-1} (spring) and 0.5 ms^{-1} (neap) and Pahurehure Inlet, 0.9 ms^{-1} (neap).

Prevailing surface-wind directions are from the south-west (average 26% of a year), north to northeast (24%), and west (10%), whereas it is calm for 13% of the time. The median wind speed at 10m height is 6 ms^{-1}. Sustained winds >15 ms^{-1} are seldom experienced (0.2%) and are usually associated with cold, unstable south-west airstreams" (Bell et al., 1998).

6.7.3 Tidal range power

Manukau Harbour's maximum tidal range of 3.3 metres at spring tide and a minimum range of 2 metres at neap tide is too small to consider a feasible tidal range power generation plant (at least using current barrage/dam type systems) for the foreseeable future.

A tunnel connection between Manukau Harbour and Waitemata Harbour (between New Lynn and Blockhouse Bay) could be used to exploit the ebb-flow from approximately three hour tidal time difference. While the amplification of the tide within the harbour would be beneficial, the tidal range again is likely to be too small for this type of plant to be considered feasible.

There are numerous small inlets within both the harbours around Waitakere that could be dammed to provide small tidal range generation plants. The cost and potential impact on the environment would make these unfeasible for the foreseeable future.

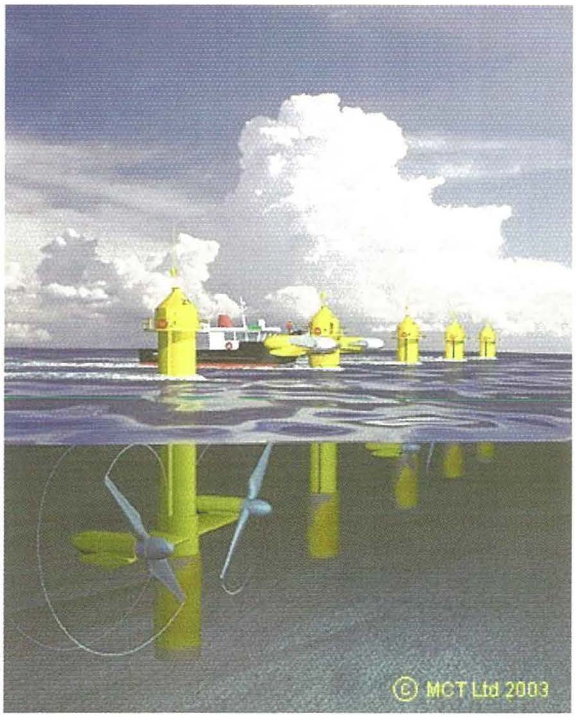
6.7.4 Tidal flow and ocean current power

Manukau Harbour with a narrow entrance (approx 2kms wide and 30-50m deep) and large area (368 km^2 at spring tide reducing by 60% during neap tide) offers some potential for tidal flow power generation. The ocean current strengths at the harbour entrance are 1.8 ms^{-1}. The tidal volume in-fall and out-fall of water is the largest of any harbour in the world.

The technology to extract power from the tidal flow is still at the prototype stage, and thus few indicators of the overall available power from these systems in Manukau Harbour are available. One system under research and development by Marine Current Technologies (MCT) (Figure 35) consists of twin axial flow rotors of 15m to 20m in diameter, each driving a generator via a gearbox much like a hydro-electric turbine or a wind turbine. The twin power units of each system are mounted on wing-like extensions either side of a tubular steel monopile some 3m in diameter which is set into a hole drilled into the seabed from a jack-up barge. These units would be set up in arrays, similar to wind farms for commercial production. The stated basic requirements for cost-effective power generation from tidal streams using MCT's technology are a mean spring peak velocity exceeding about 2.25 to 2.5 ms^{-1} (4.5 to 5 knots) with a depth of water of 20 to 30m. The rated output of each twin rotor monopile unit would be rated at 750 to 1200kW (the variation depending on the rated velocity for the site chosen) (Marine Current Turbines, 2003).

Despite the large in-fall/out-fall, the peak currents of 1.8 ms^{-1} within the Manukau Harbour entrance channel would appear to be too low for economic recovery of electricity using this system. The cost effective criteria may change once a commercial scale product has been developed (post phase 3 development in 2004/05). It may also be possible and feasible to incorporate a wind turbine onto the monopole increasing the overall output of each unit. The impact on navigation, marine life as well as the effects of shifting sediments would all need to be fully understood before suitable power systems become available.

Figure 35: MCT tidal current turbines with one raised for maintenance (artist impression)



Source: (Marine Current Turbines, 2003)

Other system proposals look to exploit the ocean currents that are present in rip tides and channels along the coastline. These systems may prove useful in niche applications in the longer term. At this stage they are very immature technologies and no useful analysis can be provided.

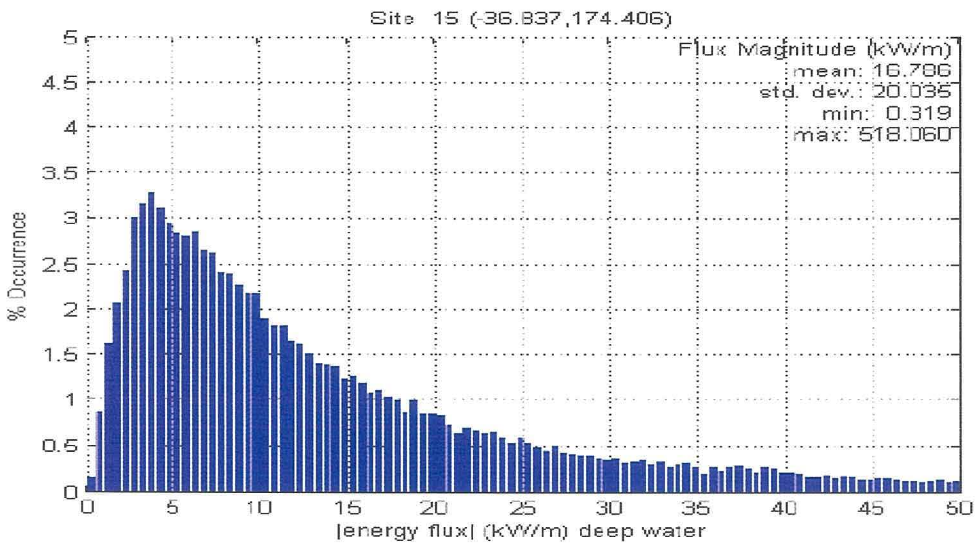
Tidal flow power is one technology that may prove feasible in the future. Given the major resource in the Manukau Harbour entrance channels, the technologies in this arena should be watched for further developments.

6.7.5 Wave power

Wave energy is mainly generated by the interaction of the wind moving over the ocean. Due to the density of water, the energy present in a wave front is more concentrated than either the available wind energy or the solar energy from which the winds are derived.

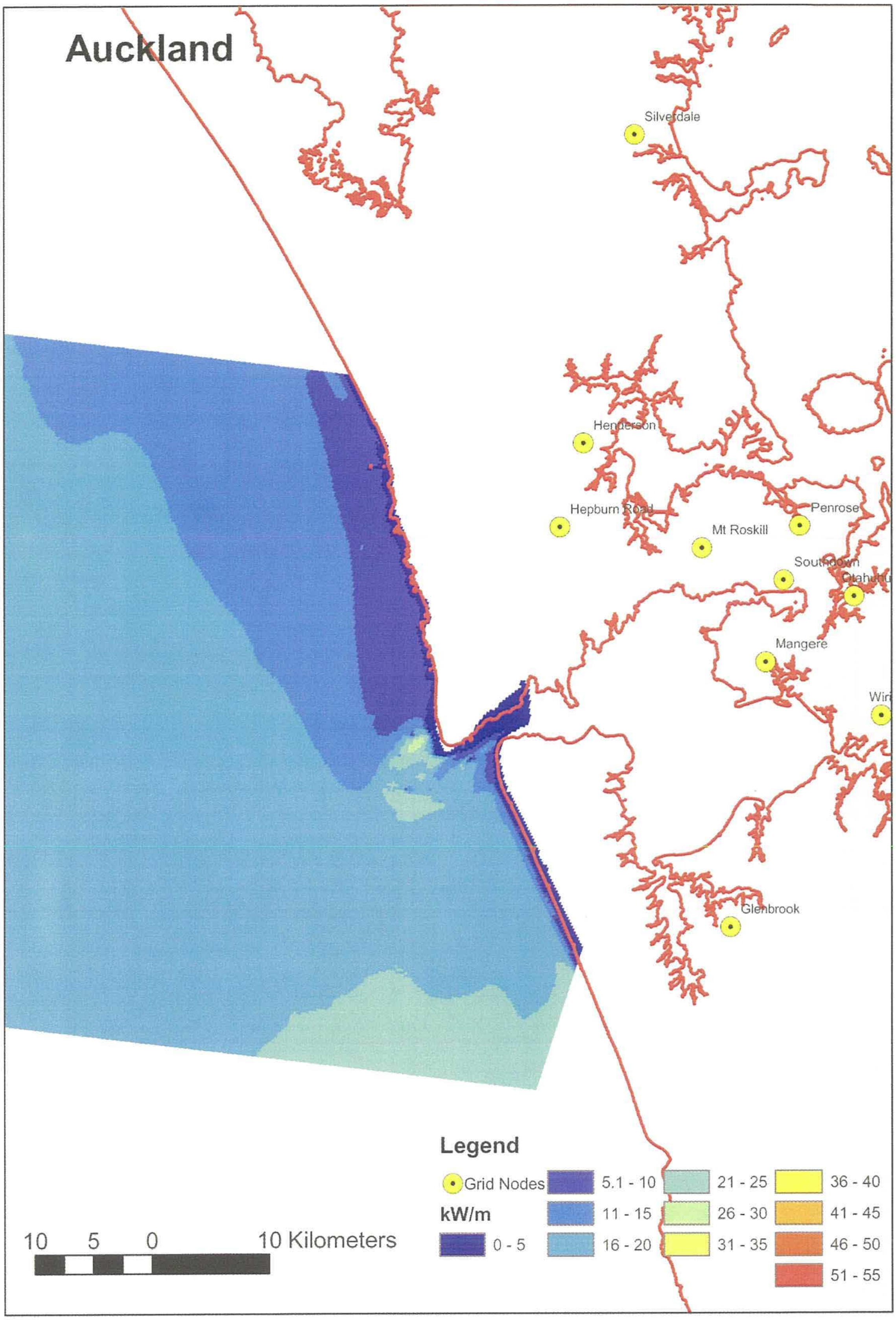
The West Coast of Waitakere has an excellent wave resource and has been identified as an area technically capable of producing wave power. A profile of the available energy per metre of wave front is shown in Figure 36. Bathymetry studies performed by Frazerhurst (2005) demonstrate that the area around the mouth of the Manukau Harbour offers good wave conditions for wave power generation (Figure 37). The access to the harbour for maintenance and operational support makes this location even more desirable.

Figure 36: Waitakere deep water wave energy profile



Source: (Frazerhurst, 2005)

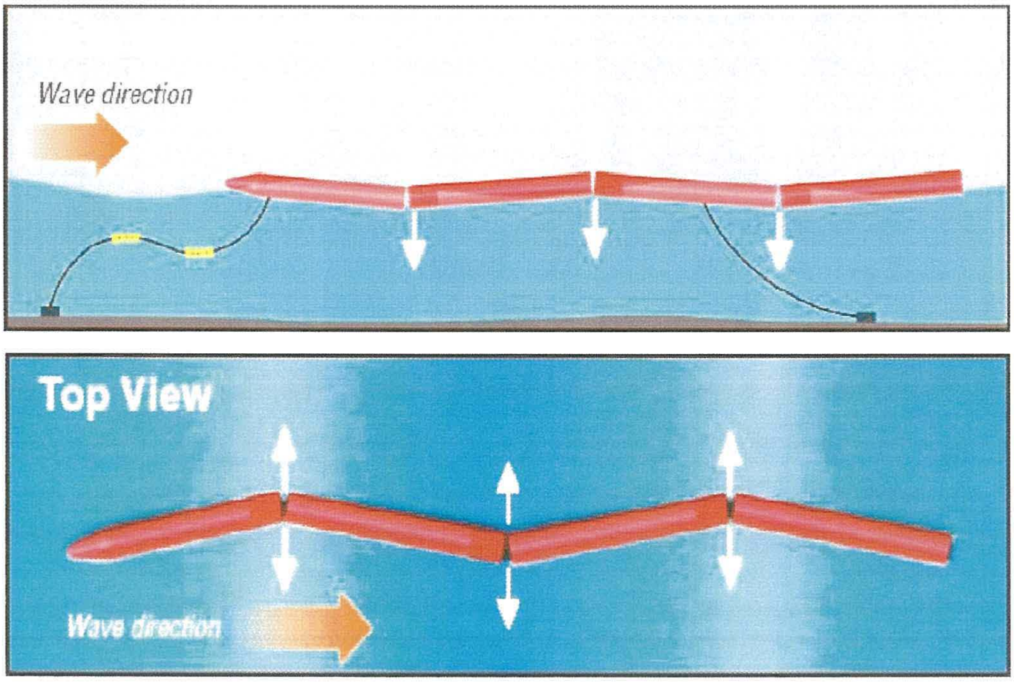
Figure 37: Waitakere wave bathymetry



Source: (Frazerhurst, 2005)

The immaturity of suitable generation equipment in the commercial environment and lack of suitable wave climate data makes feasibility hard to establish at this time. One potentially deployable device that is producing commercial electricity is the Pelamis device (Figure 38) manufactured by Ocean Power Delivery (OPD) in the UK. This device has been assessed by E2I EPRI, a leading US ocean energy assessment programme. Using the E2I EPRI methodology, Pelamis performance data and Waitakere wave data, Frazerhurst (2005) determined that a Pelamis device off the coast of Waitakere would have a rated capacity of 197 kW and an annual generation of 690 MWh. While other sites rate higher in terms of output (Table 23), the proximity to the major load centre, would make the consideration of this device in the waters of Waitakere attractive.

Figure 38: Pelamis WaveGen



Source: (Ocean Power Delivery, 2005)

Table 23: Pelamis assessment in NZ waters using E2I EPRI methodology

Site	Rated Capacity (kW)	Capacity Factor	Power Ave (kW)	Annual Generation (MWh)	% of Time	% of Energy
Hokianga	206	40.0%	82	721	91%	91.16%
Auckland	197	40.0%	79	690	90%	90.45%
Great Barrier Island	156	40.1%	63	548	51%	50.62%
Taranaki	250	40.0%	100	877	97%	97.41%
Mahia	195	40.0%	78	683	90%	90.42%
Wellington	138	40.1%	55	485	75%	74.50%
Greymouth	287	40.0%	115	1006	95%	95.40%
Canterbury	239	40.0%	96	837	97%	97.25%
Otago	232	40.0%	93	813	97%	97.11%
South	494	40.0%	198	1731	98%	98.46%

Source: (Frazerhurst, 2005)

It is important to note that the current Pelamis device has been designed and built to operate in European wave conditions (choppy water with a smaller significant period). A device designed for NZ waters may be larger when tuned to NZ conditions and produce a better power performance profile. The Pelamis device when fully commercially operating will be installed in large arrays forming a wave farm (Figure 39). Given the above data it would take 1278 devices to generate enough electricity to meet the Waitakere City average annual power demand. This figure reduces to approximately 450 devices if High EEIP savings were to be made.

Figure 39: Pelamis wave farm - artistic impression.

Source: (Ocean Power Delivery, 2005)

A newspaper report from the Sunday Star times dated Sunday, 24 April 2005, stated that an Auckland company, Power Generation Projects Ltd, is negotiating with OPD to build Pelamis devices to be deployed off the west coast of both the North and South Islands (Sheeran, 2005).

6.8 Bioenergy

6.8.1 Municipal solid wastes (MSW)

The Waitakere Refuse and Recycling Transfer Station receives and processes waste, separating it into categories (glass, plastic, metal, wood, green waste etc). Items of value are recovered. Approximately 62% of the total waste stream is organic in nature (timber, paper and putrescibles) (Figure 40 and Table 24). The green waste is composted onsite and useable timber is made available for firewood. The remaining waste (and other waste from Auckland region) is transferred to Redvale landfill. Mighty River Power operates a landfill gas to electricity plant at this site where there are three generator units with 2.7MW capacity. The plant has an electrical efficiency of approximately 30% (Bioenergy Association of New Zealand, 2005).

Figure 40: Composition of Waitakere City waste stream

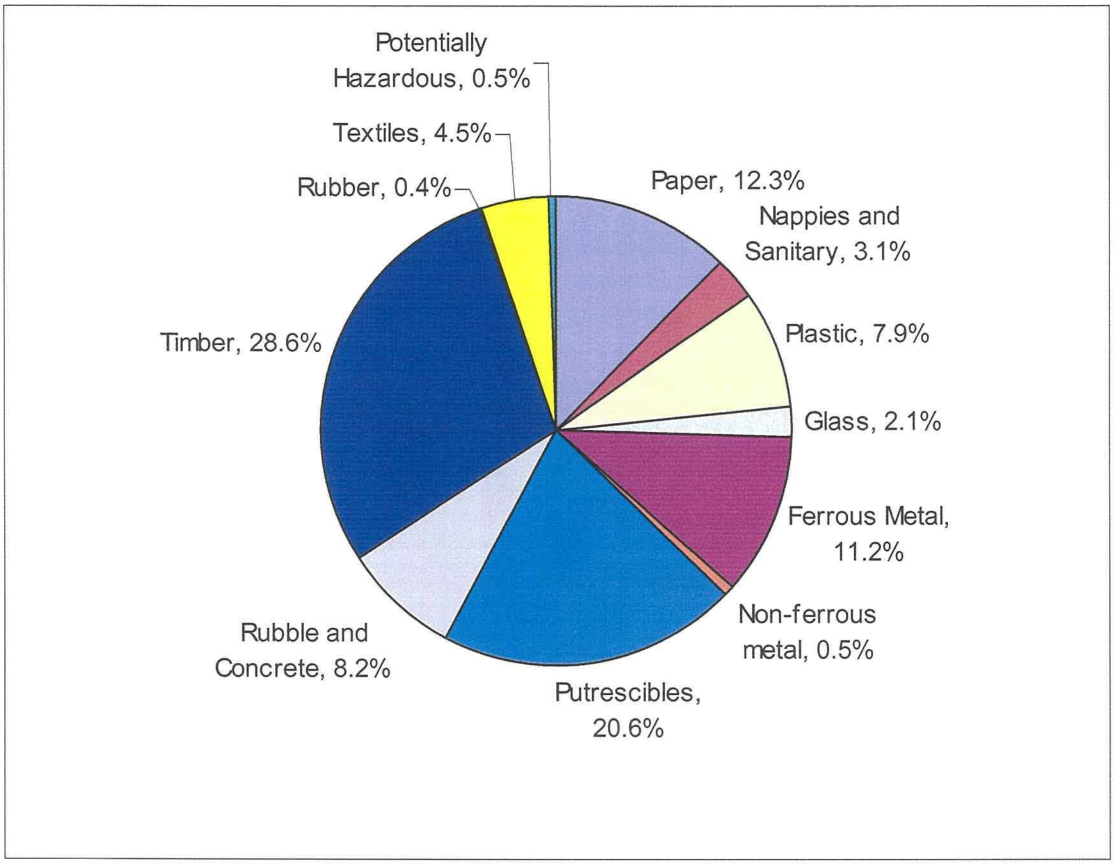


Table 24: Waitakere City rubbish as analysed at transfer station

	Compostion as analysed in 2003	02/03 Tonnes	03/04 Tonnes
Paper	12.3%	14694	16434
Nappies and sanitary	3.1%	3703	4142
Plastic	7.9%	9438	10555
Glass	2.1%	2509	2806
Ferrous metal	11.2%	13380	14965
Non-ferrous metal	0.5%	597	668
Putrescibles	20.6%	24610	27524
Rubble and concrete	8.2%	9796	10956
Timber	28.6%	34167	38213
Rubber	0.4%	478	534
Textiles	4.5%	5376	6013
Potentially hazardous	0.5%	597	668
Non defined	0.1%	119	134
	100.0%	119466	133613

Waitakere City Council has considered several alternative approaches for "energy from waste" (EfW) schemes, notably the Olivine proposal (in conjunction with the other Auckland regional councils) and the ISIS approach (EECA & CAE, 1996). To date none of these EfW schemes have been progressed. Indeed many similar schemes internationally have had limited success due to the inconsistency of waste composition and its effect on plant economics. MSW energy conversion is not renewable, though the derivation of maximum economic benefit from the lifecycle of a product through reuse, recycling and/or energy conversion means that this stream is worthy of consideration from an energy management and efficiency of resource use point of view. The greatest part of the energy content imbedded in this waste stream is that from the petrochemical derived plastics. Burning plastic provides 4.75 times the energy output for plastic as compared to non-plastic garbage on a weight for weight basis.

The latest initiative by Waitakere City Council, in conjunction with North Shore City Council is to create a more efficient curb side collection of recyclables and to develop a separate curb side organic waste collection. The energy saved and emission reduction obtainable from the recovery and multiple reuse of recycled combustible materials is greater than the energy obtainable from their consumption in any EfW scheme.

Alternative energy conversion processes exist for wood (currently domestic firewood), and organic material that would obtain greater energy potential than currently obtained through current processes. The proportion of treated timber in the waste stream is unknown and conversion of such timber to energy by incineration or other means may prove to be problematic given the nature of the chemicals involved in the treatment process. Green waste can also be converted into energy instead of being composted as is currently happening.

6.8.2 Metropolitan green waste (MGW)

Currently green waste collected at Waitakere Refuse transfer station is composted on site using Vertical Composting Unit (VCU) technology. As composting is an aerobic process, little usable gas by-products are produced.

Alternatively, the green waste could be anaerobically treated within a digester process (similar process to the sewage sludge treatment at Manukau) to produce a biogas.

In 2003/04, 7807 tonnes of MGW were presented at Waitakere Refuse transfer station. This quantity would produce just less than 1 million cubic metres of biogas per year. The waste solid sludge from the digester could be applied to land as a fertilizer or plant growth medium (after separation of the liquid fraction) or as an animal feed supplement (Sims, 2002).

6.8.3 Sewerage sludge

Sewage from Waitakere City is processed at the Manukau sewage treatment facility that was completed in 2004. Within this facility, as part of the secondary treatment process the sewage sludge is processed through seven anaerobic digesters. In this process, acid forming bacteria convert the organic materials into organic acids, which are in turn converted into methane and carbon dioxide gases by methane forming bacteria.

This process within the seven digesters produces 35,000 cubic metres of biogas per day. This fuel is supplied to four 1.7 MW gas engine/generators (each with capacity to supply electricity at a level equivalent to the demand of 200 households). Enough biogas is produced to run 2.5 of the engine generators and contribute approximately 50% to the plant's electricity demand and provide all the heating for the treatment process. Technology enhancements that increase gas production at the site could see approximately 80% of the treatment plant's electrical demand produced on site.

6.8.4 Woody biomass

Waitakere has no logging and saw milling operations producing woody biomass from processing wastes. The Svenka Cellulosa plant in the City producing paper tissues does bring logs into the city for processing with black liquor and solid residues produced that may have some energy potential. No detailed data was able to be found to quantify the potential of these by-products. If woody biomass energy conversion was to be considered within Waitakere City, then most likely, specific energy plantation crops would need to be established and developed at to a size that can produce a commercial return to landholders as well as being able to economically support the establishment and continued operation of the downstream energy conversion plant. CAE (1996) estimated an achievable yield of approx 20 ODt/ha/year using harvestable coppice cropping techniques with Eucalyptus brookerana and/or Eucalyptus globulus planting. With breeding and selection programmes this yield could be increased to around 30 ODt/ha/year.

Much of the available rural land (non urban, non horticultural, non protected) in Waitakere is in small lot sizes (2.5 hectares or less). While this land is largely economically unproductive or under productive, there would be little chance of establishing a large enough crop with certainty of supply, to be viable, either to the landholder or processing plant operator. Furthermore, even if economics could be established, the relative complexity of the proposal compared with larger rural operations would mean that Waitakere based proposals would be a poor choice for potential investors.

Domestic firewood production crops and processing could be established on a much smaller scale than larger commercial woody biomass to electricity conversion operations. Domestic cooking, wetback water heating and space heating can be provided very efficiently using well established technologies. The state of the art conversion technologies can produce virtually no pollutants. The relative greenhouse gas and particulate emissions and overall system efficiencies from firewood consumption vs. coal powered electricity generation have not been analysed fully for the NZ situation.

The planting and consumption of bioenergy crops is seen as CO_2 neutral where the resource is sustainably managed. However biomass combustion can emit small quantities of particulate, nitrogen oxides and will generate ash (EECA & CAE, 1996).

Biomass removal from a plantation will also remove nutrients from that site. These can be replaced through natural inputs (at a cost and requiring active management) such as nitrogen fixation, sewage sludge spraying and ash return.

6.8.5 Agricultural and marine biomass crops

Energy crops such as straw, corn, sugar beet, hemp and possibly some marine crops could all be farmed to provide a directly combustible material or produce a secondary combustible fuel (e.g. ethanol or methane). These crops can be grown as either the primary crop or as a part/by-product of a multi-use crop.

The potential of growing such crops in Waitakere is constrained by the lack of available agricultural land, particularly which is able to be farmed using broad acreage machinery that would result in higher efficiency.

Marine crops such as kelp and sea grasses are largely not researched but are unlikely to be viable or considered due to their difficulty of containment and other potential ecological impacts.

6.9 Geothermal energy

The Waitakere ranges are largely composed of Waitakere Group rocks of early Miocene age that were derived from volcanic activity and subjected to uplifting and erosion over the last 15-20 million years. Sea level changes associated with glaciations have deposited coastal sediments in the valleys and caused valleys to be eroded well below the present sea level. The soils of the central rolling and hilly land of the Waitakere Ranges are the moderately leached Waitakere Clays. From Huia to Parau, the predominant soils are the strongly leached Cornwallis Clays and the moderately leached Parau Clay loams. In the valleys and along the coast are the brown stony clays and silt loams of the weakly leached Huia steepland soils (WaterCare, 2001a).

The volcanic origin of the Waitakere area and the confirmation of clay soil covering would indicate that some geothermal gradient would exist beneath the city. Indeed a hole drilled to 435m in Blockhouse Bay Geological Formation reputedly yielded warm water (Hayward, 1983).

6.9.1 Hot spring analysis

The temperatures found in the analysis of the geothermal hot water springs around Auckland and surrounding districts provide another strong indication that a geothermal gradient may exist in Waitakere and the temperature range to be expected (Table 25). Unfortunately little publicly or other available data have been found, and with initial discussions with geological experts there does not appear to have been a great level of exploration drilling and geological/geothermal studies conducted within Waitakere City.

Table 25: Geothermal gradients found at regional hot springs

Hot water Springs	Temperature range (°C)
Parakai springs	Max temp 65 °C
Waiwera	45 -52 °C (1 hole at 377m measured 48.7 °C)
Miranda	56 °C (64 °C found in 1 shallow well)

Source: Institute of Geological and Nuclear Sciences, 2004

Temperatures within the range indicated by the hot springs analysis, if found within Waitakere City, would be unsuitable for direct electricity generation but could be suitable for geothermal ground source heat pumps, Stirling engine systems and heat transfer systems. These systems could utilise the energy obtained for space and water heating applications including domestic heating, pool heating, fish farming and horticulture.

Much further investigation is required to determine the nature of the resource, its potential, restrictions, sustainability as well as technical analysis and economics of utilisation.

7 Discussion and Conclusions

During the initial stages of developing the scope of this study, it was thought it would simply be an assessment of the renewable energy resource potential of Waitakere City. It rapidly became clear that if progress is going to be made and the 2020 vision of becoming a net energy source rather than an energy sink was going to be realised, then a combination of energy conservation, energy efficiency and renewable energy generation would be required. Furthermore in looking at the energy supply problem holistically, the indirect use of energy within the city from goods and services provided to the city from outside the city boundary should also be targeted.

This report outlines the potential for new initiatives to be developed. What follows is a summary of the areas of particular interest, and actions that could be taken to progress some of these energy initiatives. A number of potential flagship projects are also identified which would increase energy awareness of ratepayers, introduce energy auditing and efficiency measures and make progress towards increased renewable energy utilisation.

7.1 Current measures

The power generation systems that have been installed, proposed within the city, or use resources derived from the city are relatively small but are none the less significant. They represent electricity that does not need to be generated and transmitted from elsewhere with associated losses or problems. Such projects include:

- Watercare hydro – 0.075MW hydro plant at Waitakere water treatment plant and proposed hydro plant at Nihotupu bypass channel
- Landfill gas – wastes buried in Rosedale landfill where a landfill gas to electricity generation plant operates.
- Sewerage gasification – sewage supplied to Manukau treatment station anaerobic digestion (biogas) plant for electricity generation.

Waitakere City has embraced the current "reduce, reuse, recycle" campaign which also encapsulates energy management. The city has made some important moves toward energy sustainability, through its EcoCity initiatives. The utilities of the city such as water supply, sewage treatment and rubbish all contain energy generation plants.

Council is working hard to increase the level of community involvement in these initiatives. The energy saved is very significant in reducing the region's demand for electricity as well as the raw products, transportation and associated costs required for manufacture. "Reduce, reuse, recycle" is a key element in energy reduction that the whole community can actively participate in and be proud of the outcomes obtained.

7.2 Demand management

Energy efficiency and energy conservation are measures that can consistently and predictably achieve energy savings and are critically important to achieve energy reductions through the daily and seasonal peak periods. This is a major advantage over many renewable energy generation technologies which are not able to provide such a consistent outcome. It also can offer a direct saving to the network operators though reduced peak/non-peak load and allowing the delay in capital expenditure for network peak growth. Energy efficiency measures alone can achieve significant progress towards achieving the objective/vision of becoming a net energy source rather than an energy sink by 2020.

The technologies used in obtaining energy savings are well proven and readily available to consumers. There is no need for leading edge technologies with associated risks. Some of the technologies can be installed by consumers directly without specialist training, allowing a rapid take up and short timeframe to see benefits. The benefits derived from these initiatives can have wide ranging benefits beyond the energy saving, such as improved health, welfare, education, employment and social well-being. These initiatives could release significant amounts of cash (approx up to $54M p.a.) into the local economy. Demand management is a winning strategy.

Lighting offers the quickest win opportunity. Simply by changing high energy use light bulbs in residential dwellings from incandescent to compact fluorescent tubes, up to 80% of lighting energy use can be eliminated. In the commercial and industrial sector similar levels of savings can be made but will require electrician input to change older style fluorescent tubes and other fittings with energy efficient equivalents. The simple payback of these initiatives is nominally less than 1 year, representing excellent economic payback.

Insulation and household weatherisation are critical energy saving initiatives in the residential sector. Here the payback may not be realised as readily in terms of energy savings due to consumers under heating their homes currently to below minimum levels recommended by the World Health Organisation. The Universal Declaration of Human Rights affirms access to adequate housing as a vital part of human rights. Article 25.1. states that "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family...". While owner/occupiers have a social responsibility to themselves, it could be argued that the approximately 30% of Waitakere households that are rented to others are in breach of the intent of the Universal Declaration of Human Rights as these home made available to tenants have failed to provide a standard of living adequate for the health and well-being of the occupiers to a level set by the WHO. It could also be argued that the government is in breach of the intent of this declaration by not ensuring that the building and tenancy regulations contain adequate standards for health and well-being. It seems particularly remarkable that most houses in Waitakere City (even newly built homes, which are far too often built inappropriately to the local climate which then allows weather-tightness problems to develop) have insulation levels that are lower than a traditional pre-colonisation Maori reed hut.

The benefits derived from super insulation (insulation beyond the minimum requirement) and weatherisation of homes reducing moisture and mildew growth, are well proven and significant. The energy savings obtainable are also very important, not only in reducing overall energy consumption, but also at daily and seasonal network load peaks. Thus, they have an overall economic value much greater than the nominal tariff applied by electricity retailers.

The reasons outlined above give good grounds for the mandating of the installation of proper (much higher than current) levels of insulation in existing and new houses. Existing dwellings with minimum required levels of insulation can have additional ceiling insulation laid over existing insulation to achieve these new standards. The Waitakere Council should be encouraging that improved insulation levels be set into law within the Building Act, promoting improved insulation levels through its building consent processes (as required to facilitate by the Building Act 2004), mandating by building covenant where possible and seeking ways to finance and provide insulation to the community (possibly through charitable trusts, such as being done by Energy Options in the Bay of Plenty).

Water heating technologies offer good overall energy savings. The use of cylinder wraps and pipe lagging is one area of energy efficiency improvement that has been widely adopted within the residential community, due to the low capital cost, ease of self installation and benefit obtained. An audit of households could quickly and relatively cheaply check these installations and install wraps and lagging in the remaining households. The benefits obtained would affect the overall energy demand levels, but due to ripple control, may not reduce the peak energy consumption.

The installation of solar hot water heating systems or air sourced heat pump hot water systems is well recognised as producing good energy savings. The technologies are well proven but continue to have very low uptake within the market. The main problems with solar hot water systems are capital price, complexity of installation, and the marketing hype not matching the perceived performance of the systems. Air sourced heat pumps are much easier to install but also have a high capital price, may have noise and airflow issues, require more maintenance and the market largely doesn't know of their existence. Air sourced heat pumps have a better seasonal performance than solar systems and can produce hot water with some efficiency during the night, as they exploit the latent heat in the air rather than the direct solar energy from the sun. The most economic time to replace a system is when the existing system fails or in a new building. EECA loan schemes are available for both systems but these offers are no better than what most electrical goods retailers are offering on consumer goods. Clearly most consumers would rather spend $5000-$6000 on something that is going to give a direct gratification rather than a long term economic benefit. These hot water systems also don't appear to add to the sale value of a house. Clearly the only ways to encourage these systems is to offer large incentives, and/or mandate these systems such as is being done in Victoria, Australia. Mandating of such systems would also lead to a price differential in the housing market between those with systems installed and those without.

The replacement of expired hot water cylinders with ultra efficient (extra insulated) A grade cylinders offer a solution that provides a lower capital cost than solar derived technologies, easier installation (straight replacement of existing system as long as cylinder physically fits) and still provide some energy and economic benefits. The energy argument against this approach is that the life of the cylinder is 25 years and given that the most economic time to install an energy efficient solution is at the point of expiry of the existing system or in a new dwelling, thus the most energy efficient solution (air sourced heat pump or solar system) should be installed at this time. Hot water systems rarely reach conscious thought outside of these times unless an energy crisis draws their attention. The window of opportunity is small and may only come once in 25 years, thus it is imperative that appropriate mechanisms are in place to ensure the best solution is selected and installed so the best energy and economic outcomes can be achieved.

In the current housing market, there is no additional market value placed on buildings that have installed energy efficient technologies that provide lower energy consumption. Items with long economic payback such as solar hot water systems can therefore represent a cost to the installing party and the benefit will be derived by subsequent occupiers at no cost. Various methods are available to correct this market failure. One is to introduce a household energy rating system. There have been trials of this in Christchurch (using the BRANZ Green Home Scheme (utilising ALF model)) and systems implemented in other countries (e.g. FirstRate in Victoria, Australia, NatHers in Australia). The approach taken in Portland, Oregon, USA, is to conduct a free (City funded) energy audit and at that time, implement minor measures (cylinder wraps, lagging, door and window seals etc) and to provide literature and education to home occupiers. Portland has also implemented schemes specifically targeting rented dwellings, recognising the problems of occupation without ownership or financial ability to implement energy solutions. (A case study of Portland energy initiative is provided in Appendix E). The mandating of installation of various energy efficiency measures is increasingly being used overseas (e.g. Victoria, Australia and California, USA) to achieve energy outcomes. These mandatory measures would create direct house price variation between those that have implemented the measures and those that have not. Waitakere Council should consider mandating of energy efficiency measures and how it can encourage such regulation to be implemented.

Business and industrial energy efficiency measures are often business and site specific. In Waitakere City many small and medium enterprises (SMEs) could benefit from energy auditing but lack the awareness. Due to other business commitments, energy initiatives usually take low priority. One approach that could be implemented is for Council to fund systematic energy audits throughout SMEs and to rate businesses by energy efficiency as a marketing measure to influence consumer behaviour towards these businesses (similar to current food standard rating).

Large energy intensive industries should have energy managers and be conscious of energy efficiency. As this is a relatively small group of companies, a forum could be set up, that would include Waitakere Council, EECA and interested power companies to share information, and to encourage action. Exploratory investigations of each company by the council and EECA could be used to establish the levels of energy efficiency, staff awareness and to build a framework to achieve ongoing energy consumption reductions. A cluster analysis approach (as successfully deployed in Kalundborg, Denmark) may be useful where one industry generates a surplus of consumable energy (such as heat or hot water), that could be used by surrounding industries, or residences.

7.3 Renewable energy

There is a limited amount of land based renewable energy resource available in Waitakere City. The best resources are solar, wind and potentially geothermal. The best resources overall, excluding solar based hot water heating, for the city are based within the Manukau Harbour and off the coastline from wave, offshore and inshore wind and tidal current electricity generation. The good news is there is sufficient resource available to meet the total needs of the city and to easily meet the 2020 vision of becoming a net exporter of energy. This goal can be achieved using proven technologies and would, in general, have very little ecological impact on the environment. Some of the generation solutions are economic today, some are marginal and some will require a small shift in current prices and/or implementation costs to become economical (Table 26). Solar photovoltaic generation will still require a substantial shift in prices/costs to become economic in all except for remote off grid applications.

Solar hot water heating technologies are the best current opportunity that can be widely used and is able to be used within the urban environment without any problems. These systems offer well proven technologies, reasonable economic returns but continue to be little used due to perceived high capital cost and complications of installation. EECA has a low interest loan system in place to promote the use of these systems but when compared to other loans for items such as home entertainment, cars and luxury goods, these loans don't offer sufficient incentive for consumers to divert some of their income. As has been proven overseas (notably in Victoria, Australia), such incentives rarely work sufficiently and some level of mandatory use is required. This is highlighted by the fact that these systems are most economical when installed in new dwellings or when existing systems have expired and/or require replacement. This opportunity on average comes once every 25 years and for replacement of existing systems the window of opportunity is only several days long.

Table 26: Summary of renewable energy resource potential in Waitakere City

Renewable Energy Generation	Resource potential	Technology status	Economic in Waitakere	Comments
Solar based systems				
Solar thermal hot water	Universal	Commercial	Yes	Requires encouragement
Air source heat pump hot water	Universal	Commercial	Yes	Requires encouragement
Passive solar design	Universal	Commercial	Yes	Requires encouragement
Passive solar heating	Universal	Commercial	Yes	Requires encouragement
Thermal mass	New homes	Commercial	Yes	Requires encouragement
Natural ventilation	Universal	Commercial	Yes	Requires encouragement
Solar photovoltaics	Future/ Universal	Commercial	Future?	Only electricity generation technology suitable within urban environment
High temperature solar concentration systems	Nil	Commercial	No	
Solar chimney	Nil	Commercial	No	
Solar ponds	Nil	Commercial	No	
Ocean thermal energy conversion (OTEC)	Nil	Commercial	No	
Photo-chemical energy conversion	Future	Future	Future?	
Wind				
Wind energy (land based)	Very limited	Commercial	No	Lack of transmission access and negative ecological impact
Offshore (and Inshore) wind energy	Good/ Excellent	Commercial	Yes	Positive ecological impact
Water Energy				
Hydro power	Very limited	Commercial	Yes	In place
Tidal range power	Very limited	Commercial	No	
Tidal flow /ocean current power	Some future	Developmental	Future?	Effect on shipping?
Wave power	Excellent	Newly commercial/ developmental	Possibly	Keep close watch on these technologies
Bioenergy				
Municipal solid wastes (landfill gas)	Limited	Commercial	Marginal	In place
Municipal solid wastes (energy from waste)	Limited	Developmental	Marginal	
Metropolitan green waste (MGW)	Limited	Commercial	Yes	
Sewerage sludge		Commercial	Yes	In place
Woody biomass	Very limited	Commercial	no	
Agricultural and marine biomass crops	Maybe?	Future	Future?	complex ecological issues
Geothermal Energy				
Low temperature geothermal applications	Likely	Commercial	Maybe?	Requires investigation

Solar photovoltaic electricity generation has the potential to meet the net generation of the entire city. The technology is well proven but the cost remains prohibitively expensive due to both the cost of the solar cells and the cost of the balance of system components (particularly the inverter). These costs are expected to reduce over time but that time may exceed the 2020 target for the council vision.

Land based wind generation is marginal given the long transmission paths to suitable wind sites in the South West corner of the city, the likelihood of objection to developing the area particularly given the Waitakere Council supported submission before the government to protect the Waitakere Ranges from further development. Inshore and offshore wind development is quite another story. There is potentially a large wind energy resource within the Manukau Harbour that could be economically extracted. Danish and other European studies have shown that there can be a positive ecological effect on the local marine environment due to the reef effect around tower bases offering increased breeding grounds for local marine life. Noise is not likely to be a problem due to the distance to any potential neighbours. The economics of offshore wind generation have moved significantly over recent years to a point where these systems can be as economic as land based wind farms due to longer generation plant life, improved foundation systems, higher and less turbulent winds than on land and greater experience in operation. The main problem in locating a wind farm in the harbour is likely to be based on aesthetics. While some will see a certain beauty in the wind farm others will see it as an interruption to their view of the harbour. Unfortunately these people cannot see the fossil fuel emissions and effects that such a proposal would be replacing. The resource potential is significant enough for further feasibility studies to be considered, starting with desktop feasibility analysis and wind measurement studies. Offshore wind generation off the Waitakere coastline is less likely to be considered due to the lack of transmission network availability on the west coast of the city. It would be more likely that such schemes would be installed off the Awhitu coastline where transmission access is greater, and can be combined with the proposed Awhitu wind farm.

Wave farms offer a very serious and significant energy resource that is only just becoming a commercial reality. While there are many unique and often novel solutions being developed, the Pelamis wave generation system appears to be offering a commercial solution, to a point where a New Zealand company, Power Generation Projects Ltd, is negotiating to implement this solution within New Zealand. Bathymetric studies conducted by Frazerhurst (2005), indicate that there is potentially viable, economic wave resource of the coast of Waitakere City near the mouth of the Manukau Harbour. Such is the vast potential of this resource, both locally and nationally that further and significant studies should be instigated, on the resource, on the technologies to convert this resource into usable energy and on the likely impact on the marine environment. An opportunity exists for a locally based tertiary institution to become the leader in this field.

Tidal current energy has yet to be proven commercially viable in conditions similar to that in the Manukau Harbour entrance. The vast inflow and outflow of water in the harbour offers a significant resource if a solution can be found that is both technically and economically feasible. The limits of the total resource available will mean this will always be a niche solution but one that could conceivably add to the electricity generation capacity of the network. While some interesting and technically feasible solutions have been developed, these are yet to be fully proven and commercially viable. This solution is worthy of keeping an eye on for future development but no further analysis would be practical at this stage.

Geothermal energy within the city offers an interesting prospect. Its resource potential has not been adequately investigated but some extrapolation of studies found in and around the city would indicate that some level of usable resource is likely to exist. The likely temperature range of around 45 °C would mean that uses would be for hot water preheating and low temperature applications. There hasn't been a wide variety of technology solutions developed to use such low temperature geothermal resource within a mild climate like Waitakere City. The water heating potential of this resource could make significant energy savings within the city. Drilling costs of commercial bore holes needs to be established for desktop feasibility analysis to see if an economic solution is possible. Once this is established, test drilling and further analysis can take place.

On a micro scale, small wind, hydro and solar PV applications may prove feasible, particularly where off grid solutions are required. These solutions will require site specific analysis. Such small applications will not figure significantly in achieving the 2020 vision.

Hydrogen fuel cells have not been considered in this study as at this time hydrogen production requires either the electrolysis of water using electricity or the reformation of gas. Either way hydrogen is currently only a storage mechanism rather than a renewable fuel in its own right.

Storage of electricity within the local network can offer considerable network savings by lowering the peak supply (and hence not requiring upgrades to network components) that is currently supplied from the Transpower network. Storage solutions to network capacity constraints may be worthy of consideration by power companies but were beyond the scope of this study.

7.4 Flagship projects

7.4.1 Northern strategic growth area (NSGA) solar initiative

The Northern Strategic Growth Area (NSGA) is an area to the north west of the city that will surround the proposed motorway extensions connecting the Westgate intersection of the North Western Highway with a new highway through to Hobsonville and Greenhithe, and another new highway through to Kumeu. This area will be the major residential, commercial and light industrial growth area with the city in the coming years.

It is strongly recommended that energy conservation measures (as well as water conservation and sustainable development measures) be incorporated into the development that will occur in this area. These measures will require the mandating through covenant, district planning and any other means available to the City Council.

Designs of subdivisions should incorporate the basic principles of passive solar design to ensure that each dwelling is able to access and maintain access to the available solar resource. Special vegetation controls would also be required to ensure available sunlight is not denied to any particular dwelling and to ensure solar panels can produce maximum output. Solar derived hot water solutions must be mandatory. Building designs must have increased levels of insulation and weatherisation. Council must be able to ensure that proposed designs incorporate energy efficiency measures including passive solar elements, energy efficient lighting plans and reduced flow shower systems. Reduced water consumption measures (such as rainwater collection and storage systems connected to toilets, grey water reuse and water efficient toilets) would also offer energy savings through reduced pumping and filtration requirements.

The NSGA should become the blueprint of how all new subdivisions in New Zealand are established by being a model of good design and energy efficiency. Such a development would challenge architects, developers and consumers to move beyond the aesthetic, maximization of profit and lowest initial cost, to solutions that achieve the best possible outcome in terms of human comfort, energy efficiency, reduced wastage and lower long term cost. Such solutions will benefit home and business owners, electricity network operators, the local economy and society.

7.4.2 Energy audits – residential and business

The first step in solving a problem is to identify that it is a problem and to quantify its size. Energy audits offer a means to establish the extent of the energy wastage and the potential for energy efficiency measures to reduce overall energy consumption. Such intrusions into residences and businesses also offer opportunity to educate about energy efficiency, market potential solutions and even to install some of those solutions that require little effort such as energy efficient lighting, hot water cylinder wraps, pipe lagging and some weatherisation measures. The quantification of cost and energy saving potential of larger measures such as insulation and solar derived hot water systems would prove valuable in developing and targeting schemes to maximise the overall energy efficiency and well-being of the city.

Residential, small commercial and large business energy audits each require different approaches and should be separated accordingly. With some 55,000 residential dwellings, and 10,500 businesses, this audit process would represent a major undertaking in terms of time, cost and labour. Suitable training must be provided, for energy audit teams and solution implementers. Providing these services early, would mean that skills would be developed that could be transferable to other regions ensuring ongoing employment opportunity for participants. Such audit schemes have been successfully implemented in Portland, Oregon, USA, where a variety of subsidies and funding have made the process possible and feasible. In Waitakere City such a scheme would require a variety of businesses, institutions and government department support and funding. This would be challenging to instigate. There would be an advantage to being the first movers to secure sufficient funding. Early instigation would also lead to early derivation of flow through benefits from greater energy efficiency such as more disposable income for residents and increased health and well-being.

7.4.3 Manukau Harbour wind farm assessment

The potential of the wind resource within the Manukau Harbour environment offers the greatest immediate and economic renewable energy solution to the city. The initial pre-feasibility analysis within this report requires follow up with more detailed analysis that would include detailed wind measurement, feasibility analysis, technical analysis, ecological impact assessment, ownership and governance analysis (given location and seabed ownership dispute) and RMA assessment. Much of this is similar to a land based wind farm but would include some elements that have not been tested in a New Zealand environment.

The location of this resource close to such a large energy sink, the potential size of the usable resource and potential economic feasibility would make this project particularly appealing to a variety of business interests. The main risks once the wind measurements have been confirmed arise from seabed ownership and RMA. These risks should not be underestimated.

7.4.4 Marketing campaigns

A campaign of 'walking the talk' could be implemented whereby Waitakere City Council instigates energy efficiency measures within its own business operations, its staff dwellings and to the rental accommodation under its control. Such initiatives will lead to the people being involved and influencing their friends and family. This, in theory at least, should lead to exponential growth in awareness and knowledge of energy saving initiatives. Such a campaign by the Council leading by example would help develop the skills and techniques required for wider initiatives while using an understanding audience. Placement of marketing material around the building consent department and building consent staff discussing energy efficiency measures with clients would influence energy awareness at a crucial stage of development, and get the message to the building industry, architects and developers.

Secondly, a programme of energy audits and upgrades across the educational institutions within the city would educate the next generation about the effects of energy management and create another avenue of influence on families. Such a campaign would assist the schools in reducing one of their cost streams and allow savings made to be diverted to other educational needs. Schools currently actively promote ecology, recycling and waste reduction measures so energy efficiency would add nicely to this portfolio of conservation education. The main energy consuming activities in schools are likely to be lighting (replacing existing fluorescent tubes with more efficient ones), classroom heating (radiant heating replaced by heat pumps maybe) and to a small but growing extent computers (replace CRT screens with LCD for high use computers).

It would be appropriate that such campaigns include water saving measures (that will lead to energy conservation at the pumping stations) and sustainable development. The key will be to keep the message simple, clear and consistent.

7.5 Conclusions

Waitakere City does have the resources available to become a net energy supplier to the national grid. This report has given a view of what options are available, the levels of technical maturity and current economic status. Some potential flagship projects have been identified and described. The city council must develop a comprehensive energy plan to progress the energy opportunities available in a cohesive and coordinated manner. Much work already done by other cities to develop energy strategies, policies and projects can be incorporated into such an energy plan. As part of ICLEI including Agenda21, Waitakere City has good access to these resources.

The energy plan must include both energy efficiency and renewable energy initiatives. While renewable energy projects may have more appeal in terms of visibility, large increments of gain and compactness of implementation, it is the labour intensive, diverse and small increments of gain of energy conservation and efficiency measures that will have the greatest benefit in the short-term and have the largest spin-off benefits to the overall welfare of the community. The cumulative efforts by many people will be a significant factor in deferring and/or alleviating the requirement for additional energy generation development and transmission infrastructure upgrades. It is these wider gains to the whole community that are the key driver for the council to develop and implement such an energy plan.

APPENDICES

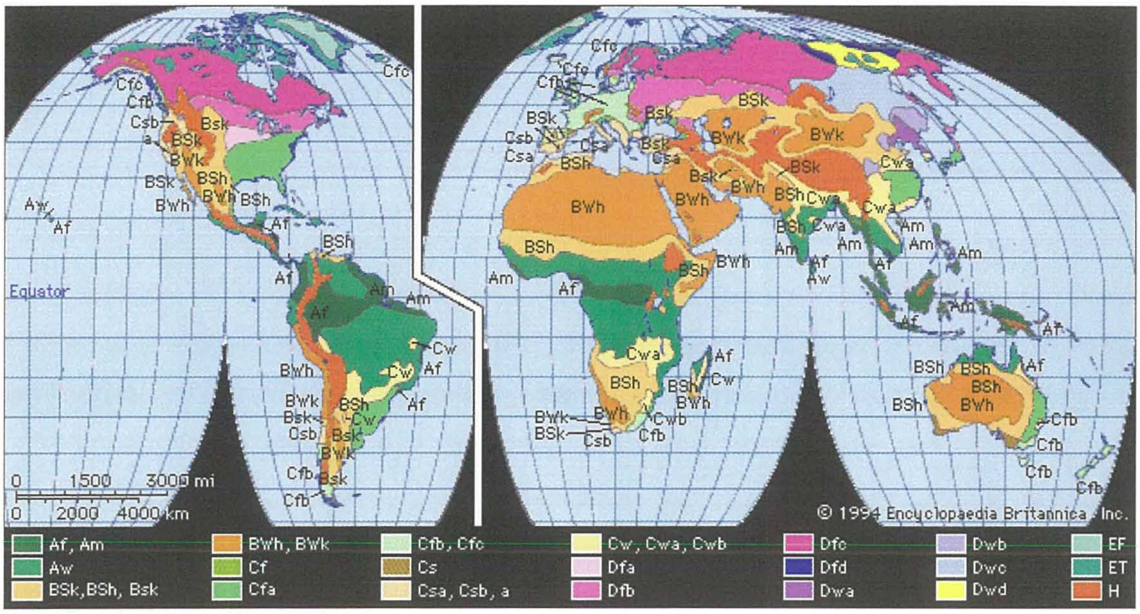
A Waitakere Climatic Resource

Data has been taken using Henderson as the location (Latitude -38.88, Longitude 174.63, Altitude above sea level 6m) and ASHRAE data for Auckland. Analysis and mapping used The Weathertool software (Marsh, 2002).

A.1 Climate classification:

Source: (Marsh, 2002)

Figure 41: Global climate classifications using Köppen System



Using the Köppen System of climate classification developed by German climatologist and amateur botanist Wladimir Köppen in 1928. Auckland is classed as Climate type Cfb where:

Major climate type - C = Mild Mid latitude Climate type – Coldest Month above 0 °C, but below 18°C, warmest month above 10 °C. This climate generally has warm humid summers with mild winters. It extends from 30 to 50 degrees of latitude mainly on the eastern and western borders of most continents.

Precipitation subtype - f - constantly moist: rainfall consistent throughout the year (for A, C, or D climates)

Temperature subtype - b - warmest month below 22 C (for C or D climates)

Giving the overall description of this climate type of:
Cfb - Marine climates that are found on the western coast of most continents. They have a humid climate with short dry summer. Heavy precipitation occurs during the mild winters because of continuous presence of mid-latitude cyclones.

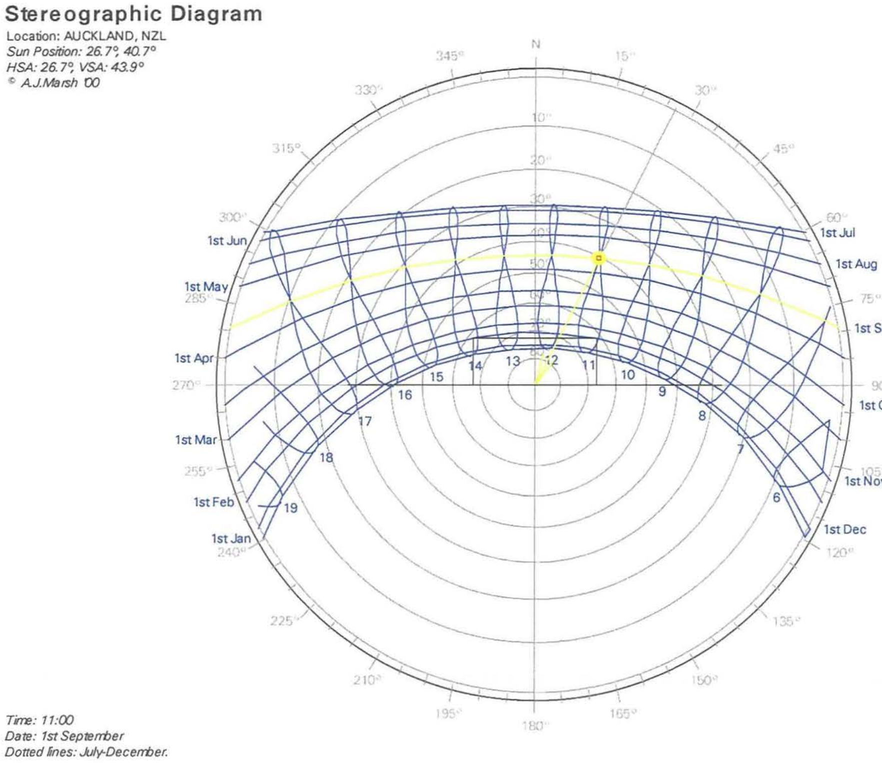
A.2 Solar resource

The Solar resource is first defined by the position of the sun relative to the earth, then by its intensity and finally by the efficiency of the conversion device to convert the available energy into a usable form.

A.2.1 The solar position

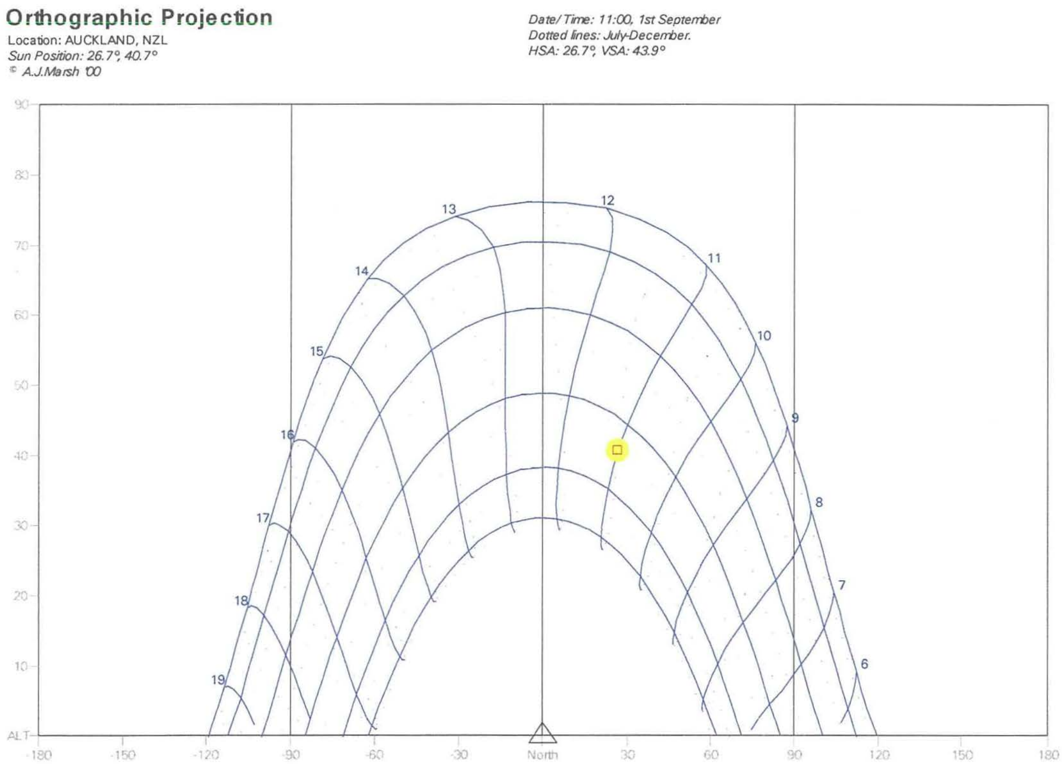
In the stereographic view, each concentric circle represents an increase in the suns altitude by 10 degrees (horizontal at outer edge, increasing to vertical (90 degrees) at centre of diagram. The degree markings around the outside of the diagram represent the position of the sun in the horizontal plane relative to the observer. The top point in the diagram represents solar north (Approximately 19 degrees west of magnetic north in Auckland). Each arc in the diagram represents the horizontal and vertical position of the sun for a given day (denoted on the side of each line). Notably in the summer the suns rises and set from/to positions further south and reach a point higher in the sky during the day. In winter the sun rises and set at positions further north and reaches a much lower position in the sky throughout the day. The vertical swirling lines represent the hour of the day in normal time (excluding daylight saving) Showing the sun rising from the east and setting in the west. The yellow line and circle denotes the trajectory and position of the sun for 1 September and at 11am.

Figure 42: Solar Position - stereographic diagram



The same information can also be represented in and Orthographic projection which shows the same trajectories in a different format.

Figure 43: Solar position - orthographic projection



This information may be used in assessing the level of shading that will occur at a site and how that shading will impact the capture of the solar resource. The use of a Solar Pathfinder tool allows a site specific study to be made and to calculate the total percentage of available radiation that will be incident upon a collection surface.

It is recommended that a solar device should not be shaded for the key collection times of between 9 am and 3 pm. Shading in times outside this zone will only have small impact on the total collection potential of a device.

Recommendation:
The solar zone on the roof space should be protected by a rule that will allow the removal of vegetation which impedes on the solar collectors in the key collection times. For Waitakere this would mean an exclusion zone at approx 17 degrees vertical above the roofline at angles 45 degrees horizontal either side of Solar North.

A.2.2 Solar radiation

The energy from the sun travels to earth with relatively little interference (extraterrestrial radiation) until it reaches the earth's atmosphere where this extraterrestrial radiation is reflected and refracted by clouds and particles within the atmosphere. The resulting radiation which is measured at a site is called global radiation. This global radiation has three components. Firstly, the direct radiation that has arrived directly from the sun. Secondly the diffuse radiation which has been refracted through the earth's atmosphere Cloud cover, water vapour, particles, and greenhouse gases) and thirdly the albedo radiation which is radiation reflected back of the earths surface.
The interaction of these three components on a particular surface at a defined slope and azimuth (horizontal angle relative to solar North) will determine the amount of radiation incident upon that surface.

Figure 44: Average global radiation on a horizontal surface.

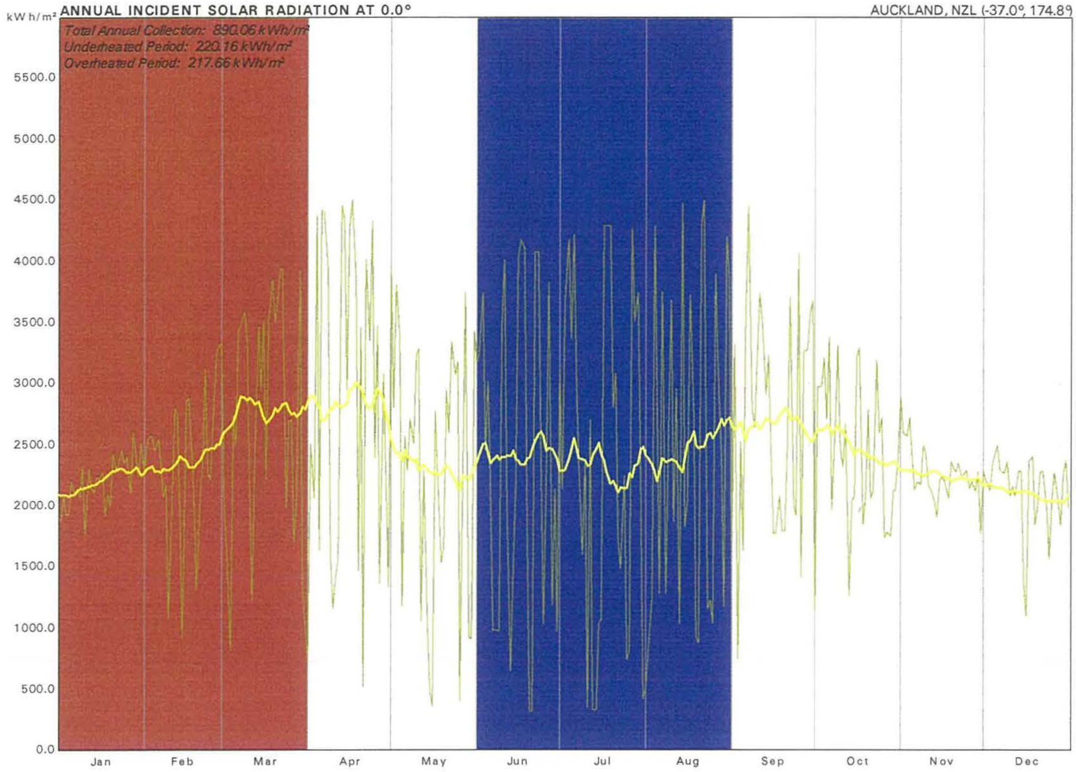
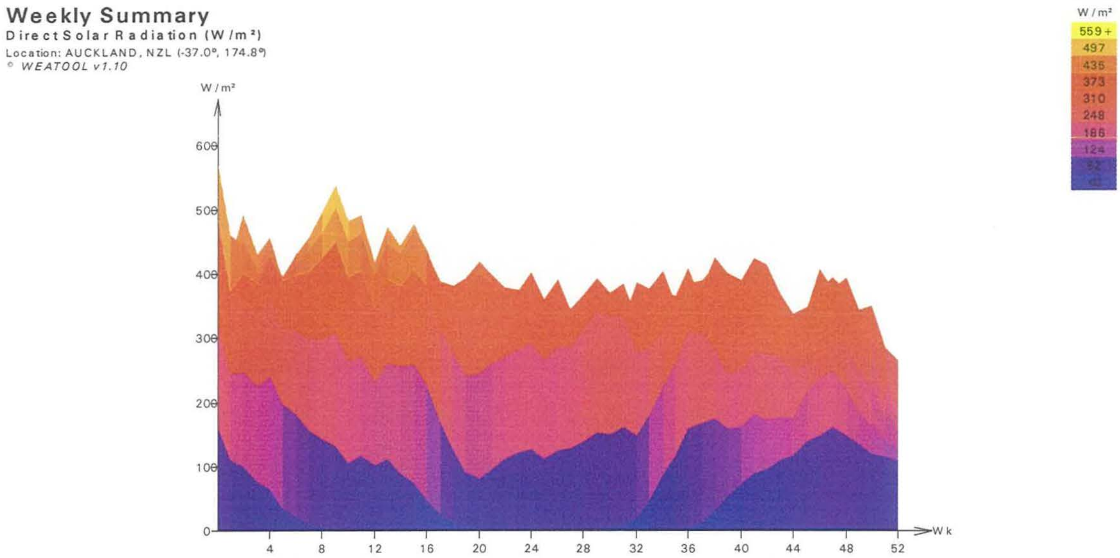


Figure 45: Direct radiation - averaged trend



Note: Each line represents the hour of the day (Morning to solar noon only visible). Again, this profile can also be represented on the stereographic diagram.

Figure 46: Direct radiation - stereographic diagram - Jan to Jun

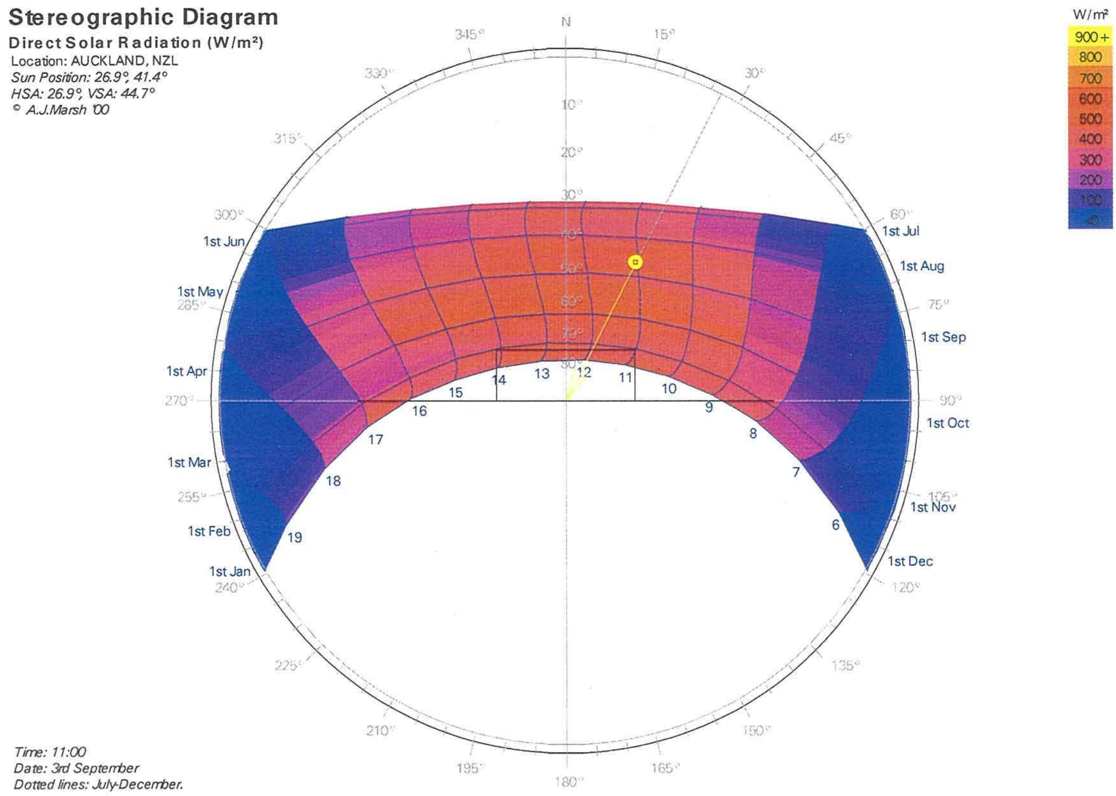


Figure 47: Direct radiation - stereographic diagram - Jul to Dec

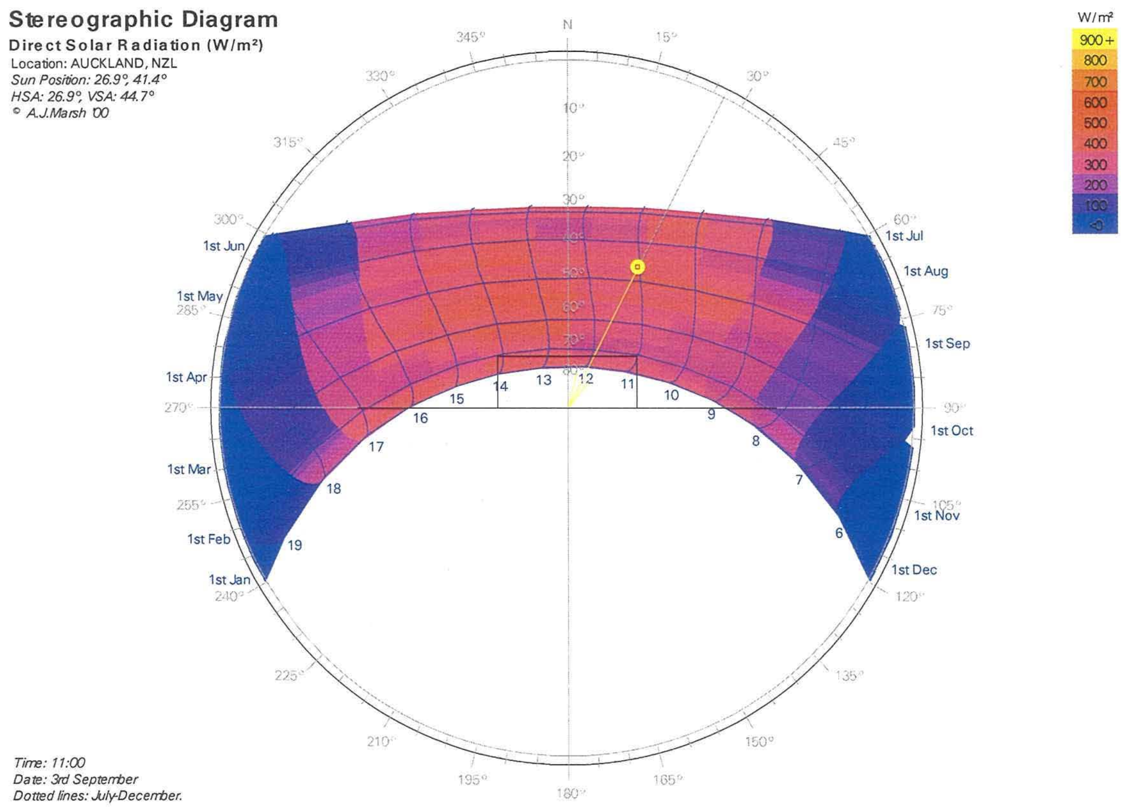
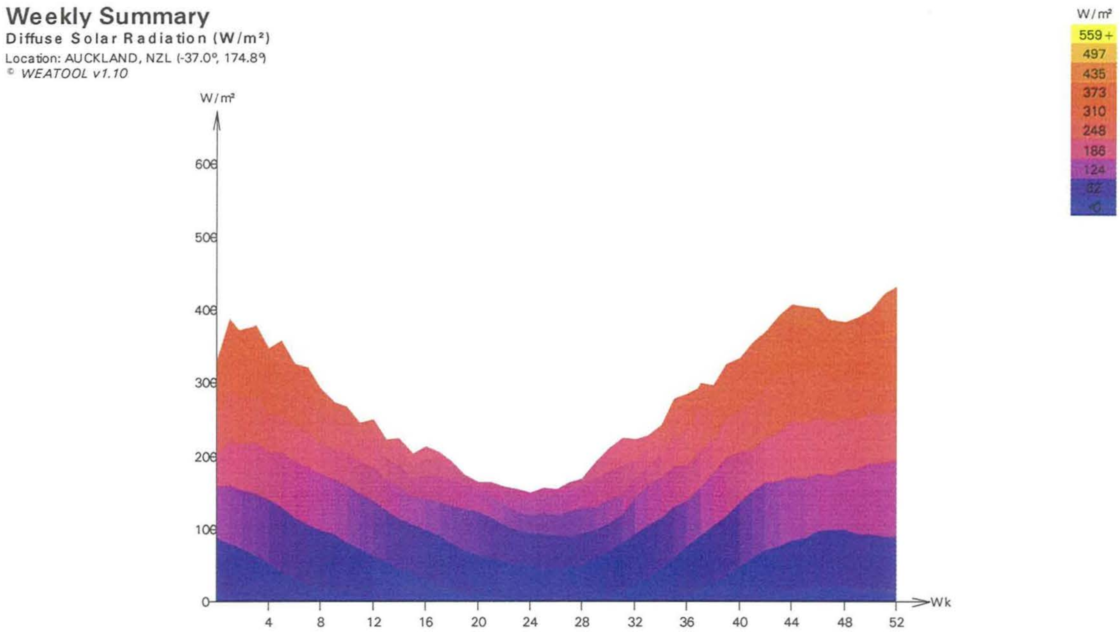


Figure 48: Diffuse radiation - averaged trend



Note: Each line represents the hour of the day. (Morning to Solar Noon only visible)

Figure 49: Diffuse radiation - stereographic diagram - Jan to Jun

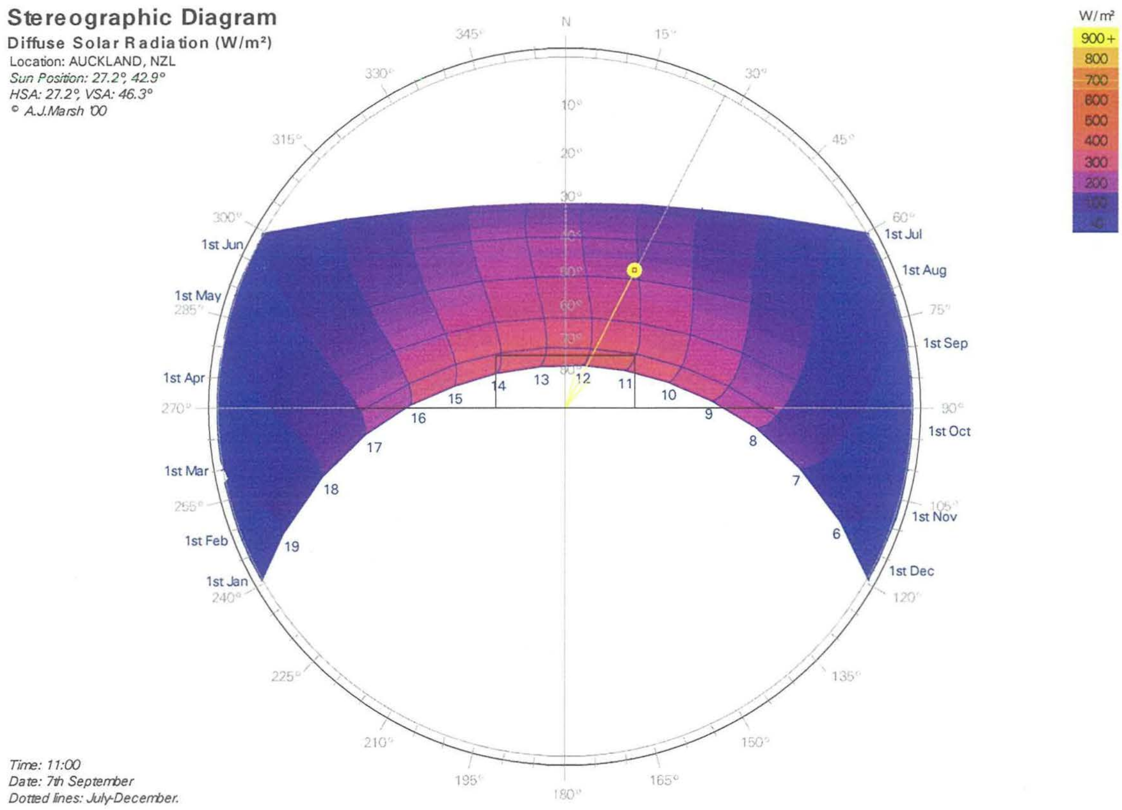
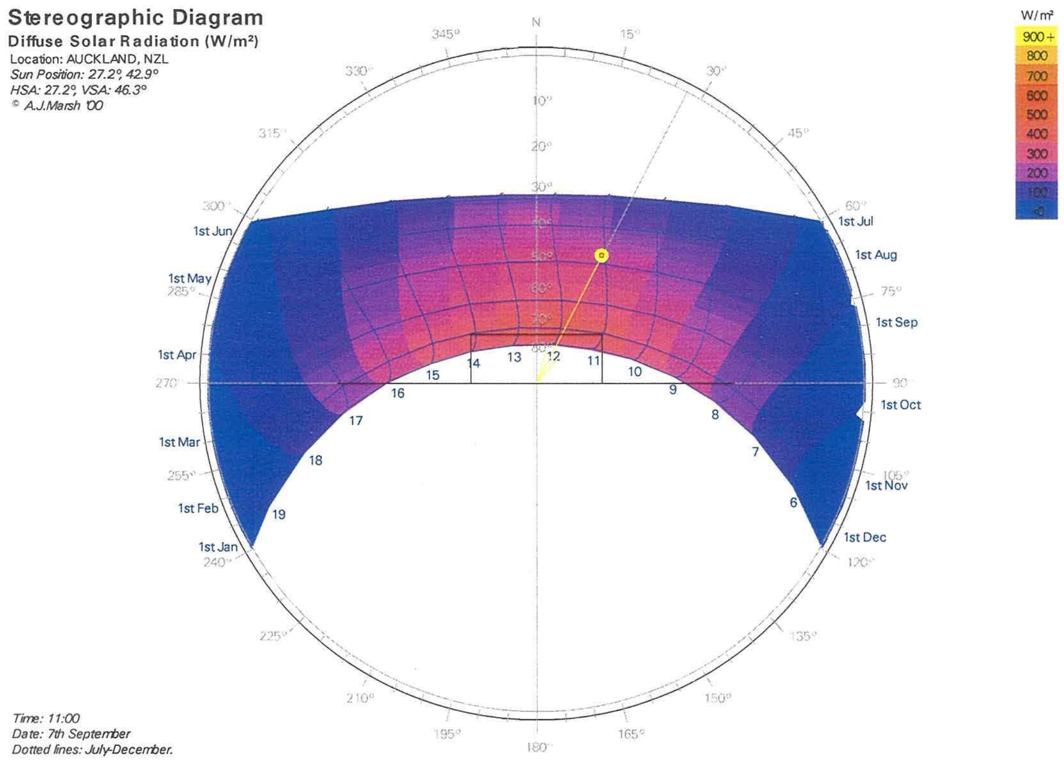
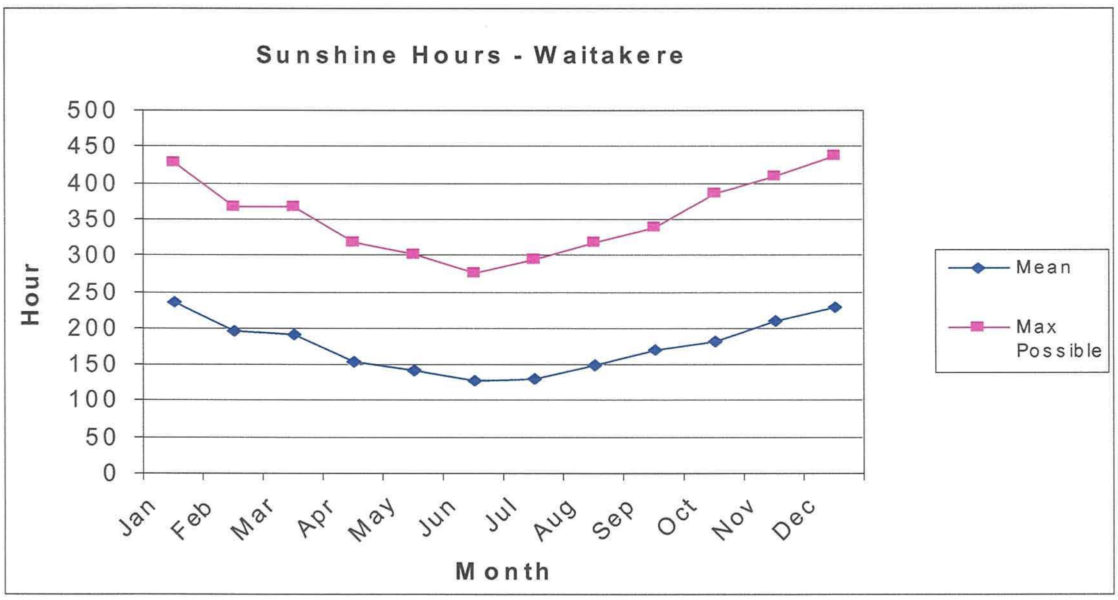


Figure 50: Diffuse radiation - stereographic diagram - Jul to Dec.



A.2.3 Sunshine hours

Figure 51: Sunshine hours



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year
Mean	235	194	191	152	141	126	129	149	169	181	208	227	2102
Max Possible	427	366	367	317	300	274	293	317	338	385	408	437	4229
Percent of possible	55%	53%	52%	48%	47%	46%	44%	47%	50%	47%	51%	52%	50%

A.3 Wind resource

Figure 52: Wind speed – annual range – averaged trend

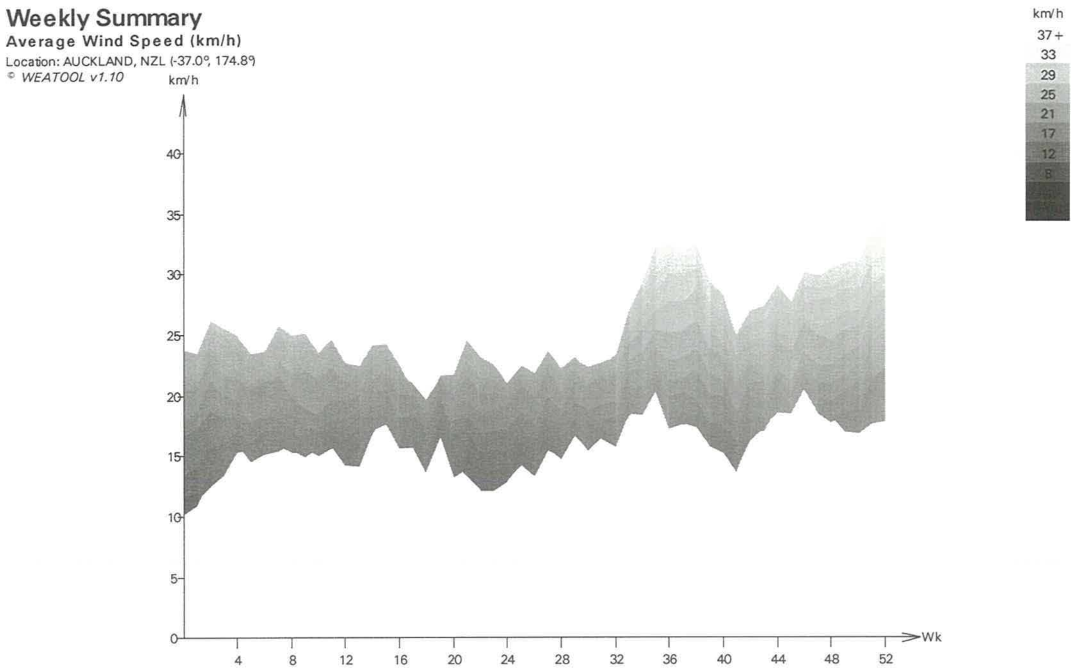


Figure 53: Wind rose - annual

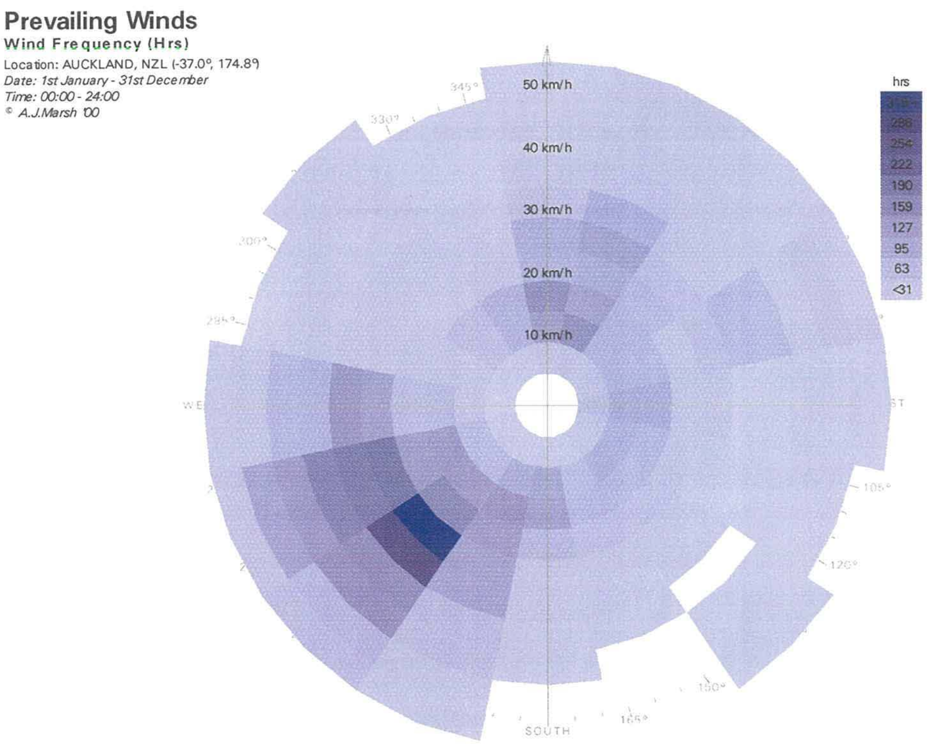
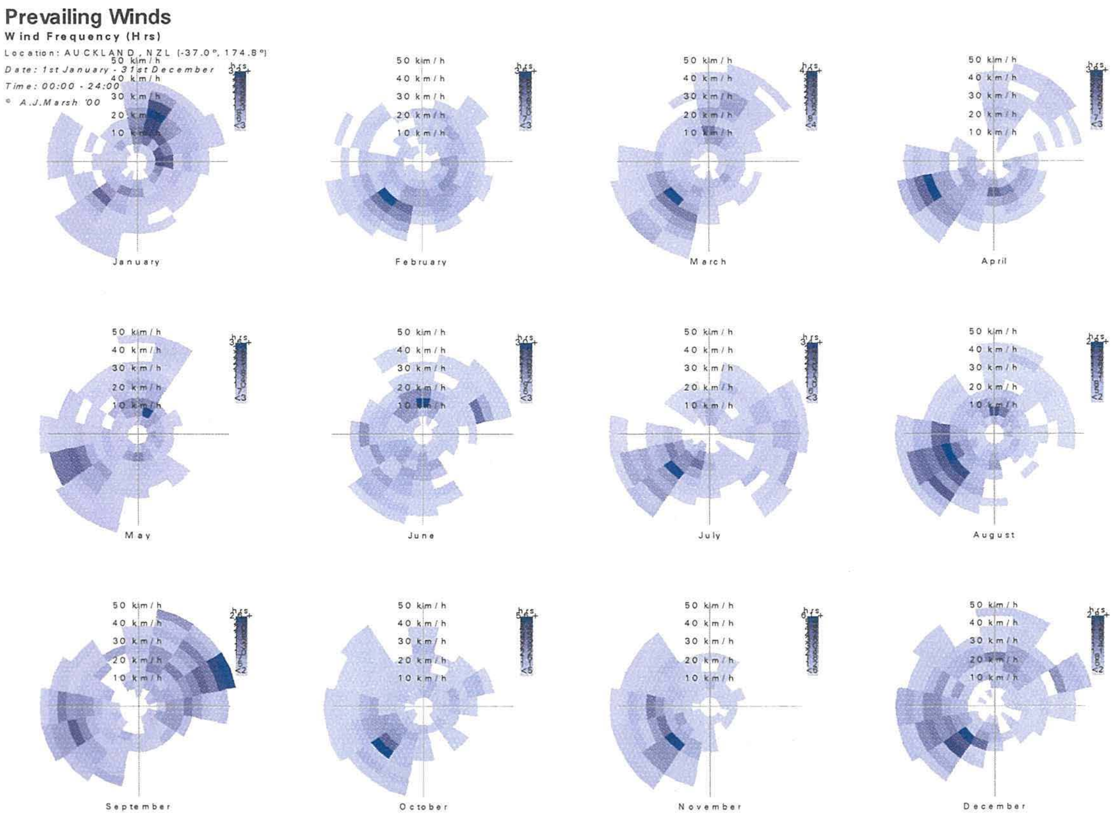
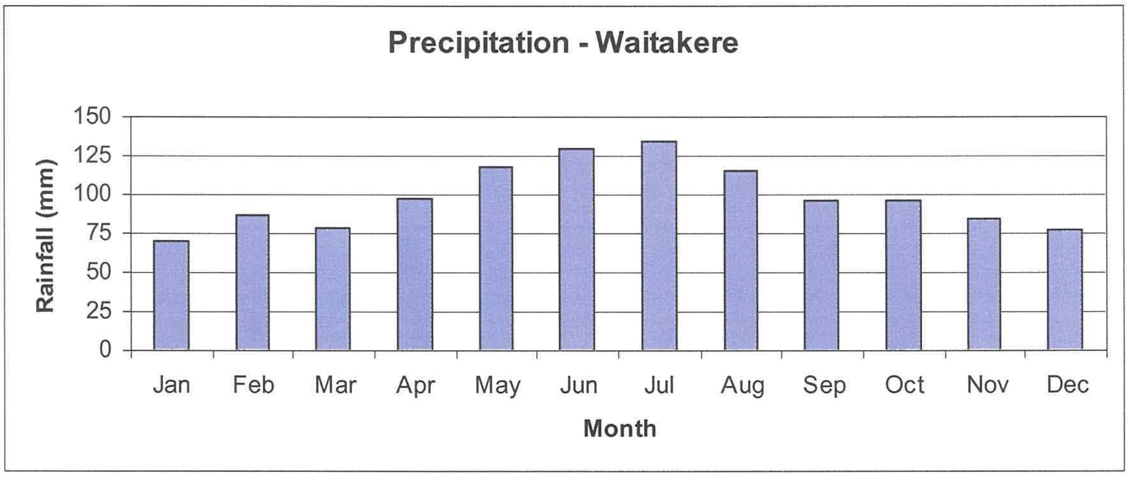


Figure 54: Wind rose - monthly



A.4 Precipitation.

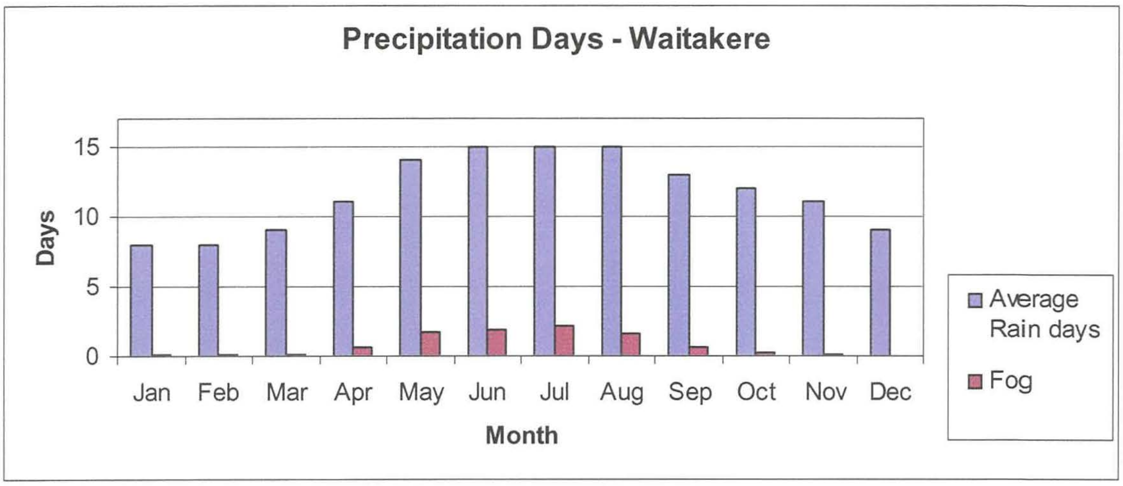
Figure 55: Rainfall - monthly



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation (mm)	70	87	79	98	118	130	135	115	96	96	84	77	1185

Precipitation days:

Figure 56: Precipitation days

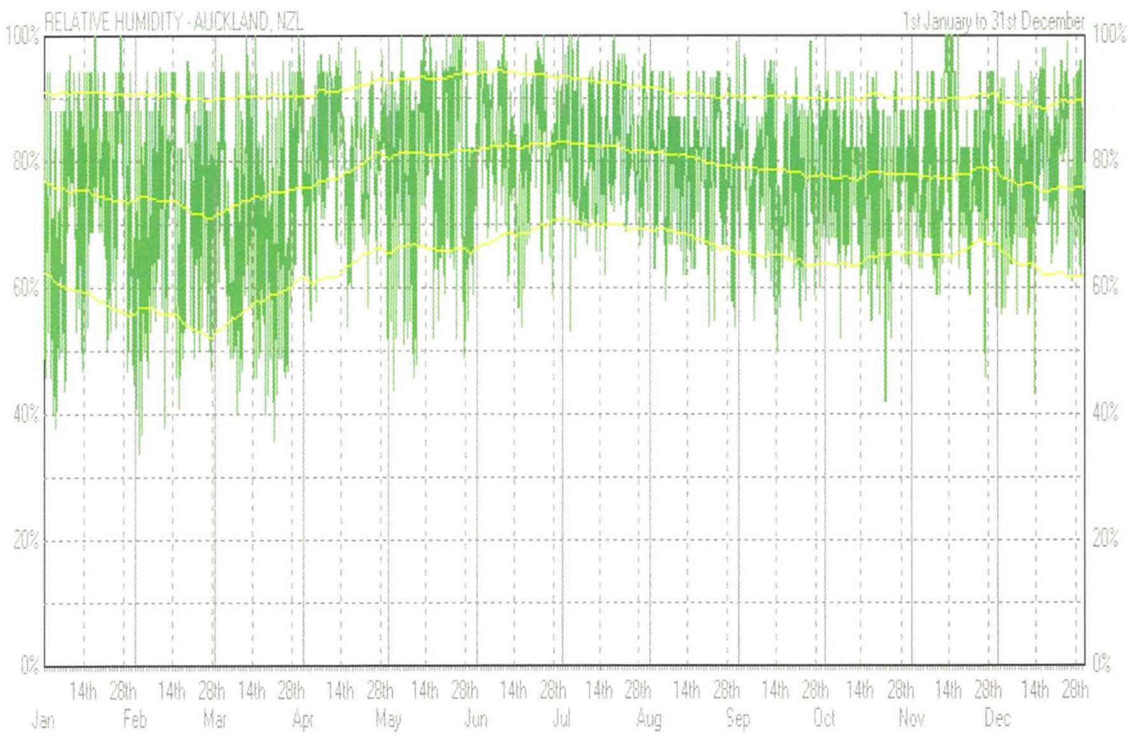


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Rain days	8	8	9	11	14	15	15	15	13	12	11	9	140
Fog	0.1	0.2	0.2	0.7	1.8	1.9	2.2	1.6	0.7	0.3	0.1	0	9.8

A.5 Other climate measurements

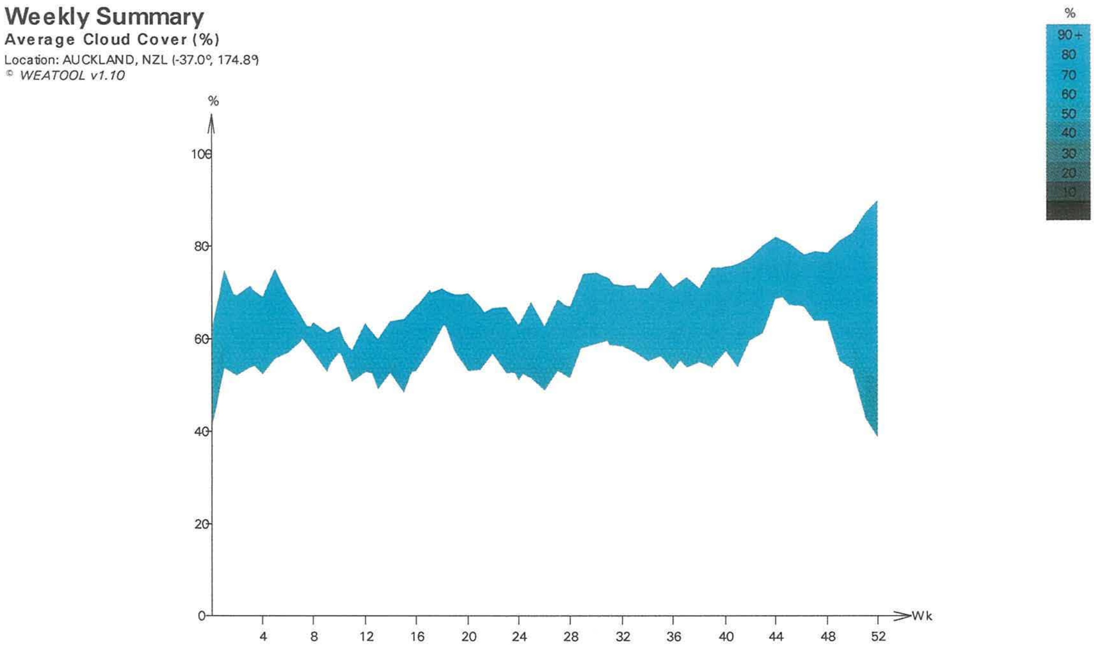
A.5.1 Relative humidity

Figure 57: Relative humidity - with min, max and average trend lines



A.5.2 Cloud cover

Figure 58: Cloud cover (average %)



A.5.3 Temperature

Figure 59: Dry bulb temperature - with min, max, average trend lines

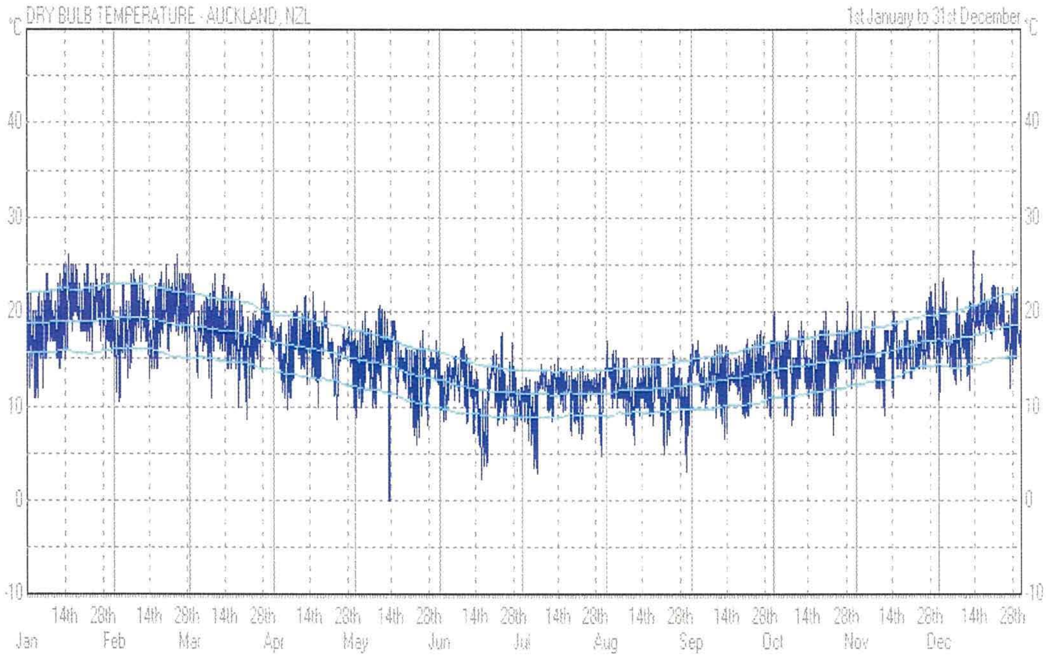
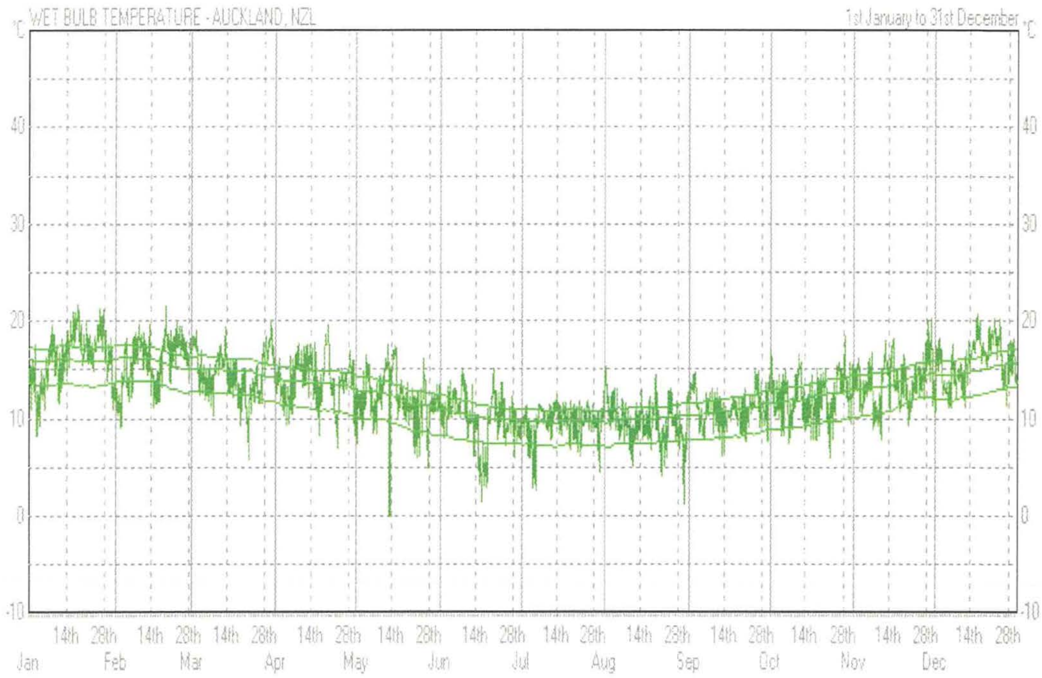
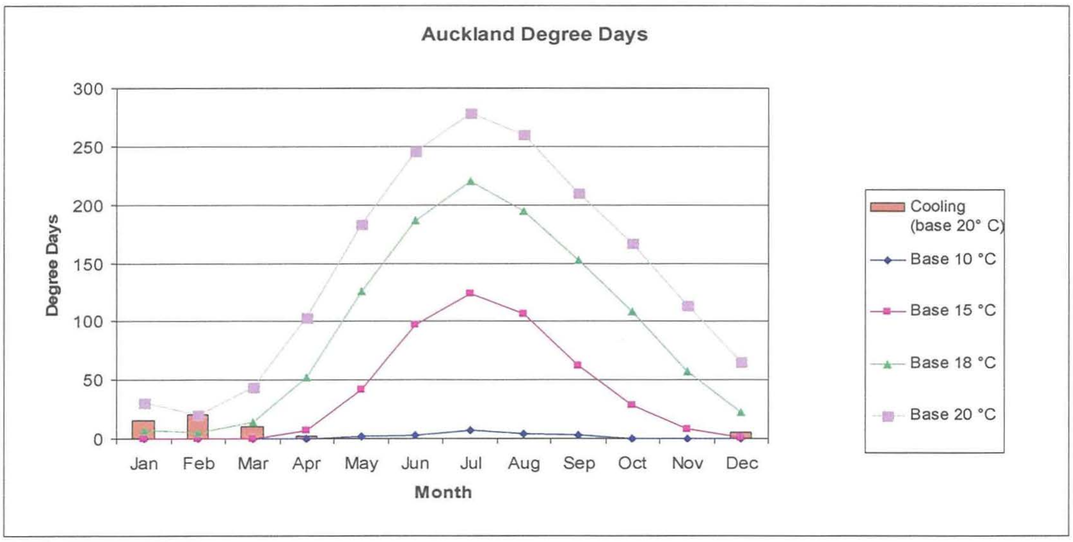


Figure 60: Wet bulb temperature - with min, max, and average trend lines



A.5.4 Degree days

Figure 61: Degree days (multiple bases)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Heating													
Base 10 °C					2	3	7	4	3				19
Base 15 °C				7	42	97	124	106	62	29	8	1	476
Base 18 °C	7	5	14	52	126	186	220	195	153	109	57	23	1147
Base 20 °C	31	20	44	103	183	246	279	260	210	167	114	66	1723
Cooling (base 20 °C)	15	20	10	2								5	52

Definition of degree days

Source: (Vesma)

When you use fuel or electricity for space heating, demand will tend to vary according to how cold the weather is. When the outside air is above a certain temperature your building won't need heating. This is what we will call the 'base temperature'. In the UK it's common to assume a value of 15.5 Celsius, but this is just a historical convention. If the average outside air temperature on a given day is below this base temperature, you will need heat; and your heat requirement that day will be in proportion to the temperature deficit in degrees. Add up the daily temperature deficits over a month and you get cumulative *degree-days* (degrees multiplied by days). These cumulative degree days are, by definition, proportional to cumulative heat requirements over the same period. Thus a month in which 360 degree-days are clocked up is 'twice as cold' as one with a total of 180 degree-days.

Your space-heating demand is proportional to the regional degree-day value for the month in question.

The daily result for **heating** degree days, D_h, is selected from the following formulae:

Condition	Formula used
$T_{max}<T_{base}$	$D_h=T_{base}-(T_{max}+T_{min})/2$
$T_{max}>=T_{base}$	$D_h=(T_{base}-T_{min})/2-(T_{max}-T_{base})/4$
$(T_{max}+T_{min})/2>T_{base}$	$D_h=(T_{base}-T_{min})/4$
$T_{min}>T_{base}$	$D_h=0$

The daily result for **cooling** degree days, D_c, is selected from the following formulae:

Condition	Formula used
$T_{min}>T_{base}$	$D_c=(T_{max}+T_{min})/2-T_{base}$
$T_{min}<=T_{base}$	$D_c=(T_{max}-T_{base})/2-(T_{base}-T_{min})/4$
$(T_{max}+T_{min})/2<T_{base}$	$D_c=(T_{max}-T_{base})/4$
$T_{max}<T_{base}$	$D_c=0$

B Energy Efficiency Measures

Source:(Armstrong & Sustainable Energy Authority of Victoria, 2003)

B.1 Residential

Table 5.1 Residential energy efficiency improvement potential (EEIP) by application and unit costs

Sector	Source	Energy Use 2000 (PJ/yr)	EEIP		EEIP $2001 (installation unit cost)		Notes	References
			Low	High	Low	High		
Building Shell	Existing dwellings pre 2003	N/A	20%	50%	$1500	$5000	Low: ceiling insulation and draft sealing High: Low + some wall and floor insulation, window treatments shading.	AES RE 1994, SEAV First Rate SEAV 2002e
	New dwellings post 2003	N/A	30%	50%	$2100	$4000	BAU assumes – 5 Star for Victoria, 3.5 Star for rest of Australia. Low: increase ratings by 1.5 stars. High: energy ratings beyond 6.5 for Victoria and beyond 5 elsewhere in Australia.	ABCB 2002, SEAV 2002e
Space Conditioning Equipment	Gas heating (natural gas & LPG)	73.3	20%	60%	0	$500	Low: condensing appliances High: Low + improved duct insulation, improved burners, heat exchange and controls	SEAV 2002a, CAE 1996, EA 1998
	Electric heating	7.1	25%	70%	$200	$1000	Low: heat pumps 3.5 compared to 1.5 star High: heat pumps, 5 star replacing most resistive heaters	SEAV 2002c, SEAV 2002f
	Wood heating	61.4	30%	70%	$200	$1500	Low: high efficiency heaters replacing low efficiency units High: Low + high efficiency units replacing open fires	CAE 1996, SEAV 2002i
	Other (Coal Petroleum Products	2.9	-	-	-	-	Not analysed	
	Electric cooling	5.8	10%	35%	0	$300	Low: 4 star compared with 1-2 star High: 6 star compared with 1-2 star	AGO 2000 SEAV 2002c, CAE 1996
	Total (in shell)	170.4	39%	79%	-	-	Weighted average	
Water Heating	Gas (Natural gas & LPG)	46.9	20%	35%	$100	$300	Low: 5 Star compared with 2 star High: Higher efficiency, insulation, electronic ignition, continuous flow	SEAV 2002c SEAV 2002b, EA 1998

Table 5.1 Residential energy efficiency improvement potential (EEIP) by application and unit costs								
Sector	Source	Energy Use 2000 (PJ/yr)	EEIP		EEIP $2001 (installation unit cost)		Notes	References
			Low	High	Low	High		
	Electric	48.0	20%	80%	$50	$1500	Low: insulation and cylinder design High: heat pumps	EA 1998
	Solar hybrid (replacement gas/electricity)	(-2.4)	–	75%	–	$2000	Low: in absence of subsidies not cost effective compared with electric and gas system EE High: 50 per cent solar by 2010	ERDC 1994
		Reduction in purchased energy use and cost						
	Hot Water Management	N/A	30%	40%	$50	$200	Low: Low flow showers. High: Low + insulation pipe sizing and layout	EA 1998
	Total	**92.5**	**36%**	**81%**	-	-	Weighted average	
Lighting	Electric	16.7	40%	75%	$50	$200	Low: Selective use of fluorescent lighting High: Efficient lighting and distribution systems	GAE 1996, EA 1998
Cooking	Electric	8.4	20%	40%	$50	$100	Low: increased microwave use. High: Low + improved resistive cooking appliances.	AES RB 1994
	Gas (Natural gas and LPG)	6.8	10%	30%	$50	$100	Low: insulation/sealing High: Low + fan forced ovens.	AES RB 1994, AGO 2002a
	Total	**15.2**	**16%**	**36%**	-	-	Weighted average	
Appliances	Refrigeration/ freezing (new)	28.7	30%	75%	$50	$200	Low: new to meet 2001 US MEPS High: Fans, door seals, improved compressors, insulation and power factors	EA 1995, Geller 1992, GAE 1996
	Dishwashing	1.8	10%	20%	$50	$125	Low: Drive systems controls.	AES RB 1994
	Clothes Washing	1.9	20%	40%	$125	$250	High: Low + hot water economy.	AES RB 1994
	Clothes Drying	1.8	15%	60%	$50	$350	Low: clothes washer drying efficiency High: heat pump	
	Home entertainment, Computers*	17	40%	75%	–	–	Penetration increasing. Very limited data. Significant EE potential	AGO 2002b
	Other (misc small appliances)*	33.9	10%	45%	–	–	Penetration increasing – mainly electric some gas use. Limited data.	SEAV 2003 estimates.

Table 5.1 Residential energy efficiency improvement potential (EEIP) by application and unit costs								
Sector	Source	Energy Use 2000 (PJ/yr)	EEIP		EEIP $2001 (installation unit cost)		Notes	References
			Low	High	Low	High		
TOTAL		391.1	34%	73%	-	-	Weighted average of all EEIs	

* Not included in inputs for economic modelling

B.2 Commercial

Table 5.3 Commercial energy efficiency improvement potential (EEIP) by application									
Sector	Sub-sector	Energy Use (1998-99 PJs) Factored up to 2000/2001 PJs				EEIP %		Notes	References
		Total	Electricity	Gas	Other (includes petroleum & biomass)	Low	High		
Space Conditioning (HVAC)	Space Heating	64.7		46.4	12.6	20%	50%	High & Low: Efficient condensing heaters and building envelope improvements - insulation, solar gain, building mass, window treatment	CAE 1996, AEEIRB 1994, PCA 2001, ABARE 2002c, GBP 2002
			5.7			20%	60%	Low: 60L building: 10% - hybrid passive and mechanical ventilation heating and cooling, widened internal temperature control band, heavyweight structure, low emissivity double glazing High: includes building envelope improvements, insulation, solar gain, building mass, window treatment	GPB 2002, CAE 1996, AI 2002, PCA 2001, ABARE 2002b
	Air Handling	30.6	30.6			10%	70%	Low: Sacramento Municipal Utility Customer Service Centre: 4.6% - underfloor ventilation (Shepard 1995) High: City Hall, Phoenix: 70% - eliminated oversized fans and installed variable speed drives, improved efficiencies in motors and driven equipment, improved duct design and controls (Shepard 1995)	AEEIRB 1994, Kinetic 1997, AI 2002, ABARE 2002b, Shepard 1995
	Cooling	36.2	36.2			35%	55%	Low & High: Building envelope, shading, oversized water cooled condensers, EE fans and duct systems, economisers, absorption cooling, evaporative cooling, desiccant drying, passive cooling, reduce lighting loads, office equipment, variable speed drives, optimise internal loads and solar gain Low: American Family Insurance HQ: 4.5% - Water side economiser; Sacramento Municipal Utility Customer Service Centre: 3.8% - underfloor ventilation (Shepard 1995)	CAE 1996, AEEIRB 1994, Kinetic 1997, ABARE 2002c, GBP 2002, Shepard 1995

Table 5.3 Commercial energy efficiency improvement potential (EEIP) by application

Sector	Sub-sector	Energy Use (1998-99 PJs) Factored up to 2000/2001 PJs				EEIP %		Notes	References
		Total	Electricity	Gas	Other(includes petroleum& biomass)	Low	High		
	Cooling (cont.)							High: 60% building, 80% - hybrid passive and mechanical ventilation heating and cooling, widened internal temperature control band, optimised natural ventilation, heavyweight structure and night purging with cool air, solar shading and low emissivity double glazing, effective management of lighting and office equipment energy demands. (GPB 2002). Tarry and Pathway Social Housing 88% - argon filled low-e glass, heat recovery ventilators, envelope insulation, ceiling mounted hydronic convectors, absorption chiller, cogeneration, building mass, temperature excursions to 80 degrees F. (Shepard 1995)	
	Pumping	5.5	5.5			20%	40%	Low & High: includes building envelope improvements	DISR 2001, ABARE 2002b
	Total HVAC	137	78	46.4	12.6	29%	90%	Low: Florida Museum 11% - heat pipe exchanger installed in one air handler. (Shepard 1995) High: (CAE 1996) - gain avoidance (internal and external), more efficient mechanical cooling, supplemental alternative cooling and improved controls. Widened temp control band, night purging with cool air. EEI measures can also significantly reduce capital expenditure on equipment through, for example, lower heating and heating requirements, particularly in new buildings.	GPB 2002, Shepard 1995, CAE 1996, ABARE 2002b
Lighting		37.4				21%	90%	Low: Building glazing, fluorescent technologies, HID lamps, halogen lamps, luminaire diffusers/controllers, luminaire reflectors, electronic ballasts, compact fluorescents, installation design, control systems	CAE 1996, RMI 1994, GBP 2002, Audin 1994, AES/RS 1994, PCA 2001, ABARE 2002b

Table 5.3 Commercial energy efficiency improvement potential (EEIP) by application

Sector	Sub-sector	Energy Use (1998-99 PJs) Factored up to 2000/2001 PJs				EEIP %		Notes	References
		Total	Electricity	Gas	Other(includes petroleum& biomass)	Low	High		
	Cooling (cont.)							High: 60% building, 80% - hybrid passive and mechanical ventilation heating and cooling, widened internal temperature control band, optimised natural ventilation, heavyweight structure and night purging with cool air, solar shading and low emissivity double glazing, effective management of lighting and office equipment energy demands. (GPB 2002). Tarry and Pathway Social Housing 88% - argon filled low-e glass, heat recovery ventilators, envelope insulation, ceiling mounted hydronic convectors, absorption chiller, cogeneration, building mass, temperature excursions to 80 degrees F. (Shepard 1995)	
	Pumping	5.5	5.5			20%	40%	Low & High: includes building envelope improvements	DISR 2001, ABARE 2002b
	Total HVAC	137	78	46.4	12.6	29%	90%	Low: Florida Museum 11% - heat pipe exchanger installed in one air handler. (Shepard 1995) High: (CAE 1996) - gain avoidance (internal and external), more efficient mechanical cooling, supplemental alternative cooling and improved controls. Widened temp control band, night purging with cool air. EEI measures can also significantly reduce capital expenditure on equipment through, for example, lower heating and heating requirements, particularly in new buildings.	GPB 2002, Shepard 1995, CAE 1996, ABARE 2002b
Lighting		37.4				21%	90%	Low: Building glazing, fluorescent technologies, HID lamps, halogen lamps, luminaire diffusers/controllers, luminaire reflectors, electronic ballasts, compact fluorescents, installation design, control systems	CAE 1996, RMI 1994, GBP 2002, Audin 1994, AES/RS 1994, PCA 2001, ABARE 2002b

Table 5.3 Commercial energy efficiency improvement potential (EEIP) by application									
Sector	Sub-sector	Energy Use (1998-99 PJs) Factored up to 2000-2001 PJs				EEIP (%)		Notes	References
		Total	Electricity	Gas	Other (includes petroleum & biomass)	Low	High		
Lighting (cont.)								optimised natural lighting, daylighting, maintenance, metal halide & compact [illegible] – EEI also gives reductions in cooling load. High: 80% cut [illegible] 90% with [illegible] natural lighting, effective management of lighting, high efficiency artificial lighting GBP(2002); Boeing plants 90% – metal halide lamps RMI(1994)	
Water Heating		9.6	4.5	3.1	2.0	35%	65%	Low: Water flow and pressure management, improved combustion, insulation (tanks & pipes). High: water pre-heat (heat reclaim), heat pumps, solar	AES RB 1994, CAE 1996, ABARE 2002b
Cooking		2.8	0.8	2.0		20%	40%	Low: Higher efficiency equipment. High: Microwave substitution	AES RB 1994, ABARE 2002b
Refrigeration		17.6	17.6			25%	50%	Low: Insulation, improved sealing, covers, controls. High: advanced systems, high efficiency motors and compressor systems, maintenance	AES RB 1994, ABARE 2002b
Office Equipment		7.6	7.6			30%	60%	Low: Reduction in standby losses, flat screens. High: PC technologies, Energy Star program, energy efficient processors, avoiding computer room air conditioning.	AES RB 1994, RCEP 1998, ABARE 2002b
Elevators		1.6	1.6			10%	25%	Low & High: improved drive systems	AES RB 1994, RCA 2001, ABARE 2002b
Other		4.2	0.6	3.4	0.5	20%	40%		AES RB 1994
Overall		218.1	140.1	52	14.6	27%	70%	Weighted average	GBP 2002, RCEP 1993, AGO 1999, CAE 1996, ABARE 2002b

B.3 Industrial

Table 5.6 Industrial energy efficiency improvement potential estimates by sub-sector								
Division	Sub-division		Energy Use 2000-01 (PJ) (ABARE 2002c)	Energy Efficiency Improvement Potential		Notes*		References
				Low	High	Low	High*	
A Agriculture	01-04	Agriculture (non-motor fuel)	11.49	20%	50%	High Efficiency motors, Variable Speed Drives, PLC controls, improved hot water and cooling systems.	High efficiency motors, PLC controls, further improvements in heating and cooling systems	DITR 2003a, AGMEB 2000, AGO 2000a, SEAV/EPA 2002
B Mining	11-15	Mining (non-motor fuel)	199.86	20%	50%	High Efficiency motors, Variable Speed Drives, PLC controls.	Further improvement through High Efficiency Motors, PLC controls	DITR 2003a, AGMEB 2000, AGO 2000d, SEAV/EPA 2002
C Manufacturing	21-29	Total Manufacturing	1191.1	23%	46%	Potential is weighted average of potentials for sub-divisions.		
	21	Food, Beverage and Tobacco Manufacturing	165.5	35%	55%	Boiler controls, upgrade steam system, replace steam with hot water, upgrading of combust cogeneration systems, insulation, High Efficiency motors, Variable Speed Drives, PLC controls, compressed air improvements	Boiler controls, economisers, further upgrading and greater application of cogeneration systems, High Efficiency Motors, PLC controls, compressed air improvements, low grade heat recovery	SFOV 1999, SEDV 1993, SEAV 2002h, WO 1990, SEAV 2002g, DITR 2003a
	22	Textile, Clothing, Footwear and Leather Manufacturing	15.6	25%	45%	Boiler controls, upgrade steam system, improve controls on driers and high grade heat recovery from driers, High Efficiency Motors, Variable Speed Drives, PLC controls, compressed air improvements	Boiler controls, economisers, improve controls on driers and low grade heat recovery from driers, High Efficiency Motors, PLC controls.	SEAV 2002n

Table 5.6 Industrial energy efficiency improvement potential estimates by sub-sector								
Division	Sub-division		Energy Use 2000-01 (PJ) (ABARE 2002c)	Energy Efficiency Improvement Potential		Notes[1]		References
				Low	High	Low	High[1]	
	23-24	Wood, Paper and Printing	75.4	20%	45%	Boiler controls, economisers, upgrade steam system, replace steam with hot water, improvement in cogeneration systems, High Efficiency Motors, Variable Speed Drives, PLC controls, compressed air improvements	Boiler controls, economisers, improve controls on driers and low grade heat recovery from driers, further improvement in cogeneration systems, High Efficiency Motors, PLC controls	SEAV 2002h, GFOV 1989, SECV 1993, DITR 2003b, AI 2002
	252-9[1]	Petroleum, Coal, Chemicals	373.0	25%	45%	Boiler controls, economisers, upgrade steam system, replace steam with hot water, High Efficiency Motors, Variable Speed Drives, PLC controls	Boiler controls, economisers, improve controls on driers and low grade heat recovery from driers, High Efficiency Motors, PLC controls,	WC 1993, SEAV 2002h, GFOV 1989, SECV 1993, TMES 1995, SEDA 2001
	26	Non-Metallic Mineral Product Manufacturing	81.8	30%	50%	Improved process heat production and management	More extensive and deeper application of low improvements, higher efficiency processes.	AESIRB 1994, ABARE 2002a, SECV 1993, EA 1998

1. ANZSIC 25 sub-sector also includes petroleum refining (251) which was excluded from the analysis; the other ANZSIC 25 sub-sectors include over 100 PJ of energy used in feedstock (non-energy) uses. This use was included in the analysis but probably should have been omitted as although there are potential process improvements to reduce feedstock use for a given output, most of the improvement is not strictly energy efficiency improvement.

Table 5.6 Industrial energy efficiency improvement potential by sector								
Division	Sub-division		Energy Use 2000-01 (PJ) (ABARE 2002c)	Energy Efficiency Improvement Potential (%)		Notes[1]		References
				Low	High	Low	High[1]	
		263 Cement, Lime, Plaster and Concrete	-	30%	50%	Improvements to heat production and management and some introduction of higher efficiency processes	Further improvements to heat production and management, higher efficiency processes, higher efficiency drive systems, cement blending	
		264 Non-metallic Mineral Products n.e.c.	-	-	-			
	27	Metal Product Manufacturing	545.4	20%	42%			
		271 Iron and steel (excluding coke oven)	151.3	20%	55%	More efficient heat production and management (process controls, etc.), higher efficiency electric drive systems	New high efficiency processes, further application of low EEIs.	GFOV 1989, SECV 1993, AESIRB 1994, ABARE 2002a, SEAV 2002h
		272-273 Basic Non-ferrous Metals	351.6	15%	35%	More efficient heat production and management (process controls, etc.) and improvements in cogeneration and electric drive systems	Further improvements as per low plus introduction of higher efficiency processes	DITR 2003b, DISR 2000, GFOV 1989, SECV 1993, CISR 2000a
		274-276 Other Metal Products	12.3	20%	45%	Improved heat management and electricity systems	Further improvements as per low EEIs	WC 1993
	28	Machinery and Equipment Manufacturing	23.5	25%	55%	High Efficiency Motors, Variable Speed Drives, PLC controls, compressed air improvements, improved heating systems	High Efficiency Motors, PLC controls, further heating process improvements.	SEAV 2002h, GFOV 1989, SECV 1993

Table 5.6 Industrial energy efficiency improvement potential by sector								
Division	Sub-division		Energy Use 2000-01 (PJ) (ABARE 2002c)	Energy Efficiency Improvement Potential (%)		Notes*		References
				Low	High	Low	High*	
	29	Other Manufacturing	[illegible]	[illegible]	50%	High Efficiency Motors, Variable Speed Drives, PLC control, compressed air improvements, improvement in heating systems	High Efficiency Motors, PLC control, further heating system improvements.	SEAV 2002c, SECV 1989, SECV 1993
E Construction (non-vehicle)			2.04	[illegible]	40%	Heating and electricity system improvements.	Further improvements in gas dryers and electricity systems	[illegible] 2002
TOTAL			1,404.46	22%	46%			

Note * High efficiency potential is achieved by completing both low and high efficiency potential initiatives. Low potential covers improved maintenance, modification of existing equipment and processes and the replacement with higher efficiency equipment at end of life. High potential covers further upgrades of equipment and the introduction of new higher efficiency processes.

C Architectural Design Principles:

C.1 Passive solar heating and cooling (Kachadorian):

There are no obvious "cookbook recipe" for the basic design parameters of a Passive Solar House (Kachadorian, 1997). The design usually involves an iterative process of:

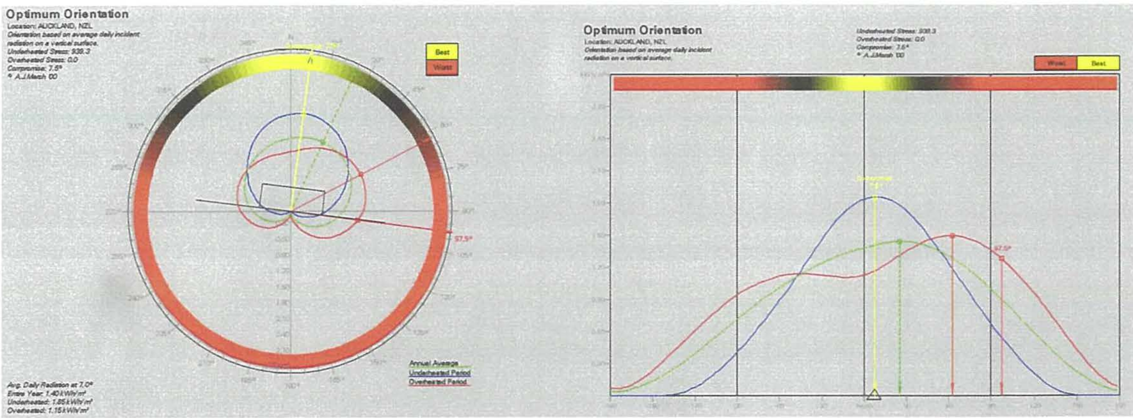
1. Conduct site analysis
    a. Plot shadow patterns on 21 June for buildings, trees, vegetation and land masses
    b. Design North windows for sun access from 9am to 3pm (sun is 45 degrees East/West of North)
2. Develop a design
3. Calculate R values for walls, glass, roof and floor.
4. Calculate the overall predicted heat loss of the home

C.2 Principles of passive solar heating and cooling (Chiras).

Source: (Chiras, 2002) with adaptation to Waitakere conditions

1. Choose a site with good solar exposure Orient the East-West (long) axis of the home within 10 degrees of True (Solar) North.
    - *True (Solar) North is 19 degrees west of magnetic north for Waitakere*

Figure 62: Optimal solar exposure for Waitakere City

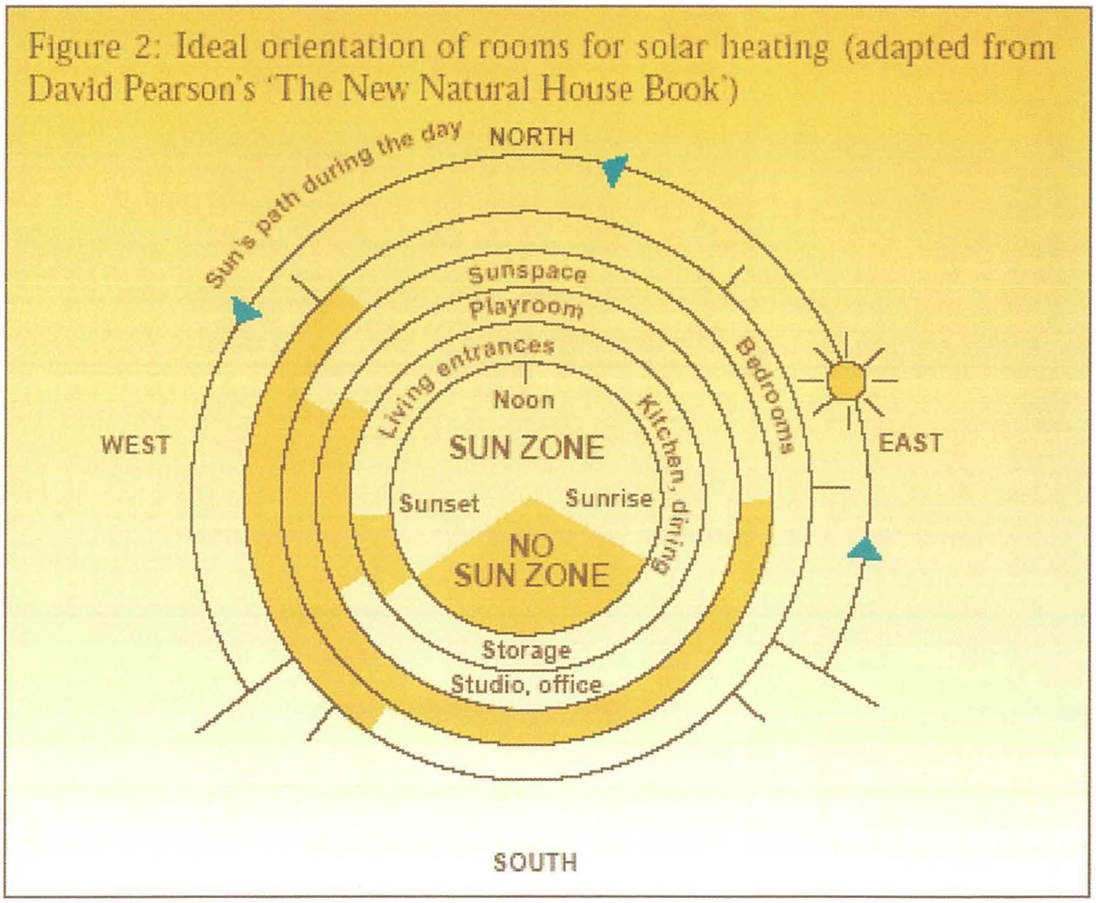


Optimum orientation is 7.5 degrees East of Solar North (therefore 12.5 West of Magnetic North). This is based on average daily radiation on a vertical surface (e.g. Building wall/window).

2. Concentrate windows on the north side of the house
    - *Approx 10-20% of house's floor area (Rule of thumb starting point)*
3. Minimise east and West glazing
    - *Approx 2-3% of house's floor area (rule of thumb starting point)*
    - *Provide overhangs and shade to regulate solar gain*
4. Provide sufficient amount of well-positioned thermal mass for heating and cooling
    - *Insulate ceilings, walls, floors and foundations*
    - *Building code insulation levels are minimum levels, and insufficient for an energy efficient design. A well insulated house will exceed these levels and only coast on average an extra $300 (EECA).*
    - *Houses with floor insulation are 1.0 degrees Celsius warmer than those without (Isaacs, 2003)*
    - *Thermal drapes that are sold often do virtually nothing to stop heat flow. To be effective they must:*
    - *Seal tightly to the window frame at the bottom, sides and to some degree the top to prevent convection with room air temperature*
    - *The curtains must contain a layer of material that is impervious to air flow and moisture*
    - *The curtain material(s) should provide resistance to heat transfer(Chiras, 2002).*
5. Protect insulation from moisture.
    - *Moisture is a conductor thus reduces the R value of the insulation.*
    - *Remove sources of moisture (vent kitchen, bathroom, clothes drier directly to outside*
    - *BRANZ studies indicate that Auckland has the highest prevalence of condensation and moisture problems.*
    - *Strong dependence on insulation level (BRANZ)*
    - *Condensation control depends on adequate ventilation (but not too much), adequate heating and adequate insulation.*
6. Insulate the house well to make it easy to maintain high interior temperatures and warm interior wall surfaces.
    - *Use full cavity insulation*

7. Design house so that rooms are heated directly and for optimal natural heat distribution
8. Create sun-free zones for computer work and television watching
9. Seal leaks and cracks to reduce air infiltration but ensure adequate ventilation for fresh air
    - *Good design and construction should achieve a low air leakage rate of 0.5 ACH (Air changes per Hour)*
10. Provide sufficient properly sized, environmentally responsible back-up heating and cooling systems
    - *Provide low level (100 Watt) of continuous supplemental winter heat to each bedroom not solar heated to minimise condensation.*
    - *Protect homes from winter winds by landscaping, earth sheltering, and other measures. (Prevailing wind is South Westerly).*
11. Design interior space to correspond with solar gain and living patterns.

Figure 63: Ideal orientation of rooms for solar heating



Source: EECA

D Gridded wind speed data for NZ

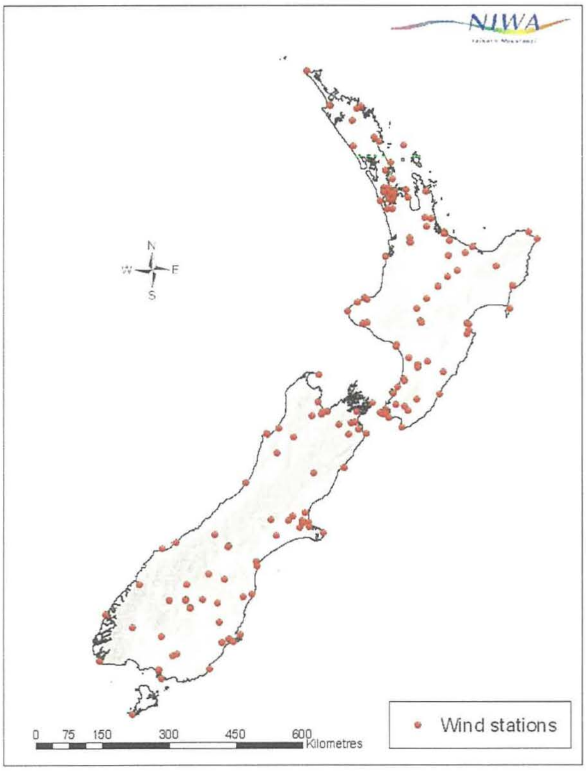
(The following has been provided by Dr Andrew Tait at NIWA – as the explanatory note to the interpolated wind analysis mapping supplied by NIWA for this report)

This document is a reference guide for the gridded wind speed data. The following information is covered: the mapping methodology, estimated data accuracy, the intended uses of the data, where to go for more detailed analyses, and terms and conditions for using the data.

D.1 Description of the mapping methodology

The gridded data have been interpolated from climate stations throughout the country where wind speed at 10 m above the ground has been recorded during the period 1971–2000. Figure 64 shows the location of these stations.

Figure 64: Climate stations with wind speed data recorded during the period 1971-2000



At each station, the average 9am (local time) wind speed for each month and year during the 30-year period were calculated. Some stations have data for the full period, while others have data for only a few years. Stations with at least two years of data were selected. Table 27 lists these stations and the number of years of record during the period 1971–2000.

Table 27: Climate station details (extracted from complete NZ list)

Agent number	Name	NZMG Easting	NZMG Northing	Height (masl)	No. of years
1400	WHANGAPARAOA AWS	2674600	6509200	89	8
1410	WHENUAPAI AERO	2655400	6488800	26	26
1425	AUCKLAND CITY EDR	2666500	6481000	75	2
1434	AUCKLAND CITY	2666501	6481000	75	18
1439	MUSICK POINT	2679900	6482000	18	3
1500	MANUKAU HEADS 2	2647700	6459900	244	4

Decile statistics were calculated for every station from the monthly and annual data. Decile values represent the statistical distribution of the data in fractions of every tenth percentile. Thus, there are 11 deciles; the minimum, 10th percentile, 20th percentile, ..., median, ..., 80th percentile, 90th percentile, and the maximum for each month and the year. Deciles can be used to assess the probability of exceeding certain critical threshold wind speeds (e.g. 8 m/s). For example, if the 8 m/s threshold for a given location is only reached at the 90th percentile for the month of January, it can be concluded that this location typically has an average 9am wind speed in excess of 8 m/s in January only 10 % of the time. Put in other words, one January in ten, on average, will have an average 9am wind speed equal to or exceeding 8 m/s.

The monthly and annual deciles were interpolated from the station locations to a regular grid with spatial resolution of 500 m. The interpolation scheme used was a thin plate smoothing spline. The software package used was the Australia National University "ANUspline" version 4.1, February 2000.

Thin plate smoothing splines provide a robust way of incorporating variables other than location (i.e. easting and northing) that may improve the accuracy of the interpolation. For example, most meteorological variables, such as air temperature, rainfall, and evaporation, are affected by altitude; thus it makes sense to interpolate these parameters using a spline model with two position variables and a linear dependence on elevation. The broad spatial pattern is determined by the two position variables, while the inclusion of elevation modifies the broad pattern to give more precise representations of the higher resolution variability. Wind speed is generally related to elevation, that is higher speeds tend to occur at higher elevations. However elevation alone does not completely capture the spatial wind speed pattern. For example, coastal speeds are significantly higher than inland areas due to the amount of exposure to the prevailing winds, and channelling effects caused by the confluence of airstreams (e.g. through Cook Strait) are not related to elevation.

For this analysis, easting, northing, and a daily air temperature range covariate were used to map wind speed. Daily temperature range is related to wind speed as low temperature ranges tend to occur on mountain tops, near coasts, and at other exposed areas due at least in part to wind action. Likewise, high temperature ranges tend to be associated with sheltered locations. The average temperature range data for each month and the year were also fitted using a spline interpolation of station data, where the covariates were easting, northing, and elevation. Thus, both the temperature range and elevation pattern are incorporated into the wind speed interpolations. Also, in some areas where the distribution of climate stations is inadequate to properly depict the local wind speed pattern, the data are adjusted towards the pattern present in nearby topologically-similar areas with adequate data density.

As each decile was interpolated independently, it was not guaranteed that the values at every grid point would form a monotonically increasing sequence (i.e. the minimum is less than the 10^{th} percentile which is less than the 20^{th} percentile, etc.) To build in some dependency between the decile surfaces the following scheme was adopted. Only the median was fitted directly; each percentile above the median was transformed to be the difference between itself and the adjacent lower one (e.g., the 60^{th} percentile becomes the 60^{th} percentile minus the 50^{th} percentile); for the percentiles below the median the difference was taken the other way (e.g., the 40^{th} percentile becomes the 50^{th} percentile minus the 40^{th} percentile). After the interpolations were performed, the decile variations were recovered by adding the resulting fitted fields together.

D.2 *Estimated data accuracy*

The estimated data accuracy of the gridded wind speed data for most of the country is approximately ± 1 m/s. High elevation areas, where climate stations are sparse and wind data are generally of short duration, have more uncertainty and hence the estimated data accuracy is probably nearer ± 2 m/s.

The data are extrapolated with some account taken of terrain; however local small-scale increases (e.g. speed-up over ridges and hills) are unlikely to be correctly identified. This is in part due to the 500 m spatial resolution of the gridded data. Low wind areas are likely to be more reliably identified than high wind areas, and wind speeds are not independent of sheltering caused by trees.

D.3 Intended uses of the data

The data may provide a range of applications including the assessment of sites suitable for the generation of wind energy. As indicated in the previous section, some care should be taken when interpreting the data with respect to the estimated data accuracy. However, these data are regarded as well suited to identifying locations where more detailed investigations involving models and/or anemometer measurements can and should be performed.

The national coverage of the data lends itself toward comparison studies, including questions such as how do wind speeds over a range of hills in Otago compare with those over the Tararuas. Moreover, because there are data grids for every month, an analyst can look at the month-to-month variations in wind speed at any site. This may be of particular importance for a project where wind energy is sought to offset the seasonality of hydropower generation.

By analysing all the deciles at a single point, an analyst can determine the probabilities of occurrence, which are directly related to risk. Often only the median (or the average) wind speed is calculated and assumptions are made about the variability. The use of all the deciles is therefore strongly recommended. At this site the entire annual wind speed distribution exceeds 8 m/s and the median is approximately 8.75 m/s. Thus is likely to be a very reliable location for generating wind energy and further site-specific analysis should be undertaken. Deciles can be plotted for any location.

D.4 More detailed analyses

The gridded data should be used for identifying areas where more detailed studies should be undertaken. Such studies should include wind measurements which may be supplemented with modelling to estimate the fine-scale perturbations in the wind field. NIWA can help with both of these types of information.

D.5 Contact information

If you have any questions regarding the data, please contact:

Dr Andrew Tait
NIWA
Private Bag 14901
Wellington

Ph: (04) 386-0562
Fax: (04) 386-0574
Email: a.tait@niwa.co.nz

E Case study – Portland, Oregon, USA

From: (The Climate Group)

Located in the American northwest, Portland, Oregon is a city of 500,000 people set in a broader metropolitan area of 1.3 million. In 1993, the city became the first local government in the US to adopt a plan to address global warming. It is also one of only a handful of cities that have set a target for wider city emissions rather than those associated just with local government. Since the climate change plan was introduced Portland has bucked the national trend by reducing per capita emissions of greenhouse gases by 13% while experiencing strong economic and population growth. The city has achieved this by focusing on a number of key areas:

E.1 Energy efficiency and green buildings

Energy efficiency has always been a priority for the city. Within the city government, an energy–management programme called City Energy Challenge has reduced the city's energy bill by $11 million since 1991. Recently the city completed converting its traffic signals to highly efficient LED bulbs, an improvement that saves the City almost 5 million kWh per year and over $500,000 annually in energy and maintenance costs.

This energy efficiency work has been extended to the residential and business communities via the Energy Trust of Oregon. Founded in 2000 the trust administers energy efficiency and renewable energy programs for customers of the region's utilities. In its first 2 years the trust provided energy efficiency incentives to over 200 businesses and 14,000 Portland households generating annual bill savings of $1.5 million.

The city has also established itself as a leader in the field of 'green building'. In 2000 Portland launched a program offering technical assistance, education and financial incentives for green building to the design, development and building communities and to homeowners. Since 2001 the City has provided technical and financial assistance to more than 300 local buildings.

E.2 Renewable energy

In addition to work on energy efficiency, Portland's Local Action Plan on Global

Warming sets aggressive goals for renewable resources, instructing the City to acquire 100% of its energy needs from renewable sources by 2010 with an interim target of 10% by 2003. Actual renewable energy purchased currently stands at around 11%.
In order to meet its long term goal the City has invested in a number of new schemes including hydroelectric turbines in its drinking water reservoir system and a fuel cell powered by waste methane. Most significantly, in June 2003, the City purchased green energy certificates representing nearly 44 million kWh of wind power – enough to supply nearly 4,000 homes for a year. In recognition of the city's accomplishments, the US EPA named the City of Portland the Green Power partner of the year for 2003, the first municipality to earn this accolade.

E.3 Further actions

Other initiatives under Portland's climate change plan include requirements for businesses to develop plans to recycle a minimum of 50% of their waste and a significant new initiative on commercial food waste collection due to launch in 2004. The City has also looked to forestry and offsets to minimise its climate impact, pursuing an aggressive tree planting policy. In 2001 and 2002 the City's Bureau of Environmental Services and Parks and Recreation planted over 600,000 trees. Finally, communication and education, both to business and the general public, form a critical part of Portland's overall policy.

E.4 Next steps

Although per capita emissions in Portland have come down, absolute emissions are still hovering at around 1% above 1990 levels (although real reductions have been achieved over the last 2 years). There are a number of projects in the pipeline – the feasibility of a utility-scale wind power project to supply City facilities is currently being explored. Portland, by making the right choices, has shown that it is possible to be a thriving city whilst addressing the challenge of climate change.

Achievements:

> 75% growth in public transit use since 1990

> 13% reduction in per capita greenhouse gas emissions since 1990

> 10% of local government's energy currently sourced from renewables

> Construction of over 40 high-performance green buildings

> Planting of over 750,000 trees and shrubs since 1996

Benefits:

> Savings of $11 million on the city's energy bill since 1991

> Savings of $300 million on energy bills for business and residential customers since 1990

> Co-benefits including cleaner air, easier transportation access and more trees

Targets:

> Reduction of the City's emissions by 10% by 2010 (not just from Government estate)

> To purchase 100% of local government energy from renewable sources by 2010

Future Priorities:

> Taking forward plans for a utility-scale wind power project to supply city facilities

> Achieving 60% recycling rate by 2005

> Participation in the Chicago Climate Exchange

E.5 Resources

There is a lot of information available on the various initiatives that Portland has developed to address renewable energy and energy efficiency. Some of this information can be obtained from:

City of Portland: www.portlandonline.com

In particular,

Energy Policy:

http://www.portlandonline.com/auditor/index.cfm?&a=36237&c=31220

Local Action Plan on Global Warming (April 2001):

http://www.portlandonline.com/shared/cfm/image.cfm?id=25050

Green Building:

http://www.portlandonline.com/auditor/index.cfm?&c=34835

Portland Energy Conservation, Inc (PECI): www.peci.org

Portland office of Sustainable Development: www.sustainableportland.org

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