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East Harbour

Assessment of Possible Renewable Energy Targets

– Direct Use: Geothermal

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Background

The Energy Efficiency and Conservation Authority (EECA) sought assistance in furthering its understanding of possible renewable energy targets for direct use of energy in particular for the geothermal sector. This is part of the process of informing the final New Zealand Energy Efficiency and Conservation Strategy in order to state targets to achieve policies and objectives that are measurable, reasonable, practical and appropriate. As such, the scenario development in this report is tied back in to the Ministry of Economic Development's "New Zealand's Energy Outlook to 2030" (Energy Outlook).

Report Outline

Current assessed usage of geothermal energy for direct use applications is around 10.7PJ/year. The report provides a review of the likely types of future uses and users by sector and indicates that there is likely to be a strong future for heat pump applications despite current low usage in New Zealand, there is a strong correlation of geothermal resources with forestry, and encouragement for shallow wells and downhole heat exchangers through Regional Policy Statements could encourage greater uptake. Various drivers are discussed from both the users perspective and developers perspective with a view to breaking a disconnection between them. Comparative costs are then presented for industrial and smaller scale technologies to show that there are immediately or near competitive technologies, though it is recognised that price is not the only driver. Finally, a view is developed on the possible uptake of geothermal energy from which possible targets can be inferred. Two specific targets are recommended (with the possibility of a third regional target), along with means of measuring these, and possible methods of encouraging their achievement.

Geothermal Resources

Geothermal energy is a form of renewable energy. The geothermal resources available at accessible depths in New Zealand far exceed any imaginable usage, though a distinction must be made between resources, reserves and economically recoverable energy. As a rule geothermal energy must be used near where it is found rather than being piped many kms to an interested user.

Total national geothermal resources are summarised in Table ES 1, including their location.

Table ES 1: A Summary of the Total Geothermal Resource in New Zealand (of which only a Small Portion will be Economically Recoverable, and only a Portion will be Used Directly)

Resource Type	Consumer Heat Capacity (PJ/year)	Comments
Conventional		
High Temperature	356	Resources are concentrated in the central North Island and near Kaikohe. Most of this high temperature resource will be dedicated to electricity generation.
Low Temperature/springs	>235	Resources are more widely scattered, but are commonly rural or remote. More could be done with these though further definition of resources is required.
Unconventional		
Enhanced Geothermal Systems (Hot Dry Rock)	5,820	The method for assessment still needs to be refined. Development costs for direct use have not been researched but would not justify a small development. There may be cheap entry options on margins of high temperature fields or using abandoned oil and gas wells.
Geothermal Heat Pumps	>59	These can be used virtually anywhere nationally, and are now economic for any demand greater than that of a large domestic home. There are excellent opportunities for waterside developments or in moist sandy soils.

In considering the location of geothermal resources, there is a strong correlation between location of high temperature geothermal resources and plantation forests and associated forest processing plant. Given the high heat demand in forest processing, this suggests the possibility of direct use of geothermal energy in forest processing, and this has been the case historically. This is most evident at Kawerau where a single geothermal steam supply supplies pulp and paper mills with an energy quantity that matches the sum of all geothermal industrial supply anywhere else in the world.

Technologies for Direct Use

There are a range of means of accessing geothermal resources (including simple collection of spring water through to drilling wells) and disposing of unused energy. Frequently, unused energy is thought of as waste, but discharge from an application is not waste until treated as such by the user. When treated in this manner it can pose problems, say for downstream cascade users. Any developer of supply for direct heat use needs to keep a focus on supplying a quality trouble-free product to the user.

This report has assessed that geothermal heat pumps are commercially viable now for demands greater than that generated by a large house. While heat pumps push the definition of "geothermal" to the limit, they are routinely regarded as geothermal technology in international reporting. These just rely on the more stable temperatures of soil or ground water compared to the more variable air temperature, to create a heat pump more efficient that air source heat pumps i.e. they could potentially be used anywhere and do not rely on the traditional "geothermal areas" to operate. Installed capital costs are high compared with a range of other technologies, but fuel costs (electricity) are low because of their high efficiency.

As a comparative example of geothermal heat pump costs, the total installed geothermal heat pump system with a peak heating duty of 20kW (say a small commercial application) would have a capital cost of around $24,000 and require only 4kW of electric power, while an air-source heat pump system for the same duty would cost $19,000 and require 5.5kW of electric power. Even a small geothermal heat pump system for domestic purposes will cost around $12,000, this being a significant deterrent to uptake.

Traditional and Potential Direct Users of Geothermal Energy

Geothermal direct use played an important role in some early Maori communities. Current use nationally is about 10.7PJ/year, with about half being located in industrial applications at Kawerau. The Kawerau development is so large by world standards that it accounts for half of the world industrial geothermal direct heat use. Nationally, in terms of heat use, this is followed in magnitude by a mixture of bathing, space and water heating uses. Some of this latter demand is directed to the tourism industry, which has strong links to geothermal resources. Heat pump uptake is currently miniscule compared with its potential.

Internationally, bathing and space heating dominate direct geothermal use. However internationally the single greatest category of usage is that of heat pumps, following significant and exponential growth in use over the last 10 years. Given the current favourable pricing of heat pumps in New Zealand, there is no reason why significant exponential growth should not occur here also.

Indicative heat loads have been analysed for a range of use sectors, as a precursor to assessing typical costs and unit costs of various development types. From recent household energy surveys a significant discovery is that New Zealand residential space and water heating can be categorised into essentially only two zones: Southland/Otago and the rest, with deep south homes consuming about 60% more on water and space heating than other homes.

There are a range of other areas that could see growth in direct heat use in future including hotels, schools, government, greenhouses, and most notably the forestry sector.

Qualitative Review of Key Drivers

An analysis of possible key drivers from a user's perspective for the uptake of geothermal energy for direct heat use indicates that while commercial drivers should reasonably dominate, many other factors come into play resulting in decisions that do not appear economically rational. There are a range of positive drivers including pressure to clean up air (forcing substitution of fossil fuels and inefficient log fires), and new pressures for healthy and energy efficient homes. Countering this will especially be an aversion to paying a high capital cost for a geothermal option, with associated drilling risks, and some consenting restrictions. Suggested drivers from a user's perspective include:

- General concern over rising fuel prices
- New developments or plant replacement
- A requirement for a quality fuel supply
- Concern over past bore closures
- Co-location of resource and user
- Concern over CO_2 and other air emissions
- Concern over current levels of domestic heating
- Aversion to high capital expenditure on energy
- Constraining resource consenting policies
- Current knowledge of geothermal resources suitable for direct use
- Current technology and cost trends for plant and equipment using geothermal energy

There is increasing interest and action with respect to direct use of geothermal energy from a developer's perspective. The major geothermal electricity developers (Contact Energy, Mighty River Power and Tuaropaki Trust) all have some recognition of the value of diversification of energy supply options to include direct heat use. However, future direct use projects will have to be on a commercial basis (not always the case in the past when Government was the developer which has created low expectations on the part of these developers).

The types of developers who will be involved in major investments include:

- Major national geothermal power developers
- A range of active Maori trusts suitably located over geothermal resources
- Potential utility and energy service companies e.g. Energy for Industry
- Drillers
- Geothermal heat pump specialists
- Property developers, and
- Investment bankers

Because of the high exploration and development costs of geothermal development it is expected that larger developments will partly happen through investment by utilities and energy service companies. Initial ventures are now being considered e.g. the New Zealand Clean Energy Centre/Energy for Industry hospital and school heating project in Taupo. It seems that a business model based around multiple smaller sales through hard-wired connections with frequent billing, is a better model for the proliferation of small scale development expected in the near term.

Direct Cost Comparisons for Some Specific Technologies and Applications

At the industrial scale of supply, cost curves for delivered heat energy based on fuel costs suggested in the MED's Energy Outlook publication show that a revenue-neutral diversion of steam from a geothermal power station yields a heat price less than most other competing fuels. The curves also indicate that there is a minimum size for a Greenfield geothermal project to be viable (probably in the 10 to $30MW_{th}$ range). This corresponds to the demand of a large timber drying kiln operation.

A comparison with electricity price shows that conventional geothermal heating options based on shared wells are viable for space and water heating of average and above sized homes. Similarly they look financially attractive for a range of commercial applications. Heat pumps, which have far greater applicability nationally, are viable for large homes (or average Deep South homes) and above. Again, there are a range of commercial applications that are viable.

A View of Potential Uptake of Direct Heat Use

As a means of roughly apportioning uptake between regions and between times, an assumption was made that a "price driver" will influence uptake, such that uptake for a particular market sector will be proportional to the difference between unit costs and local electricity price. This has led to a different view on uptake to that given in the Energy Outlook. Three scenarios were considered to give a range of uptakes.

Table ES 2: Summary of Scenarios used in the Assessment of Potential Uptake of Geothermal Direct Heat Use

	Scenario Source	Assumptions
Scenario 1	Energy Outlook Base Case[1]	Current direct heat use is unchanged, based on MED's original assumptions.
Scenario 2	Energy Outlook Base Case	Uptake varies according to the price driver discussed above.
Scenario 3	Energy Outlook Carbon Charge Case[2]	Uptake varies according to the price driver discussed above, the driver being greater because of the carbon charge.

Various data sets were reviewed to determine factors for apportioning usage by region and time.

Finally, apportionment between sectors was based on subjective views of uptake, based on comparisons with assessments for other technologies using similar methodology, as summarised in Table ES 3:

[1] The Energy Outlook Base Case is essentially a Business-as-Usual case with moderate GDP growth, oil prices around current levels, continuing gas discoveries, energy efficiency improvements at historical rates and no carbon charge.

[2] The Energy Outlook Carbon Charge Case is a sensitivity case in the Energy Outlook that does include a carbon charge of $15/tonne of CO_2. While a carbon charge as such may not be introduced, this does represent the effect of a price on carbon whether through a tax or emissions trading.

Table ES 3: Summary of the Subjective Views of Uptake

Application	Total Market Penetration by 2030[3]	Rationale/Comment
Conventional Direct Heat		
Homes	0.02% nationally but with high uptake regionally	Assume uptake is limited to Taupo, Rotorua and Tauranga. Uptake at other locations is limited by consenting regime, or economic climate, or may fall within error noise. Predominantly new homes with a retrofit uptake rate at about 1/10th of that of new houses
Hotels	see comment	There is already significant uptake. Assume 2 new hotels (1TJ/year each) in each of Taupo, Rotorua and Tauranga.
Schools	see comment	There is already significant uptake. Assume 3 new schools (1.3TJ/year) in Taupo, Rotorua and Tauranga.
Dairy farms	see comment	Assume 3 large farms (0.05TJ/year each), potentially over high or low temperature fields
Public Service	0	Ignored, as additional use will be within error noise. Frequently, the public service does not own property so will be restricted in ability to encourage high capital, low running cost options.
Hospital	see comment	Uptake is expected at Taupo hospital eventually. Heat use will be of the order of 20TJ/year.
Green houses	see comment	Assume 1 green house (64TJ/year each after expansion) per developed high temperature field in co-operation with land owners. A 2 ha area is a significant glass house area. Assume initial 2 ha development followed by a second development. 9 developed or potentially developable fields currently do not have greenhouse heat supplies from the generators. At 1.6GJ/m^2, this implies total uptake of 580TJ/year.
Kiln drying and forest products	see comment	Assume 1/10th of CNI biomass demand (30TJ/year) will be met by displacing wood processing residues from Kawerau boiler supplies to free this material for pelletising. 20MW_{th} kilns (about 400TJ/year) will be installed on 4 more of the 9 high temperature fields currently without kilns.
Geothermal Heat Pumps (nationally)		
Homes	0.5% (about 10,000 homes)	Assume the limiting factor will be the extent of penetration in Southland/Otago. An assumption is made that about 2.5% of all new Southland/Otago homes will have these in 2030 while retrofits will be at 1/10th of the rate of new homes under scenario 2. This takes into account the preference for low capital cost status quo, and psychological/traditional enjoyment of fire i.e. preferential uptake of pellet burners.
Hotels	2%	Many large hotels will be in built up areas without the possibility of significant grounds. Hence heat pump opportunity might be limited to about 2% of all hotels rooms by 2030.
Schools	2%	Retrofitting of biomass boilers to fossil-fuel boilers will be easier and cheaper than retrofitting of heat pumps. However a 2% penetration should still be possible based on favourable economics when analysed over time.
Dairy farms	see comment	Assume 5 large farms.
Public Service	1%	Although public servants are expected to take the lead, ability to use heat pumps will be limited because of the usual built up environment in which these commercial-type buildings exist, and because properties are generally rented.
Hospital	0	Assume delivered temperatures make this an unattractive option, due to hospital requirements for higher temperature conditions for sterilisation.
Green houses	2%	Heat pumps can readily meet all heat needs. However, greenhouses also need CO_2, so some burning of biomass (or fossil fuel) could be needed. Heat pumps are capital intensive while greenhouses may be short-lived. Penetration is unlikely to exceed 2%
Forest products	0	Required temperatures are above the supply capability of heat pumps

[3] There have been additional assumptions around the intermediate 2020 year uptake which are reflected in the final summary table.

This enabled calculation of total possible uptake in each scenario as shown in Table ES 4.

Table ES 4: Summary of the Expected Uptake of Geothermal Energy Direct Use under the Previously Discussed Scenarios.

	Current Consumer Energy (PJ/year)	Expected New Uptake by 2020 (PJ/year)	Expected New Uptake by 2030 (PJ/year)
Scenario 1 Base Case MED	10.7	0	0
Scenario 2 Base Case mod	10.7	1.9	3.0
Scenario 3 Carbon Charge mod	10.7	2.0	3.2

Scenario 1 shows the MED Base Case assumption that there will be no effective change in direct use. Scenario 2 is also referenced to the MED Base Case, but instead of assuming fixed direct use shows progressive uptake of geothermal direct use options through to 2030 (with further growth expected beyond that). Growth expectations are strongly based on the financial viability of direct use projects but suppressed by a range of other factors. In Scenario 3, pricing of carbon will raise electricity prices, and so will drive a higher uptake of renewables, especially in the domestic heating market. The effect of the carbon charge is muted (and largely lost in rounding) by the assumptions that the big direct use projects (e.g. greenhouses and kilns) are unaffected by price and are simply related to the presence of a geothermal power station on a field.

Major direct use growth is expected to be through brownfield developments commonly linked to power station developments. While this report discusses greenhouses and timber drying kilns, these are just likely examples of what could be quite varied projects. In total, about 1.5PJ/year by 2020 and 2.2PJ/year by 2030 of additional direct use energy is expected to be provided in this context, linked to the wider field developers. While it is not clear whether this use will represent substitution of fossil fuels elsewhere or simply new growth, what is clear is that it represents a growing contribution of renewables to the energy needs of the national economy.

A total major project target of 1.5PJ/year by 2020 and 2.2PJ/year by 2030 would represent an achievable stretch. It can be thought of as a growth for major direct use projects of approximately 1PJ/year/decade. This compares with a past growth rate (after deducting the exceptional Kawerau supply) over the last 5 decades of approximately 1PJ/year/decade over all market segments of geothermal direct use. While past development has been in ‘fits and starts’ with recent stagnation, the projection does appear to be both a stretch and achievable.

These types of developments (involving reservoir assessments, wells, fittings, pipes and pressure vessels) draw on the traditional skills of New Zealand geothermal consultants and contractors to the electricity generation industry i.e. requires heavy engineering skills. These developments assist developers in small step outs in terms of diversification of supply. They will be based on commercial advantage for both the developing host and the direct user.

The following table summarises the expected uptake across a range of applications after the deduction of the major projects.

Table ES 5: Relative Contributions of Independent (i.e. not Including Major Projects) Geothermal Developments Including Both Conventional Direct heat Use and Geothermal Heat Pumps under Scenario 2 and 3 (PJ/Year)

Market Sector	2020		2030	
	Scenario 2 Base Case	Scenario 3 Carbon Charge	Scenario 2 Base Case	Scenario 3 Carbon Charge
Home (heat pumps)	0.22	0.28	0.58	0.73
Greenhouses (heat pumps)	0.08	0.08	0.08	0.08
Schools (heat pumps)	0.04	0.04	0.04	0.04
Accommodation (heat pumps)	0.03	0.03	0.03	0.04
Hospital (wells)	0.02	0.02	0.02	0.02
Homes (wells)	0.01	0.01	0.02	0.02
Public Service (heat pumps)	0.01	0.01	0.01	0.01
Accommodation (wells)	0.01	0.01	0.01	0.01
Totals	**0.41**	**0.48**	**0.79**	**0.95**

In terms of calculations, heat pump penetration of the market is expected to be quite significant with a total of approximately 3,800 pumps by 2020 and 10,000 pumps by 2030 expected to be installed in domestic houses, with a further 150 larger heat pumps in other market sectors. These could potentially save consumption of 160GWh/year of electricity by 2030 because of their high coefficient of performance. This number of heat pumps is consistent with exponential growth observed internationally with this technology, contrasting with the very small number currently being installed. As such, it represents a potentially achievable stretch target.

This target for heat pump uptake contrasts with the target for major geothermal projects in that it draws on a different skill-set and is accessible to a wider range of New Zealanders. Heat pump installations are achieved with the assistance of plumbers and electricians at the domestic and commercial level. While some basic training is required for the installer, this technology is a sound investment for large homes and commercial applications. Its encouragement allows a much wider portion of New Zealanders to be involved in installation of/investment in renewable energy options.

Further growth in small scale domestic use of geothermal energy is likely, say using shallow wells feeding homes, or downhole heat exchangers in the traditional geothermal areas like Taupo, Rotorua or Tauranga. A more active domestic geothermal drilling program is expected in these traditional geothermal areas. Again, these projects can be commercially attractive, but are physically restricted to a few towns and cities, for which they may have regional but not national significance. Consequently, the final scale of growth is likely to be dwarfed by heat pumps and major station-linked projects.

While targets for small scale domestic use of geothermal energy using shallow wells or downhole heat exchangers would not represent a significant contribution to New Zealand's energy needs it is an area where targets would draw attention to the opportunity and assist in changing mindsets currently limiting increased use of these technologies. If regional targets for small scale domestic use of geothermal energy using shallow wells or downhole heat exchangers are considered, then it should be possible to formulate a target for the Waikato and Bay of Plenty regions, possibly based on number of wells drilled. Alternatively if an energy target is wanted then a target based on an increase of 0.04PJ/year by 2020 and 0.05PJ/year by 2030 would be a stretch but achievable if commercial and institutional uses were targeted.

In the three targets suggested above, the driving forces will be commercial, so not in the direct control of government. However, government can play a role in providing an environment that will assist uptake by these commercial interests. This can include:

- Through pricing externalities such as emissions into the energy market through a price on carbon,
- Through active support of projects at the consenting stage through whole-of-government submissions in support,
- Through ongoing streamlining of the RMA consenting process with a view to timeliness and lower cost,
- Through clear direction to consenting authorities of the value of geothermal direct use, and encouragement of appropriate sustainable use[4] of geothermal resources (in fact many Regional Councils recognise this now, however greater encouragement needs to flow down to some District Councils),
- With loans and grants paralleling other government efficiency schemes, and
- With tools such as the 'Projects to Reduce Emissions' mechanism specifically targeting direct use (in contrast to the electricity market where a carbon price clearly will flow through the whole market).

Targets need to be measurable and will require active monitoring by government. Currently, few companies import heat pumps, so a tally of numbers should be readily achieved, though actual heating duty may be unknown. This is a similar approach to that proposed for solar hot water heating.

In the case of major projects, some of these may require separate consenting to that of the power stations, so consents could be monitored to measure progress. In practice, the number of projects and associated developers will be limited, and it may simply be a matter of maintaining relationships and information flows with these key parties. This report has indicated the range of parties for which relationships and monitoring will have to be established. EECA has already sponsored one geothermal direct use survey, and funded the start of a direct use database. Further funding could be directed in this direction. The end result will be a tracking of major projects and general indication of growth in minor sectors of the geothermal direct use market.

Final Recommendations

It is recommended:

1. That consideration be given to the following geothermal direct use targets:

    a. Installation of 3,950 geothermal heat pumps by 2020 and of 10,150 geothermal heat pumps by 2030 representing 0.4PJ/year and 0.8PJ/year respectively, plus,

    b. Development of an additional 1.5PJ/year "major" direct use projects by 2020 and 2.2PJ/year "major" direct use projects by 2030, plus

    c. Development of an additional 0.04PJ/year "shallow well and downhole heat exchanger" direct use projects by 2020 and 0.05PJ/year "shallow well and downhole heat exchanger" direct use projects by 2030.

2. That measurement of targets as outlined above should be:

    a. By a tally of heat pumps as provided by importers

[4] This might eventually require a National Policy Statement on direct use. Currently several councils are excessively precautionary. Geothermal developments could be proceeding now in Rotorua using downhole heat exchangers.

   b. By relationships with/information flows from key developers and/or ongoing sponsorship of the development of a direct use database and direct use surveys.

   c. Number of shallow well and downhole heat exchangers installed.

3. That assistance be provided to commercial parties in meeting these targets through any or all of the following means:

   a. Pricing externalities such as emissions into the energy market through a price on carbon,

   b. Active support of projects at the consenting stage through whole-of-government submissions in support,

   c. Ongoing streamlining of the RMA consenting process with a view to timeliness and lower cost,

   d. Clear direction through Regional Policy Statements of the value of geothermal direct use, and encouragement of appropriate sustainable use[5] of geothermal resources (in fact many Regional Councils recognise this now, however greater encouragement needs to flow down to some District Councils),

   e. With loans and grants paralleling other government efficiency schemes, and

   f. Possibly with tools such as the "Projects to Reduce Emissions" mechanism specifically targeting direct use (in contrast to the electricity market where a carbon price clearly will flow through the whole market).

[5] This might eventually require a National Policy Statement on direct use. Currently several councils are excessively precautionary. Geothermal developments could be proceeding now in Rotorua using downhole heat exchangers.

1 Introduction

The Energy Efficiency and Conservation Authority (EECA) sought assistance in furthering its understanding of possible renewable energy targets for direct use of energy in particular for the geothermal sector. This is part of the process of informing the final New Zealand Energy Efficiency and Conservation Strategy in order to state targets to achieve policies and objectives that are measurable, reasonable, practical and appropriate.

This report has been jointly prepared by East Harbour Management Services (East Harbour) and GNS Science.

The purpose of this report is to provide up-to-date data, information and analysis towards the formulation (together with strategic context) of a 2020 and a 2030 target for geothermal energy used to provide heat to residential, commercial, agricultural and industrial premises.

2 Geothermal Resources

The following chapter assesses New Zealand's geothermal resources and their location. It covers the full spectrum of resources, without an assessment of economic reserves. Later chapters discuss economics and provide a view on potential uptake. It finishes with some specific locational considerations.

Discussions on New Zealand geothermal resources frequently start and finish with high temperature resources, where the focus has been on electricity generation. To varying degrees, geothermal energy can be found at any location and New Zealand can be thought of as one big geothermal system. Within this system, there are pockets of surface and subsurface temperatures where heat can be extracted economically from fluids and/or rock. The resources available within New Zealand for heating purposes include:

Conventional sources:

- high temperature hydrothermal resources, located in the Taupo Volcanic Zone (TVZ) and Ngawha, capable of either direct use, or use in association with electricity generation, and

- low temperature hydrothermal resources, including hot and warm springs found in both the North and South Islands some of which have minimal surface features[6].

Unconventional sources:

- enhanced geothermal systems (involving extracting deep heat after possibly enhancing permeability), and

- geothermal heat pumps environments (including beside waterways, and warm water in flooded underground coal and mineral mines).

It should be noted that in Europe or the United States, geothermal heat pumps would be considered in the "conventional source" category, but uptake is only just commencing in New Zealand, albeit with tried and tested technology.

[6] Most of New Zealand's lower temperature resources are undeveloped or under-developed. Principally only those with surface features in convenient locations have been significantly developed.

2.1 Resource Assessment

2.1.1 High Temperature Hydrothermal Resources

New Zealand's geothermal resource base is large, and is currently the second largest renewable energy source contributing to the national energy supply. Geothermal energy derives from heat contained in the earth or groundwaters, and can therefore be regarded as unlimited in quantity.

The high temperature hydrothermal systems are principally located in the Taupo Volcanic Zone and at Ngawha in Northland.

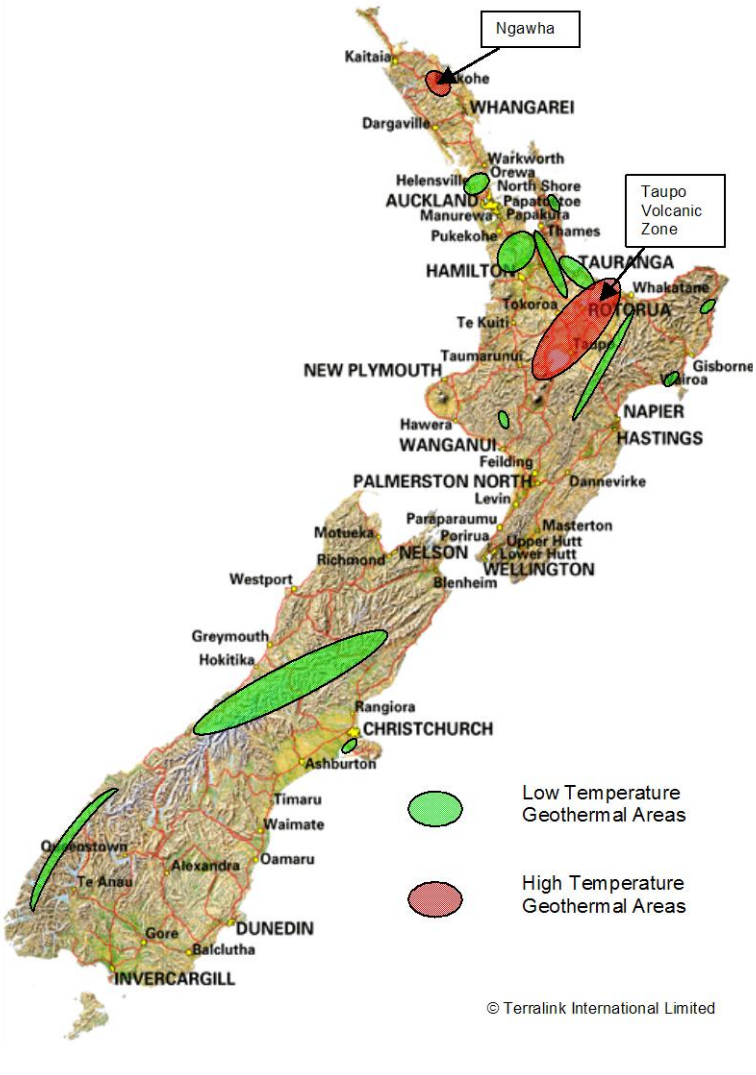

Figure 2.1: Location of conventional geothermal resources in New Zealand (after East Harbour 2004)

There have been several assessments of New Zealand high temperature resources. Any assessment is limited by the lack of published information in the public arena, a problem partly attributable to:

- the consenting regime (including exploration licensing),
- previous Crown investment in wells and a desire to secure a return on these,
- inconsistency in the distinction between resources and reserves, and
- commercial requirements of confidentiality.

Nevertheless, there is sufficient information coupled with experience to gain an assessment for the purposes of this report. Table 2.1 shows the latest assessment by Lawless, modified to reflect heat supply rather than electricity generation. This replaces the heat source assumptions produced in much previous literature which has been based on an energy conversion factor of 10% for conversion of wellhead energy to electricity with a 50%[7] factor for heat used directly and resulting in the MW heat capacity of a field being assumed to be 5 times the MW electrical capacity of a field[8].

Table 2.1: Quantity of High Temperature Resources – Mid Range Values Only (based on Lawless 2004[9])

Field	Resource Area (km^2)	Depth to Reservoir (m)	Resource Thickness (m)	Void Space (%)	Mean Temperature (°C)	Heat Capacity (PJ/year)
Fields available for further development						
Horohoro	0	500	2000	10	200	1
Kawerau	35	400	2100	8	270	68
Mangakino	8	800	1700	10	230	7
Mokai	6	700	1800	10	280	21
Ngatamariki	10	400	2100	8	260	18
Ngawha	18	400	2100	4	240	11
Ohaaki	10	400	2100	8	270	20
Rotokawa	18	500	2100	10	280	45
Rotoma	5	500	2000	8	240	5
Tauhara	15	500	2000	12	260	48
Tikitere-Taheke	35	500	1800	10	240	36
Wairakei	20	350	2150	15	255	77
Subtotals	**180**					**356**
Fields with various levels of protection						
Atiamuri	0	800	1700	10	220	1
Ketetahi	12	800	1700	8	240	15
Orakei-Korako	10	400	1800	10	250	17
Reporoa	9	700	1500	10	230	6
Rotorua	4	500	1800	10	240	5
Te Kopia	10	500	2000	10	240	14
Tokaanu	20	800	1700	8	260	30
Waimangu	12	400	2100	10	260	42
Waiotapu	20	500	1800	10	275	51
Subtotals	**97**					**181**
Means and Totals:	**277**			**9.5**	**250**	**537**

It is recognised that some of the high temperature fields in Table 2.1 already have some development, but will be developed further by motivated electricity supply companies, principally for electricity generation. It is the scale of an electricity development project that helps to justify the risk involved in exploring and drilling a new field, with this scale almost never matched by direct heat

[7] The International Energy Agency has a default assumption that there is a 50% conversion factor when comparing primary energy with consumer energy (IEA Statistics (2005) *Renewables Information 2005 Edition*). A study of New Zealand direct heat use showed for 2005 primary energy supply was 21PJ/year yielding consumer energy of 10PJ/year, and so was consistent with international experience (Brian White (2006) *An Assessment of Geothermal Direct Heat Use in New Zealand*).

[8] In practice, the rejection temperature for heat applications will be lower for heat applications than for electricity generation so a fresh calculation would yield an even higher estimate of potential.

[9] Jim Lawless (2004) *Maintaining Leadership in Geothermal Energy Generation in New Zealand*

applications[10]. The size of large scale electricity development projects means that, say, a well failure can have its costs recovered over several wells whereas much smaller direct heat applications will be far more sensitive to this risk as they are generally undertaken in isolation.

However there will also be some opportunity for direct use through parallel development[11] with electricity generation such as occurs at Mokai, or cascaded development[12] as occurs at Wairakei. Other fields may be developed in a precautionary manner, especially if development is occurring near built up areas or tourist features. There are various degrees of protection on fields, and some of these still allow limited development for direct heat purposes, as demonstrated by geothermal heat use at Waiotapu and Orakei Korako.

The potential for cascaded direct use is possibly overstated in many previous studies. In practice, the rejection temperature set for a power station, especially on higher temperature fields, is based on a perceived acceptable level of risk in terms of silica scaling. A lower temperature may lead to heightened risk of clogging injection wells when fluid is returned to the reservoir. For this reason, it is unlikely that much heat will be available for cascaded direct use, unless silica removal techniques are utilised. While silica can be problematic, its removal could result in a saleable by-product.

Cascade opportunities might start to develop at future dates because:

- Exploitation of high temperature fields is likely to be targeted by developers initially, and these will be more heavily saturated with silica than lower temperature fields. As time progresses, these reservoirs will start to cool resulting in lower silica levels than initially designed for, opening the possibility of onsale of some direct heat from these initial developments.

- Some future electricity generation developments will be in progressively less favourable conditions as the prime sites are taken up as a priority. A point may be reached for lower temperature resources where cost and thermodynamic tradeoffs will limit generation size rather than silica saturation levels. In that case, cascaded use may be a possibility from the start of a development.

Current stations are assumed to be limited by silica saturation conditions so are not able to supply cascade applications, with the exception of the component of hot water currently being directed to the surface. Currently some hot water is rejected from Wairakei development to the Waikato River and from the Kawerau development to the Tarawera River.

One old study of the Wairakei field[13] showed that in February 2000 while the station was producing 164 MWe, about 105 MW (3.2PJ/year) of heat was being discharged to air from steam through the steamfield silencers, about 95 MW (2.9PJ/year) of heat was being lost to air through the drains and 84 MW (2.5PJ/year) of heat was lost to the Waikato River. More recently some of this heat (0.8PJ/year) has been provided in a parallel manner to the NETCOR tourism venture. Further development of any of these heat streams may present practical and security risks.

[10] The Kawerau development is a large scale development, which by itself, still exceeds the total remaining world quantity of geothermal heat supplied for industrial heat purposes.

[11] Parallel development – a development where both heat use and electricity generation occur in parallel, either from separate wells or a common energy supply system.

[12] Cascaded development – a development where heat use and electricity generation occur in series. Normally heat use is the cascaded application taking some form of heat from the electricity generation supply. Kawerau is a contrasting example where electricity generation by Bay of Plenty Electricity is cascaded from the direct heat use application.

[13] Brian White (2000) *Wairakei Energy and Efficiency Audit*. A report by PB Power for Contact Energy

At Kawerau, waste water on one side of the Tarawera River passes through Lake Umupokapoka to dissipate heat[14], while water on the other side of the river passes through a long cooling channel before discharge to the river[15]. The steamfield owner tried to maximise heat loss to minimise heat impacts on the river, but did not use more productive technologies. Recent ownership change of the steamfield development from the Crown to Ngati Tuwharetoa Geothermal Assets may see renewal of these smaller direct heat applications. If only half of the heat available in these current waste streams could be made available then 1PJ/year could be offered[16]. Conceivably this could be to greenhouses. Half of the resource has been suggested arbitrarily to take account of the intense land use in the area.

High temperature fields have some CO_2 emissions which must be managed by developers. Table 2.2 shows assessed emissions in 2001. Fields such as Ngawha are reported to have reduced in emission rates since that time. It should be noted that geothermal emissions are relatively low compared with fossil fuel emissions performing the same duty (though the context here refers to electricity generation).

Table 2.2: New Zealand Geothermal Field Emission Rates (based on electricity generation)

	MW	**GWh**	**Steam (t/h)**	**Gas (%)**	**CO_2 (kt/year)**	**CO_2 (g/kWh)**
Ohaaki	40	343	348	2.86	86	249
Wairakei	161	1,384	1,377	0.59	44	32
Poihipi Road	25	212	200	0.43	7	35
Rotokawa	28	210	144	2.00	22	105
Mokai	61	430	308	1.30	28	66
Kawerau	32 (equiv.)	262	257	2.82	59	226
Ngawha	9	77	428 (total fluid)	1.32	46	597
Average	**51**	**417**	**437**	**1.62**	**42**	**100**
Coal Best Practice						955
Oil Best Practice						818
CCGT						430

2.1.2 Low Temperature Hydrothermal Resources (Including Hot and Warm Springs)

There are 25 major hot spring systems in the Taupo Volcanic Zone and at least another 100 outside this region (Figure 2.2), containing at least one spring. In some regions such as Waiwera, Parakai and Tauranga, most of the springs have disappeared because of groundwater changes, and all hot waters are presently discharged from wells.

In practice, springs are evidence of an underlying warm or hot reservoir. The cessation of a spring does not represent the loss of a resource. The spring gives a minimum estimate of the natural recharge of the reservoir, though it is likely to be a significant underestimate due to subsurface flows

[14] In the past, a landowner built a greenhouse beside the lake and regulated water flow from the lake to control heat flow through the soil to his greenhouse.
[15] Bay of Plenty Electricity owns electricity generation facilities on either side of the river extracting heat from a portion of the available hot water for electricity generation.
[16] This rough estimate is based on Kawerau brine flows given in Geothermal Direct Use Report (White 2006)

mixing with other groundwater. In most cases, neither the extent of the reservoirs has been estimated, nor practical limits assessed on development.

There are several areas in which springs are (or have been) common. The most notable is the Taupo Volcanic Zone. Other areas include the vicinity of Kaikohe, north of Auckland, a large area north and east of Hamilton, the region between Matamata and Thames, the vicinity of Tauranga, an area between Poverty Bay and the Bay of Plenty, and through the Southern Alps.

Based solely on spring flow rather than any assessment of heat in place within reservoirs, the Taupo Volcanic Zone has at least 7,500 MW_{th} (230PJ/year) of energy available from surface springs, including springs in the Waikato River, Lake Taupo and Lake Rotorua (Bibby et al, 1995). At least another ~150 MW_{th} (4.5PJ/year) are present in hot springs outside the region, with 130 MW_{th} (4PJ/year) in the North Island and 20 MW_{th} (0.6PJ/year) in the South Island.

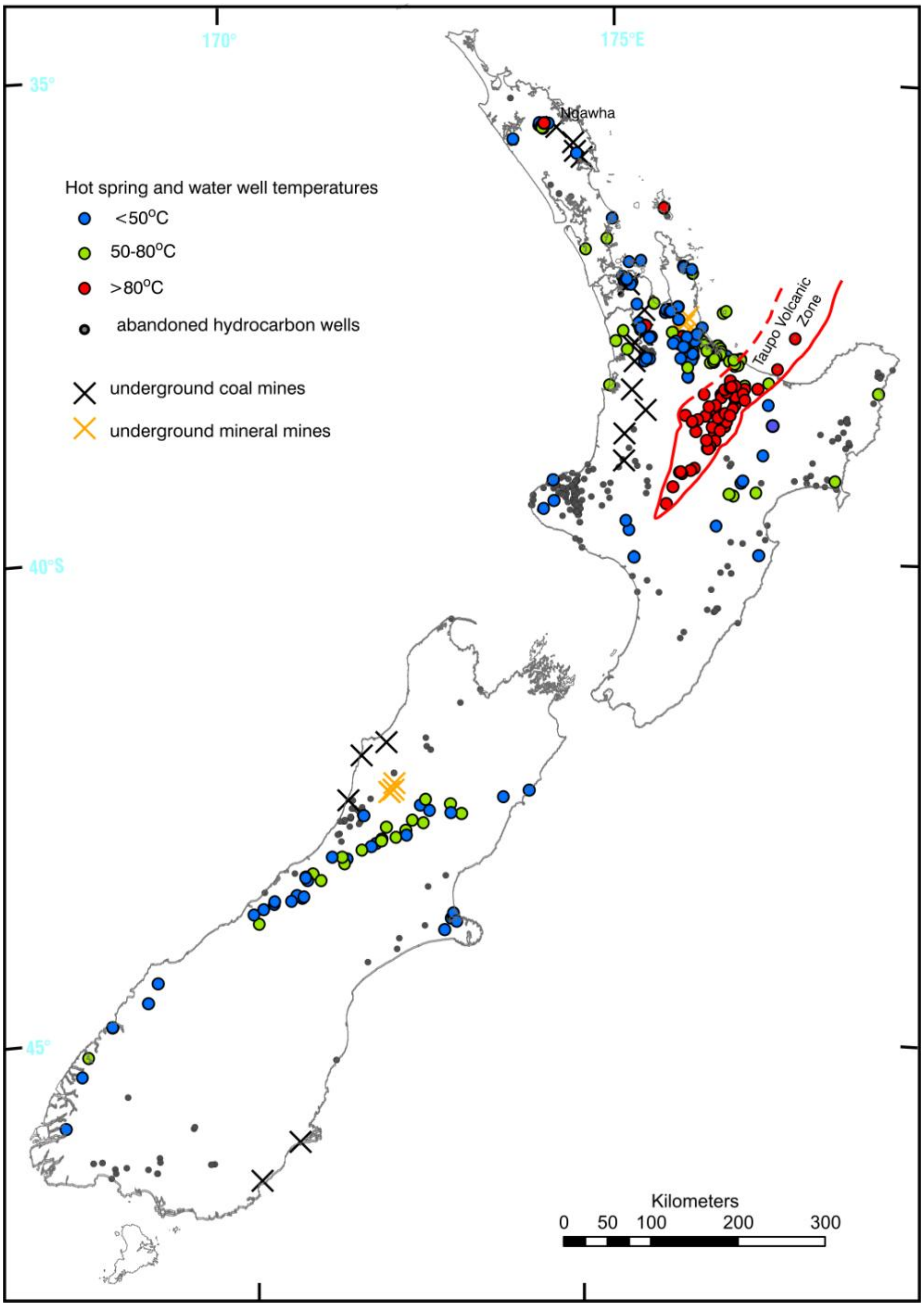

Figure 2.2. Location map of some geothermal sources including hot spring systems and their maximum surface discharge temperatures, abandoned onshore hydrocarbon wells and abandoned flooded underground coal and mineral mines (Reyes, 2007).

2.1.3 Enhanced Geothermal Systems (Hot Dry Rock)

There is growing interest in extraction of energy from enhanced geothermal systems (EGS), which includes a subset of projects previously referred to as "hot dry rock" projects. An exploration consenting regime has been established in Australia which has lead to the initiation of numerous projects. A recent US study undertaken through the Massachusetts Institute of Technology (MIT) on "The Future of Geothermal Energy" has focussed on the potential of EGS developments in the United States.

EGS developments take advantage of the conductive temperature gradient present in the earth above its molten interior. They are "enhanced" when zones of effective heat transfer are created by fractures generated (or exist) say by pumping water at high pressure. Normally an EGS development will involve at least two wells, to act as producers and injectors so that heat may be continuously mined between them.

The MIT methodology has been applied to New Zealand to give an assessment of available energy from EGS resources in New Zealand.

The area used is based on a total area of 185,579 km^2, about 70% of the New Zealand landmass excluding national parks, forest parks, reserves and protected land – see Figure 2.3.

The starting point for an assessment of energy from EGS systems is measured temperature profiles from widespread wells. In New Zealand, oil and gas wells have bottom hole temperatures which can give a rough assessment of the temperatures intersected (see Appendix 1).

There are 349 onshore abandoned hydrocarbon wells in New Zealand (Figure 2.4) drilled to depths of 17 to 5,065 m with bottomhole temperatures from 16^{o}C to 170^{o}C. Forty percent of these wells (140) are found in Taranaki, within or near populated areas. Wells >4000 m are mostly found in Taranaki, except for one in the East Coast. Seventy-five percent (265) of the onshore wells have bottom hole temperatures <75^{o}C, and 15% (55) have temperatures between 100-120^{o}C. Except for 3 wells, all wells with bottom hole temperatures >120^{o}C are found in Taranaki. The 3 wells outside Taranaki are found in Northland (125^{o}C), East Coast (150^{o}C) and in the West Coast of South Island (130^{o}C; Reyes, 2006).

The areas where the thermal gradient[17] is greater than 33^{o}C/km consist of:

South Island	18,800 km^2 (12% of South Island)
North Island including	20,350 km^2 (18% of North Island)
(Taupo Volcanic Zone	7200 km^2)
(Coromandel	2400 km^2)
(the rest of North Island	15550 km^2)

Within the Taupo Volcanic Zone and the Coromandel, the rock formations are dominated by volcanics where the heat capacity and density are 0.79 kJ/kg and 2800 kg/m^3, respectively. Outside the Taupo Volcanic Zone the rock formation at depth is dominated by greywacke with a heat capacity and density of 0.92 kJ/kg and 2670 kg/m^3, respectively.

The areas where the thermal gradient is at least 21^{o}C/km and ranges up to about 33^{o}C/km consist of:

South Island	75,000 km^2 (47% of South Island)
North Island	71,422 km^2 (61% of North Island)

[17] Thermal gradient is the change in temperature with depth e.g. a 33^{o}C/km gradient indicates that for every 1 km depth increase the temperature increases 33^{o}C. At 3km the temperature should be 99^{o}C plus the ambient temperature of about 15^{o}C resulting in a temperature of 114^{o}C

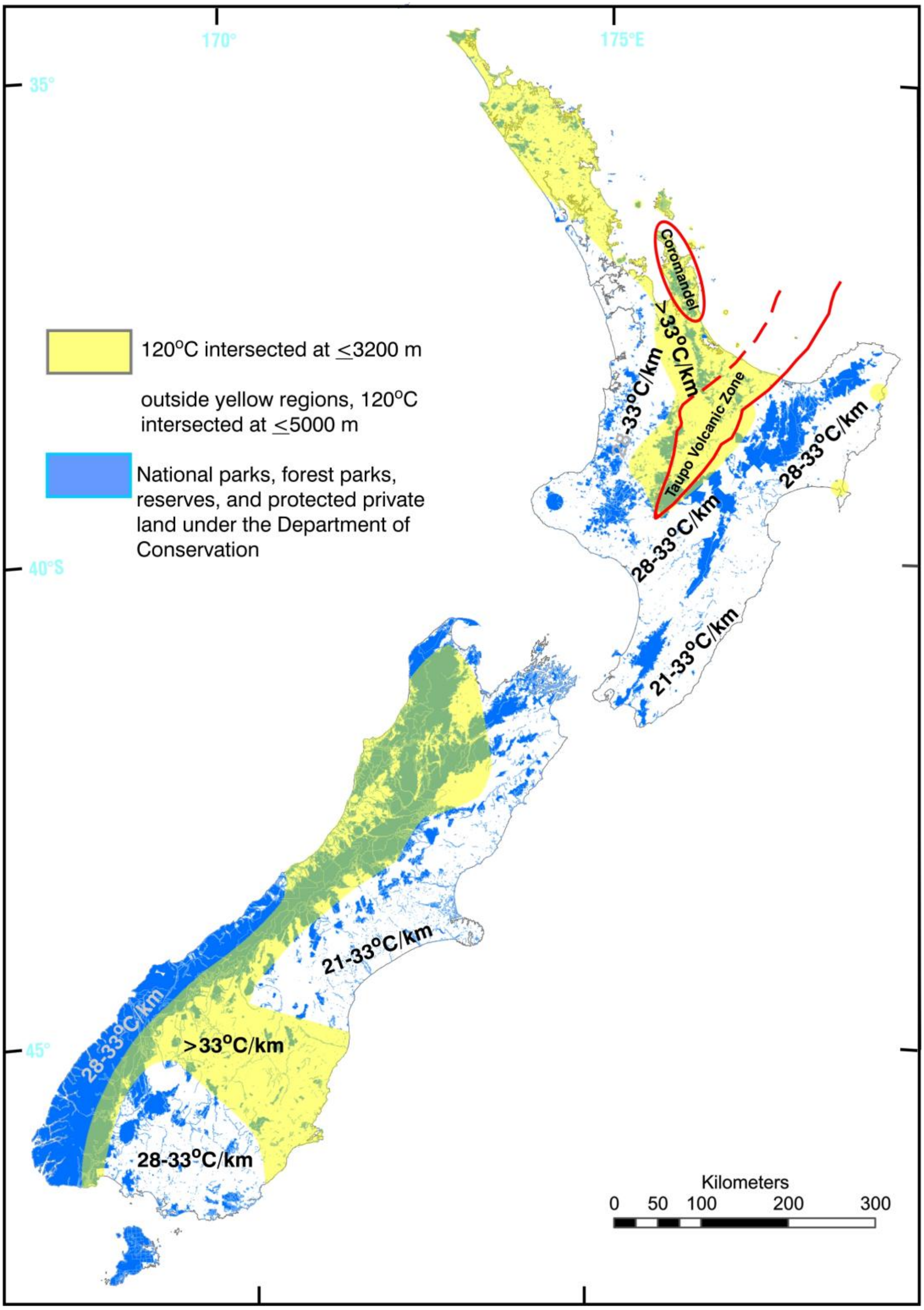

Figure 2.3. Areas used in calculating the minimum potential heat energy in the rock using shallow and deep-seated conductive heat (Reyes 2007).

A reference temperature of 50°C has been chosen to reflect the temperature on which existing commercial hot pool developments have been based on, for which well drilling was required. This temperature is also useful for space heating requirements. Cooling of the reservoir below 50°C is assumed to lead to abandonment. The EGS assessment takes into account all rock over this temperature.

The MIT study assumed that rock would only be allowed to cool by 10°C. While there is no obvious reason why the rock matrix could not be cooled down to 50°C, this added restriction would imply a more sustainable resource use.

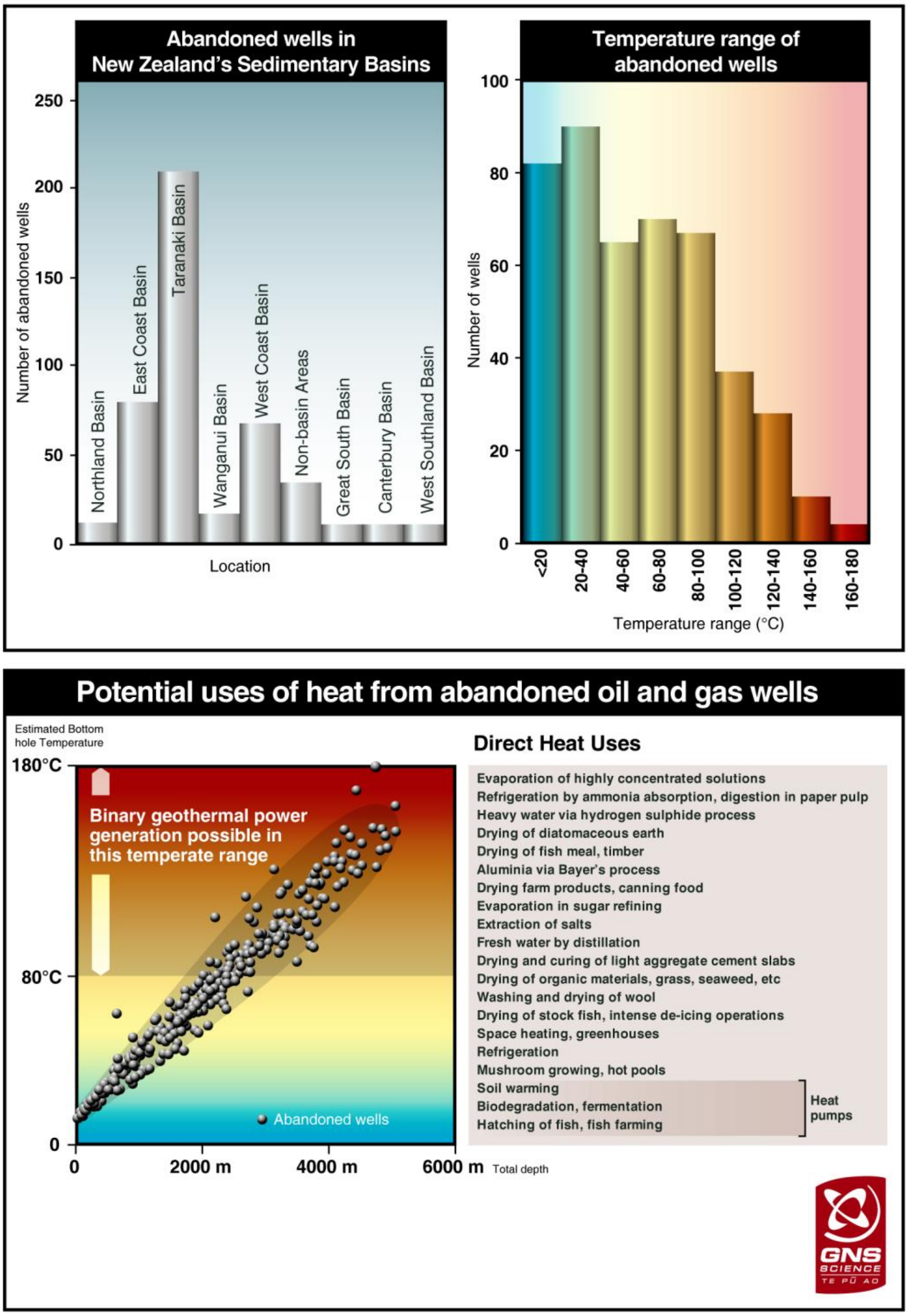

Figure 2.4. Abandoned hydrocarbon wells in offshore[18] and onshore New Zealand showing the number of wells in various basins, temperatures and possible geothermal uses (Reyes 2007).

The MIT study considered all heat between 3,000 and 10,000 m depth with a focus on heat for electricity generation. For this assessment of heat for New Zealand direct use applications, because abandonment temperature is not as great as for electricity generation, shallower depths can be considered. Maximum depth is taken as 5,000m consistent with the deepest wells drilled in New Zealand.

Calculations of heat in place i.e. the total EGS resource are provided in Appendix 2 and are summarised in the following table.

[18] The well with the highest estimated bottomhole temperature is an offshore well.

Table 2.3: Summary of the Assessed Heat Available from the New Zealand EGS Resource

Area	Area (km^2)	Depth (m) where 50°C intersected	Depth (m) where 60°C intersected	Volume 50°C to 60°C (km^3)	Volume 60°C to 5000m (km^3)	Cgw kJ/kg	ρ gw (kg/m^3)	PJ/ year
>33°C/km[1]	29,550	1,060	1,360	8,950	107,450	0.92	2670	98,080
-TVZ	7,200	640	820	1,310	30,110	0.79	2800	24,700
-Coromandel	2,400	920	1,180	630	9,160	0.79	2800	7,610
21-33°C/km	146,428	1,300	1,670	54,230	488,090	0.92	2670	451,450
Total	185,579							581,840
2% recovery of heat from ground								11,640
50% conversion efficiency								5,820

[1]minus the area of the TVZ and Coromandel where rocks would be mainly volcanics and the thermal gradients at least 55°C/km and 38°C/km, respectively; $\Phi = 0.1$; $C_{water} = 4.18$ kJ/kg; $\rho_{water} = 1000$ kg/m^3;; C gw = heat capacity of greywacke; ρ gw = density of greywacke; life of development is assumed to be 30 years[19]

Assuming a 30 year project life, a recovery factor of 2%[20], and an energy conversion factor of 50% implies a direct use potential of over 5,800 PJ/year. This energy availability exceeds New Zealand's total energy inputs from all sources by an order of magnitude.

This calculation takes no account of the amount of energy that might be economic. However, there will be obvious high priority targets including:

- Lateral and vertical extensions of known high temperature fields. There will clearly be abnormally high temperature gradients in the vicinity of these fields. Rock fracturing techniques could give access to new sectors of the resource to either supply the power station or adjacent users.

- Use/modification of existing abandoned hydrocarbon wells. Existing wells give cheaper access to a deep resource. Drilling records may indicate deep warm or hot reservoirs. Recompletion of these wells to seal off hydrocarbon zones and produce from (or inject into) these reservoirs could be commercially attractive. One well in New Plymouth has already been adapted as a heat source for a swimming pool and source of mineral drinking water.

2.1.3.1 Position on EGS Resources for the Remainder of this Report

While there may indeed be some uptake of EGS resources, particularly taking advantage of modified abandoned oil and gas wells, there are still many unknowns. Development costs are highly uncertain. Risks are high. Economies of scale, particularly for direct use currently and in the periods up to 2020 and 2030 do not justify these risks or expenditure. Thus, although the resource is of great magnitude, applications for this resource are not considered for the remainder of the report.

2.1.4 Geothermal Heat Pumps

Geothermal heat pumps are distinct from the more common air source heat pumps because they exchange heat from the ground or groundwater, which is at more stable temperatures than air.

[19] Throughout this report greywacke density data is from Malengreau et al 2000, and the upper value for andesite is from Johnson and Olhoeft (1984). The heat capacity of greywacke is that of sandstone (www.edumine.com) and the heat capacity of granite (www.EngineeringToolbox.com) at 27°C and 100 kPa is used as a proxy for andesite. Water constants are from Weast et al (1989)

[20] A recovery factor of 2% is the most pessimistic recovery estimate within the MIT study. Optimistic views ranged up to 40%.

The heat exchanger is either located in vertical wells, potentially up to 50m deep, or in horizontal trenches possibly only 1 or 2 m deep. They work best in damp conditions, emphasising that it is the continuous flushing of groundwater that make them most effective. However, a lower bound estimate of heat available can be made by looking at the heat gradient and total heat in the top 50m (outside the excluded areas indicated in the previous section), and allowing this to cool to ambient conditions. Calculations are undertaken in Appendix 3.

Table 2.4: Summary of Lower Bound Calculations for Heat Available to Geothermal Heat Pumps

Region	Area (km^2)	Depth (m)	½ (Tf-To) (^oC)	Volume (km^3)	C_{rock} (kJ/kg)	ρ_{rock} (kg/m^3)	Heat Supply (PJ/year)
>33^{o}C/km[1]	29,550	50	0.83	1,478	0.92	2,670	107
-TVZ	7,200	50	1.38	360	0.79	2,800	40
-Coromandel	2,400	50	0.95	120	0.79	2,800	9
21^{o}C-33^{o}C/km	146,429	50	0.68	7,321	0.92	2,670	433
Total	185,579						589
10% recovery of heat from ground							59

[1]minus the area of the TVZ and Coromandel where rocks would be mainly volcanics and the thermal gradients at least 55^{o}C/km and 38^{o}C/km, respectively; Φ = 0; C_{water}= 4.18 kJ/kg; ρ_{water}= 1000 kg/m^3; C gw = heat capacity of greywacke; ρ gw = density of greywacke; life of heat pump application is assumed to be 30 years.

Note that assumptions here are very conservative. They take no account of flushing of heat by groundwater of the possibility of the heat pump operating in cooling mode in summer.

Geothermal heat pumps work best in moist sandy or moist soil environments. Consequently, there may be preferential uptake in valley floors, on plains or in coastal areas. No specific study of the best locations have been undertaken for this study.

2.1.4.1 Flooded Mines

There are 22 abandoned underground coal mines and at least 9 gold and one copper mines which are flooded. Estimated temperatures in mines range from 18^{o}C to 24^{o}C in coal mines, with a mean of 18^{o}C. Temperatures are higher in gold mines at 19^{o}C to 35^{o}C with a mean of 23^{o}C mainly because the mines are as deep as 700 to 850 m.

Arguably, the energy associated with this water has largely been accounted for in the assessments for heat pump purposes. However, the flooded areas may allow a cheaper and more effective large scale heat pump operation where they are suitably located e.g. in places like Huntly or Thames[21].

2.1.4.2 Waterside Developments

Any development located by water, whether it be a lake, harbour, river, stream, drain or irrigation ditch, can use the water as a heat source or sink as part of a heat pump application. A large Blenheim house uses water diverted from a nearby irrigation ditch as a heat source for home heating. A Taupo application draws water from Lake Taupo. In other countries, there are apartment and commercial developments in wharf environments that take advantage of sea water, and the same could be done in Wellington or Auckland harbours say for offices or apartments.

Assessments of the uptake of this resource have been included in the later assessment of heat pump uptake.

[21] In some cases there may be fluid chemistry issues with flooded mines.

2.2 Existing Land Use in the Vicinity of Geothermal Resources

Geothermal energy would normally be used in the immediate vicinity of the resource. Consequently, current land use will partly determine potential applications of the geothermal heat available.

A superficial review of conventional geothermal resource locations shows that most of these are located in rural environments[22]. A quarter are in remote areas (e.g. in forest parks or on remote islands) and would not normally be considered for development beyond casual bathing. About 10% would have housing (including those that might otherwise be considered of a rural nature such as Waihi and Waiwera).

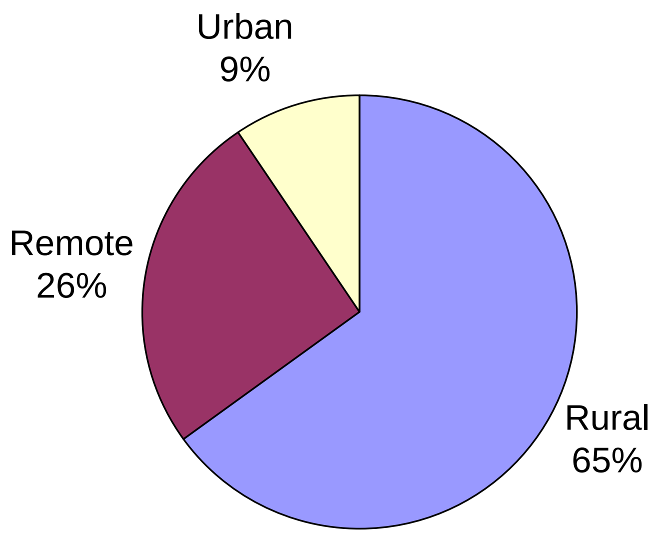

Figure 2.5: Land use associated with conventional geothermal resources

Remote locations are not considered further.

Rural environments offer flexibility of use. Farm or forestry land will initially have very low intensity of energy use on a GJ/m^2/annum basis, though the cost of energy supply to rural sites may become an increasing issue. However land can be converted to more intensive energy use, say through the installation of greenhouses, or through radical change such as the development of an industrial site on the land. A greenhouse may have an energy intensity of the order of 1-3 GJ/m^2/annum principally for heating.

Possibly more important from a development point of view is the strong correlation between the locations of several of the high temperature fields in the Taupo Volcanic Zone and the major forest plantations and processing plant in the Central North Island (see Figure 2.6). The forest concentration necessitates the concentration of wood processing plants, which include pulp and paper mills and kiln drying operations. This processing plant has a heat requirement which the high temperature fields can meet or supplement. In practice this market sector has been the major user of geothermal heat (focussed on the Kawerau mills), both in the past and in the latest major direct use projects.

Urban environments are marked by a higher density of energy demand due to population density. Domestic premises have an energy intensity of around 0.3 GJ/m^2/annum and commercial premises,

[22] This review was based on a scan of the geothermal areas listed in Appendix 4. In turn, this list has been taken from White (2006) *An Assessment of Geothermal Direct Heat Use in New Zealand*

hotels etc may have intensities of around 1 GJ/m^2/annum based on floor area[23]. In practice, much of a developed site may not be covered with building floor, so effective energy intensity for a site may be a fraction of the stated value, with much of this being for space or water heating. There may also be more intensive industrial uses in some parts of the urban environment.

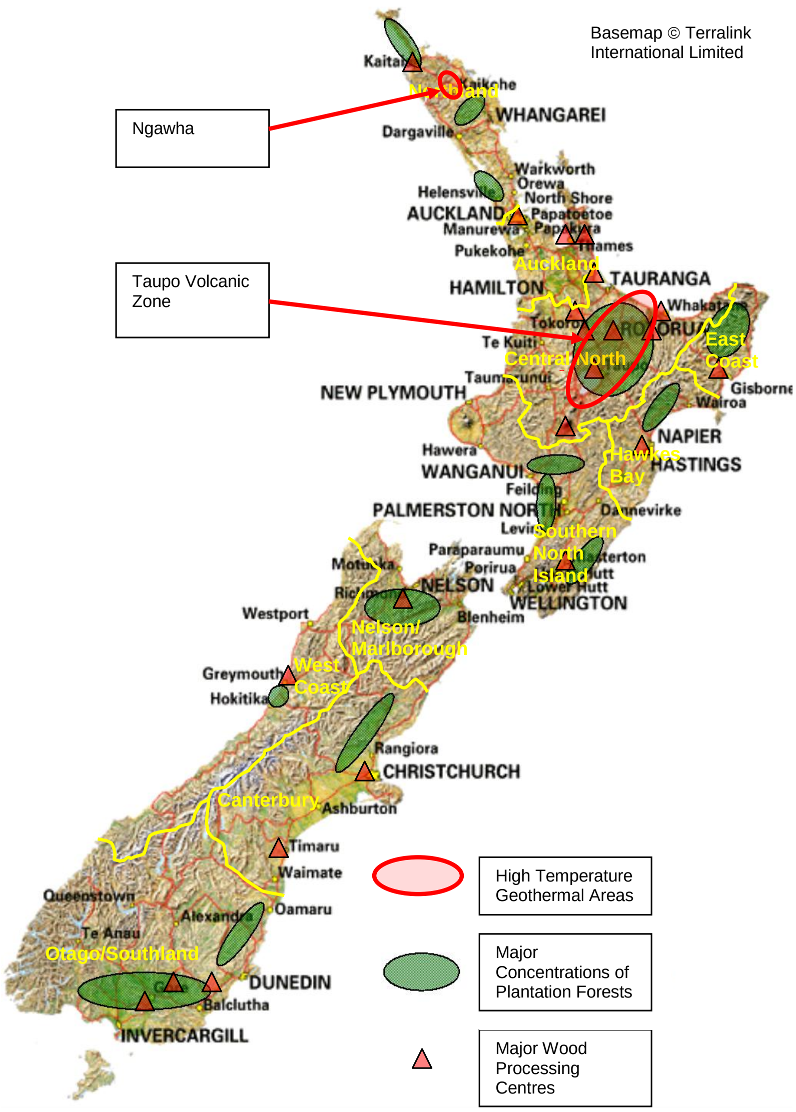

Figure 2.6: Correlation between high temperature fields and major forest processing centres (East Harbour 2005)

2.3 Issues Arising from Intensity of Energy Use

A review of heat available from high temperature fields shows that these can generate of the order of 2 GJ/m^2/annum of heat (see Table 2.1), while enhanced geothermal systems may only generate 0.03 GJ/m^2/annum (see Table 2.3).

From section 2.3, energy use intensity is likely to be less than 1 GJ/m^2/annum. A comparison between supply and demand energy densities has implications for development. The heat demand for direct use from a high temperature field will be less than it is capable of supplying. To utilise a

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[23] EECA (2000) *The Dynamics of Energy Efficiency Trends in New Zealand – A compendium of energy end-use analysis and statistics.*

field's full potential it will be necessary to include a more intensive energy use such as electricity generation or a large industrial heat use. EGS resources may be more closely matched to load in terms of energy intensity.

In terms of forestry, processing heat demands are significant, and high temperature fields in the vicinity can help to meet demands.

2.4 Summary

Geothermal energy is a form of renewable energy. The geothermal resources available at accessible depths in New Zealand far exceed any imaginable usage, though a distinction must be made between resources, reserves and economically recoverable energy. As a rule geothermal energy must be used near where it is found rather than being piped many kms to an interested user, but having said that, there are examples where geothermal heat is piped many 10s of kms when there is demand and sufficient value in the supply of heat e.g. Iceland.

Total national geothermal resources are summarised in the following table, including their location.

Table 2.5: A Summary of the Total Geothermal Resource in New Zealand (of which only a Small Portion will be Economically Recoverable, and only a Portion will be Used Directly)

Resource Type	Consumer Heat Capacity (PJ/year)	Comments
Conventional		
High Temperature	356	Resources are concentrated in the central North Island and near Kaikohe. Most of this high temperature resource will be dedicated to electricity generation.
Low Temperature/springs	>235	Resources are more widely scattered, but are commonly rural or remote. More could be done with these though further definition of resources is required.
Unconventional		
Enhanced Geothermal Systems (Hot Dry Rock)	5,820	The method for assessment still needs to be refined. Development costs for direct use have not been researched but would not justify a small development. There may be cheap entry options on margins of high temperature fields or using abandoned oil and gas wells.
Geothermal Heat Pumps	>59	These can be used virtually anywhere nationally, and are now economic for any demand greater than that of a large domestic home. There are excellent opportunities for waterside developments or in moist sandy soils.

In considering the location of geothermal resources, there is a strong correlation between location of high temperature geothermal resources and plantation forests and associated forest processing plant. Given the high heat demand in forest processing, this suggests the possibility of direct use of geothermal energy in forest processing, and this has been the case historically. This is most evident at Kawerau where a single geothermal steam supply supplies pulp and paper mills with an energy quantity that matches the sum of all geothermal industrial supply anywhere else in the world.

In many cases direct use intensity will not challenge a field's ability to supply. If a field's potential is to largely be met then electricity generation or an intense industrial application will have to be included in the suite of development options.

3 Technologies for Direct Use of Geothermal (Including Heat Pumps)

This chapter briefly describes the technologies involved in direct use of geothermal energy. The focus is on delivery of heat, rather than the details of specific applications. There are a range of means of both accessing the resource, and then finally rejecting geothermal fluids, of which wells are just one example.

Considerable detail on technologies and direct use applications are summarised in the GNS Science report "Practical Guide to Exploiting Low Temperature Geothermal Resources", and the following discussion is partly based on that report. It also draws on discussions held with various New Zealand direct heat users as part of the development of a direct use data base commenced by the New Zealand Geothermal Association as part of the EECA/NZGA geothermal direct use assessment.

3.1 Accessing Geothermal Heat

A survey of direct heat users shows the following sources of heating:

- Naturally warm ground – siting of dwellings on warm soil was one of the traditional methods of space heating used by Maori. In a more recent case at Kawerau, a greenhouse was located beside a geothermally-sourced lake and heat to the greenhouse was regulated by control of lake level through adjustment of a weir at the lake's outlet[24].

- Warm/hot springs – many people visit natural hot springs for bathing. There are many relatively unspoiled springs in remote areas of New Zealand. Transient pools can be created at places like Hot Water Beach for bathing. Some of the New Zealand springs have had various degrees of modification e.g. shaping, concreted margins and changing sheds (examples include Ngawha Springs, the Okoroire Hot Springs in the Waikato area, and the Waitangi Soda Springs at Rotoma). In the EECA/NZGA direct heat assessment, this level of modification is not recognised as a direct heat use application. However, in many cases water is collected and diverted from springs for use in other applications. This relatively cheap collection system sets the trigger level for recognition as direct heat use. While some examples may be on a small scale (e.g. for swimming pool use at the Kamo Springs holiday park) others can involve large quantities of heat and fluid (e.g. for swimming pool use at Morere on the East Coast or at Waikite in the Taupo Volcanic Zone). Given that springs have natural variability in flow and temperature, there is some risk in using this method of heat collection.

- Hot streams – a variation on use of springs is tapping into hot streams.

- Artesian wells – the drilling of wells involves a step up in costs. High temperature wells are often artesian (i.e. flow under their own pressure e.g. as found in Tokaanu, Taupo, Rotorua or Kawerau), but some low temperature wells are artesian also. Wells can be drilled with a range of drilling equipment and have a variety of designs depending on the nature and depth of the resource, and the quantities of heat required. Consequently well costs can vary from $6,000 (say for a low cost Taupo well) to $6 million (as for some wells at Kawerau).

- Pumped wells – often wells will tap a shallow aquifer and will require pumping. There are many examples of this in the Hauraki Geothermal Region and around Tauranga. Designs are site-specific but pump impellors may be only 10's of meters deep. Internationally, there

[24] This greenhouse is no longer operational

are pumped systems linked into large scale district heating schemes. For local applications the pumps may be operating in 40 -60°C fluid, but there are examples in the US where pumped systems exist with field temperatures exceeding 150°C.

- Wells with downhole heat exchangers – rather than extract fluids from the ground there has been a recent trend towards use of downhole heat exchangers (DHEs) to extract heat directly from a reservoir. This is an option favoured by some regional councils whose management of the resources involves maintenance of water levels. These involve a well with downward and upward legs of a closed-circuit pipe. Within the well there may be means of encouraging local hot circulation of fluid to maximise heat transfer. Water (or other fluid) passing down the pipe is heated as it descends but can cool on ascent, especially at shallow depths within the well.

- From other geothermal fluid users – In some cases, wells have capacities in excess of the demands of the primary geothermal fluid users. In these cases costs can be reduced by sharing them across multiple users. The opportunity exists for other consumers in the immediate vicinity to negotiate use of the heat supply. While there is a commonly held belief that there is little opportunity for district heating in New Zealand, there are many examples of limited schemes. As an example in Rotorua in 1985 there were a total of 188 domestic wells but these were connected to 1512 separate users i.e. the mini-schemes averaged 8 users per well. One of the largest schemes that was impacted by the forced well closures in Rotorua had 95 domestic users linked to it. It is apparently not uncommon for recent Tauranga wells to be linked to 5 or so users.

- Special cases of wells – there are some special cases where wells have been drilled for other purposes. The obvious examples are oil and gas wells. Through penetrating to great depths, they intersect the natural conductive thermal gradient evident everywhere. In many parts of New Zealand, this gradient averages around 28°C/km. Since some oil and gas wells are drilled to 4 or 5 km in depth, these can intersect temperatures exceeding 160°C which is suitable for a wide range in applications (including electricity generation). There is one known case of an old oil well in New Plymouth that is now used for swimming pool heating and as a source of mineral water.

- Ground temperatures for heat pumps – heat pumps allow the use of low grade ground temperatures (still an example of “geo” “thermal” heat) almost anywhere in New Zealand as a source of heat. Heat pumps take advantage of the fact that soil and surface water temperatures do not vary to the same extent that atmospheric temperatures do – there is thermal inertia for these denser media. They do not rely on elevated temperatures as found in traditional geothermal areas.

  Within the category of groundsource heat pumps, heat can be accessed either by horizontal arrays of pipes within a shallow trench or from shallow vertical wells. The trench would typically be just over 1 m deep (potentially within the service trench to a new home or office), while the shallow wells depending on load may not be much deeper than pile foundation holes. Use of vertical holes has an appeal to drillers while trenching can be undertaken by building contractors. The pipe within the trench or well is normally thin-walled polyethylene pipe that acts as a heat exchanger, and contains water and possibly an antifreeze. The rate of heat transfer between the loop pipe and the surrounding ground is determined by the thermal conductivity of the ground. Favourable conditions require sandy ground, water saturated with high solar radiation (allowing extraction of 35-40 W/m^2) while the lower end of the scale would include pumice soils (as found in typical geothermal areas) and well drained stony ground in shaded areas (allowing heat extraction rates of only 8-12 W/m^2).

- Surface water temperatures for heat pumps – There are many surface waters, such as the sea or rivers, that can act as heat sources for heat pumps. Slightly warm well water was used for many years in a Hamilton commercial application. Shallow wells immediately beside Lake Taupo have been used recently. Another application has involved use of irrigation water as the heat source – clearly this could be an option for many farmers where homes are located near canals or irrigation ditches that are in continuous use. Sea water is an obvious heat source not currently used in New Zealand but with considerable potential. Any harbour-side development could tap into this, whether it is for large scale commercial developments or canal-based luxury holiday homes.

3.2 Disposing of Waste Fluids

Because use of geothermal heat often involves taking fluids from some location, there will also be disposal issues. The following describe options that are currently practiced in New Zealand.

- Onto land – This option can be relatively inexpensive in rural or remote areas, and can be quite acceptable environmentally when the fluid is relatively pure or if the ground is thermally active. The Ohaaki Timber Kilns send their waste water to a surface area designated and consented for such use.

- Into waterways or drains – this option is taken up almost universally for low temperature resources. Examples include Waiwera and Parakai near Auckland, most of the warm and hot springs through the Hauraki and Northern Geothermal Regions, and Hanmer and Maruia developments in the South Island. In terms of higher temperature fields, Arataki Honey on the Waiotapu geothermal field disposes of fluids from their well into surface geothermal water, while the Tokaanu public pool rejects its waste geothermal water to the hot Tokaanu stream. A large proportion of water from the Kawerau field is still disposed of to the Tarawera River. Similarly, many of the cascaded uses at Wairakei eventually dispose of their waste to the Waikato River. For Kawerau and Wairakei, river disposal is an historical option and reinjection into shallow and deeper wells has been trialled elsewhere on these fields.

- Into shallow wells – in some cases fluids may not be of sufficient quality to enter surface waterways, in which case an inexpensive option is to use shallow wells. One example of use of shallow wells for disposal is the Esendam greenhouse at Horohoro. This technique, along with disposal into shallow waterways was extensively used at one time in Rotorua. A weakness with the method is that fluids may simply enter shallow groundwater aquifers and may not directly return to the source reservoir. This has led to a restriction on this practice in the Rotorua area with a preference to return fluids to the source reservoir to maintain water levels, or not to extract fluids at all (only heat through downhole heat exchangers).

- Into deep wells – In the case of large scale commercial and industrial applications involving large quantities of hot, highly mineralised fluids, deep reinjection may be a preferable means of disposal. This is undertaken by Contact Energy for their supply to the Tenon kilns at Tauhara, but deep reinjection is still an exception rather than the rule for direct heat use.

- To adjacent users – One advantage of geothermal heat is the possibility of cascaded use. In this case, a portion of waste from one process may be passed to another user. In practice, cascaded use most commonly refers to downstream use of heat from geothermal power stations. However, there are some interesting applications at Kawerau. Norske Skog Tasman (NST) delivers low pressure steam to the chemical pulp mill now owned by Carter Holt Harvey Tasman. CHHT return condensate to NST. Elsewhere on the Kawerau site Carter Holt Harvey Woodproducts receive geothermal steam in parallel with NST for their kiln drying operation, but deliver their condensate back to NST for use in their feedwater system. In this case absorption of geothermal condensate has a range of positive benefits including offsetting the need for a further take of surface water by the mill.

Note that in the cases of downhole heat exchangers or of closed loop geothermal heat pumps, there are no fluid disposal issues.

3.3 Drilling and Wells

Many of the resource access or fluid disposal options outlined above involve wells. Well drilling is a major cost for a direct use geothermal project. Tapping a shallow reservoir is carried out using a rotary drilling rig and can be done in stages. The casing and wellhead differ for pressurised aquifers and non-pressurised aquifers.

Well costs vary considerably according to a number of factors but especially depth and diameter. A shallow Taupo well may cost as little as $6,000, while a deep well at Kawerau supplying either a power station or the mill could cost up to $6,000,000. Well life is of the order of 20 years.

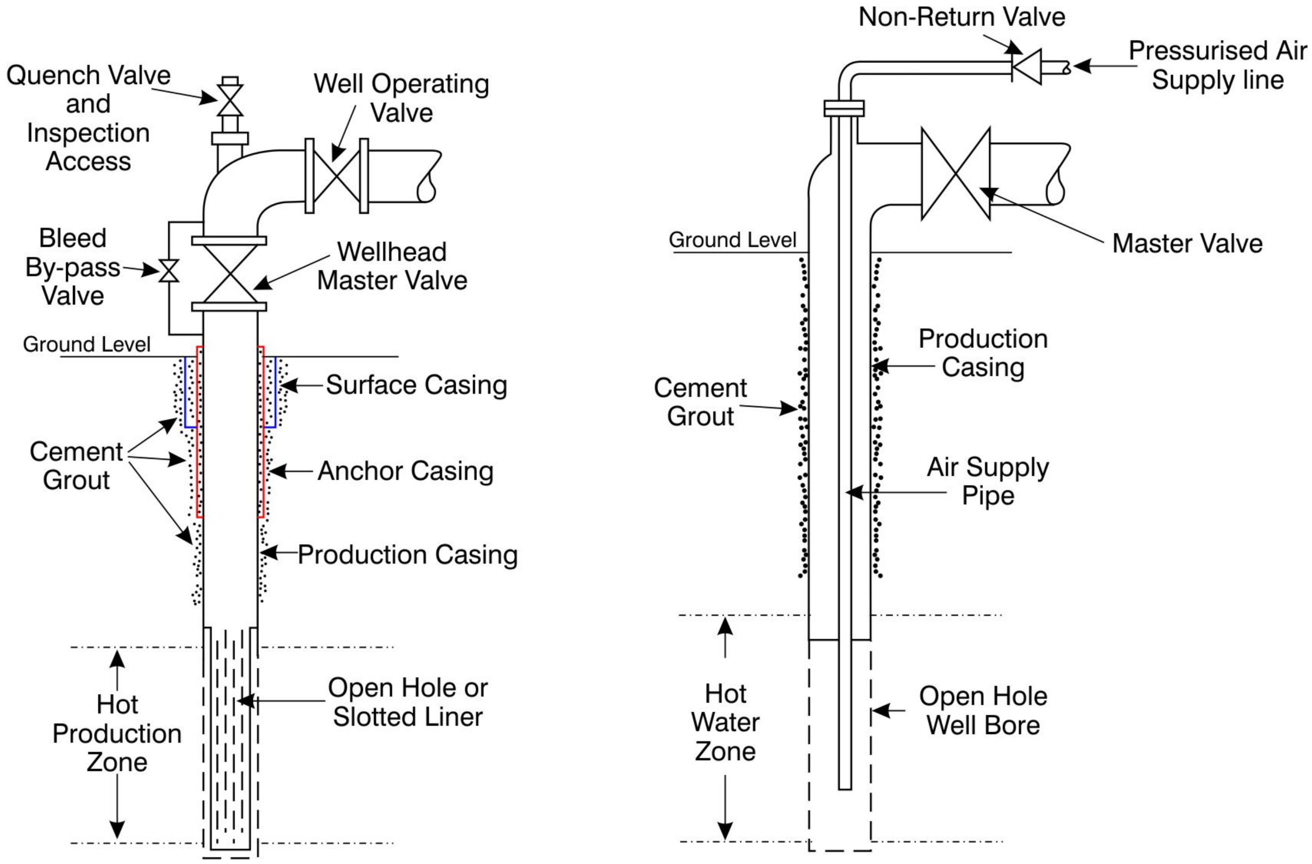

Figure 3.1. Typical wellhead and casing arrangements for pressurised and non-pressurised wells (Thain et al 2006)

3.4 Heat Exchangers

Heat exchangers transfer heat from a geothermal fluid to a closed process fluid loop. Most geothermal fluids, because of their elevated temperatures, contain a variety of dissolved chemicals. These chemicals can be corrosive or troublesome (in terms of scaling) so that it is advisable in many cases to isolate the geothermal fluid from the process to which the heat is being transferred. The main types of exchangers used are either plate heat exchangers or shell and tube heat exchangers (see Figure 3.2). The main advantage of the plate heat exchanger over the shell and tube design is their superior thermal transfer performance and smaller space requirements, but this is offset by greater cost.

Figure 3.2. Plate heat exchanger at the Taupo Prawn farm (Thain et al 2006)

The down hole heat exchanger (DHE) (Figure 3.3) is an example of a specific application designed to avoid either reducing pressures in an aquifer or disposing of fluids after use. The following figure shows a common design. In New Zealand the DHE has generally been used for small domestic applications serving a few households or an industrial application requiring a thermal output of around 100 to 150 kWt. Overseas DHE installations are credited with outputs of several MWt. DHE have been installed in wells of 200m depth. However because of the low output of these devices it is generally economic to operate DHEs only in wells of less than 100m.

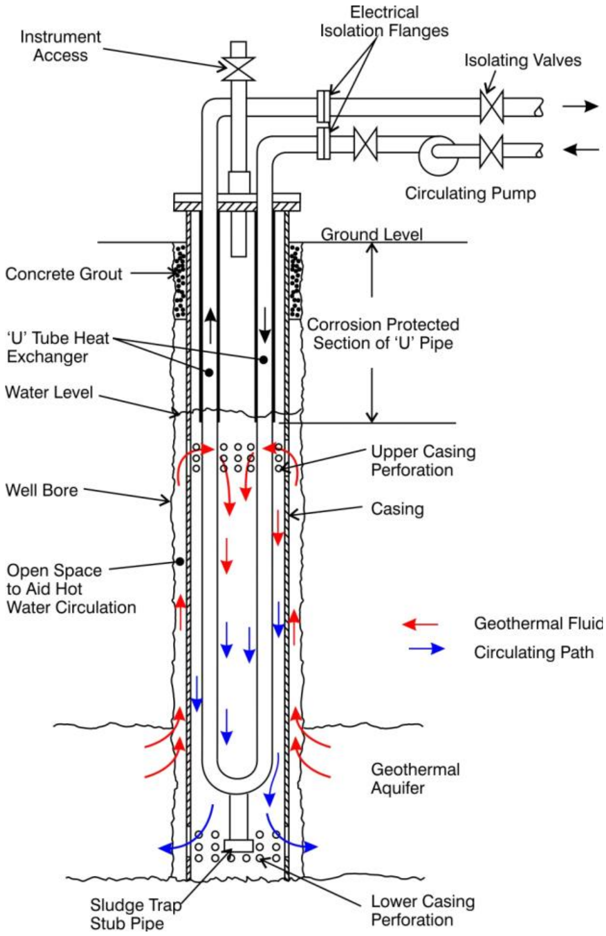

Figure 3.3: Typical down-hole heat exchanger with promoter tube casing (Thain et al 2006)

Down hole heat exchangers have a significant advantage over conventional geothermal well developments where the geothermal fluid is extracted. The down-hole heat exchanger allows the extraction only of heat and leaves the fluid within the earth undisturbed. This allows geothermal heat to be extracted from near sensitive geothermal areas such as the geysers and tourist attractions at Rotorua. From a resource consenting point of view this overcomes the majority of problems associated with geothermal fluid extraction.

3.5 Heat Pumps

Heat Pumps have been mentioned in this report already. Heat pumps work in a similar way to refrigerators – they take heat from one place and transfer it to another, using electrically-driven compressors (Figure 3.4). The electrical energy to run the system is a fraction of the final heat delivered. Depending on the type of heat pump system used, it is possible to get 3 – 6 kW of heating from 1 kW of electricity, with the ratio being known as the Coefficient of Performance (COP). Normal electric resistance heaters have a COP of one. Heat pumps are more expensive to buy and install than resistance heaters, but are justified on the basis of avoided electricity cost over the life of the heat pump.

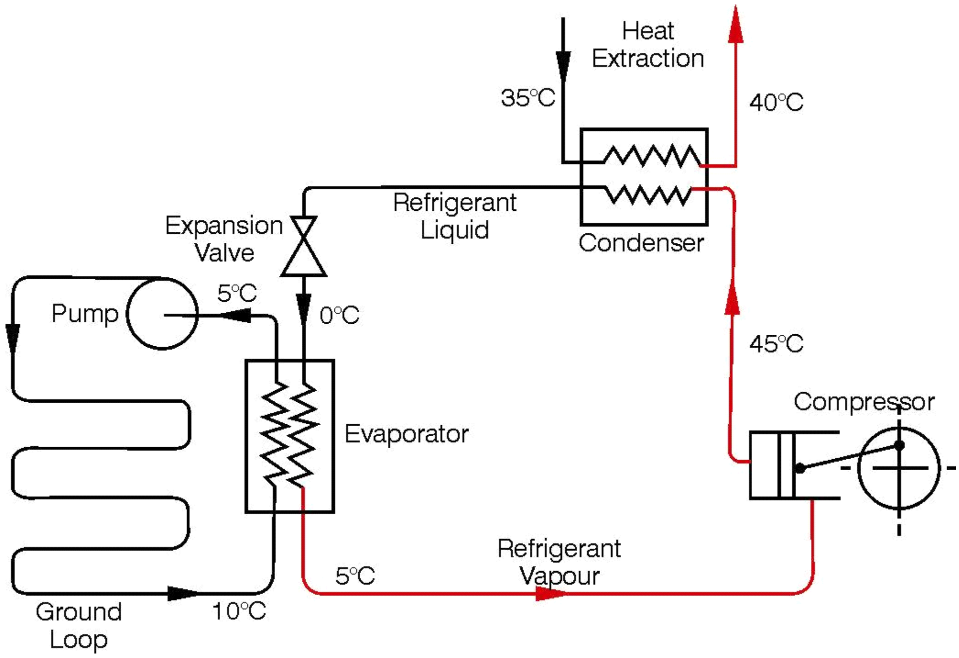

Figure 3.4. Typical components of a heat pump system (Thain et al 2006)

Most installed heat pumps are air-sourced in which heat drawn from the air outside the building is transferred indoors. Although such systems have high efficiency (COPs up to 5), the efficiency decreases as the outside air temperature varies with the seasons or between day and night. Essentially more electrical work must be done in colder conditions because there is less heat in the air and a greater temperature difference between outside temperature and the desired inside temperature. Average COPs end up in the 2-3.5 range.

Geothermal heat pump systems are very similar to air source heat pumps, but take advantage of the thermal inertia in ground and surface waters. Temperatures do not vary in ground or water as much as in air. This is illustrated in Figure 3.5. There is no reliance on elevated ground temperatures as might be found in traditional “geothermal” environments so geothermal heat pumps can be installed anywhere where the ground is adequately conductive, essentially requiring moist conditions.

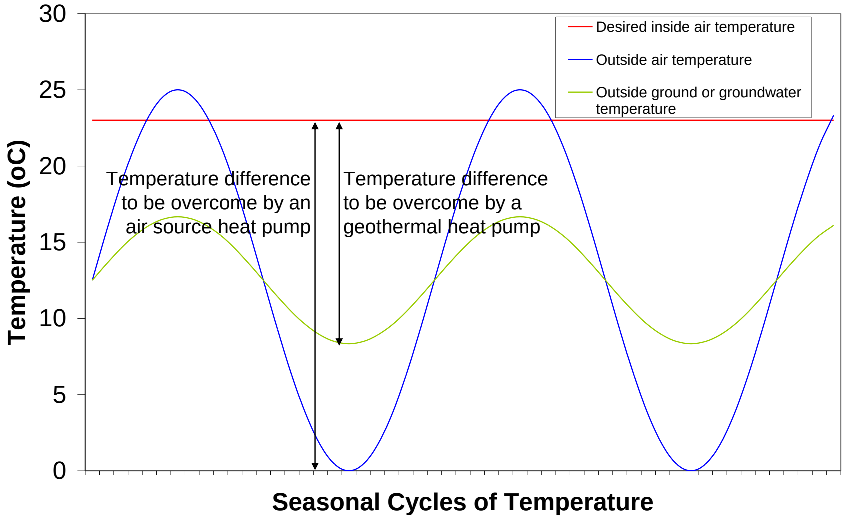

Figure 3.5. Illustration of the steadier ground temperatures for a geothermal heat pump that contribute to its higher overall efficiency than air source heat pumps.

The systems can use the following means of accessing heat:

- External closed loop ground source system with polyethylene pipe acting as a heat exchanger with the ground, either:
    - Placed horizontally in a trench, say a slightly deeper services trench of around 1-2 m depth, or
    - Run in vertical boreholes, or
- Pumping surface water
    - Directly through a heat pump, or
    - To an area in which polyethylene pipe has been laid for a closed loop system.

The heat pump can provide space heating by:

- Ducting warm or chilled air to various areas of the building
- Delivering warm water either:
    - To radiators located on walls, or
    - To an underfloor heating system, made up of a labyrinth of polyethylene pipes embedded in the concrete floor of a house[25].

Where warm water is produced, heat pumps can also be used to preheat water for household hot water requirements or for swimming pools.

The design based on water systems is similar for any fuel source whether for electricity, gas, coal or oil. It follows that retrofitting a geothermal heat pump system could readily be done. Normally, the systems will have programmable control systems and sectored heating allowing convenient and appropriate heating.

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[25] Underfloor systems are superior for delivering space heating, but the method cannot produce space cooling because the cold surface is likely to cause air moisture to condense on the floor.

There are obvious environmental and energy savings associated with use of these systems. In addition, geothermal heat pumps take up less space that conventional heating and cooling systems. Operation is relatively quiet. There is virtually no concern for coil freezing in contrast to air-source heat pumps.

There are examples of geothermal heat pump systems installed in New Zealand on large houses. Domestic applications overseas are relatively common in some areas. A large Hamilton office once had a geothermal heat pump system, but the office has subsequently been demolished. Internationally, application examples include heating the Sydney Opera House, various apartment and high rise buildings, while use in schools in the USA is common. In the latter case schools offer large playing fields in which loops can be laid, and radiator systems that allow retrofitting.

Current geothermal heat pump systems in New Zealand have working fluid temperatures around the 50°C range, which is adequate for preheating domestic hot water. New designs now being developed in China have working temperatures in the 70°C range, allowing full substitution of electric or gas hot water systems.

Table 3.1. Example Costs of Heat Pump Systems Including a comparison with air source heat pumps

Heating Capacity	6kW[26]	20kW[27]	726kW[28]	20kW air source heat pump[17]
Capital Cost (NZ$)	Heat pump $6-7,500 Ground loop $2,300[29] Underfloor/hot water system $2,500 Total cost ~ $12,000	Total cost ~ $24,000	Total cost ~ $488,000	Total cost ~ $19,000
COP	4	5	4.3	3.7

3.6 Other Specific Technologies and Applications

The GNS Science Report "A Practical Guide to Exploiting Low Temperature Geothermal Resources" contains a range of descriptions of direct use applications in New Zealand. In particular the report discusses timber drying and greenhouse heating systems.

3.7 Summary

There are a range of means of accessing geothermal resources (including simple collection of spring water through to drilling wells) and disposing of unused energy. Frequently, unused energy is thought of as waste, but discharge from an application is not waste until treated as such by the user.

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[26] Example provided by Ian Thain in the GNS report "A Practical Guide to Exploiting Low Temperature Geothermal Resources"

[27] Examples provided by Phil Davis of Warmfloor Heating

[28] Example from Wang, Z and Wang, H (July 2006) *Economic Analysis of Water Source Heat Pump System* in Proceedings of the 7th Asian Geothermal Symposium

[29] Assuming favourable sandy moist soil

When treated in this manner it can pose problems, say for downstream cascade users. Any developer needs to keep a focus on supplying a quality trouble-free product to the user.

This report has assessed that geothermal heat pumps are commercially viable now for demands greater than that generated by a large house. While heat pumps push the definition of “geothermal” to the limit, they are routinely regarded as geothermal technology in international reporting. These just rely on the more stable temperatures of soil or ground water compared to the more variable air temperature, to create a heat pump more efficient that air source heat pumps i.e. they could potentially be used anywhere and do not rely on the traditional “geothermal areas” to operate. Installed capital costs are high compared with a range of other technologies, but fuel costs (electricity) are low because of their high efficiency.

As a comparative example of geothermal heat pump costs, the total installed geothermal heat pump system with a peak heating duty of 20kW (say a small commercial application) would have a capital cost of around $24,000 and require only 4kW of electric power, while an air-source heat pump system for the same duty would cost $19,000 and require 5.5kW of electric power. Even a small geothermal heat pump system for domestic purposes will cost around $12,000, this being a significant deterrent to uptake.

4 Traditional and Potential Direct Users of Geothermal Energy

The following chapter looks at historical and current use of geothermal energy, discussing past trends. Major users are briefly discussed, and a view is developed on who future users are likely to be (including heat pump applications) based on both New Zealand trends and experience from overseas studies. The chapter finishes with a discussion of individual sectors within New Zealand to broadly determine parameters for the assessment of potential uptake.

4.1 Historical and Current Use and Users

For centuries, geothermal waters have been used for direct heating in a wide range of domestic, agricultural and industrial applications. The following diagram (a revised Lindal diagram) illustrates these potential applications. In New Zealand, Maori pioneered the use of geothermal energy sometimes co-locating villages to take advantage of thermal and other properties. Focussing on the thermal properties, direct use included for cooking, home heating and bathing.

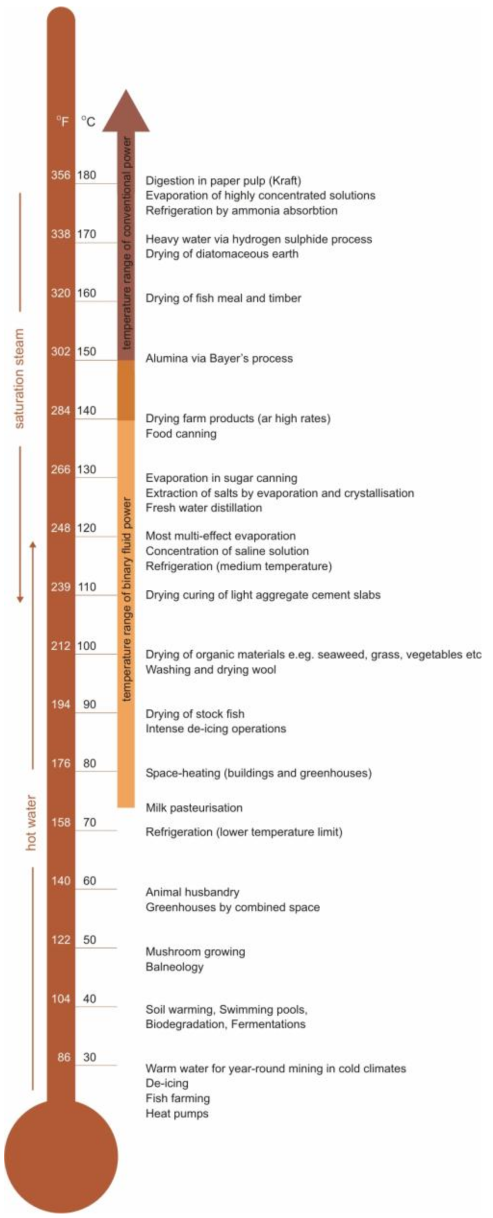

Figure 4.1 Revised Lindal diagram showing applications for geothermal resources (Thain et al 2006)

A century (and more) ago there was a strong link between tourism and geothermal use. Most commonly, geothermal waters were used for bathing complexes. These complexes were located in the Taupo/Rotorua area, but also in places like Hanmer and Maruia in the South Island, the Hauraki plains (especially at Te Aroha, but also Okoroire), north Auckland (Parakai and Waiwera) and Northland (including Ngawha). Warm waters for bathing were both soothing while reputedly having healing properties. By 1904 there were over 100,000 visitors to spa baths in New Zealand[30].

One of the first large scale industrial uses of geothermal energy was at Kerepehi hot springs, in the Hauraki geothermal region, where water at about 57^{o}C was tapped by shallow wells and used for flax washing, with some limited domestic use. Use finished with the demise of the flax industry.

The pulp and paper, and timber processing developments at Kawerau were the most significant industrial application developed in recent times. Processing facilities were located on the site to take advantage both of the forestry resource, proximity to port and energy from both the Kawerau geothermal field and from the nearby Matahina hydro power station. Direct heat use at Kawerau was (and still is) the largest industrial direct use application in the world. Initial steam supply to the mill commenced in 1957 predating the commissioning of Wairakei power station as the first large scale commercial development of a wet steamfield in the world.

From the 1950's, a national energy crisis acted as a driver to accelerate direct use of geothermal energy in places like Rotorua, Taupo and to a far lesser extent at Tokaanu for space and water heating, and heated pools. This was especially focussed on the hotel trade[31] but also on domestic heating. A second energy crisis in the 1970's had a similar effect.

Rotorua use of geothermal fluid for direct heating (and cooling), with significant withdrawal and little reinjection started to impact on the geysers (and therefore potentially on tourism) and eventually led to forced bore closures within a 1.5km radius of Pohutu geyser from 1986[32]. While this particular action was necessary, it also marked the turning point for direct use development within New Zealand. A new operating regime with an emphasis on reinjection or use of downhole heat exchangers has now seen recovery of many of the thermal features and establishment of clearly sustainable levels of development.

The following tables, taken from the EECA/NZGA direct heat assessment (White 2006) illustrate current supply and use.

[30] http://www.teara.govt.nz/EarthSeaAndSky/HotSpringsAndGeothermalEnergy/GeothermalEnergy/1/en

[31] The Rotorua hospital is another notable user.

[32] Bore closures began in 1986. The majority of closures (largely due to the enforcement regime but some due to a discouraging resource rental regime that is no longer present) occurred between June 1987 and March 1988.

Table 4.1: Assessed Primary Energy Supply for Geothermal Direct Heat Use in 2005 (TJ/year) (White 2006)

Geothermal and Council Regions	Space Heating	Space Cooling	Water Heating	Greenhouse Heating	Fish and Animal Farming	Agricultural Drying	Industrial Process Heat	Bathing and Swimming	Other Uses	**Total**
Northern										
Northland								71		**71**
Auckland								144		**144**
Waikato	0							165		**165**
Hauraki										
Waikato								94	2	**95**
Bay of Plenty					6			1,253		**1,259**
Rotorua-Taupo										
Waikato	26		5	319	1,502		993	1,919	1,284	**6,048**
Bay of Plenty	38						10,585	2,171		**12,794**
Miscellaneous North Island										
Gisborne								0.4		**0**
Hawkes Bay								16		**16**
Taranaki								0.2		**0**
South Island										
Marlborough	0									**0**
Canterbury								56		**56**
West Coast								36		**36**
Total	**64**	**0**	**5**	**319**	**1,508**	**0**	**11,578**	**5,925**	**1,286**	**20,684**

Table 4.2: Assessed Geothermal Direct Heat Use in 2005 (TJ/year) (White 2006)

Geothermal and Council Regions	Space Heating	Space Cooling	Water Heating	Greenhouse Heating	Fish and Animal Farming	Agricultural Drying	Industrial Process Heat	Bathing and Swimming	Other Uses	**Total**
Northern										
Northland								6		**6**
Auckland								65		**65**
Waikato	0							63		**63**
Hauraki										
Waikato								20	2	**22**
Bay of Plenty					2			412		**414**
Rotorua-Taupo										
Waikato	13		3	167	271		398	1,238	844	**2,935**
Bay of Plenty	19						5,315	786		**6,120**
Miscellaneous North Island										
Gisborne								0.1		**0**
Hawkes Bay								3		**3**
Taranaki								0.2		**0**
South Island										
Marlborough	0									**0**
Canterbury								30		**30**
West Coast								14		**14**
Total	**32**	**0**	**3**	**167**	**273**	**0**	**5,713**	**2,638**	**846**	**9,672**

The largest single use is the industrial use at Kawerau. The geothermal steam supply (about 320t/h) to the Norske Skog Tasman pulp and paper mill and the adjacent users is the largest industrial application of geothermal direct use in the world. The facility was established at the site to take advantage of the geothermal heat supply, which commenced 50 years ago and continues at high levels today. Steam is directed to heat exchangers, feed water heaters, recovery boilers, a kiln drying operation, other pre-evaporators and a stripping plant that takes collected geothermal condensate and supplies it to the mill make up water supplies. Also in this process is cogeneration plant whose heat usage was not included in the statistics in Tables 4.1 and 4.2 from the EECA/NZGA direct heat assessment (White 2006). However for this report, because heat in cogeneration facilities has been included in the definition of direct use for consistency with Ministry of Economic development modelling, the energy associated with this generation (415TJ/year) should be included in both the supply and use tables.

Other industrial uses are mainly focused on kiln drying applications. These are present at Kawerau, Ohaaki and more recently Tauhara (though Tauhara heat supply values have not been included to Tables 4.1 and 4.2 at this stage). Geothermal heat from high temperature fields (either water or steam) can be readily adapted to high temperature kiln drying operations. Kilns include overseas designs and a local product from Windsor Engineering. Clearly the wood products market is a major user of this heat.

The next largest category of geothermal direct heat usage is bathing and swimming. Depending on location in the country these facilities are developed privately or by local councils. A survey of use shows this to be a dynamic area of development. There seems to have been investment in improving the standard of many bathing and swimming facilities in recent years, both in terms of general environment, but also in terms of efficiency and control. This has been partly driven by consent and health requirements but also for sound commercial reasons. In some areas use for bathing is decreasing. One example is Hot Water Beach, where a holiday park with its associated pool has been closed in preparation for subdivision of coastal property. Several developments are on Department of Conservation land and operated under licence e.g. Tokaanu and Morere. While further development of these facilities may be possible, operators have found this to be difficult.

Table 4.2 shows a significant “other use” in the Waikato area. This is the NETCOR development at Wairakei representing a tourist development that recreates a geothermal environment in terms of “geysers” and silica terraces. It has been included as a direct use because of the significant investment in piping and fluid diversion and manipulation, and revenue received from this direct use. It is a cascade use from the Wairakei power station steamfield operation, employing a number of people on the land, demonstrating traditional Maori lifestyle in a geothermal environment.

The next most significant category of usage is fish and animal farming (in New Zealand this is entirely restricted to fish and prawn farming). The largest single development is the prawn farm at Wairakei. Again this is a cascade development located at Wairakei to take advantage of waste heat coming from the steamfield. The facilities have been expanded from their initial size in the 1980s. The heat source has changed from an initial heat exchanger drawing water from the hot stream, to piped water from the steamfield, to water of a lower temperature following commissioning of the Wairakei binary plant. There were plans for significant expansion of this farm producing Malaysian prawns. However, this facility now appears to have focussed on meeting a local tourist need and providing dining facilities close to Taupo. There is a second fish farm located at Papamoa where water is pumped from a well to assist with the raising and quarantine of tropical fish.

Greenhouse heating is the next most significant category. There is a large greenhouse located at Mokai. This is just in the final stages of being expanded from 5 ha to 10 ha in covered area. During the survey for the EECA/NZGA assessment (White 2006), several other greenhouse operators (and potential operators) were identified and included in the results. Several sites were identified that had ceased operation.

Space heating is the next largest category. Dominant users are domestic consumers, some hotels and hospitals. Commercial development is very limited. Included in statistics for this category are several uses of geothermal heat pumps in non-traditional areas of geothermal application e.g. Blenheim or Hamilton.

Water heating using geothermal heat appears to be uncommon. In practice, the methodology used in the survey did not allow separation of water heating or space heating from swimming pool heating, so heat was shown as feeding pools as a default. Water heating may be a significant portion of what is indicated as “bathing and swimming”.

Space cooling applications are shown as zero, though at least one Rotorua hotel is known to use space cooling. Nevertheless opportunities will be limited to large commercial (especially hotel) situations in areas of elevated geothermal temperatures.

Currently, there is no agricultural drying in New Zealand, though there would seem to be opportunity. A lucerne drying facility which operated at Ohaaki for a number of years was decommissioned several years ago. There are a number of kiln drying operations for lumber, but these have been counted in the industrial process heat category[33].

Several improvements to the data in Table 4.2 were mentioned in the previous paragraphs. Table 4.3 shows a revised table. Of the revisions to the 2005 data, 5% is associated with growth (but this growth is of a one-off nature).

Table 4.3: Revised Assessed Geothermal Direct Heat Use for 2007 (TJ/year)

Council Regions	Space Heating	Space Cooling	Water Heating	Greenhouse Heating	Fish and Animal Farming	Agricultural Drying	Industrial Process heat	Bathing and Swimming	Other Uses	**Total**
Northland								6		**6**
Auckland								65		**65**
Waikato	13		3	334	271		797	1,321	846	**3,585**
Bay of Plenty	19				2		5,730	1,196		**6,947**
Gisborne								0.1		**0**
Hawke's Bay								3		**3**
Taranaki								0.2		**0**
Marlborough	0									**0**
Canterbury								30		**30**
West Coast								14		**14**
Total	**32**	**0**	**3**	**334**	**273**	**0**	**6,527**	**2,638**	**846**	**10,653**

4.2 A Baseline for Geothermal Direct Heat Use

There are public databases of geothermal direct heat use in New Zealand. Data series include:

- Ministry of Economic Development Energy Data File (MED 2006) – in turn this data is obtained from Statistics New Zealand, which draws heavily on data supplied by Environment Bay of Plenty
- There are country assessments prepared by the geothermal community for World Geothermal Congresses held every five years – these have been incomplete.

The Energy Efficiency and Conservation Authority sponsored the New Zealand Geothermal Association to produce "An Assessment of Geothermal Direct Heat Use in New Zealand", with the final report being published in July 2006. That report identified a number of weaknesses with the data in these data series.

As a consequence of the EECA/NZGA assessment, MED has revised their Energy Data File series for geothermal consumer energy back to 2000, but data prior to that may still contain errors. The series since 2000 indicates static use (i.e. neither increasing nor decreasing overall) at around 9.7PJ of consumer energy, which is supported by anecdotal information.

[33] Old New Zealand country reports at World Geothermal Congresses used to include timber kiln drying as an agricultural drying application, but this is not the appropriate category.

At some stage there is a need to attempt corrections further back in time. Critical elements of this reassessment would include a close look at the dominant use at Kawerau (for which some steps upward in production are evident in published information on total mass flow), and also for Rotorua (which experienced step increases in the 1950s and 1970s associated with national energy crises, then forced or incentivised bore closures in the late-1980s[34]). The reassessment could also consider the commissioning dates of major heat loads at Mokai, Ohaaki and Wairakei to develop an approximate use profile.

A review of published geothermal direct use data within the Energy Data File shows a temporary trebling of direct use through the 1980's which is not thought to be real as there is no known driver for such an increase during that period.

4.3 Potential Direct Users of Geothermal Heat

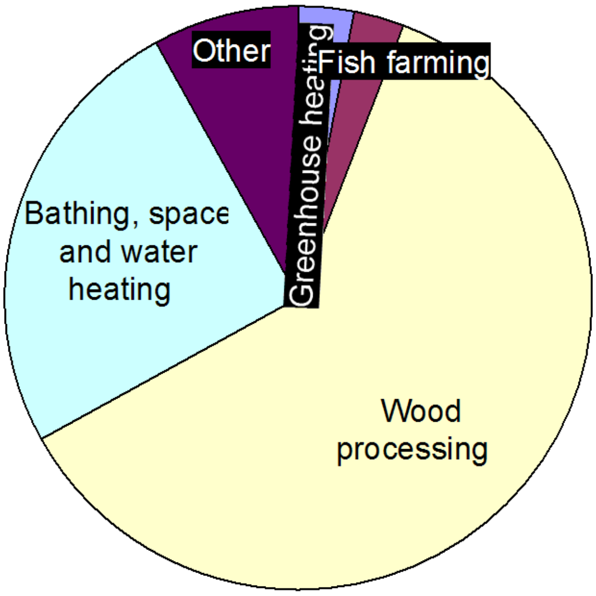

Figure 4.2. 2007 New Zealand geothermal direct heat use split according to energy consumed (see Table 4.3).

From the history of geothermal energy direct use in New Zealand there are clearly several sectors of the economy that have had an interest in developing geothermal resources and these will continue to do so, as shown in Figure 4.2. These include forestry operations (including kiln drying), a limited number of domestic and commercial users (whether for heated swimming pools or space heating), tourist operations (including hotels), a limited number of greenhouse operators and a limited number of fish farmers.

International trends in direct use have been reported by John Lund et al at the World Geothermal Congress 2005[35], and are summarised in Table 4.4.

[34] Environment Bay of Plenty (2005) *Rotorua Geothermal Field Management Monitoring Update: 2005*

[35] Lund, JW, Freeston, DH and TL Boyd (2005) *World-Wide Direct Uses of Geothermal Energy 2005.* Proceedings World Geothermal Congress 2005 Antalya, Turkey

Table 4.4: Summary of the Various Worldwide Direct Use Categories (Utilisation TJ/year) (Lund et al 2005)

	1995	2000	2005
Geothermal heat pumps	14,617	23,275	86,673
Space heating	38,230	42,926	52,868
Greenhouse heating	15,742	17,864	19,607
Aquaculture pond heating	13,493	11,733	10,969
Agricultural drying	1,124	1,038	2,013
Industrial uses	10,120	10,220	11,068
Bathing and swimming	15,742	79,546	75,289
Cooling/snow melting	1,124	1,063	1,885
Others	2,249	3,034	1,045
Total	**112,441**	**190,699**	**261,418**

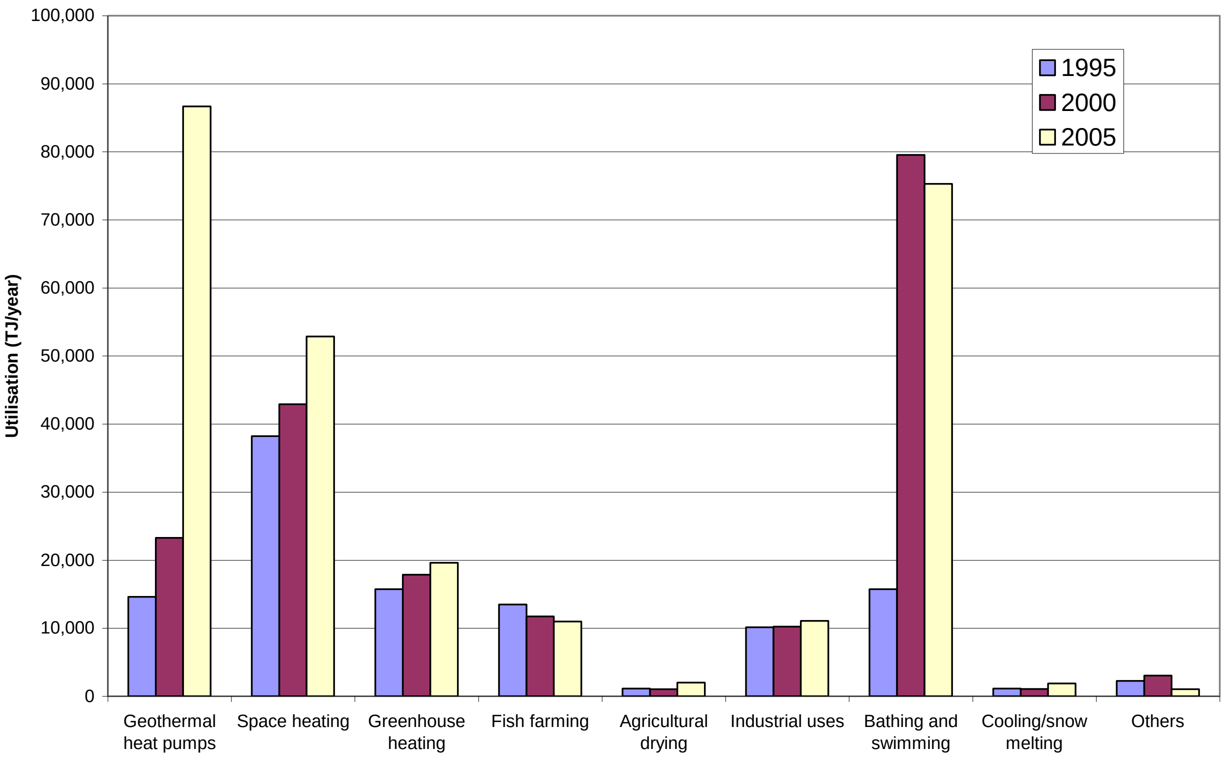

Figure 4.3: Graphical presentation of worldwide use emphasising dominant categories and areas of growth

Several features stand out from this table and Figure 4.3. Most notably, geothermal heat pump applications have been subject to enormous growth rates (see also Figure 4.4) and now dominate as the single largest category of geothermal direct use in the world[36]. Space heating applications have enjoyed steady growth. After this, it is noted that space heating and bathing and swimming combined account for about half the world market. New Zealand is unusual in having industrial use dominating, such that industrial use at Kawerau accounts for just over half of the world industrial use of geothermal energy. Clearly demands of this magnitude are exceptional.

Based on this international experience, the greatest opportunity for growth lies at the smaller scale end of the market with space and water heating opportunities either using traditional warm and high

[36] A recent news article reported that in China geothermal heat pump energy delivered rose from 6,570 TJ/year in 2004 to 17,140 TJ/year in 2006, emphasising the ongoing exponential growth of this market segment.

temperature geothermal resources, or more particularly heat pumps. On this basis, the business models that could see the most growth are those based around distribution of heat to multiple small users, and on supply and installation of specialist equipment such as heat pump systems.

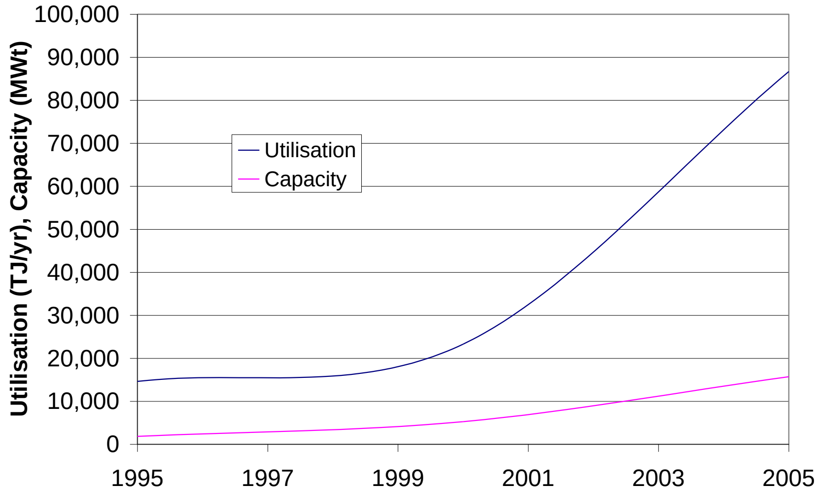

Figure 4.4. Illustration of the accelerated worldwide uptake of geothermal heat pumps over the last decade (data from Lund et al 2005).

4.4 Sector Considerations

4.4.1 Residential

The New Zealand Energy Data File shows 65PJ/year of energy being consumed by the residential sector. BRANZ is just completing it's Household Energy End-use Project effectively surveying the details of energy use in 400 homes around the country. The end result will be the ability to effectively model household energy use and assess the benefits of various energy proposals.

None of the BRANZ survey homes had traditional geothermal heating or geothermal heat pumps, though benefits might be readily modelled.

Based on the houses surveyed, there appear to be only two heating zones in New Zealand when taking into account the combined heat requirements of space heating and water heating[37]: a cold south including Southland and Otago (and possibly the West Coast, though no houses were surveyed there), and the rest of New Zealand. The heating load (excluding other energy use for lighting, appliances, etc) is about 60% greater in the south than elsewhere. This suggests that any heating solutions will have far greater applicability in Otago or Southland than the Waikato or Auckland, though a viable system heat pump system has already been installed in a large Hamilton home.

The HEEP study showed that water heating requirements roughly matched current space heating requirements, though this varied regionally (about half in Dunedin, double in Wellington and equal in Auckland). Demand for personal showering correspond to peak space heating periods at either end of the work day, though some water heating requirement can be shifted out of the peak period. Swimming pool heating would add to the load further, but can all be arranged to occur off-peak.

Eventually, specific modelling should be undertaken for specific conditions. However, the following conditions have been modelled for this study.

[37] Further zonation is evident when considering space heating only.

Table 4.5. Scenarios modelled with a focus on larger high end homes.

Location	Wellington	Auckland	Dunedin	Dunedin
Heating duty	Average house[38] Space and water heating duty	Large house Space and water heating with pool	Average house Space and water heating duty	Large house[39] Space and water heating with pool
Peak power (kW)[40]	7	13	8	10
Energy requirement (kWh)	6,000	10,000+4,000	10,000	16,000+4,000

Any future applications are likely to be focussed on the new home market, though retrofits might be possible in older homes using radiator heat distribution systems. There may be incentives to install such systems in places like Invercargill, which would appear to have suitable soil conditions and increasing requirements to clean up air conditions in winter.

The residential market has significant competition from other heating technologies such as air source heat pumps for space and water heating, and solar water heating. Both these technologies have lower capital costs and easier installation than ground source heat pumps or conventional geothermal heating. These technologies also suit the smaller heat demand of residential users.

4.4.2 Hotels

Heat duration curves allow accurate assessments of the annual heating duty on heat supply plant, showing the number of hours through a year when heat loads will be above a certain level. Thus, if a heat load is designed for a maximum capacity, it gives a visual measure of the amount of surplus capacity that might frequently be present. Scion has been involved with detailed energy studies on a range of properties in Rotorua. Figure 4.5 shows the heat duration curve for a hotel in Rotorua which is assumed to be typical of hotels throughout New Zealand. It indicates favourable conditions for high capital cost/low operating cost heat plant because typical load is relatively high at around 60% of peak.

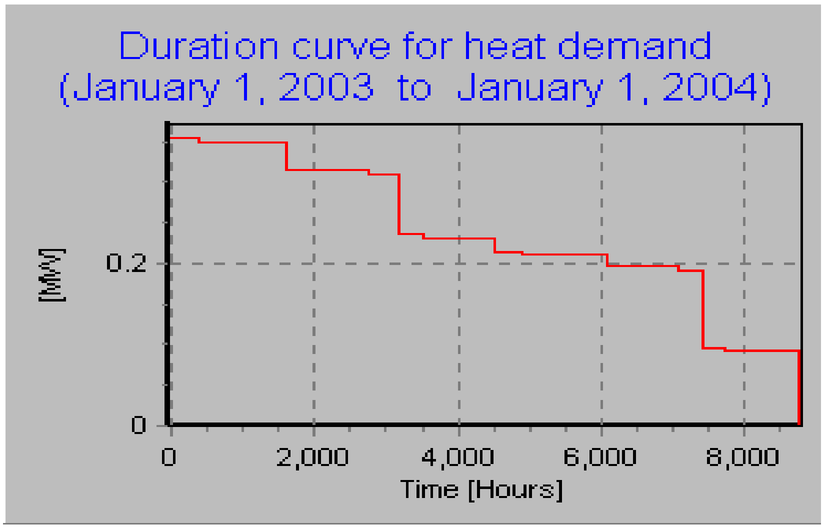

Figure 4.5. Heat duration curve from a hotel, with annual demand including space heating, hot water and washing.

EECA has previously studied energy demand in a range of sectors[41] and while the data is dated and requires updating it is the primary data available. For the hotel sector, average consumption was

[38] Average house is based on the average HEEP study house size in a particular area

[39] Large house has 60% higher energy consumption that an average house

[40] Peak power is approximate and based on assessed peak power from a BRANZ 2006a study focussed on space heating.

about 75GJ/year per bedroom of which about 19% was for water heating and 25% for space heating, so combined heating load was about 33GJ/year per bedroom (0.009GWh/year). The EECA survey indicated that of the total geothermal heat provided to hotels, about 30% was for space heating while 70% was for water heating. Data is available on hotel rooms by region.

The average hotel had 30 bedrooms. From the heat duration curve, the typical peak load for the average hotel will be 55kW with a 1.0TJ/year (0.28GWh/year) load.

4.4.3 Schools

The heat duration curve for a school is less attractive than for a hotel, in that demand is at a high level for a relatively short period then boilers are idle for long periods. More use is made of school boilers where there is a swimming pool, or after-hours learning, or where the school is a boarding school. A heat duration curve from Scion research is shown in Figure 4.6. Although the load factor will be much less than for a hotel, the higher demand means some economies of scale can be achieved in terms of the cost of any heat plant. This type of curve would probably favour a low capital/high fuel cost heat option, unless the school could be linked through to other users in a community heating scheme.

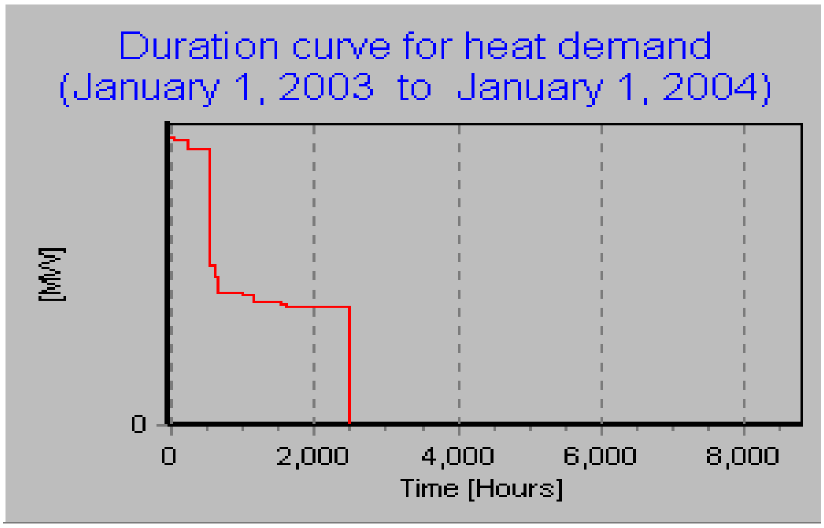

Figure 4.6. Heat duration curve for a primary school with heat covering space heating and a heated swimming pool.

It is noted that schools in the USA have preferentially taken up geothermal heat pumps implying that fuel costs may be excessive. A review of the BANZ/EECA Heat Plant database confirms that large New Zealand schools do have heat plant capable of MW duty, while demand in universities is an order of magnitude greater again. The curve in Figure 4.6 suggests a 1MW heat source could supply about 1.4GWh/year of heat.

Other data on school energy use suggests that the total annual heating requirement could be of the order of 750kWh/person, though is highly variable.

The use of geothermal energy in the school sector is expected to be in competition to the use of wood pellets. The cost for use of wood pellets has an advantage where existing coal boilers can be converted to being fuelled by wood pellets.

[41] EECA (2000) *The Dynamics of Energy Efficiency Trends in New Zealand – A compendium of energy end-use analysis and statistics.*

4.4.4 Local and Central Government

Under the draft New Zealand Energy Efficiency and Conservation Strategy, government is expected to lead the way in terms of energy efficiency and renewables maximisation. Government offices will essentially be a subset of the commercial sector in terms of energy use. The EECA survey referred to earlier (EECA 2000) shows that energy use per person in the commercial sector is about 55GJ/person/year of which 13% is for water heating and 39% is for space conditioning. Hence total annual heating requirement is about 7,900kWh/person. In 2001 there were approximately 32,000 state employees suggesting a total annual heating energy consumption of 0.9PJ/year. Building load factors are unknown. In practice, most state sector buildings are leased, and landlords will be little motivated to make a high capital investment for energy plant to save their tenants on operating costs.

4.4.5 Greenhouses

Greenhouses are becoming an increasingly common means of intensive horticulture. In New Zealand these are usually single-skinned (either glass or plastic). Many of these are not heated, but those focussed on tomatoes, capsicum and cucumber generally are (MAF 2003). Heating requirements are low grade and could be satisfied by a range of means, but energy use can be of the order of 2.7GJ/m^2 [42], though is assessed at being closer to 1.6GJ/m^2 (MAF 2003). Heat pumps exchanging heat with groundwater were recognised as viable as early as 1996. Heat pumps have the advantage that they can be used for cooling also.

Geothermal steam supplies have already proved sufficiently attractive to enable greenhouses to be established on operating geothermal fields. Developments have included: a demonstration facility at Ohaaki, various private greenhouses at Kawerau, an orchid house at Wairakei, a plant nursery at Tauhara, and the recently expanded 10 ha Gourmet Mokai development. There are also smaller developments in warm and hot spring areas such as found at Horohoro. These developments are frequently led by local land owners, but several fresh ventures have been established on leased land.

Where geothermal fluids are utilised that have high CO_2 content (or if the CO_2 can be extracted from adjacent larger scale geothermal applications sufficiently cleaned of sulphur) then this has an additional benefit for growers.

Greenhouse heating is currently often by burning of diesel, gas or oil. Geothermal energy is a suitable replacement for these fuels.

4.4.6 The Forestry Sector

The wood processing industry has already been highlighted as a sector that has been a heavy user of renewable energy, whether biomass or geothermal energy, and will continue to use this.

This report is being produced in parallel with a report on the direct use of woody biomass (East Harbour and Scion 2007). The biomass report has a discussion on forestry potential which is not repeated here. That report recognised that the forestry sector currently is a strong user of biomass processing residue as an energy source. The report also hypothesised that this processing residue is of such a quality that it could form a suitable feed stock for pelletising and onsale at a premium price. In that scenario, alternative fuels will be required to offset diverted processing residue. The Biomass report considers substitution with collected and processed forest landing material. However, for the central North Island, high temperature geothermal fields may also be able to provide the heat source. The following table summarises wood processing heat plants that may be able to use geothermal heat.

[42] Based on discussion in White, B (2006) *An Assessment of Geothermal Direct Heat Use in New Zealand*

Table 4.6. Potential Sites that may Use Geothermal Energy in the Central North Island through to 2030

Plant	Processing Plant Type	Annual Demand (PJ)	Installed Capacity (MW)	Fuel
Various CNI sawmills[43]	Sawmill, kiln drying	3.72		various
Laminex[44], Taupo	Panel (MDF)	3.92	17	biomass
Kawerau	Pulp and paper	12.67	550	mainly biomass and geothermal

On the basis of this table, further uptake of geothermal energy in the forestry sector in the period to 2020 and 2030 is likely to be limited to kiln drying operations (of which the 20MWth Tenon development at Taupo (see Figure 4.7) is an example of a large development) and possible displacement of biomass at Kawerau.

Figure 4.7. Recently commissioned Contact Energy geothermal heat supply to the Tenon kilns at Taupo (courtesy of Contact Energy).

The use of geothermal energy in the forest processing sector will have strong competition from wood processing and forest residues which are a natural by-product of forestry and wood processing. Wood residues are otherwise wasted so their use is determined principally by economics although their sourcing can be variable from one year to the next. Geothermal energy on the other hand will usually be supplied by a third party that understands the resource and associated

[43] Many of these will still be outside geothermal areas.

[44] The Laminex plant was destroyed in a recent fire and is unlikely to be rebuilt

risks, and that can convert all costs and risks into a price for heat that can be acceptable to both parties.

Note that the parallel report on direct use of biomass (East Harbour and Scion 2007) envisages ways in which some of the current wood processing residues can be released for pelletising. Part of the solution could be additional geothermal steam supplies to forestry, allowing forestry operations to diversify into energy sales of wood pellets.

4.4.7 Other Major Industry

Other major industries that may have use for lower grade heat include the dairy and meat sectors.

The dairy industry is one of our major export earners. On-farm heating requirements include farmhouse requirements and some within the dairy shed. Opportunity for heat pumps has been recognised for some time, though this was initially focussed on extracting heat from milk (initially at 32°C) in the chilling process and adding it to water for washing purposes[45]. Water heating is the largest consumer of power in the dairy shed. There is opportunity for a range of heating options.

There were 14,400 dairy farms consuming an average of 22,000 kWh/year per farm, of which 33% was for water heating (say 0.026TJ/year per average farm).

Meat and dairy processing sectors are major users of heat. However, the minimum temperature requirements are beyond the scope of standard heat pump systems, and with the exception of the Reporoa dairy factory, none of the works are associated with high temperature geothermal fields. Under the proposed new Environment Waikato Geothermal Plan, Reporoa is classed as a “research” field. In effect significant development will not be possible without new research, especially focussed on possible links to adjacent “protected” fields. The end result will be effective protection of the Reporoa field also. Thus, although the potential heat requirement for these sectors is large, there is no ability for geothermal energy to meet this need unless there is a significant change in the Regional Plan constraints on Reporoa. These sectors are not considered further.

In the meat and food processing industry, there is often a need for temperatures greater than 80°C implying that only high temperature fields could directly supply this heat (though low temperature fields could serve a pre-heating function). In practice there are few of these facilities established beside high temperature geothermal fields, Arotaki Honey at Waiotapu being one exception. Hence there are simple locational reasons why these processing sectors will not take up geothermal energy in future.

4.5 Summary

Geothermal direct use played an important role in some early Maori communities. Current use nationally is about 10.7PJ/year, with about half being located in industrial applications at Kawerau. The Kawerau development is so large by world standards that it accounts for half of the world industrial geothermal direct heat use. Nationally, in terms of heat use, this is followed in magnitude by a mixture of bathing, space and water heating uses. Some of this latter demand is directed to the tourism industry, which has strong links to geothermal resources. Heat pump uptake is currently miniscule compared with its potential.

Internationally, bathing and space heating dominate use. However the single greatest category of usage is that of heat pumps following significant and exponential growth in use over the last 10 years. Given the current favourable pricing of heat pumps in New Zealand, there is no reason why significant exponential growth should not occur here also.

[45] Centre for Advanced Engineering (1996) *Energy Efficiency: A Guide to Current and Emerging Technologies*

Indicative heat loads have been analysed for a range of use sectors, as a precursor to assessing typical costs and unit costs of various development types. From recent household energy surveys a significant discovery is that New Zealand residential space and water heating can be categorised into essentially only two zones: Southland/Otago and the rest, with deep south homes consuming about 60% more than other homes on water and space heating.

There are a range of other areas that could see growth in direct heat use in future including hotels, schools, government, greenhouses, and most notably the forestry sector.

5 Qualitative Review of Key Drivers

This chapter sets out the key drivers from a user's perspective then from a developer's perspective, ultimately with a view to seeing how a disconnection between these parties can be broken to progress future developments.

5.1 Key Drivers from a User's Perspective

The internal drivers (opportunities and threats) for development of direct use applications from a users perspective are seen as follows:

- General concern over rising fuel prices
- New developments or plant replacement
- A requirement for a quality fuel supply
- Concern over past bore closures
- Co-location of resource and user
- Concern over CO_2 and other air emissions
- Concern over current levels of domestic heating
- Aversion to high capital expenditure on energy
- Constraining resource consenting policies
- Current knowledge of geothermal resources suitable for direct use
- Current technology and cost trends for plant and equipment using geothermal energy

5.1.1 General Concern Over Rising Fuel Prices

The public is generally aware that fuel and electricity prices are rising. This is forcing reconsideration of energy options for all user types. Geothermal energy may be seen as a means of isolating the user from future fuel price movement. Clearly the price of a geothermal option would have to be seen as attractive for this option to be taken up. Discussion of comparative energy prices is covered in Section 6 of this report.

Equally, if the public perception is that energy price is unstable then this may have the effect of delaying a decision on new heat plant until trends have settled.

5.1.2 New Developments or Plant Replacement

Whenever a new development is being considered, appropriate energy options will be reviewed by the user. This will also apply to replacement of aging heat plant. The high capital investment required at these times gives users the opportunity to make a decision based on lifecycle costs, without having to face aversion to writing off existing capital intensive heat plant that may still have significant useful life remaining if they were to replace existing plant at any other time.

EECA has sponsored the development of a heat plant database, managed and available from the Bioenergy Association of New Zealand. This database can provide an indication of when existing boilers will face replacement. In some cases, there may be geothermal options available.

5.1.3 A Requirement for a Quality Energy Supply

In most cases, heating is a means to an end. It is a necessary service within a business or home established with an entirely different focus, other than heat itself. Thus heating options should ideally be trouble-free and reliable, and should rarely be a cause for concern after installation.

This consideration seems to have been lost on some developers. There is considerable risk to a developer in providing a substandard energy supply to a user. As an example at Ohaaki, a geothermal steam supply was made available to a small timber drying kiln (Hicksons Timber, later owned by R & B Whale). Steam was flashed off waste water that was otherwise being directed to surface disposal. Occasionally the separator would flood, causing silica-saturated brine rather than steam to flow through the kiln tubes. Ultimately, for a wide range of reasons, but with quality of supply being one of them, a decision was made to relocate to a central mill site and to change from a geothermal heat source to a coal-fired boiler.

A risk with any cascaded use of geothermal energy is that it involves passing what might be thought of as a “waste” product to another user, and in this form it is likely to be troublesome. Ideally the user would like fluid conditions modified to avoid ongoing difficulties, but this will come at a cost. As an example, the Prawn Farm at Wairakei receives its energy through a heat exchanger, so it is protected from scaling and contamination risk. Only heat is being transferred from Contact to the Prawn Farm.

Modern geothermal heat pump applications offer fully engineered solutions with automatic control of heat to different locations within a property. This type of quality product can operate quietly in the background and has left users very satisfied.

5.1.4 Co-location of Resource and User

As a rule, geothermal energy should be used close to the field. There are exceptional cases, such as found in Iceland, where geothermal energy can be piped for 70 km from distant fields before being distributed for essential heat.

While there are some major users located on geothermal fields, generally major users are located elsewhere. With that in mind, it is a major step for an industry to consider relocation of facilities and staff to a new probably rural setting. This sort of decision can take several years to research and commit to.

Potential developers have reported negotiation with parties considering relocation to take advantage of geothermal heat. In several of those cases, the company considering relocation has also considered wider relocation options, and has decided that the general business environment in Australia is better than in New Zealand and so has relocated there.

Often, when a major industry has been established, the owners want an energy option that can be brought to site, rather than consider relocation, as may be required to take advantage of commercially viable geothermal fields. As a rule, energy is a factor in production, but is a major factor only in rare cases, pulp and paper manufacturing being one example.

5.1.5 Concern over CO_2 and Other Air Emissions

There is growing concern over the impacts of ongoing CO_2 emissions, particularly with respect to possible impacts on climate change. At one level this is a concern of heat consumers and may encourage the selection of renewable energy options over fossil fuel options for direct heat use applications.

When the concern is stemming from government, there can be a range of measures to encourage a shift from fossil fuel to renewables.

While there is some recognition that there is some CO_2 emissions from geothermal resources, the emissions levels are low, especially so for direct heat use, where the efficiency of the application is possibly 5 times greater than for electricity generation, thus requiring far less fluid for the same energy duty. As a rule, the emissions from geothermal energy are not a concern to developers.

In a number of locations there is growing concern over particulate emissions from fossil fuel sources. Regional and local councils are imposing restrictions on heating options in places like Rotorua and Christchurch. These restrictions can be accompanied by programmes to replace smoky fires, whether they are wood- or coal-fired, with some form of low emission technology. In both of the cases cited there could be geothermal solutions. In Rotorua, this could include use of shallow wells (possibly with downhole heat exchangers), while in Christchurch geothermal heat pumps could play a part. These considerations have impacted on the view developed in this report of the uptake of the respective technologies in these areas.

Note that it is unlikely that geothermal heat pumps would be sponsored in preference to say air source heat pumps when grants are involved by local government or lines companies. These would simply consider load reduction against capital investment. In that case, the long term benefits associated with the lower electricity consumption of a geothermal heat pump would not be recognised.

5.1.6 Concern over Past Bore Closures

It appears that domestic and commercial development of geothermal direct heat use was progressing well in the central North Island until the forced bore closures in Rotorua in the late 1980s. People had moved to Rotorua to take advantage of the geothermal resource, there were active drilling programmes and companies designing and installing surface plant including heat exchangers. Significant private capital investment was involved, then had to be written off because of a government decision.

This decision appears to have influenced a national view of the risk associated with geothermal investment. However, it was clearly linked to one field and use that had clearly proceeded beyond acceptable levels. Regional and District Councils now have an active focus on management of their resources under mandates through the Resource Management Act, so similar action will not recur. This change in attitude is already occurring in Rotorua where downhole heat exchangers are being encouraged.

Greater uptake of geothermal energy will continue to be constrained until Councils recognise that reservoir developments can be sustainably managed if properly engineered and monitored.

5.1.7 Concern over Current Levels of Domestic Heating

It is now recognised that many New Zealand homes are too cold, and that this is impacting health and possibly income. Consequently, users may choose to raise home temperatures, either by increasing a building’s insulation levels, or simply by increasing heating requirements. Increased heating requirements may alter the optimal solution from one type of fuel to another, especially favouring more capital intensive solutions as are associated with geothermal solutions.

5.1.8 Aversion to High Capital Expenditure on Heating

People are still averse to high capital expenditure on heating options. In the New Zealand domestic market, homes are kept for around 7 years before owners sell and move to another property leaving many consumers concerned that they will not recover their investment over that period. Depending on how the proposed Home Energy Rating Schemes (HERS) currently being set up by EECA is structured (particularly if potential house purchasers are able to relate energy rating to a dollar value per year or to a sense of comfort level), this situation may change, with homeowners being able to point to benefits that can lead to long term cost reductions for the potential buyer.

Note that in Europe, where homes may be kept for generations, owners are less averse to long term investment in property improvements.

5.1.9 Constraining Resource Allocation Policies

In the past some regional and district councils have taken an ultra precautionary approach to consenting, naturally setting up road blocks to development. Council positions are generally becoming more permissive, especially towards smaller projects e.g. as per recent changes to the Environment Waikato Geothermal Plan and Geothermal Policy Statement. For some time, domestic consumers have been able to proceed with developments on fields like those under Taupo and Tokaanu under a simple General Authorisation. Direct use of geothermal energy is a highly efficient energy option and should be encouraged, if necessary through a National Policy Statement.

5.1.10 Current Knowledge of Geothermal Resources Suitable for Direct Use

In reviewing drivers for investment in geothermal direct heat, it seems that ignorance of the opportunity has been a major factor behind the lack of forward momentum. Notable in this is the lack of information on geothermal heat pumps, or of potential installers.

High temperature fields are researched by the major developers, but the details of their commercial research is generally confidential, with limited releases through public notices and conference papers.

The lack of a licensing regime as operated for oil and gas exploration means that resource information can be held tightly by current developers thus placing barriers for new entrants to enter the geothermal market. The oil and gas exploration licensing regime allows exploration companies exclusive access provided they proceed to development within a specified time period. There are also requirements that some geotechnical information is lodged with the Crown Minerals Division of the Ministry of Economic Development. If development does not proceed then the information becomes available to other potential explorers. This ensures that a national database of geotechnical data is established.

Leading edge research has been sponsored by the Foundation for Research Science and Technology, but this is of a limited nature. Research on low temperature fields has been minimised, partly because of the lack of clear users and partly because it falls into the category of “boring science”. While some characteristics of low temperature fields are known, their areal and vertical extent is still largely unknown. On this basis, there is unnecessary risk for a potential developer in tapping into the warm reservoirs, especially where drilling rather than simply collecting spring water is being considered because of the potential size of a development.

Direct geothermal heat use could be significantly increased if more information on the use and economics of down hole heat exchangers was available to residential, commercial and industrial heat users.

5.1.11 Current Technology and Cost Trends for Plant and Equipment using Geothermal Energy

Conventional fluid extraction technology for exploiting geothermal energy has not changed much in recent years. However, some technologies such as for extraction of heat from enhanced deep geothermal systems and geothermal heat pumps are new to New Zealand, and people are generally not aware of these as options.

Heat pumps have been studied in the past, but analysis will have been based on more expensive options than the currently imported Chinese units. Reduced costs are now starting to swing this as a viable option, especially for large domestic or commercial developments.

Improvements in the design of down hole heat exchangers has opened this technology for wider use. It also has the advantage of extracting heat rather than geothermal fluid which results in significantly less geothermal field management issues arising.

Enhanced Geothermal System technology could be used to access heat, but this has not been applied to direct heat use applications to date, because of uncertain economics and because of limited economies of scale.

Other than the new source of cheaper heat pumps and down hole heat exchangers, geothermal costs have been relatively stable in recent years. There may have been a recent increase in the last two years associated with an increase in steel and shipping costs.

5.2 Key Drivers from a Developer's Perspective

5.2.1 Major National Geothermal Power Developers

The major investors in geothermal developments in recent years have been the generator-retailers Contact Energy and Mighty River Power, together with Maori Trusts. Other parties have undertaken limited investment but because of a lack of security over exploration and investigations they have not proceeded.

5.2.1.1 Contact Energy

Contact Energy is a publicly listed company now with Origin Energy as its major shareholder. It's primary focus is on the generation and retailing of electricity (with about 28% of the generation market and a slightly smaller percentage of the retail market), but as extensions of these activities is also involved in gas markets, and steam sales (including geothermal steam for direct use). Contact's Annual Report to 30 June 2006 had a particular focus on geothermal development, noting "There is huge potential for New Zealand's strong geothermal resource to provide greater levels of renewable electricity **and heat** at a time when New Zealanders are demanding ever-increasing amounts." The Annual Report also describes Contact as being involved in two business segments, both of which are defined in a manner that gives room for ongoing investment in geothermal direct heat use. These segments are described as:

- "Retail – encompassing any activity that is associated with Contact's supply of **energy** to end-use customers as well as related services
- Wholesale – encompassing any activity that is associated with Contact's generation of electricity **or steam**, and Contact' sales to the wholesale electricity market."

Contact's steam sales are from steam supplies from their Te Rapa gas-fired cogeneration plant to Fonterra and from a number of geothermal heat supplies. In total, steam revenue makes up about 1% of total wholesale revenues.

The 20MW_{th} steam supply to the Tenon Taupo plant on the Tauhara field was commissioned in 2006 and directly substitutes fossil fuels previously used at the Tenon site. Discussions between heat users in the area and the field developers stretched back many years predating the Contact split from ECNZ in 1996. Active negotiations by Contact and Tenon took two years to finalise. The Tenon supply offered a low cost development option, utilising production and injection consents already held, that could be developed well in advance of their plans for a Tauhara power station[46]. The small-scale development directly on the Tauhara field has the potential to alleviate fears within residents of Taupo that a Tauhara development will accelerate subsidence or hydrothermal eruptions. The Tenon development has proceeded on a fully commercial basis, and Contact staff

[46] Contact announced intentions around a 200MWe Tauhara Power Station in February 2007.

have indicated that this is the type of large scale commercial development they will actively seek in future.

Contact remains involved in a proposed mini-district heating scheme (also involving New Zealand Clean Energy Centre, Energy for Industry and local consultants) that may eventually link a Taupo school and the Taupo hospital to a geothermal supply.

Contact supply geothermal energy for direct use purposes to a range of existing users in the Taupo / Ohaaki area. These include a plant nursery, a prawn farm (for optimum water temperatures for growth), an orchid greenhouse, a hotel and local offices for heating, a tourism venture reproducing the thermal environment of pre-European Maori, timber drying kiln operations, and a local marae for heating purposes. In Contact's view. most of these projects are sub-commercial arrangements, being small in scale compared to Contact's activities, with the management time associated with development and ongoing management being out of proportion to commercial benefit. Despite this view on the small scale of the projects, this group of projects still accounts for 16%[47] of the national geothermal direct heat use in total. Contact has a passive approach to this type of project, as they distract staff and management from major projects, generally related to their core business of electricity generation. Reasons for the sub-commercial arrangements include the need to dissipate heat from its surface discharges (a less common requirement for future station designs), a desire for a good working relationship with local iwi and neighbours, and inherited contracts from previous project owners.

Wairakei staff are frequently consulted by local parties on the possibility of direct use in Taupo.

5.2.1.2 Mighty River Power

Mighty River Power is one of the three State-Owned Enterprises split from the Electricity Corporation of New Zealand after its final split in 1999. Through 2005 it held 13% of both the electricity retail and generation market shares. Of the three SOE generators, it is the only one to develop a business case around geothermal electricity generation. MRP's website states that "geothermal energy is one of our core business activities and continues to be a high priority for future development." At a recent ground breaking ceremony for the Kawerau Power Station MRP Chair Carole Durbin said "The Kawerau power station is part of Mighty River Power's geothermal exploration and development programme – New Zealand's largest such programme in over 20 years. We have plans to develop around 400 MW of geothermal energy in the next five to ten years – enough power for around 400,000 homes. In addition we have identified a further 800MW of potential resource which could also be developed in the longer term."

MRP also owns the gas-fired Southdown co-generation facility with its sales of steam to Auckland industry. It manages and operates the Kawerau steamfield on behalf of Ngati Tuwharetoa Geothermal Assets with its supply that dominates all New Zealand geothermal direct use. It also manages and operates steamfield assets at Mokai for Tuaropaki Power Company including supply of heat to the Mokai glasshouse. Arguably, the Kawerau and Mokai direct heat operations are merely stepouts from MRP's primary electricity market activities. Additionally, MRP has gas exploration activities and retails some natural gas.

The 2006 Annual Report mentions the need for energy diversification within MRP, but the text associated with this seems focussed on energy sources for electricity generation, rather than diversification of energy supplies.

[47] From the NZGA/EECA report "An Assessment of Geothermal Direct heat Use in New Zealand", the total heat supply from Wairakei and Ohaaki exceeds 1500 TJ/year.

5.2.2 Tuaropaki Trust as an Example of a Progressive Maori Enterprise

The Tuaropaki Trust is a Maori Trust set up to administer land and resources in the Mokai area. The Trust has successful farming and forestry operations and established the Tuaropaki Power Company as the investment vehicle for the development of the geothermal station and steamfield at Mokai.

In 2003 Tuaropaki Trust sold a 25% shareholding in TPC to Mighty River Power, who also hold a contract for the operation and maintenance of the geothermal facilities. Tuaropaki Trust continues to hold a 75% shareholding in TPC.

TPC is the owner of the existing Mokai I station and steamfield (56 MWe), and of the recently commissioned Mokai II development (39 MWe). A third smaller stage is currently under construction. The combined output of Mokai I and II represents the largest independently owned electricity generation facility of any sort in the country.

A major geothermally heated glass house is also located on the geothermal resource, and this has been recently expanded bringing total covered area to over 10ha. The glass house takes a small amount of steam and hot water from an otherwise unutilised exploration well. Waste geothermal water and condensate is collected and piped to the power station reinjection system.

To further enhance the benefits of being on site, Tuaropaki has looked at cleaning up the gas discharge from the power station for use in the glass house. This gas is mainly CO_2 but there are traces of H_2S which might be damaging to plants if untreated gas were delivered to the glass house. Successful cleanup will mean that the small amount of gas that is produced by the station can be directed into the food chain and directly displaces CO_2 that would otherwise be purchased by the glass house to assist plant growth.

The Trust is known to be talking with other possible heat users with a view to further use of the resource under the land, while making land available for long term use (not sale) as they have already done for the glasshouse operation. The Trust is operating with a long term view, both in terms of securing benefits for future generations and current Trust beneficiaries, and in being prepared to develop relationships with other potential heat users over several years until both user and Trust are prepared to advance.

5.2.3 Other Maori Trusts

Almost all future geothermal developments on high temperature fields will involve interaction with local Maori Trusts, and in some cases will be developed by the Trusts. The Trusts have power by virtue of relevant land ownership, and their important consultation role during the resource consent process. They can choose a passive role or act progressively as at Mokai, Putauaki (Kawerau), through Tuwharetoa interests (Kawerau) or Tikitere as examples.

The recent transfer of the steamfield assets at Kawerau to Ngati Tuwharetoa Geothermal Assets demonstrates the potential power of these Maori interests. In that case, the arrangement was linked to wider settlements of Treaty of Waitangi Claims, and may be replicated in future.

5.2.4 Potential Utility and Energy Service Companies

Energy for Industry (EFI) is a business unit set up by Meridian Energy, based on an energy service company (ESCO) model. It invests primarily in heat projects for large commercial and industrial operations around the country selling heat and electricity to a range of customers. EFI has invested in a range of heat plant (including coal and biomass) and in February 2007 became a major sponsor of the Taupo-based New Zealand Clean Energy Centre. The NZCEC is promoting biomass and geothermal projects. One of the first projects being pursued with EFI funding is a geothermal direct use mini-district heating scheme linking a local school and the Taupo hospital, possibly with other incidental users. EFI's view on geothermal development is that it has not been an area of core competency (unlike biomass), but they are confident that they will be able to access the necessary advice.

Note that this attitude towards in-house expertise contrasts with the approach taken for electricity generation. For electricity generation, competency must exist within the organisation to give the Board confidence that the substantial investments involved are justified. In the case of direct use, the scale of development reduces the perception of risk.

Meridian is currently setting up a parallel ESCO focussed on the domestic house market. This group is considering a wide range of energy sources and demand-side management techniques with a view to more efficient homes. While the business model is still evolving, this may represent an opportunity for larger scale investment in geothermal heat pump systems as a supply-side energy option with general application.

Other utility owners could also develop an interest in direct supply of heat, possibly based on an industrial park or limited district heating scheme basis. Electricity lines and gas distribution companies already have business models based on physical distribution of energy via capital intensive networks to multiple sites with frequent billing, as would be required for a heat distribution business. Some of these companies may see advantage in avoiding reinforcement of their existing networks, through investment in a parallel but currently unregulated energy supply option. Nevertheless, there are no known line companies with this type of interest at present.

A possible spin-off benefit of proposed changes to legislation to further enable line companies to invest in generation is that these companies may also see the advantage of extending their geothermal developments to include reticulation of heat.

5.2.5 Drillers

Due to the relatively low number of drillers with geothermal expertise, the drivers for drillers can come down to personalities. However, drillers are starting to target certain market segments, each with their own drivers, based on their own capabilities[48]. The following discussion is based on interviews with several key drillers, rather than a comprehensive survey.

Low cost drilling into steam and warm water resources has been undertaken by Warmington Drilling Ltd of Taupo. This is a small owner-operator business with 2 drilling rigs. Warmington can supply heat in Taupo or Rotorua for a fully operational heat supply based on downhole heat exchangers costing $5-6,000. The company has drilled wells from South Waikato through to the East Coast. The owner prefers a small operation and has only been drilling around 4 wells per year in recent years. He recognises that he could market his geothermal drilling services better. Like many other drillers, his rigs can be used for a variety of other purposes. He has sufficient rigs to be able to step up activity if local competition eventuated.

Several other drillers have found that Warmington Drilling is almost impossible to compete with on price so do not operate in this domestic sector of the market. It would appear that the low costs combined with a minimal marketing have led to a special type of market failure in this segment of the heating market.

Rotorua Well Drilling is a family drilling business run out of, and focused on Rotorua. Twenty years ago, they had up to 5 rigs active with 3 rigs focussed on geothermal drilling. As for much of the industry, they currently have 1 or 2 rigs active, and limited numbers of trained crew. Because of the negative consenting regime in Rotorua referred to in section 5.1.9 , the company advises new interests in Rotorua not to drill new geothermal wells at the moment, and focuses it's efforts on

[48] Many of the drilling companies discussed here have rigs capable of drilling relatively shallow wells only (say several hundred meters). There are companies with deep drilling capabilities such as Century or overseas companies such as Ensign and Parker, but these would tend to stay focused on the electricity generation market rather than direct use applications (unless in a major industrial case like Kawerau).

replacing existing wells as they age (replacement is needed after about 20 years). This replacement work tends to be focussed on the hotel trade. They are interested in the potential of down hole heat exchangers and shallow wells for geothermal heat pumps to increase business.

Barham United Welldrillers Ltd operates out of Te Awamutu drilling in the Waikato Region including through the Hauraki plains. Most drilling is for cold water, though water quality in the Hauraki Plains is poor. Typical depths drilled range from 8 to 200m with warm water only found in localised areas. On the basis of this advice there is probably only limited opportunity unless in the vicinity of existing known hot springs for additional geothermal development.

Cameron Drilling is a small drilling company out of Tauranga and has just expanded to 3 drilling rigs because of strong growth locally. Most of their drilling is for geothermal applications, with the balance being for irrigation or frost control. Growth is being driven by a local property boom, with use being for underfloor heating or swimming pool heating at the high end of the residential market or for large chain rest homes and corporates. Word of mouth has played a major part in the extent of uptake, as typified by a wide network of medical doctors now connected to a geothermal heat source in their individual homes. The Tauranga heat delivery systems cost around $50,000, but often have up to 5 users connected to the 42-52^{o}C heat source. Wells are often around 250 to 400m deep with rare wells being drilled to 800m depth. The low temperature of wells in the region mean that drillers do not have to comply with hot well conditions imposed on geothermal wells with temperatures exceeding 70^{o}C. Note that the higher well drilling costs in Tauranga compared to those in Taupo or Rotorua are partly a reflection of the greater depth of drilling, and possible need for pumping.

There are companies like Century Resources that operate at the large scale, high temperature end of the drilling spectrum. They have traditionally focussed on deep crown wells for geothermal electricity projects, but have also drilled wells at Kawerau and recent wells at Tauhara for large scale industrial supplies.

Century Resources have subcontracted some work to other parties. Site consolidation grouting has been done by Warmington. Intermediate-sized wells have been subcontracted to Brown Bros (NZ) Ltd (of Hamilton). Brown Bros now view themselves as drilling geothermal power wells almost exclusively. In the past they have drilled wells for the domestic market and still own the small rigs to do this. However, they cannot compete with Warmington. Brown Bros would not consider a return to drilling for direct use unless there was some industry transformation. They have developed a qualified drilling base and prefer to drill to higher definite standards and are not interested in cutting corners as may be required in a domestic or commercial situation.

Initially it was thought that drillers might potentially be catalysts for geothermal development, particularly of lower temperature resources. Joint marketing of the potential of geothermal energy could secure many additional drilling contracts. It appears that this would be difficult in the domestic market because of current issues around competition and marketing, while at the industrial end of the market, drillers are dependent on the initiatives of the major electricity generators.

5.2.6 Geothermal Heat Pump Specialists

Until recently there were few “geothermal” heat pump specialists in New Zealand, and even air-source heat pumps were a rarity. The apparent lack of any specialists was a deterrent to otherwise early adopters of this technology, but this situation has changed.

Warmfloor Heating (based in Taupo) is now the most active developer of geothermal heat pump systems with installations in both the North and South Islands. The company indicates that it is extremely busy quoting on projects, and sees this particular market segment as set to take off. Warmfloor’s recent success has followed the identification and import of quality, “low” cost heat pump systems sourced in China. Warmfloor has established relationships with plumbers and electricians in many places to assist with installations. The company is considering training programmes to ensure quality of installation. The managing director is considering establishing a heat pump association, though currently is a member of the New Zealand Geothermal Association, and has links with the Solar Industries Association.

A review of growth of heat pump applications in other countries shows an exponential growth over the first few years, but it is currently very hard to gauge the potential uptake of this technology either in the short or long term. If the growth is significant, as expected in this report, then demand could outstrip the ability of one company to import, design and install systems, even allowing for company expansion.

5.2.7 Property Developers

Property developers are always looking for an edge to increase the value of their holdings. Conceivably land with an associated energy source could be an attractive package, either for electricity generation or direct heating of industry, commerce or home. Several large residential property developers are currently evaluating inclusion of renewable energy sources, including geothermal heat pumps.

5.2.8 Investment Bankers

Investment bankers can provide finance for a range of applications. During the course of this project, an investment banking firm was identified that has had a dedicated team investigating geothermal heat pump and biomass opportunities in New Zealand. They remain concerned about the negative consenting regime, about incentives for start-up businesses, and government incentives for near-commercial research and development. They are actively comparing the New Zealand investment environment with Australia's environment for such businesses.

5.3 Breaking the Disconnection between Users and Developers

Very often the potential user of direct use geothermal heat is a different person to the active geothermal developers today.

The major investors in geothermal energy these days and into the foreseeable future are the electricity generator/retail companies. Mighty River Power and Contact Energy will likely have a very heavy investment programme in geothermal electricity generation. While other investors are likely to be involved, 1,000 MWe of generation plant is likely to be installed over the next 10 to 20 years at a total capital cost around NZ$4 billion. Electricity generation is their focus but there is some room for heat supply, especially to local partners on a field, or to commercial parties of a sufficient scale.

The experience of Contact Energy is informative. The recent development of the direct steam supply to Tenon in Taupo was seen as being on a sufficient scale and value as to be attractive and to be emulated in future projects. However, Contact Energy has other heat supplies (frequently inherited) for similar quantities of heat that are seen as a distraction because of unattractive commercial terms. If a potential user wants heat from these major developers, they must be prepared to pay for the steam at reasonable rates. Opportunities may exist for suitably located major users, or within adjacent industrial parks.

The Maori Trusts will drive a connection between major electricity generation projects and direct heat projects. Their interest in the resource, the land, and bringing people back to the land will lead them to consider direct use applications which tend to involve higher staff numbers than could be placed in a power station. Very often these Trusts will partner with the generators in the initial consenting and development stage of electricity projects, and can negotiate provisions for substantial supplies with the generators. The Mokai glasshouses demonstrate the creative flair possible in terms of long term lease of land to a third party that invested in the glass house, use of an otherwise sub-commercial well as the heat supply, possible use of power station CO_2 emissions as a source of CO_2 for the glasshouses and use of the existing reinjection system for disposal.

Some of the electricity lines companies may also consider geothermal heat development. Top Energy is already a case of an electricity line company that has invested and is investing in geothermal generation. Commerce Commission restrictions on line price could force further diversification of line company businesses. Line companies represent a group of developers that have an established business model based on making physical connections from distribution networks to user properties, and billing multiple small users for energy. Limited district heating or industrial park operations have a very similar business model. This type of company has the ability to bridge the gap between energy supply and user heating needs.

The early history of electricity reticulation in New Zealand was frequently based on Tramways branching off their own supplies of electricity to interested adjacent users. The limited district heating scheme proposed for Taupo through Contact, the Clean Energy Centre and Energy for Industry may allow similar stepouts. However the real impetus to develop rational district heating schemes will come when line companies (whether based on gas, electricity, water or even telephone), with their appropriate business model start investing in these projects.

At the domestic scale there is a need for entrepreneurs in appropriate neighbourhoods to recognise that the precedent set in Rotorua for clusters of developments around a single well can be repeated effectively now. Whether they drill a well and sell shares in the well or simply onsell heat from the well is up to them, based on their own perceptions of risk and reward.

There has been long term user interest in geothermal heat pumps, but there were no known specialist suppliers and installers, and price may have been uncompetitive. Warmfloor has now broken this stalemate with lower cost equipment and an installation support programme. The company's challenge will be keeping up with demand and making room for the competition. This may require the competition to find alternative low cost suppliers of equipment or will require Warmfloor to become the principal importer for the various other design/installers.

5.4 Summary

An analysis of possible key drivers from a users perspective for the uptake of geothermal energy for direct heat use indicates that while commercial drivers should reasonably dominate, many other factors come into play resulting in decisions that do not appear rational. There are a range of positive drivers including pressure to clean up air (forcing substitution of fossil fuels and inefficient log fires), and new pressures for healthy and energy efficient homes. Countering this will especially be an aversion to paying a high capital cost for a geothermal option, with associated drilling risks, and some consenting restrictions. Suggested drivers from a users perspective include:

- General concern over rising fuel prices
- New developments or plant replacement
- A requirement for a quality fuel supply
- Concern over past bore closures
- Co-location of resource and user
- Concern over CO_2 and other air emissions
- Concern over current levels of domestic heating
- Aversion to high capital expenditure on energy
- Constraining resource consenting policies
- Current knowledge of geothermal resources suitable for direct use
- Current technology and cost trends for plant and equipment using geothermal energy

There is increasing interest and action with respect to direct use of geothermal energy from a developer's perspective. The major geothermal electricity developers (Contact Energy, Mighty River

Power and Tuaropaki Trust) all have some recognition of the value of diversification of energy supply options to include direct heat use. However, future direct use projects will have to be on a commercial basis (not always the case in the past which had created low expectations on the part of these developers).

The types of developers who will be involved in major investments include:

- Major national geothermal power developers
- A range of active Maori trusts suitably located over geothermal resources
- Potential utility and energy service companies e.g. Energy for Industry
- Drillers
- Geothermal heat pump specialists
- Property developers, and
- Investment bankers

Because of the high exploration and development costs of geothermal development it is expected that larger developments will partly happen through investment by utilities and energy service companies, and with the encouragement of Maori Trusts. Initial ventures are now being considered e.g. the New Zealand Clean Energy Centre/Energy for Industry hospital and school heating project in Taupo. It seems that a business model based around multiple smaller sales through hard-wired connections with frequent billing, is a better model for the proliferation of small scale development expected in the near term.

6 Direct Cost Comparisons for Some Specific Technologies and Applications

The following chapter uses costs reported earlier in this report or from separate studies to develop simple costs (on a $/GJ basis for large industrial applications, or a c/kWh basis for smaller applications) for comparison purposes. Cost comparisons are made with other fuels, or with the variable component of retail electricity price, to identify the circumstances in which direct use of geothermal energy is a competitive option. Based on a knowledge of when those circumstances are likely to arise, this will enable the development of a view on uptake.

6.1 Industrial Supplies of Geothermal Heat

East Harbour has reviewed the cost of a range of technologies for delivering heat to industry, focussed on the provision of a steam supply. A fuller discussion of the implications of the heat supply curves is found in Appendix 5. Figure 6.1 shows a comparison between fuels.

Note that geothermal heat for industrial applications will only be available in the Taupo Volcanic Zone and near Kaikohe (Ngawha), unless EGS supplies become economic. As far as is known, there have been no studies of adopting EGS supplies to direct heat applications and these were not modelled.

Based on the curves in Figure 6.1, stand-alone geothermal heat supplies located on conventional high temperature resources require a certain size before they become commercially competitive with coal (the principal competition). Currently, based on the assumptions of field conditions present in the model, it is difficult for a greenfield development to compete with coal for developments below a threshold 30MWth or so. A carbon charge (of $15/t CO_2) would see this threshold reduce to around 15MWth, while expected price movement for coal could see this reduced to 10MWth[49]. While exact thresholds for competitiveness will be site-specific, these calculations indicate the requirement for a significant load for a development to be commercially competitive.

A geothermal “cogeneration” price is also shown, this being the price that a generator must secure to remain revenue-neutral if it diverts its steam to another party on site. This price is lower than all other North Island fuel options, but requires a heat user to be on-site to take advantage of it.

[49] On the basis of costs presented in this report it is difficult to justify the 20MWth Tenon steam supply. Factors that may have come in to play include: an expectation of a carbon charge; expectation of rising coal prices; expectations of extensions of supply in future; write-off of some well costs against field exploration; use of a higher internal rate of return by Tenon in assessing the value of alternative heat options; and/or more favourable field conditions leading to lower costs than modelled.

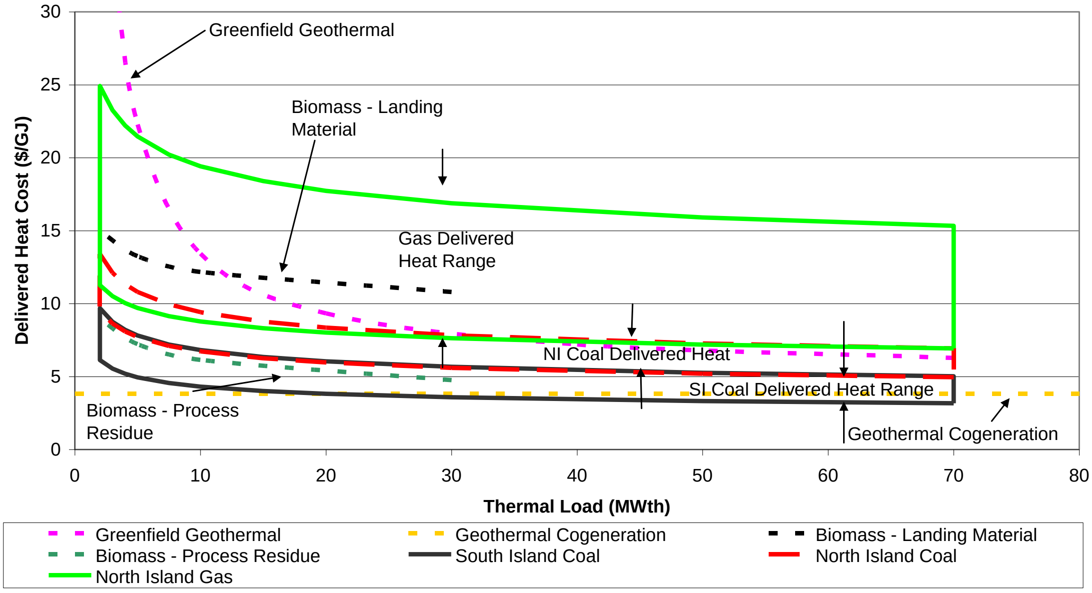

Figure 6.1. Sample output of heat cost modelling – 2005 heating costs with no carbon charge (10% IRR)

6.2 Traditional Direct Use Applications at the Smaller Scale

Typical arrangements for traditional direct use of geothermal energy have been outlined in previous chapters of this report. Typically, a shared production well will distribute heat either directly (or possibly indirectly if a downhole heat exchanger is used) to the heat exchangers of the various users. Applications could be for home heating, or for heating hotels or schools as examples (heat loads for these have already been discussed).

Unit costs for a range of heating applications have been analysed. The results are shown in Figure 6.2. In Figure 6.2, all capital and operating costs have been divided by the energy provided to derive unit costs in terms of c/kWh. This is compared with the variable component of retail electricity price as a simple means of determining clear commercial viability (strictly, capital costs of resistance heaters should be added to the comparative electricity price, making these options even more viable).

Analysis has been carried out for Weighted Average Cost of Capital of 5% and 10%. A 10% post tax real analysis is typical of what a commercial company might consider. At the domestic level there is a case for using 5%, being closer to the return that would normally be expected for an individual with investment funds.

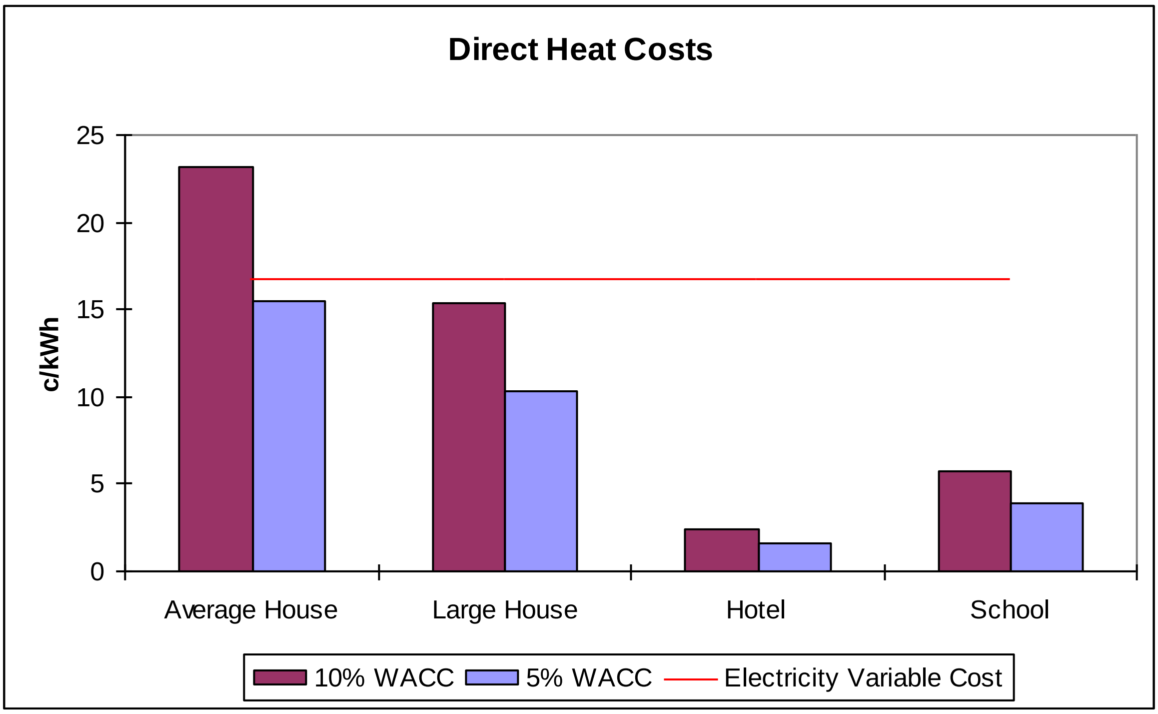

Figure 6.2. Comparison of conventional geothermal direct heat unit costs (in terms of cents per kWh of heating duty) for a range of house sizes and loads, and of larger applications with current variable electricity price

Figure 6.2 shows that for all indicative sizes of houses (from average to large) direct use of wells for water and space heating can be an attractive option, more so at lower internal rates of return. For hotels and schools (and therefore for a wide range of commercial applications) in the thermal regions, direct heating is a clear option.

Results of calculations are so attractive that assumptions have been revisited to ensure realism. A capital cost of $12,000 had been assumed for the heat supply for a large home. This was based on Tauranga wells costing $50,000, but with costs being spread over 4 users (consistent with up to 5 users being reported by Tauranga drillers). This figure is also greater than reported costs for a dedicated well in Taupo. In total, there is considerable risk for a small developer, if they do not have partners ready to share the cost and risk of drilling. The risk is much reduced for large loads where multiple wells might be required by the one developer.

6.3 Geothermal Heat Pumps

This section takes a similar approach to cost comparisons as the previous paragraphs. Unit costs for a range of heating applications (domestic and "commercial") have been analysed. The results are shown in Figure 6.3. These show that for larger homes, and therefore for a wide range of commercial applications, heat pumps can be cheaper options than consumption of electricity in resistance heaters. Note that we are comparing only the variable component of unit electricity prices of the national average incumbent retailer price. Also note that this comparison price varies with scenarios and time. A carbon charge of $15/t CO_2 will add about 1c/kWh to the comparison electricity price, while by 2020 electricity price would have risen by 3c/kWh under the MED Base Case scenario. Thus the comparison electricity price could eventually be 4c/kWh higher than indicated by 2020 and beyond.

Results are consistent with national and international experience.

In essence, it takes a relatively large heat load to justify installation of a heat pump. Average houses will not be able to access the technology unless in the south of the country and using a lower internal rate of return. Larger homes, especially in the south of the country, can justify the investment now, whether analysed at 5% or 10% internal rates of return. Large hotel loads and school loads (as for a wide range of commercial applications) can be justified now at any IRR. In other words they could be installed tomorrow based on sound commercial thinking. At a lower IRR a much wider range of large houses can support heat pump installations. Carbon charges and expected future movement in electricity price (from Energy Outlook scenario modelling) make subtle improvements to the economics, but do not alter the overall impression of attractiveness.

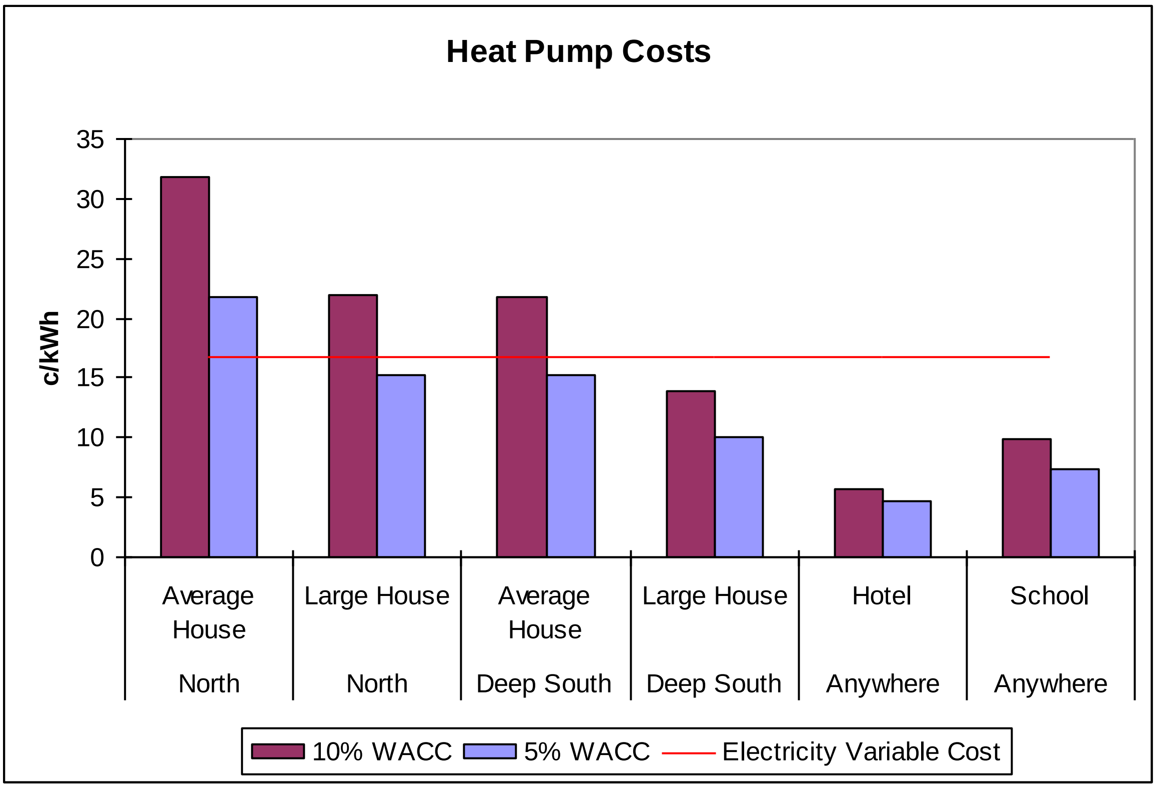

Figure 6.3. Comparison of heat pump unit costs for a range of house sizes and loads (in terms of cents per kWh of heating duty), and of larger applications with current variable electricity price

At 10% IRR, an average-sized house outside Otago/Southland could not justify the investment, but an average Otago/Southland house would be marginal. A large house (with energy usage being about 60% higher than average with some supplementary off-peak heating requirements) becomes attractive anywhere in the country. The space and water heating load levels looked at for this report are not as great as the maximum size identified in the BRANZ HEEP survey where 20% of houses had heating requirements greater than 14,000kWh/year and 10% of houses had heating use greater than 20,000kWh/year. There is clear potential for large houses with high demand, especially in the colder south of the country, to install these units.

Heat pumps have been installed in a large home in Hamilton and a large Blenheim home, including provision for pool heating. These may have been marginal applications, but may also reflect that private investment has a lower IRR, possibly closer to 5%.

Despite the low load factor for schools and hotels, heat pumps in these locations are clearly viable options at either 10% or 5% IRR. A prerequisite is a substantial area that could be damp. Hence this could be applied to many schools because of their playing fields. Resorts could also take advantage of this, as could some institutions. Uptake is easiest for new installations, but retrofitting in schools or similar environments using already plumbed radiator heaters would also be relatively easy.

6.4 Summary

At the industrial scale of supply, updated cost curves for delivered heat energy taking into account current capital costs and fuel costs suggested in the MED's Energy Outlook publication show that a revenue-neutral diversion of steam from a geothermal power station yields a heat price less than most other competing fuels. The curves also indicate that there is a minimum size for a Greenfield geothermal project to be viable (probably in the 10 to 30MW_{th} range). This corresponds to the demand of a large timber drying kiln operation.

A comparison with electricity price shows that conventional geothermal heating options based on shared wells are viable for space and water heating of average and above sized homes. Similarly they look financially attractive for a range of commercial applications. Heat pumps, which have far greater applicability nationally, are viable for large homes (or average Deep South homes) and above. Again, there are a range of commercial applications that are viable.

7 A View of Potential Uptake of Direct Heat Use

This chapter finally pulls together the various strands of discussion to assess uptake by sector (and region) and then to make recommendations on possible geothermal direct use targets.

7.1 Ministry of Economic Development Baseline Projection

The Ministry of Economic Development (MED) has been consulted to determine their Energy Outlook[50] Base Case assumptions.

MED's Base Case is intended to represent a business as usual case, essentially a middle path between optimistic and pessimistic view points. As such it can be used to gauge the impacts of actual and possible policy actions.

There was no specific modelling of geothermal direct use in MED's modelling for Energy Outlook except for the forestry sector. In that case, estimates had allowance for Mighty River Power's new Kawerau power station, which needed to be deducted for this study. This power station will have all generation used at the Kawerau site though it will feed the national grid. It will sit independent of the current steam supply to the mill site. As such, it is not true cogeneration and has been deducted from the direct use estimates. On this basis, the MED forecast is for continued steady use of geothermal energy in the forestry sector.

The absence of an estimate for the balance of all other geothermal direct use reflects a view that whatever market share that has been achieved at the start of the modelling period will be maintained. Hence, the MED Base Case projection is implicitly continued use at around 10.7 PJ/year of consumer energy.

However during the preparation of this report, there have been clear indications of a recent upturn in direct use, at least in the Tauranga area. However, there are also some counter trends. Ultimately, minor changes at a domestic level are swamped by the expected steady use at Kawerau, so a projection of continued direct use at current levels is not unreasonable.

7.2 Resource and User Considerations

7.2.1 High Temperature Geothermal Resources

High temperature geothermal resources will preferentially be developed by electricity companies for electricity generation. Electricity generation has a scale of operation that justifies field investigation and the effort necessary for land negotiation and consenting. It allows a concentration of drilling that can help to alleviate drilling risk.

There may still be minor direct use applications on a range of fields, possibly in association with land owner interests (including local Maori trusts). These applications could parallel the original applications at Ohaaki: green houses and marae heating, followed by kiln drying operations where the field is close to forest processing centres.

Some electricity companies are looking for additional steam (or heat) sales beside intended electricity developments. Generally potential users will be limited to existing types of users or to businesses that must remain in New Zealand. These types of businesses include: forest processing, meat processing and dairy processing industries. During the period covered by this study businesses that are considering relocation or expansion are assumed more likely to relocate

[50] Ministry of Economic Development (September 2006) New Zealand's Energy Outlook to 2030

offshore for better business conditions than relocate to another site in New Zealand for lower energy costs.

District heating projects may spread from initial demonstrations, as is proposed at Taupo (a supply to a school and the local hospital). There are still many people thinking that district heating is not viable in New Zealand, despite historic domestic applications (up to 95 houses connected to one system in Rotorua at one stage), and an increasing incidence of industrial parks linking heat supplies for several industrial/commercial/institutional parties.

7.2.2 Lower Temperature Geothermal Resources

There are numerous lower temperature resources, with dimensions and locations still poorly defined. Tauranga resources are already being developed for high end space and pool heating, often in mini-schemes in which a well use is shared amongst 4 or 5 users. Surrounding land includes specialist orchards and cropping, for which production could be improved through greenhouse use. Land through the Hauraki plains or parts of the Waikato have been developed for farming, but could also be developed for greenhouses.

Greater promotion of the use of down hole heat exchangers such as is occurring in Rotorua could increase utilisation of this technology in geothermal fields which are currently under protection by Regional Plans. There is large unrealised potential applications for accommodation, residential and industrial direct heat uses throughout the Waikato / Taupo / Bay of Plenty area.

7.2.3 Enhanced Geothermal Systems

This report includes only a minimum assessment of heat potential from enhanced geothermal systems emphasising a resource greater than national demand. There is still poor definition of costs and feasibility at particular sites, though this may ultimately depend on intended use.

There may be application to power generation, again because it provides a necessary scale of development. Initial location for such developments are likely to be vertical and lateral stepouts from high temperature geothermal fields.

Existing abandoned oil and gas wells can provide a cheaper entry to use of widespread geothermal energy at depth, but there are still costs involved in converting and recompleting these wells in order to discharge or inject water from useful levels. One well has already been used for heating purposes.

7.2.4 Geothermal Heat Pumps

International experience, coupled with calculations to show that large applications can be economic now in New Zealand, support a contention that this is an area of development set for tremendous growth.

Large domestic applications, particularly in the lower South Island can be justified now. Internationally there is exponential growth of the application suggesting that price should continue to drop over the next few years.

Heat pumps can readily be designed into new building developments for space heating and water heating. They can be retrofitted to space heating systems based around hot water radiator heating linked to extensive open grounds. This suggests strong opportunities for retrofitting into some schools, and possibly hospitals. There is an unrealised potential in waterside (particularly harbour-side) developments, especially for offices, apartments and public buildings for space and water heating.

There may be rare opportunities near old mines but generally concentration of use will be so small as to make this market segment negligible.

7.3 Three Scenarios

Ultimately this report aims to give an indication of uptake by region and under various scenarios. As part of an integrated approach across government, any scenario development in this report informing EECA's position was to be tied back to the Ministry of Economic Development's "New Zealand's Energy Outlook to 2030" (or Energy Outlook).

MED's Energy Outlook Base Case forms one scenario. The Energy Outlook Base case is essentially a Business-as-Usual case with moderate GDP growth, oil prices around current levels, continuing gas discoveries, energy efficiency improvements at historical rates and no carbon charge.

For this report, alternate views were developed based on the recognition that geothermal energy is commercially viable. While a range of factors will influence uptake, a price driver will clearly play some role. The pressure to take up one of these capital intensive but green options will be proportional to the difference between its unit cost and that of the prevailing fuel options (Figure 7.1).

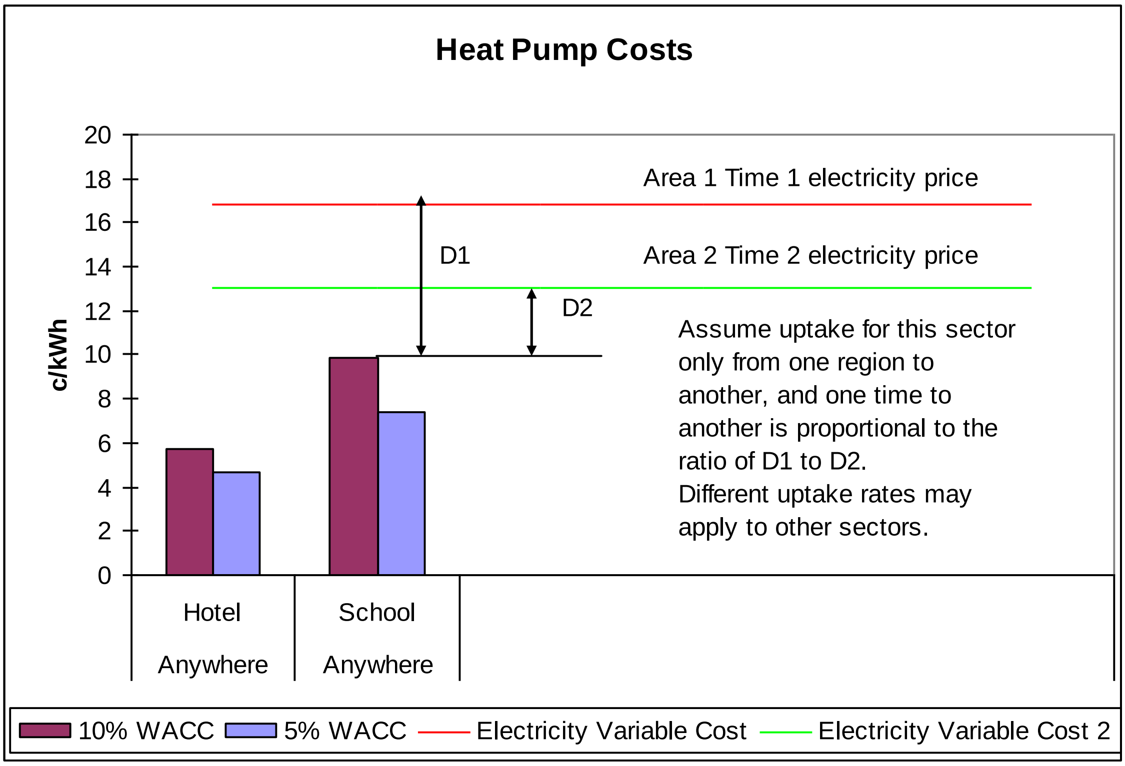

Figure 7.1. Illustration of the price driver principal used in the allocation of uptake between the regions and between prices and costs generated for the various scenarios.

With this in mind, two other scenarios were developed: one based on an alternative view of uptake influenced by Outlook Base Case fuel prices, and another with uptake based on Outlook Sensitivity Case: Carbon Charge fuel prices. The Energy Outlook Carbon Charge Case is a sensitivity case in the Energy Outlook that does include a carbon charge of $15/tonne of CO_2. While a carbon charge as such may not be introduced, this does represent the effect of a price on carbon whether through a tax or emissions trading.

Table 7.1. Summary of the Three Scenarios

	Scenario Source	Assumptions
Scenario 1	Energy Outlook Base Case	Current direct heat use is unchanged, based on MED's original assumptions
Scenario 2	Energy Outlook Base Case	Uptake varies according to the price driver discussed above
Scenario 3	Energy Outlook Carbon Charge Case	Uptake varies according to the price driver discussed above, the driver being greater because of the carbon charge

In turn, all prices were regionally adjusted taking account of energy distribution costs, and usually adjusted for size of consumer (i.e. domestic, commercial, and industrial).

Note that while unit cost examples have been undertaken for homes, schools and hotels, these are indicative only. Specific unit cost calculations were not undertaken say for government buildings or greenhouses, but the closest analogous unit costs were selected as a means of determining the driver as a crude means of apportioning uptake between scenarios and regions.

It is also recognised that there can be some irrational (non-commercial) drivers. These may see uptake where price may not otherwise support uptake. (Why would anyone choose a Mercedes over a Ford, except for non-commercial reasons?) A separate spreadsheet has been developed to reflect this.

In turn, actual apportionment between sectors was based on subjective views of uptake summarised in Table 7.2.

Table 7.2. Summary of the Subjective Views on Uptake

Application	**Total Market Penetration by 2030**[51]	**Rationale**
Conventional direct heat		
Homes	0.02% nationally but with high penetration regionally	Assume uptake occurs in the major centres of Taupo, Rotorua and Tauranga. Uptake at other locations is limited by consenting regime, or economic climate, or may fall within error noise. Predominantly new homes with a retrofit uptake at about 1/10th of that of new homes.
Hotels	see comment	There is already significant uptake. Assume 2 new hotels (1TJ/year each) in each of Taupo, Rotorua and Tauranga.
Schools	see comment	There is already significant uptake. Significant competition from conversion of coal burners to use wood pellets. Assume 3 new schools (1.3TJ/year) in Taupo, Rotorua and Tauranga.
Dairy farms	see comment-	Assume 3 large farms (0.05TJ/year each), potentially over high or low temperature fields
Public Service	0	Ignored, as additional use will be within error noise. Frequently, the public service does not own property so will be restricted in ability to encourage high capital, low running cost options.
Hospital	see comment	Uptake is expected at Taupo hospital eventually. Heat use will be of the order of 20TJ/year.
Green houses	see comment-	Assume 1 green house (64TJ/year each after expansion) per developed high temperature field in co-operation with land owners. A 2 ha area is a significant glass house area. Assume initial 2 ha development followed by a second development. 9 developed or potentially developable fields currently do not have greenhouse heat supplies from the generators. At 1.6GJ/m^2,

[51] There have been additional assumptions around the intermediate 2020 year uptake which are reflected in the following summary table

		this implies total uptake of 580TJ/year.
Kiln drying and forest products	see comment	Assume 1/10th of CNI biomass demand (30TJ/year) will be met by displacing wood processing residues from Kawerau boiler supplies to free this material for pelletising. $20MW_{th}$ kilns (about 400TJ/year) will be installed on 4 more of the 9 high temperature fields currently without kilns.
Geothermal Heat Pumps (nationally)		
Homes	0.75%	Assume the limiting factor will be the extent of penetration in Southland/Otago. 20% penetration of the above average home market in Southland/Otago is assumed there by 2030 under scenario 2. This takes into account the preference for low capital cost status quo, and psychological/traditional enjoyment of fire.
Hotels	2%	Many large hotels will be in built up areas without the possibility of significant grounds. Hence heat pump opportunity might be limited to about 2% of all hotels rooms by 2030.
Schools	2%	Retrofitting of biomass boilers to fossil-fuel boilers will be easier and cheaper than retrofitting of heat pumps. However a 2% penetration should still be possible based on favourable economics when analysed over time.
Dairy farms	see comment	Assume 5 large farms.
Public Service	1%	Although public servants are expected to take the lead, ability to use heat pumps will be limited because of the usual built up environment in which these commercial-type buildings exist, and because properties are generally rented.
Hospital	0	Assume delivered temperatures make this an unattractive option, due to hospital requirements for higher temperature conditions for sterilisation.
Green houses	2%	Heat pumps can readily meet all heat needs. However, greenhouses also need CO_2, so some burning of biomass (or fossil fuel) could be needed. Heat pumps are capital intensive while greenhouses may be short-lived. Penetration is unlikely to exceed 2%
Forest products	0	Required temperatures are above the supply capability of heat pumps

Key regional statistics have been reviewed to assist with allocation between regions. These statistics include: population, number of homes (rented vs owned), number of pupils in schools, hotel rooms, public servants, dairy herds and green house area.

7.4 A Quantitative View on Uptake

Based on the data and assumptions outlined in the previous section, the uptake of geothermal energy may be expected under the various scenarios to be as shown in Appendix 7. The summary results are shown in Table 7.2. Regional contributions under the three scenarios are shown in Figures 7.2 and 7.3

Table 7.2. Summary of Expected Uptake of Geothermal Energy Direct Use under Various Scenarios

	Current Consumer Energy (PJ/year)	Expected New Uptake by 2020 above 2007 (PJ/year)	Expected New Uptake by 2030 above 2007 (PJ/year)
Scenario 1 Base Case MED	10.7	0	0
Scenario 2 Base Case mod	10.7	1.9	3.0
Scenario 3 Carbon Charge mod	10.7	2.0	3.2

Scenario 1 shows the MED Base Case assumption that there will be no effective change in direct use. Scenario 2 is also referenced to the MED Base Case, but instead of assuming fixed direct use shows progressive uptake of geothermal direct use options through to 2030 (with further growth expected beyond that). Growth expectations are strongly based on the financial viability of direct use projects but suppressed by a range of other factors. In Scenario 3, pricing of carbon will raise electricity prices, and so will drive a higher uptake of renewables, especially in the domestic heating market. The effect of the carbon charge is muted (and largely lost in rounding) by the assumptions that the big direct use projects (e.g. greenhouses and kilns) are unaffected by price and are simply related to the presence of a geothermal power station on a field.

Major direct use growth is expected to be through brownfield developments commonly linked to power station developments. While this report discusses greenhouses and timber drying kilns, these are just likely examples of what could be quite varied projects. In total, about 1.5PJ/year by 2020 and 2.2PJ/year by 2030 of additional direct use energy is expected to be provided in this context, linked to the wider field developers. While it is not clear whether this use will represent substitution of fossil fuels elsewhere or simply new growth, what is clear is that it represents a growing contribution of renewables to the energy needs of the national economy.

A total major project target of 1.5PJ/year by 2020 and 2.2PJ/year by 2030 would represent an achievable stretch. It can be thought of as a growth for major direct use projects of approximately 1PJ/year/decade. This compares with a past growth rate (after deducting the exceptional Kawerau supply) over the last 5 decades of approximately 1PJ/year/decade over all market segments of geothermal direct use. While past development has been in 'fits and starts' with recent stagnation, the projection does appear to be both a stretch and achievable.

These types of developments (involving reservoir assessments, wells, fittings, pipes and pressure vessels) draw on the traditional skills of New Zealand geothermal consultants and contractors to the electricity generation industry i.e. requires heavy engineering skills. These developments assist developers in small step outs in terms of diversification of supply. They will be based on commercial advantage for both the developing host and the direct user.

Table 7.3 summarises the expected uptake across a range of applications after the deduction of the major projects.

Table 7.3. Relative Contributions of Independent (i.e. not Including Major Projects) Geothermal Developments Including Both Conventional Direct heat Use and Geothermal Heat Pumps under Scenario 2 and 3 (PJ/year)

Market Sector	2020		2030	
	Scenario 2 Base Case	Scenario 3 Carbon Charge	Scenario 2 Base Case	Scenario 3 Carbon Charge
Home (heat pumps)	0.22	0.28	0.58	0.73
Greenhouses (heat pumps)	0.08	0.08	0.08	0.08
Schools (heat pumps)	0.04	0.04	0.04	0.04
Accommodation (heat pumps)	0.03	0.03	0.03	0.04
Hospital (wells)	0.02	0.02	0.02	0.02
Homes (wells)	0.01	0.01	0.02	0.02
Public Service (heat pumps)	0.01	0.01	0.01	0.01
Accommodation (wells)	0.01	0.01	0.01	0.01
Totals	**0.41**	**0.48**	**0.79**	**0.95**

Figures 7.2 and 7.3 show that all direct use continues to be focussed on the Waikato and Bay of Plenty regions, and to be highly dependent on development in co-operation with power station developers. There are subtle changes in use in other regions, and these do represent real heat use options for existing or new users.

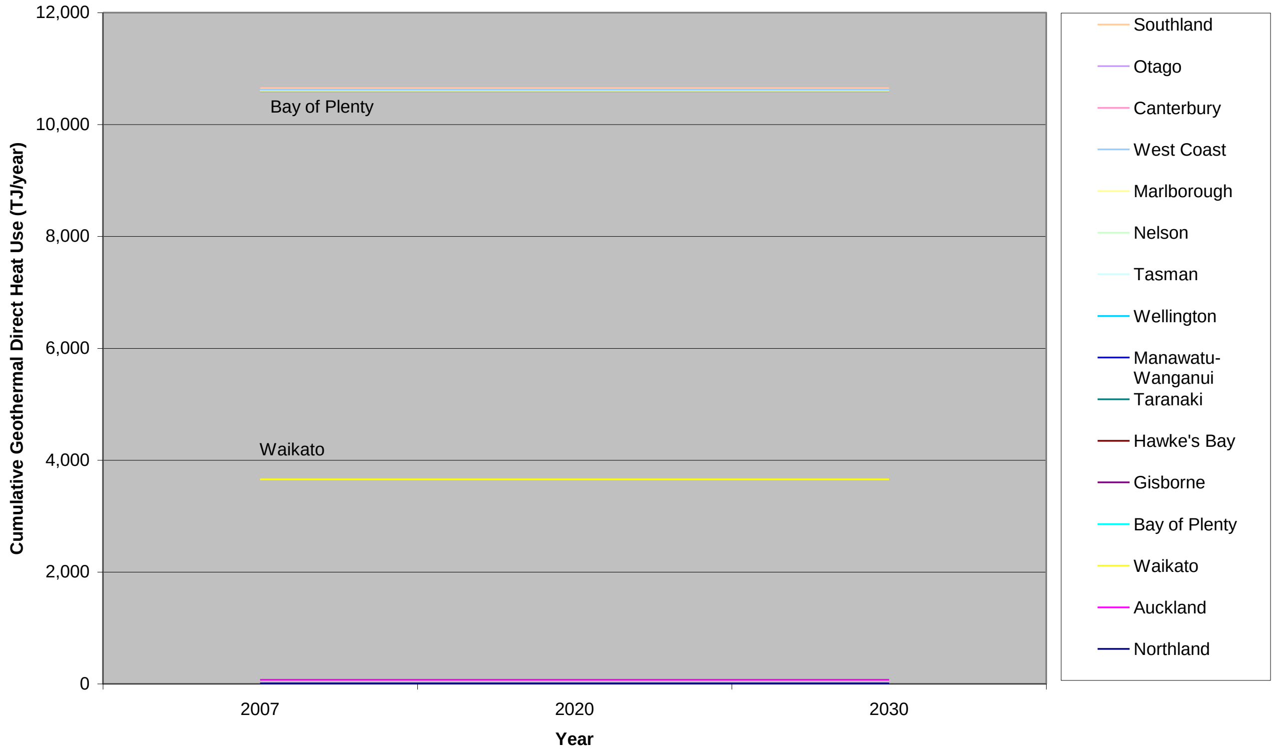

Figure 7.2 Expected geothermal energy direct use under Scenario 1 Base Case MED

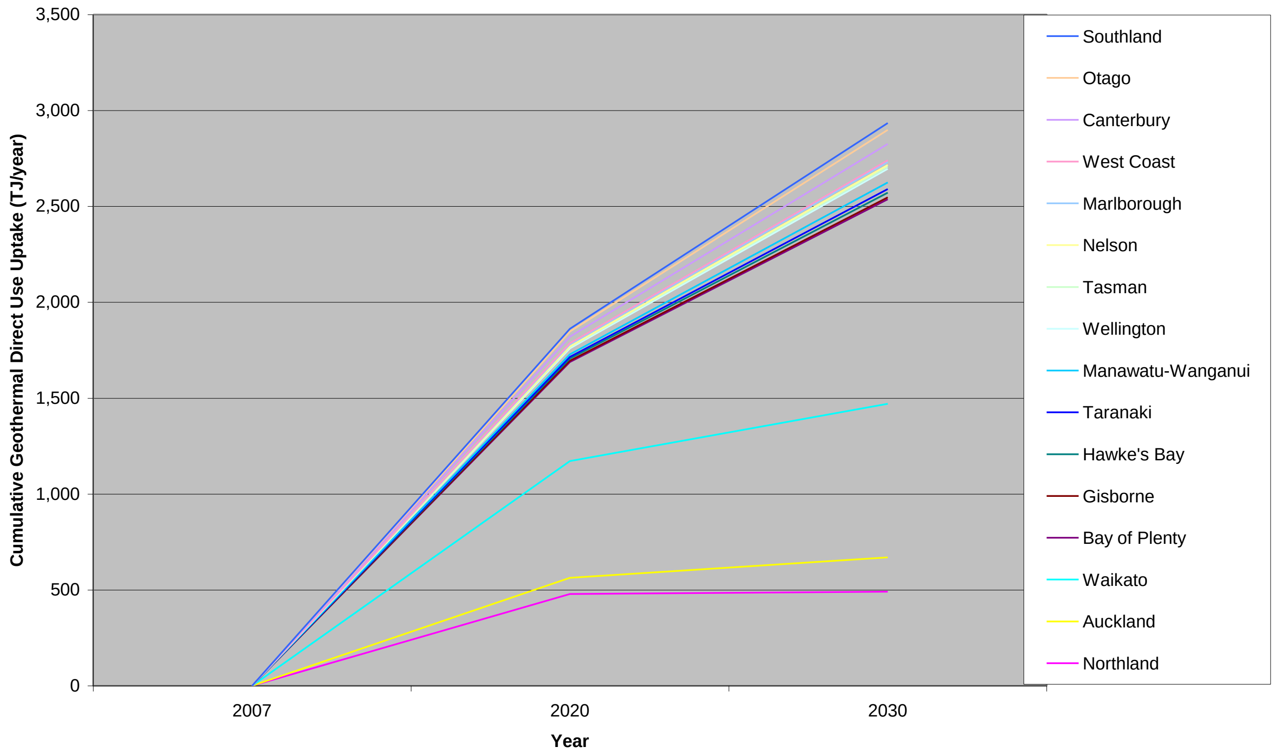

Figure 7.3 Expected geothermal energy direct use uptake under Scenario 2 Base Case modified. Under Scenario 3 Carbon Charge modified the uptake would be about 200TJ/year higher by 2030.

In terms of calculations, heat pump penetration of the market is expected to be quite significant with a total of approximately 3,800 pumps by 2020 and 10,000 pumps by 2030 expected to be installed in domestic houses, with a further 150 larger heat pumps in other market sectors. These could potentially save consumption of 160GWh/year of electricity by 2030 because of their high coefficient of performance. This number of heat pumps is consistent with exponential growth observed internationally with this technology, contrasting with the very small number currently being installed. As such, it represents a potentially achievable stretch target.

This target for heat pump uptake contrasts with the target for major geothermal projects in that it draws on a different skill-set and is accessible to a wider range of New Zealanders. Heat pump installations are achieved with the assistance of plumbers and electricians at the domestic and commercial level. While some basic training is required for the installer, this technology is a sound investment for large homes and commercial applications. Its encouragement allows a much wider portion of New Zealanders to be involved in installation of/investment in renewable energy options.[52]

Further growth in small scale domestic use of geothermal energy is likely, say using shallow wells feeding homes, or downhole heat exchangers in the traditional geothermal areas like Taupo, Rotorua or Tauranga. A more active domestic geothermal drilling program is expected in these traditional geothermal areas. Again, these projects can be commercially attractive, but are physically restricted to a few towns and cities, for which they may have regional but not national significance. Consequently, the final scale of growth is likely to be dwarfed by heat pumps and major station-linked projects.

While targets for small scale domestic use of geothermal energy using shallow wells or downhole heat exchangers would not represent a significant contribution to New Zealand's energy needs it is an area where targets would draw attention to the opportunity and assist in changing mindsets currently limiting increased use of these technologies. If regional targets are considered, then it should be possible to formulate a target for the Waikato and Bay of Plenty regions, possibly based on number of wells drilled. Alternatively if an energy target is wanted then a target based on an increase of 0.04PJ/year by 2020 and 0.05PJ/year by 2030 would be a stretch but achievable if commercial and institutional uses were targeted..

Direct use of geothermal is expected to be a continuing and expanding characteristic of the area if promoted as a main stream energy source by Territorial and Regional councils.

7.5 Potential Ways of Assisting Targets

In the targets suggested above the driving forces will principally be commercial, so not in the direct control of government. However, government can play a role in providing an environment that will assist uptake by these commercial interests. This can include:

- Through pricing of externalities such as emissions into the energy market through a price on carbon,
- Through active support of projects at the consenting stage through whole-of-government submissions in support,
- Through ongoing streamlining of the RMA consenting process with a view to timeliness and lower cost,
- Through clear direction to consenting authorities of the value of geothermal direct use, and encouragement of appropriate sustainable use[53] of geothermal resources (in fact many

[52] One word of caution is that there is currently only one or two significant players in this market in terms of importing and designing, though a range of contractors are used in installation. Opportunities are thought to be sufficiently attractive that competition will enter this market.

[53] This might eventually require a National Policy Statement on direct use. Currently several councils are excessively precautionary. Geothermal developments could be proceeding now in Rotorua using downhole heat exchangers.

Regional Councils recognise this now, however greater encouragement needs to flow down to some District Councils),

- With loans and grants paralleling other government efficiency schemes, and
- With tools such as the 'Projects to Reduce Emissions' mechanism specifically targeting direct use (in contrast to the electricity market where a carbon price clearly will flow through the whole market).

7.6 Measurement of Targets

Targets need to be measurable and will require active monitoring by government. Currently, few companies import heat pumps, so a tally of numbers should be readily achieved, though actual heating duty may be unknown. This is a similar approach that has been taken for solar hot water heating.

In the case of major projects, some of these may require separate consenting to that of the power stations, so consents could be monitored to measure progress. In practice, the number of projects and associated developers will be limited, and it may simply be a matter of maintaining relationships and information flows with these key parties. This report has indicated the range of parties for which relationships and monitoring will have to be established. EECA has already sponsored one geothermal direct use survey, and funded the start of a direct use database. Further funding could be directed in this direction. The end result will be a tracking of major projects and general indication of growth in minor sectors of the geothermal direct use market.

7.7 Final Recommendations

It is recommended:

4. That consideration be given to the following geothermal direct use targets:
    a. Installation of 3,950 geothermal heat pumps by 2020 and of 10,150 geothermal heat pumps by 2030 representing 0.4PJ/year and 0.8PJ/year respectively, plus.
    b. Development of an additional 1.5PJ/year "major" direct use projects by 2020 and 2.2PJ/year "major" direct use projects by 2030, plus
    c. Development of an additional 0.04PJ/year "shallow well and downhole heat exchanger" direct use projects by 2020 and 0.05PJ/year "shallow well and downhole heat exchanger" direct use projects by 2030.
5. That measurement of targets as outlined above should be:
    a. By a tally of heat pumps as provided by importers
    b. By relationships with/information flows from key developers and/or ongoing sponsorship of the development of a direct use database and direct use surveys.
    c. Number of shallow well and downhole heat exchangers installed.
6. That assistance be provided to commercial parties in meeting these targets through any or all of the following means:
    a. Pricing externalities such as emissions into the energy market through a price on carbon,
    b. Active support of projects at the consenting stage through whole-of-government submissions in support,

c. Ongoing streamlining of the RMA consenting process with a view to timeliness and lower cost,

d. Clear direction through Regional Policy Statements of the value of geothermal direct use, and encouragement of appropriate sustainable use[54] of geothermal resources (in fact many Regional Councils recognise this now, however greater encouragement needs to flow down to some District Councils),

e. With loans and grants paralleling other government efficiency schemes, and

f. Possibly with tools such as the "Projects to Reduce Emissions" mechanism specifically targeting direct use (in contrast to the electricity market where a carbon price clearly will flow through the whole market).

[54] This might eventually require a National Policy Statement on direct use. Currently several councils are excessively precautionary. Geothermal developments could be proceeding now in Rotorua using downhole heat exchangers.

8 References

Agnes Reyes (2007) *Sources of Energy for Geothermal Direct Heat Use*. GNS Science Consultancy Report 2007/54

Bibby H, Caldwell G, Davey F, Webb T (1995) *Geophysical evidence on the structure of the Taupo Volcanic Zone and its hydrothermal circulation*. Journal of Volcanology and Geothermal Research, 68, 29-58

BRANZ (2006) *Energy Use in New Zealand Households – Report on the Year 10 Analysis for the Household Energy End-use Project (HEEP).* Study Report No SR 155 (2006)

BRANZ (2006a) *NZBC Clause H1 Review House Insulation Cost Benefit Analysis.* Report QC 5048

Brian White (2000) *Wairakei Energy and Efficiency Audit.* A report by PB Power for Contact Energy

Brian White (2006) *An Assessment of Geothermal Direct Heat Use in New Zealand.* New Zealand Geothermal Association report prepared with EECA funding

East Harbour (2005) *Availabilities and Costs of Renewable Sources of Energy for Generating Electricity and Heat* report for MED.

East Harbour and Scion (April 2007) *Assessment of Possible Renewable Energy Targets – Direct Use: Woody Biomass.* Report by East Harbour Management Services and Scion prepared for Energy Efficiency and Conservation Authority

EECA (2000) *The Dynamics of Energy Efficiency Trends in New Zealand – A compendium of energy end-use analysis and statistics*

Environment Bay of Plenty (2005) *Rotorua Geothermal Field Management Monitoring Update: 2005*

IEA Statistics (2005) “Renewables Information 2005 Edition”

Jim Lawless (2004) *Maintaining Leadership in Geothermal Energy Generation in New Zealand.* Paper for the National Power Conference.

Johnson G and Olhoeft G (1984) in : Carmichael RS (ed), *Handbook of Physical Properties of Rocks.* 3, CRC Press, Boca Raton, Florida, USA.

José Goldemberg (February 2004) *The Case for Renewable Energies.* Thematic Background Paper presented at the International Conference for Renewable Energies, Bonn, 2004

Lund JW, Freeston DH, Boyd TL (2005) *World-Wide Direct Uses of Geothermal Energy 2005.* Proceedings World Geothermal Congress 2006 Antalya, Turkey

MAF Policy (2003) *Greenhouse Energy Use & Carbon Dioxide Emissions.* MAF Technical Paper No 2003/03 prepared by Andrew Barber AgriLINK New Zealand

Malengreau B, Skinner D, Bromley C and Black P (2000) *Geophysical Characteristics of Large Silicic Volcanic Structures in the Coromandel Peninsula, New Zealand.* New Zealand Journal of Geology and Geophysics, 43, 171-186

MIT (2007) *The Future of geothermal Energy – Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century.*

Ministry of Economic Development (September 2006) *New Zealand Energy Data File*

Ministry of Economic Development (September 2006a) *New Zealand’s Energy Outlook to 2030.*

Thain I, Reyes A, Hunt T (June 2006) *A Practical Guide to Exploiting Low Temperature Geothermal Resources.* GNS Science Report 2006/09

Wang Z and Wang H (July 2006) *Economic Analysis of Water Source Heat Pump System* in Proceedings of the 7th Asian Geothermal Symposium

Weast RC, Lide DR, Astle MJ and Beyer WH (1989) *CRC Handbook of Chemistry and Physics: a Ready-Reference Book of Chemical and Physical data.* 70th edition, CRC Press, Boca Raton, Florida, USA.

Appendix 1. Abandoned Hydrocarbon Wells

There are 349 extant abandoned hydrocarbon wells in 8 onshore sedimentary basins and several non-basin areas. These provide information on conductive heat flow in various parts of the country, and could provide a cheap entry to initial development of some sites. Bottomhole temperatures (Reyes 2007) range from 15.6 to 171°C assuming a surface temperature of 15°C. BHT = bottom hole temperature

Well Name	Depth (m)	BHT (°C)
Petroleum Creek-5	17.3	15.6
No2 Maoriland	19.0	15.7
B1	22.0	15.8
B4	24.0	15.9
Shaft	25.0	15.9
Waipai-1	45.0	16.0
No1 Lake Brunner	32.0	16.1
No4 Lake Brunner	32.0	16.1
Toi Flat-1	55.0	16.2
B2	34.0	16.2
No7 Lake Brunner	38.0	16.4
No3 Maoriland	40.0	16.4
No4 Maoriland	40.0	16.4
Westcott-1	67.0	16.4
No5 Maoriland	41.0	16.5
No1 Maoriland	44.0	16.6
Cutters Bridge-1	48.0	16.8
No1 Kotuku Consolidated	51.0	16.8
Okoke Bore	61.0	16.8
Alton	61.0	16.9
Totangi-1A	64.0	17.0
Waitangi Hill-1	64.0	17.0
Kiorereoa-3	54.0	17.1
Petroleum Creek-2	59.0	17.1
Petroleum Creek-1	64.0	17.3
Rangitaike-1	61.0	17.3
Pukerau-1	73.0	17.4
Waewaepa-1	124.0	17.7
Corehole-8	100.0	17.9
Waiotapu-1	61.0	17.9
Samuel Syndicate-6	92.0	18.1
Kaiaua-1	108.0	18.1
Taranaki Petroleum-1	94.0	18.1
Totangi-1	103.0	18.1
Taranaki Petroleum-2	97.0	18.2
Waikaia-2	121.0	18.5
No6 Lake Brunner	98.0	18.5
Bore 251	123.0	18.5
Moa Bore	140.0	18.5
Carrington Road-2	112.0	18.7
Pukerau-2	118.0	18.9
Great Barrier-2	92.0	18.9
Horotiu Bore-1	137.0	19.2
Horotiu Bore-2	137.0	19.2
No3 Bore	147.0	19.2
A1	122.0	19.4
Kiorereoa-2	109.0	19.4
Ardmore-1	137.0	19.6
Totangi-2	154.0	19.7
Te Karaka-1	152.0	19.7
No5 Lake Brunner	133.0	19.8
Totangi-2A	156.0	19.8
Rotokautuku-4	114.0	19.9
No8 Lake Brunner	137.0	19.9
Omata Bore-1	152.0	20.1
Victoria	157.0	20.2
No3 Lake Brunner	147.0	20.3
Limestone Test Bore	148.0	20.3
Waiotapu-2	113.0	20.4
Whanga Road Bore	195.0	20.4
Pukerau-3	165.0	20.5
Kauana-1	179.0	20.5
Waikaia-1	197.0	20.6
Koranga-1	273.0	20.9
Horotiu Bore-3	195.0	20.9
Kiorereoa-1	148.0	21.0
Horotiu-2	198.0	21.0
Horotiu-5	198.0	21.0
Rotokautuku-1 (Southern Cross)	145.0	21.2

RSE-2	179.3	21.3
No3 Kotuku Oilfields	183.0	21.5
No2 Kotuku Petroleum	187.0	21.7
Santoft-1	312.0	21.7
Merryvale-1	239.0	21.8
Beta	208.0	21.9
Horotiu Bore-4	229.0	22.0
Tikorangi-1	221.0	22.4
Rotokautuku-2	172.0	22.4
Rangitaike-2	194.0	22.4
Papatotara-1	261.0	22.5
Corehole-9	215.2	22.7
Prospect Valley-1	272.0	22.9
Ruby Bay-1	281.0	23.0
No2 Lake Brunner	229.0	23.2
Dargaville-1	248.0	23.3
Minerva Borehole	283.0	23.8
No2 Kotuku Oilfields	247.0	23.8
Tuatapere-1	306.0	23.9
Back Ormond Road-2	300.1	24.0
Back Ormond Road-1	301.1	24.0
Whitianga-1	295.0	24.1
RSE-1	263.1	24.3
Samuel Syndicate-1	283.0	24.4
No9 Lake Brunner	265.0	24.5
Great Barrier-1	226.0	24.7
Waikato-3	320.1	24.8
Westgas-3	310.6	25.4
No1 Kotuku Oilfields	290.0	25.4
No1 Kotuku Petroleum	293.0	25.5
Paddy Gully-1	294.0	25.5
Uruti-1	356.0	25.5
Samuel Syndicate-9	322.0	25.7
Omata Bore-2	323.0	25.8
Samuel Syndicate-2	335.0	26.2
Westgas-1	346.6	26.6
Corehole-11	423.0	27.1
Waingaromia Bore	403.0	27.1
Prospect Valley-2	430.0	27.5
Waihihere-1	421.0	27.6
Bore 252	459.0	28.1
No3 Kotuku Petroleum	375.0	28.4
Kaitieke-1	394.0	28.7

Waitangi-1 (Gisborne Oil)	450.0	28.9
Vogeltown Bore	422.0	29.1
Chertsey Bore	661.0	29.2
Centre Bush-1	498.0	29.2
Kaimata Bore	407.0	29.3
Puketaha-1	475.0	29.5
Rakaiatai-1	685.7	29.7
Dargaville-2	445.0	29.8
Waingaromia-2	502.1	30.1
Samuel Syndicate-7	457.0	30.2
Kiore-1	536.6	30.3
Samuel Syndicate-3	468.0	30.6
Waitangi-1	512.7	30.6
Corehole-10	445.0	30.7
Waitangi-1 (Taranaki Oilfields)	513.0	30.9
Koporongo-1	590.9	31.6
Te Hoe-1	627.0	32.3
Taranaki Petroleum-4	511.0	33.0
Access Road	476.0	33.1
Waikato-4	598.5	33.2
Rangitaike-1A	479.0	33.2
Rotokautuku-5	560.0	33.7
Speedy-1	876.0	33.8
Speedy-1	876.0	33.8
Peep-O-Day	917.0	34.7
Tane-1 (Mangaone)	917.0	34.7
Waitangi-2	662.0	35.2
Dobson-2	611.0	35.4
Karaka-1	614.0	35.5
Waipatiki-2	966.0	35.7
Kaiaka-1	625.0	35.8
Samuel Syndicate-8	625.0	35.8
Samuel Syndicate-5	626.0	35.9
Ohura-1	635.0	36.2
Norfolk Road Bore	762.0	36.8
Young-1	1035.0	37.2
Blenheim-2	640.0	37.6
Takapau-1	1059.0	37.7
Dobson-1	682.0	37.7
New Plymouth-1	655.0	38.1
Moturoa-3	658.0	38.2
Waipatiki-1	1097.0	38.5
Northland-1	625.9	38.8

River Road-1	789.0	39.0	Ararimu-1	1057.6	50.3
Patea East-1	1082.5	39.2	Ahaura-2	1069.0	50.6
Taipo Creek-1	679.0	39.3	Patea-1	1613.0	51.1
Leeston-1	1158.5	39.8	Hohonu-1	1039.0	51.6
Mawhera-1	697.0	39.9	Kowai-1	1410.0	51.9
Arnold River-1	710.0	40.0	Card Creek-1	1342.0	53.3
Mangatawa-1	669.0	40.5	Arcadia-1	1479.0	53.7
Gisborne-1	927.0	40.6	Bell Block-1	1131.0	54.9
Waiapu-1	774.0	40.8	Aratika-2	1149.0	55.5
Kaimiro-12	835.0	40.8	Mangaone-1	1550.0	56.3
SFL-2	908.0	40.9	Huiroa Bore	1500.0	56.4
Glenn Creek-1	739.0	41.0	Kereru-1	1939.0	56.6
Mangamahoe-1	802.0	41.7	Ohaupo-1	1207.0	57.0
Bonithon-2	764.0	41.9	Taradale-1	1660.7	57.7
Kawhaka-1	852.0	43.4	Mason Ridge-1	1880.0	58.0
Tautane-1	1328.9	43.5	Wingrove-1	1600.0	59.2
Oamaru-2	665.0	43.5	Moturoa Bore	1329.0	59.3
Tatu-1	860.0	43.7	Stantiall-1	2096.0	59.9
Waiapu-2	994.0	44.8	Kauhauroa-5	1751.0	60.0
Bell Block-2	853.0	45.1	Tarata-1	1527.0	60.8
Rotary Bore	853.0	45.1	Uruti-2	1553.0	60.9
Oamaru-1	908.0	45.3	Oru-1	1700.0	61.1
Whakamaro-1	916.0	45.5	Happy Valley-1A	1600.0	61.5
Spotswood-1	925.0	45.8	Happy Valley-1	1623.0	62.1
Waikato-5	1013.1	45.9	Ratapiko-1	1597.0	62.1
Manutahi-1	1391.0	46.1	Murchison-1	1245.0	62.4
Whakatu-1	1455.0	46.2	SFL-1	1663.0	62.5
Waikato-2	1026.2	46.3	Windsor-3	1555.6	63.1
J.T. Benny-1	1013.0	46.4	Kumara-2A	1697.0	63.5
Waikato-1	1036.0	46.6	Waimamaku-1	1273.0	63.5
Gisborne-2	1192.0	46.8	Windsor-2	1469.4	64.0
Omata-1	960.0	47.0	Kumara-2	1756.0	65.2
Bonithon-1	916.0	47.3	Rotokautuku-1	625.1	65.6
Tupapakurua-1	1150.0	47.3	Standish-1	1845.0	66.0
Maketawa-1	1135.4	47.4	Te Rapa-1	1684.0	66.3
Waikaka-1	978.7	47.6	Totangi-1B	1737.0	68.8
T.E. Weily-1	1057.3	47.7	Morere-1	2037.0	69.3
Ealing-1	1696.0	48.1	Toetoe-6A	1817.0	69.5
Niagara-2	952.0	48.5	Kokatahi-1	1914.0	69.7
Ongaonga-1	1573.0	48.7	Kauhauroa-2	2131.0	69.8
Tapawera-1	1180.0	48.7	Toetoe-2A, 2C	1829.0	69.9
Waitaria-1B	1150.0	49.0	Awatere-1	2136.0	69.9
Carrington Road-1	1042.0	49.7	J.D. George-1	1649.9	70.0

Parikino-1	2316.5	70.2	Waihapa-3	2706.0	85.9
Kaipikari-1	1854.0	70.6	Makuri-1, 1A	2500.0	86.4
Clematis-1	1800.0	70.7	Tauteka-1	2309.0	86.5
Tuhara-1B	2169.3	70.8	Tuhua-5A	2509.0	86.7
Matiri-1	1467.0	70.9	Toetoe-4A, B, C	2326.0	87.0
Kiakia-1/1A	2225.0	72.2	Tuhua-2, 2A	2529.0	87.3
Upukerora-1	2009.0	72.4	Tipoka-2	2504.0	87.7
Arahura-1	1736.0	72.9	Pukemai-1A	2432.0	88.0
Salisbury-1	2050.0	73.6	Tuhua-1 Re-entry	2564.0	88.3
Toetoe-8	1986.0	74.6	Makara-1B	2467.0	89.0
Puniwhakau-1	2146.0	75.3	Mangorei-1	2229.0	89.3
Toetoe-9	2027.0	75.8	Whangaehu-1	3495.0	89.9
Taramakau-1	2129.0	75.8	Waitaria-2	2548.1	90.2
Te Horo-1	1829.3	76.0	Tariki-4, 4C	2777.0	90.4
Kaimiro-14, 14A	1843.0	76.4	Notown-1	2116.0	90.6
Aratika-3	1729.0	76.8	Toetoe-5	2536.0	93.5
Opoho-1	2320.0	76.9	Toetoe-3	2618.0	93.5
McKee-7	2178.0	77.2	Stent-1	2710.0	93.7
Devon-2	1883.0	77.8	Pukemai-2	2631.0	93.9
Pukemai-3	2098.0	77.9	Hukarere-1	3213.2	94.6
McKee-6	2227.0	78.6	Paritutu-1	2400.0	95.0
Tuhua-3A, B, C	2125.0	78.8	Piakau-1	2905.0	95.2
McKee-2B	2237.0	78.9	Crusader-1	2441.0	96.4
Waitangi Station-1	2135.0	79.1	Tariki-2	3020.0	97.0
McKee-13	2278.0	80.1	Mokoia-1	3750.0	97.1
Te Puia-1	2042.7	80.2	Waihapa-6	3245.0	100.0
Durham-1	2303.0	80.8	Oakura-1	3220.0	100.9
Pouri-2	2233.0	80.9	Tariki-1	3191.0	101.6
Tariki North-1	2431.0	81.0	Ahuroa-1A	3153.0	102.1
J.W. Laughton-1	2135.0	81.1	Tariki North-1A	3209.0	102.1
McKee-2C	2316.0	81.2	Rotokare-1	3232.7	102.7
Harihari-1	2527.4	81.2	Makara-1	2940.0	103.2
Ahuroa-2	2465.0	83.1	Toko-2	3202.0	103.4
Toetoe-2	2276.0	83.3	Midhurst-1	3330.8	105.4
McKee-3	2400.0	83.6	Hu Road-1/1A	3350.0	105.9
Crusader-1A	2060.0	83.7	Happy Valley-1C	3131.4	106.0
Pukemai-1	2293.0	83.8	Ahuroa-1	3326.0	106.9
Toetoe-1	2310.0	84.3	Pukearuhe-1	3138.0	107.6
Toetoe-7	2315.0	84.5	Burgess-1	3264.0	108.3
Cape Egmont-1	2435.0	84.6	Cape Farewell-1	2817.0	108.9
Tariki-2A	2564.5	84.6	Opoutama-1	3658.5	112.6
Ruakituri-1	2745.0	85.6	Waiho-1	3749.4	113.2
Tuhua-8	2471.0	85.6	Wharehuia-1	3595.0	114.3

Devon-1	2868.0	116.1
Makino-1, 1AA	4100.0	116.5
Kokiri-1	3233.0	122.8
Onaero-1	3590.0	124.4
Waimamaku-2	3356.7	126.9
Manganui-2	3753.0	131.2
Pohokura South-1	3780.0	132.0
Totara-1	3965.0	132.1
Huinga-1, 1A, 1B	4373.0	133.7
Bounty-1	3131.0	134.3
Kapuni-15	4770.0	135.4
Manganui-1	3975.0	138.0
Tipoka-1, 1A	4359.0	141.6
Waihapa-1, 1A	4942.0	144.4
Ngatoro-1	4126.0	146.6
Rere-1	4351.0	149.7
Toko-1	4900.0	150.3
Cardiff-1	5064.0	152.5
Tuihu-1, 1A	4845.0	153.4
Te Kiri-1	4710.0	154.1
Inglewood-1	5061.0	164.4
New Plymouth-2	4451.6	171.9

Appendix 2. Calculation Of Available Stored Heat In Deep Wells In Sedimentary Basins And Igneous Terrain For Direct Use

Total heat in place = Heat in Rock + Heat in Circulating Fluid

Total heat in place =$[V(1-\Phi)C_{rock}\rho_{rock}(T_f - T_o)] + [V\Phi C_{water}\rho_{water}(T_f - T_o)]$

Where:

V = volume in m^3

Φ = porosity

C_{rock} = heat capacity of rock in kJ/kg)

ρ_{rock} = density of rock in kg/m^3)

C_{water} = heat capacity of water (4.18 kJ/kg)

ρ_{water} = density of water in kg/m^3 (1000 kg/m^3)

T_o = abandonment temperature (50°C or 10°C cooling)

T_f = temperature used for extracting geothermal energy

Area	Area (km^2)	Depth (m) where 50°C intersected	Depth (m) where 60°C intersected	Volume 50°C to 60°C (km^3)	Volume 60°C to 5000m (km^3)	Cgw kJ/kg	ρ gw (kg/m^3)	PJ/ year
>33°C/km[1]	29,550	1,060	1,360	8,950	107,450	0.92	2670	98,080
-TVZ	7,200	640	820	1,310	30,110	0.79	2800	24,700
-Coromandel	2,400	920	1,180	630	9,160	0.79	2800	7,610
21-33°C/km	146,428	1,300	1,670	54,230	488,090	0.92	2670	451,450
Total	185,579							581,840
2% recovery of heat from ground								11,640
50% conversion efficiency								5,820

[1]minus the area of the TVZ and Coromandel where rocks would be mainly volcanics and the thermal gradients at least 55°C/km and 38°C/km, respectively; Φ = 0.1; C_{water}= 4.18 kJ/kg; ρ_{water}= 1000 kg/m^3;; C gw = heat capacity of greywacke; ρ gw = density of greywacke; life of development is assumed to be 30 years

The total areas calculated above do not include national parks, forest parks, reserves and protected private land (Figure x).

Assumptions for use:

Drilling deep wells couplets simply for exploiting low grade heat for direct heat use may not be economically viable in the next 20 years. However, abandoned deep hydrocarbon wells can be used, instead of drilling new wells, in most of the onshore sedimentary basins of New Zealand. These would have to be unplugged, then reconfigured to preferentially tap into deep high temperature zones not contaminated by hydrocarbons (the original target of these wells).

Appendix 3. Calculation Of Available Stored Heat In Shallow Levels Available to Heat Pumps

Total heat in place = Heat in Rock + Heat in Circulating Fluid

Total heat in place =$[V(1-\Phi)C_{rock}\rho_{rock}(T_f - T_o)] + [V\Phi C_{water}\rho_{water}(T_f - T_o)]$

Where*:*

V = volume in m^3

Φ = porosity

C_{rock} = heat capacity of rock in kJ/kg)

ρ_{rock} = density of rock in kg/m^3)

C_{water} = heat capacity of water (4.18 kJ/kg)

ρ_{water} = density of water in kg/m^3 (1000 kg/m^3)

T_o = abandonment temperature (assumed to be 15°C)

T_f = temperature used for extracting geothermal energy

Note that this calculation would normally be done for a series of thin slices. The simple assumption of linear temperature gradient allows a calculation over the 50m depth potentially accessed by geothermal heat pump wells based on the average temperature over that depth.

Assumptions*:*

System used: closed loop ground source heat pump (GSHP) at 50 m depths where temperatures remain constant at about 16-18°C

Most of the wells for the GSHP will be drilled outside the Taupo Volcanic Zone and thus the majority of the wells will intersect sedimentary rocks dominated by greywacke.

Region	Area (km^2)	Depth (m)	½ (Tf-To) (°C)	Volume (km^3)	C_{rock} (kJ/kg)	ρ_{rock} (kg/m^3)	Heat Supply (PJ/year)
>33°C/km[1]	29,550	50	0.83	1,478	0.92	2,670	107
-TVZ	7,200	50	1.38	360	0.79	2,800	40
-Coromandel	2,400	50	0.95	120	0.79	2,800	9
21°C-33°C/km	146,429	50	0.68	7,321	0.92	2,670	433
Total	185,579						589
10% recovery of heat from ground							59

[1]minus the area of the TVZ and Coromandel where rocks would be mainly volcanics and the thermal gradients at least 55°C/km and 38°C/km, respectively; $\Phi = 0$; C_{water}= 4.18 kJ/kg; ρ_{water}= 1000 kg/m^3; C gw = heat capacity of greywacke; ρ gw = density of greywacke; life of heat pump application is assumed to be 30 years.

Note that assumptions are very conservative. They take no account of flushing of heat by groundwater, or of the impact of operating the heat pumps in cooling mode during the summer.

The total areas calculated above do not include national parks, forest parks, reserves and protected private land (Figure 5).

Appendix 4: Geothermal Resources and their Use

The following information is taken from "An Assessment of Geothermal Direct Heat Use in New Zealand"

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Northern Geothermal Region				
Kaikohe Hot Springs Group	Northland	3 springs but no known usage	23°C	None
Kamo Hot Springs	Northland	Bathing facilities formerly associated with hospital, but now part of the Kamo Springs Holiday Park. Springs are fed through a 20m^3 pool (flow estimated at 80 m^3/hr)	24 °C	Take: 700,000 m^3 (est) at 24 °C (101kJ/kg) = 71TJ Use: reject at say 22 °C (92kJ/kg) = 6TJ
Lake Omapere Hot Soda Spring	Northland	Man made dug pool at spring site (5m diameter pool with spring flow of 3.5-28l/s)	28-43 °C	None
Ngamokaikai Springs	Northland	None	17-30 °C	None
Ngawha Geothermal Field	Northland	Bathing in springs with essentially unmodified flow, geothermal power station not included in direct heat assessment	180-301 °C in reservoir 30-50°C springs	Negligible (but of significant cultural value)
Pakaraka Hot Springs	Northland	None	Unknown	None
SH12 (Neilson's) Soda Springs	Northland	None known, except some local use	26-29 °C	None
Taita Warm Spring	Northland	None	23 °C	None
Waiapawa Ponds	Northland	None	13-38 °C	None
Waitotara Pond Springs	Northland	None	17-28 °C	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Helensville (Parakai) Hot Springs	Auckland	About 75 wells in the past, 20 wells currently, 14 still in use, downhole pumps, depth 19-186m. Water is disposed of to large drainage ditches then a river. Wells supply hot water to 4 swimming pool/spa complexes, one old peoples home, 3 motels/apartments with hot pools/spas and 6 private pools or spas. All wells have been metered since 1985	Typically 60-65 °C	Take: 173,195 m^3 (2005) at 62 °C (259.5kJ/kg) = 45TJ Use: reject at 30 °C (126kJ/kg) so use = 23TJ
Waiwera Hot Springs	Auckland	About 49 wells currently, 37 in use, downhole pumps, typical feed 130-170m. Water is disposed of through storm water pipes to the beach or estuary. Wells supply hot water to 3 swimming pool complexes, 4 motels/apartments and 29 private pools and spas. Some water is bottled. All wells have been metered since 1985	Typically 50-55 °C	Take: 456,089 m^3 (2005) at 52 °C (218kJ/kg) = 99TJ Use: reject at 30 °C (126kJ/kg) so use = 42TJ
East Tamaki (Jeffs Road) - Whitford - Clevedon	Auckland	1 well drilled for cold water supply encountered a 45 °C reservoir at Jeffs Road so was cemented up. At Whitford there is one production bore currently unused. Consents are held by the Spencer Group (currently expired but soon to be renewed) for limited take now intended as part of a limited district heating scheme. Deep injection is likely to be required. At Clevedon a number of domestic boreholes tap 32 °C water.	32-55 °C	None
Owhiti (Waiheke Island) Hot Spring	Auckland	None known	Unknown	None
Great Barrier Geothermal Area (includes Kaitoke and Peach Tree Springs)	Auckland	1 well drilled at Tryphena to 207m but only recorded 35 °C. Bathing developed by DOC at Kaitoke	Max 85.5 °C	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Franklin	Waikato	GNS reports domestic boreholes tapping 32 °C water	32 °C	None known
Hamilton Warm Water Wells	Waikato	2 wells drilled in 1959 to 135 m - well water used for geothermal heat pump system in the Rural Bank and Finance Corporation Building - water disposed of to Waikato River. Facility decommissioned. A private heat pump system for home and pool has just been installed	27 °C	Old take equated to around 40TJ but negligible now
Horotiu Hot Springs	Waikato	None known	Unknown	None known
Kawhia (Te Puia) Hot Springs	Waikato	Public bathing in hand-dug pools on beach	54 °C	None
Lake Waikare Hot Springs	Waikato	1 production well tapping 70 °C water but unknown usage	70 °C	Unknown
Miranda Hot Springs	Waikato	A mix of springs and wells at 57 °C supply hot water to a swimming pool complex (with some underfloor heating) and adjacent holiday park pool complex	57 °C	Take: 405,000 m^3/year at 57 °C (239kJ/kg) = 96TJ Use: Reject at 35 °C (147kJ/kg) = 37TJ
Ohinewai Hot Springs	Waikato	None known - normal domestic use	23 °C	None known
Orini Hot Springs	Waikato	None known	22 °C	None known
Te Maire (Naike) Hot Springs	Waikato	There are several large springs. Water from one spring feeds into small swimming pool	64 °C	Unknown
Waikorea Hot Springs	Waikato	Undeveloped bathing and domestic use	54 °C	None
Waingaro Hot Springs	Waikato	Spring feeds public swimming pools and private hot pools at an associated motel	37-55 °C	Take: 300,000 m^3/year at 56 °C (234kJ/kg) = 69TJ Use: reject at 35 °C (147kJ/kg) = 26TJ

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Hauraki Geothermal Region				
Hot Water Beach (Orua) Hot Springs	Waikato	2 wells for Hot Water Beach Holiday Park cased to around 10m with 52 °C fluid, one well was pumped. These supplied 3 baths. The camp was permanently closed by 2005 and land is being subdivided for chalets. Public bathing in hand-dug pools on beach	52-63 °C	10-20l/min at 52 °C None now
Wigmore (Hahei) Hot Springs	Waikato	1 old shallow well (28 °C) for greenhouse heating	28 °C	Negligible
Kerepehi Hot Springs	Waikato	Unknown number of shallow wells to depths of 50m tap fluid at 57 °C. This was used for flax washing but there limited domestic use. Some wells have been drilled by Ravensdown Fertiliser Co-op	57 °C	Negligible
Manawaru Hot Springs	Waikato	None known	<58 °C	None
Mangatawhiri	Waikato	Hot water was encountered during coal exploration	Unknown	None
Ngatea Hot Water Well	Waikato	1 private well to 350m tapping 30 °C fluid but unknown use. Wells were used for hot pools, school heating and a glasshouse. All facilities have been decommissioned	30 °C	None
Okauia (Matamata) Hot Springs Group	Waikato	3 known wells and springs tapping 30-40 °C fluid for hot swimming pools (Matamata Sports Centre, Opal (Ramaroa) Hot Springs and Totara Springs) and for kiwifruit irrigation/frost protection. Former Chrystal (Okahukura) Springs hot pools have closed, but a heat exchanger supplies domestic use. Water is rejected to Waihou River	47 °C	Take (for pools) : 646,000 m^3/year = 91TJ Use (for pools) = 18.5TJ Take/Use (for irrigation/frost protection): 12,000 m^3/year at 35 °C (147kJ/kg) = 1.8TJ
Okoroire Hot Springs	Waikato	Springs feed 2 remaining bathing pools built in the 1880's. Wells have been drilled in the area but they are too hot to use for domestic water.	38-43 °C	Unknown

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Okoroire South Hot Springs	Waikato	None known	39 °C	None
Ranui Hot Springs	Waikato	None known	Unknown	None known
Scherers Road (Waharoa or Walton) Hot Springs	Waikato	Spring supplies water to private pool now overgrown with vegetation	32 °C	None
Sheehan Spring	Waikato	None known	23 °C	None known
Taihoa South Road Hot Spring	Waikato	In the past the spring was used as a private swimming bath	44 °C	None
Taputapu Hot Springs	Waikato	Springs supplied hot water to a swimming pool at Buffalo Beach. The springs do not exist anymore but a new complex is being built which will use geothermal water for hot pools	49 °C	None currently
Te Aroha Springs Group	Waikato	Hot springs used for several swimming baths (including oldest bath house in NZ). Area at one time rivalled Rotorua as a geothermal attraction	95 °C	Take: 7,600 m^3/year mostly at 95 °C = 2.6TJ Use = 1.4TJ
Waiteariki (Gravesons Road) Hot Spring	Waikato	None known	35 °C	None
Waitoa Hot Springs	Waikato	Springs previously used for bathing pool but none now. 3 wells have been drilled with one used for a pool and domestic heating	77 °C	None
Maketu Hot Springs/Little Waihi	Bay of Plenty	3 known wells feeding two pool complexes	30-42 °C	Unknown
Mayor Island (Tuhua) Hot Springs	Bay of Plenty	None known, intertidal springs	Warm	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Oropi Spa Pools	Bay of Plenty	Swimming pools	57 °C	Take: 42,000 m^3/year at 57 °C (239kJ/kg) = 10TJ Use: ~ 5TJ
Paengaroa Hot Springs	Bay of Plenty	Well water used for therapeutic swimming pool and in a motel. A farmer has reported drilling a 98 °C well on his property	37 °C	Unknown
Papamoa Hot Spring	Bay of Plenty	Water used to raise and quarantine tropical fish	26 °C	Take: 55,000 m^3/y at 25.6 °C (107kJ/kg) = 5.8TJ Use: reject at 15 °C (63kJ/kg) = 2.4TJ
Sapphire (Katikati) Hot Springs	Bay of Plenty	1 well to 61m tapping 32 °C feeds 3 swimming pools. 3 wells in area	39 °C	Take: 320,000 m^3/y at 32.4 °C (136kJ/kg) = 43TJ Use: reject at 27 °C (113kJ/kg) = 7.2TJ
Tauranga (Mauao) Geothermal System	Bay of Plenty	More than 100 producing wells of depth range 60-450m discharging 20-54 °C fluid (either pumped or artesian) for public and private swimming baths and hotel/motel complexes. Water allocation is split roughly 27% domestic, 44% commercial and 29% municipal.	<54 °C	Allocated take: 7,200,000 m^3/year at ~40 °C (168kJ/kg) = 1,200TJ Use: reject at ~30 °C (126kJ/kg) = 400TJ
Te Puke Hot Springs	Bay of Plenty	None known	Unknown	None known
Woodlands (Katikati) Hot Springs	Bay of Plenty	None known. Some local wells are hot.	38 °C	None known

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Rotorua-Taupo Geothermal Region				
Atiamuri Geothermal Field	Waikato	Springs supplied hot water to a swimming pool which has subsequently been demolished. EW notes that several bores supply domestic water for dairy shed washdown and swimming pools	59-63 ^{o}C springs 165 ^{o}C in well	None known
Broadlands (Ohaaki) Geothermal Field	Waikato	Numerous wells for power generation. Previously had heated greenhouses and timber/lucerne drying. At one stage the power station supplied CO_2 to the greenhouse. Now has timber drying (Vanner Mills takes 931,500tonnes/year at 920kJ/kg) and marae heating supplied by heat from reinjection system with disposal of fluid onto land.	Wells at 270 ^{o}C	Take (from Ohaaki waste): 931,500tonnes at 920kJ/kg = 857TJ Use: 390TJ (see Appendix 2)
Crater Lake (Ruapehu)	Waikato	None	~50 ^{o}C	None
Golden Springs	Waikato	Bathing in springs	50 ^{o}C	None
Horohoro (includes Haparangi) Geothermal Field	Waikato	Private well drilled tapping 87 ^{o}C water but no known use. Esendam family takes 72t/d of fluid at 95 ^{o}C for their glasshouses with shallow reinjection	95 ^{o}C	Take: 26,280 m^3 at 92 ^{o}C (385kJ/kg) = 10TJ Use: Assuming 50% load factor, with 8 ^{o}C temperature drop = 0.4TJ
Horomatangi	Waikato	None - discharges under Lake Taupo. System is protected from development.	>44 ^{o}C	None
Ketetahi Geothermal Area	Waikato	Scenic attraction surrounded by Tongariro National Park, warm springs for use by Tuwharetoa guests	91 ^{o}C in springs	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Mangakino Geothermal Field	Waikato	Field explored by MRP for power generation with springs submerged by Lake Maraetai. No known use	100 ^{o}C in springs	None known
Mokai Geothermal Field (includes Waipapa Springs)	Waikato	Numerous wells for power generation. Ohine-Ariki spring modified for bathing. Major 5.2 ha glasshouse (growing capsicums and tomatoes) supplied by geothermal heat from dedicated well with waste water added to power station reinjection line - there are plans for a 15 ha expansion of the glasshouses (EW consent 930748).	Well temperatures <326 ^{o}C	Use: ~140TJ based on area Take: ~280TJ
Moku-Tuhana	Waikato	Hotpool and swimming bath near Ohakuri	Unknown	Unknown
Motuoapa Hot Spring	Waikato	None known	Unknown	None known
Ngakuru Geothermal Prospect	Waikato	None - inferred to exist from resistivity measurements	Unknown	None
Ngatamariki Geothermal Field	Waikato	None, but field has power generation potential	Unknown but promising	None
Ongaroto Geothermal Prospect	Waikato	None - inferred from resistivity and from hydrothermal eruption during bridge construction. Adjacent Tirohanga youth camp has thermal tap water.	Unknown	None
Orakeikorako Geothermal Field	Waikato	Tourism is predominant use. Geothermally heated spa pools and showers are available to guests at Orakei Korako Cave and Thermal Park extracting heat for pools and water heating through heat exchangers in a spring. Springs for bathing on shore of Lake Ohakuri	<265 ^{o}C in reservoir, springs up to 100 ^{o}C	Take and use: ~0.2TJ
Reporoa Geothermal Field (includes Opaheke Hot Pools)	Waikato	Butcher's Pool is maintained by Rotorua District Council and includes sealed walkways, changing sheds and toilets, but springs are not modified	<240 ^{o}C in reservoir, springs up to 97 ^{o}C	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Rotokawa Geothermal Field	Waikato	Numerous wells for power generation. Area had been mined for sulphur and geothermal fluids were used in trials for the process. No known current use	Well temperatures ~280 °C	None
Tauhara-Taupo Geothermal Field (part of the Wairakei-Tauhara System)	Waikato	Various scenic areas. Some springs and hot water streams are used for bathing. Many private wells supply 2 major swimming complexes, 15 hotel/motel/apartment/holiday parks, 530 private homes/pools, 1 old peoples home, 1 marae, a golf course, and process heat requirements	Various temperatures in springs and wells but assumed to be ~80 °C for this assessment	Take: 4,000,000t at 80 °C (335kJ/kg) = 1,300TJ Use: reject at ~30 °C (126kJ/kg) = 830TJ (including about 8TJ for space heating) For the Golf Course Take/Use = 24TJ
Te Kopia Geothermal Area	Waikato	Tourism but no direct use (previously mushroom growing)	<241 °C in wells	None
Tokaanu-Waihi-Hipaua Geothermal Area	Waikato	Tourist facilities. Wells (and springs in the case of the pool) supply heat for 5 hotels/motels, the Tokaanu baths, 17 homes. An old well (Healy 2) discharges 780 t/day accounting for about half of the total take (not included in assessment).	Temperature >250 °C in reservoir, one well at 145 °C, springs up to boiling point	Take: 277,000t of fluid from wells at around 140°C (589kJ/kg) = 163TJ/year Use: reject at 38°C (159kJ/kg) = 119TJ/year
Tongariro	Waikato/ Manawatu-Wanganui	None. Mainly located in Tongariro National Park	Unknown	None
Waikite Geothermal Area	Waikato	Water from flowing springs used in a swimming pool complex. Extensive efforts to lose heat through sprinklers and cascade systems	<99 °C in springs	Take: 1,104,125t of water at 98°C (411kJ/kg) = 454TJ/year Use: reject at 38°C (159kJ/kg) = 278TJ/year

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Waimangu-Rotomahana Geothermal Area	Waikato/Bay of Plenty	Tourism facilities	<81 °C	None
Waiotapu Geothermal Field	Waikato	Tourism facilities. Consented users include a Hotel and the Arataki Honey Ltd. Arataki Honey uses the heat for space heating, water heating, honey heating, rearing bees, and domestic use	<295 °C	Take: about 46,000t of fluid at 145 °C (611kJ/kg) = 28TJ Use: reject at 60 °C (251kJ/kg) = 16TJ
Wairakei Geothermal Field (part of the Wairakei-Tauhara System)	Waikato	Major power generation facilities. Tourism park. Station steam is diverted to a greenhouse for orchids and a hotel. Separated water is used at a tourism park (to create silica terraces and a historical geothermal environment), and at the prawn farm. The golf course also takes geothermal water	<270 °C in wells	Location: Take: Use Greenhouse: 29TJ: 27TJ NETCOR: 1,260TJ: 820TJ Resort: 21TJ: 20TJ Prawns:1,500TJ: 270TJ Golf Course: ?TJ: ?TJ (see Appendix 2)
Waitetoko Hot Spring	Waikato	None known	Unknown	None known
Whakamaru Hot Springs	Waikato	None known (beach seeps)	Unknown	None known
Whangairorohea Hot Springs	Waikato	None known	<56 °C	None known
Awakeri (Pukaahu) Hot Springs	Bay of Plenty	3 operational wells to 98m and springs feed 56-70 °C water for swimming baths	<70 °C	Take: ~74,000t of fluid at 56 °C (234kJ/kg) = 17TJ Use: reject at 42 °C (176kJ/kg) = 4.3TJ
Humphreys Bay Hot Spring	Bay of Plenty	1 well is known but there is no known use - located on the shore of Lake Tarawera	Unknown	None known

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Kawerau Geothermal Field (includes Onepu Thermal Springs)	Bay of Plenty	Many wells supplying Norske Skog Tasman pulp and paper mill, and Carter Holt Harvey Tasman pulp and timber drying facilities. A shallow well supplies heat to a public recreation hall. Previous greenhouses have been removed.	<310 ^{o}C in wells	Take: assessed at 10,585TJ Use: assessed at 5,315TJ (see Appendix 3)
Lake Okataina Springs	Bay of Plenty	None - seeps in lake shore beach sands	30-36 ^{o}C	None
Lake Rotoiti Geothermal Area (includes Manupirua, Maraeroa, Otutarara)	Bay of Plenty	1 well drilled at Moose Lodge to 218m tapping 55 ^{o}C water for heating a pool. Possibly other private wells in the area	<130 ^{o}C in sediments	Take: about 850,000 m^3/year at 55 ^{o}C (230kJ/kg) = 193TJ Use: reject at 32 ^{o}C = 80TJ
Lake Rotokawa Geothermal Area (Rotorua)	Bay of Plenty	8 shallow wells (most < 45m) tap fluids >99 ^{o}C. All wells have artesian discharge. These heat a glasshouse, school and swimming pools	>99 ^{o}C	Allocated take: 127,000t/year but other details are unknown
Mangakotukutuku Springs	Bay of Plenty	None	24 ^{o}C	None
Matata Geothermal Prospect	Bay of Plenty	None - inferred to exist from resistivity measurements, though locals are aware of springs	Unknown	None
Mokoia Island (includes Hinemoa's Pool)	Bay of Plenty	There are several baths on SE of island	54 ^{o}C	None
Rotoma Geothermal Area (includes Tikorangi, Puhi Puhi and Otei)	Bay of Plenty	Rotoma Holiday Park has 3 small hot pools fed from a 38 ^{o}C pumped well. Waitangi (soda spring) has been modified for bathing using weir, Otei spring has disappeared. One deep well drilled (data unavailable)	springs < 50 ^{o}C, fumeroles < 90^{o}C	Take: about 94,600t at 38^{o}C (159kJ/kg) = 15TJ Use: reject at 35 ^{o}C (147kJ/kg)

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Rotorua Geothermal Field	Bay of Plenty	Numerous wells (140 production bore sites, 86 reinjection bore sites, 42 downhole heat exchangers) drilled for direct use (mostly 90-120 m deep) tapping water at around 150 ^{o}C. Various tourist attractions, Domestic and commercial heating and hot water supplies, swimming pools and mineral baths, hospital and large hotel air conditioning. Increasing use of reinjection and downhole heat exchangers but a general reduction in use overall. About 69% of the water take is for commercial uses, 26% for domestic uses and 5% for municipal use	<194 ^{o}C in wells, springs to 100 ^{o}C	Take: Approximately 3,540,000tonnes/year at about 540kJ/kg = 1,900TJ plus a further 20TJ from downhole heat exchange Reinject: 3,180,000t/ year at around 85 ^{o}C (356kJ/kg) = 1,130TJ Other surface water: 260,000t = 90TJ Use = 1,900 + 20 - 1,130 - 90 = 700TJ
Taheke Geothermal Area	Bay of Plenty	Springs are used for bathing	<97 ^{o}C	None
Tarawera Geothermal Area (includes Te Rata and Humphrey's Bay Springs)	Bay of Plenty	Springs are used for bathing	<90 ^{o}C	None
Tikitere (Ruahine Springs) Geothermal Area	Bay of Plenty	Tourism at Hells Gate. About 11 wells supply heating for mushroom growing (?), holiday camp, private baths. About 35% of heat goes to private uses and 65% to commercial uses	<190 ^{o}C assume 130 ^{o}C for wells	Allocated take: 154,000t/year at 130 ^{o}C (546kJ/kg) = 84TJ Use: reject at 100 ^{o}C (419kJ/kg) = 20TJ
Waiaute Springs	Bay of Plenty	None	23 ^{o}C	None
Whale Island (Moutohora) Geothermal Area	Bay of Plenty	None	100 ^{o}C	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
White Island (Whakaari)	Bay of Plenty	Private scenic reserve, formerly used for sulphur mining	<350 °C	None
Misc North Island Thermal Springs				
Manaohau Hot Spring	Bay of Plenty	None known (located in Urewera National Park)	Unknown	None
Pukehinau (Waikokopu) Hot Springs	Bay of Plenty	None known	45 °C	None
Te Puia Hot Springs	Gisborne	Bathing facilities at hotel and hospital only. Methane gas emissions were previously used for lighting but now banned.	<100 °C	Take: ~ 2,000 m^3/year at 50 °C (209kJ/kg) = 0.42TJ Use: reject at 35 °C (147kJ/kg) = 0.12TJ
Mangatainoka (Mohaka) Hot Spring	Hawke's Bay	Spring feeds two-level DOC trampers baths in Kaweka State Forest	59 °C	None
Maungataniwha Hot Spring	Hawke's Bay	None known (located in Urewera National Park)	Unknown	None
Morere Hot Springs	Hawke's Bay	Water is collected from 3 springs then used for 5 bathing pools in a bush setting	62 °C (now 50 °C)	Take: 77,380 m^3/year at 50.2 °C (210kJ/kg) = 16TJ Use: 66,325 m^3/year dropping to 40 °C = 2.8TJ
Ohane Spring	Hawke's Bay	Undeveloped bathing	45 °C	None
Puketitiri (Mangatutu) Hot Springs	Hawke's Bay	Bathing (spa pool size) facility fed from spring near roadend in Kaweka Forest	52 °C	Negligible
Tarawera Hot Springs	Hawke's Bay	Old bathing facilities fed by springs. 3 wells were drilled unsuccessfully. Now officially closed by DOC	38-49 °C	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Waipiropiro Hot Spring	Hawke's Bay	None known - in Ruahine Forest Park	40 ^oC	None
Jerusalem Hot Springs	Manawatu-Wanganui	Plant cultivation	25 ^oC	Negligible
Pipiriki (Waiora) Hot Springs	Manawatu-Wanganui	None	23 ^oC	None
Upokongaro	Manawatu-Wanganui	Potable water	21 ^oC	Negligible
Arawhata Hot Springs	Taranaki	None known	20-29 ^oC	None known
Taranaki Mineral Pools (Bonithon-1 Well)	Taranaki	Pool and spa facilities developed to take advantage of a 1906 1000m deep oil and gas well. Uses gas for supplementary heating	27 ^oC	Take and Use: 2,130 m^3/year x 113kJ/kg = 0.240TJ
South Island Thermal Springs				
Banks Peninsula (includes Purau)	Canterbury	In the past, Cass Bay water has been used as potable water, with some limited use for bathing and watering plants in a glasshouse. No current use	30 ^oC	None
Cow Stream Springs	Canterbury	None known	52 ^oC	None known
Cox River Spring	Canterbury	None known	Unknown	None known
Grantham River Spring	Canterbury	None known	Unknown	None known
Hanmer Springs	Canterbury	Various springs and wells (3 successful producers) feed large open air pool and other spa facilities. There is a mix of direct use and heat exchangers	52 ^oC	Take: 260,000m^3/year at 52 ^oC (218kJ/kg) = 56TJ Use: reject at 24 ^oC av (100kJ/kg) = 30TJ
Hope River Springs	Canterbury	Natural springs used for bathing	50-54 ^oC	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Hurunui River Springs	Canterbury	Natural springs used for bathing, 5-6 hr tramp	29-55 °C	None
Iron Gate Stream	Canterbury	Unused river and intertidal springs in Kaikouras	23 °C	None
Kahutara River Spring	Canterbury	None	34 °C	None
Lewis River (Sylvia Flat) Springs	Canterbury	Slightly modified pool used for bathing, accessible from road	44 °C	None
McKenzie Stream Spring	Canterbury	Spring used for bathing	38 °C	None known
Timaru Warm Wells	Canterbury	Warm water recorded in wells tapping Papakaiao reservoir but no use known	Unknown	None known
Barrier River Spring	West Coast	"Warm" spring with H_2S reported by hunters	Unknown	None
Copland River (Welcome Flat) Springs	West Coast	Springs feed a series of man-made bathing pools in Westland National Park, 7-8 hr tramp	56 °C	None
Deception River Spring	West Coast	Undeveloped bathing	38 °C	None
Fox River Spring	West Coast	None known	34 °C	None
Franz Josef (Waiho River, Hans) Spring	West Coast	None - covered by river gravel	44 °C	None
Haupiri River Spring	West Coast	Undeveloped bathing - on shore of Lake Brunner	46 °C	None
Kokatahi River Spring	West Coast	None known	49 °C	None known
Lake Christabel (Grey River) Spring	West Coast	None known	Unknown	None known
Maruia Hot Springs	West Coast	Water is pumped from springs and from a well to a hotel complex including Japanese bath house, 6 private spas and 2 rock pools	55-60 °C	Take: 158,000t per year at 55 °C (230kJ/kg) = 36TJ Use: reject at 36 °C (151kJ/kg) = 14TJ

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Mungo River (Brunswick) Springs	West Coast	Springs used for bathing, 1-2 day tramp	66 °C	None
Otehake River Spring	West Coast	Used for bathing by trampers, 3-3 1/2 hr tramp	40 °C	None
Otira River Spring	West Coast	None known	31 °C	None
Taipo River (Fraser, Julia Hut) Springs	West Coast	Spring used for bathing, 1-2 day tramp	70-82 °C	None
Toaroha River (Cedar Flats) Springs	West Coast	Spring was once boarded in for bathing, 3 1/2 hr tramp	46-71 °C	None
Waitaha River Hot Springs	West Coast	Used for bathing by trampers	48 °C	None
Wanganui River Springs (includes Hendes Ferry, Hot Springs Creek, Smythe Hut, Amethyst)	West Coast	Used by trampers, 7-9hr tramp. Some springs are within 15 minutes of carpark. 3 groundwater wells have been drilled (1 with 38 °C water)	38-55 °C	None
Whataroa (Perth River, Scone Hut, Nolans Hut) Springs	West Coast	None known	30-66 °C	None
Anchorage Cove Spring	Southland	None - under sea vents	61 °C	None
Henry Burn Spring	Southland	None - pool in Fiordland National Park - described as a warm spring	Unknown	None
Irene Valley Spring	Southland	None - spring in Fiordland National Park	23-29 °C	None
Transit Valley Spring	Southland	None - spring in Fiordland National Park	Unknown	None

Appendix 5. Heat Supply Curves

An intention of this report is to enable an assessment of potential uptake of renewable energy options under a range of scenarios.

Given that costs are an essential driver of industry, supply curves have been derived for a range of energy conversion technologies. The supply curves show total cost to industry of a particular heat supply option, including fuel cost, capital cost and operating costs. All analysis has assumed a 10% internal rate of return (IRR). Plant life is 30 years. Fuel cost inputs have been taken from MED's "New Zealand's Energy Outlook to 2030" using the Base Case and Carbon Charge sensitivity case.

The results of modelling are shown in the following figures, based on present costs and expected costs in 2020 and 2030.

While there are differences between the curves, the implications for geothermal energy are consistent throughout.

Under recent and future gas price movements, the overall cost of a gas heat development has lifted to the point where it is difficult to justify in terms of new development at a 10% IRR. This situation will be reinforced as gas prices continue to rise. While gas will continue as a valuable fuel for electricity generation, price signals for direct users of gas are discouraging. There may be other drivers, such as it's handling convenience that continue to see some marginal uptake. Further, many gas users may have a shorter term view and higher IRR, all of which will favour gas. However, heat plant owners will be considering their options as their existing heat plant comes up for replacement. They will consider coal or renewables where these are available.

The price of coal heat plants, when coal is supplied from local mines continues to be competitive with gas, with or without carbon charge. In the South Island, coal has few competitors with neither gas nor conventional geothermal energy being available, but biomass process residue-based heat plant supplying strong competition especially in 10 to 15 years time or immediately if a carbon charge is applied to heat plant. For the most part, South Island coal supplies will be unchallenged.

Based on the various cost assumptions feeding in to these curves, biomass landing material will not provide competition for South Island coal on price or convenience under any scenario. It may be able to compete with North Island coal on price in high coal-priced areas by 2020 and especially for thermal loads less than 20 or 30MWth.

Biomass process residue-based heat plant is already strongly competitive with all fuels in the North Island, and with higher priced South Island coals. A carbon charge applied now to heat plant, or general expected moves in coal price by 2020 will leave this heating option unchallenged at most locations.

Stand-alone geothermal heat supplies based on conventional high temperature resources require a certain size before they become commercial. Currently, based on the assumptions of field conditions present in the model, it is difficult for a greenfield development to compete with coal for developments below a threshold 30MWth or so. A carbon charge (of \$15/t CO_2) would see this threshold reduce to around 15MWth, while expected price movement for coal could see this reduced to 10MWth[55]. While exact thresholds for competitiveness will be site-specific, these calculations indicate the requirement for a significant load for a development to be commercial.

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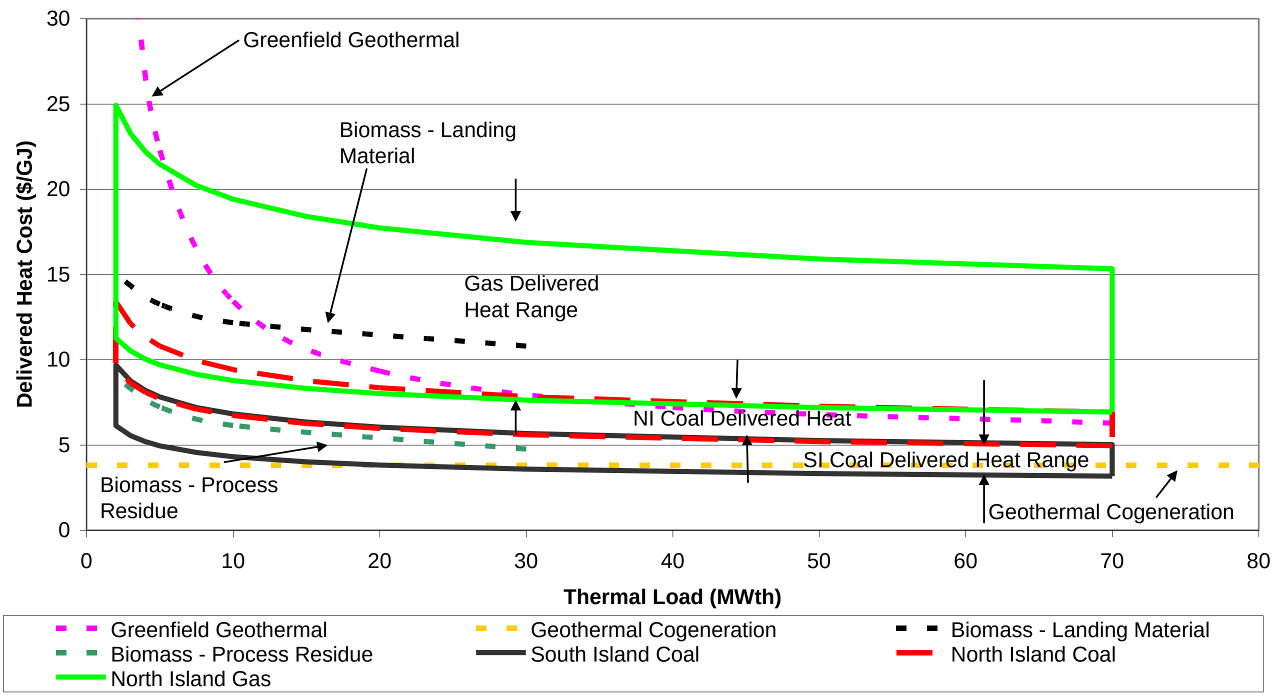
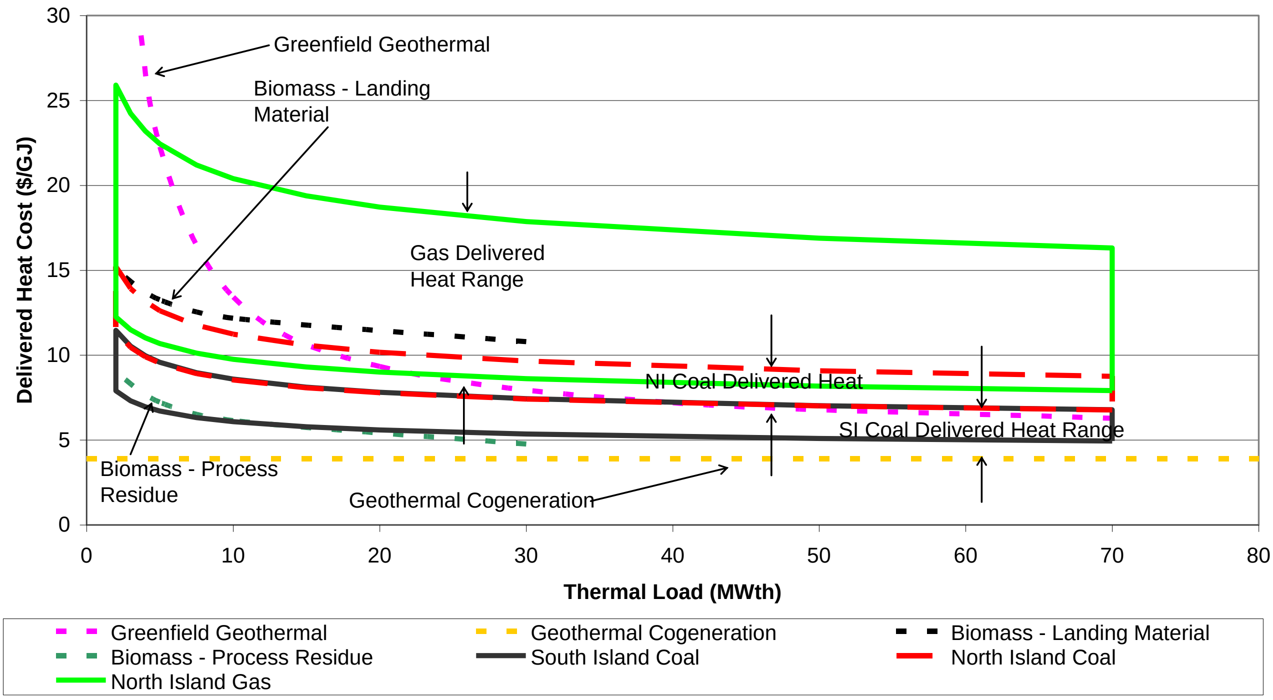
[55] On the basis of costs presented in this report it is difficult to justify the 20MWth Tenon steam supply. Factors that may have come in to play include: an expectation of a carbon charge; expectation of rising coal prices; expectations of extensions of supply in future; write-off of some well costs against field exploration; and/or more favourable field conditions leading to lower costs than modelled.

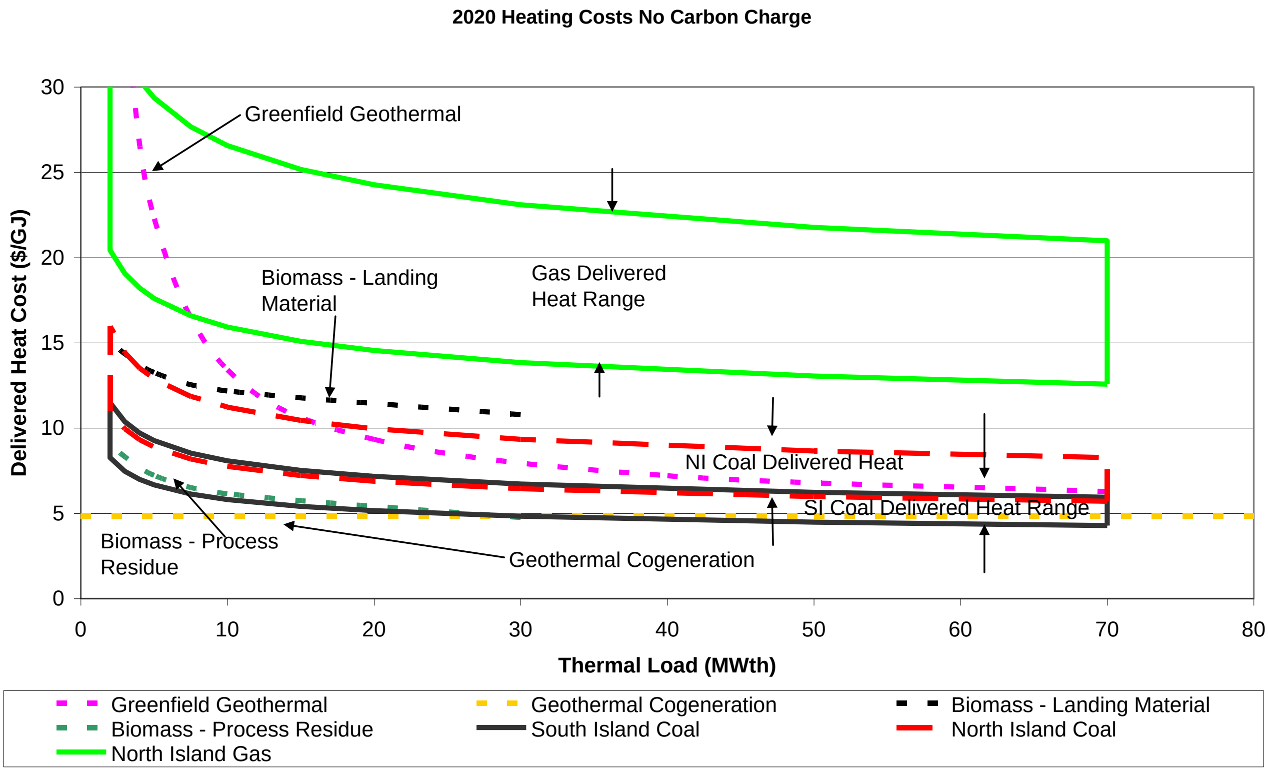
A geothermal "cogeneration" price is also shown, this being the price that a generator must secure to remain revenue-neutral if it diverts its steam to another party on site. This price is lower than all other North Island fuel options, but requires a heat user to be on-site to take advantage of it.

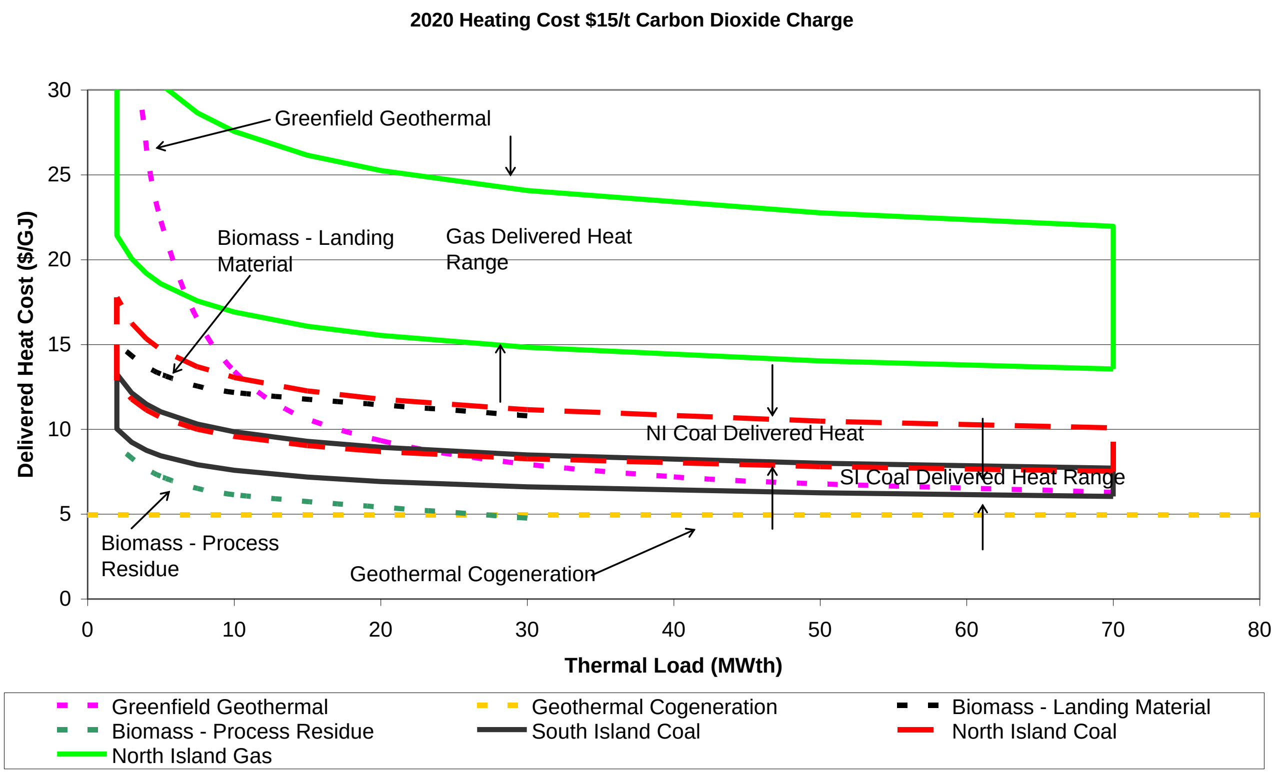
2005 Heating Costs No Carbon Charge

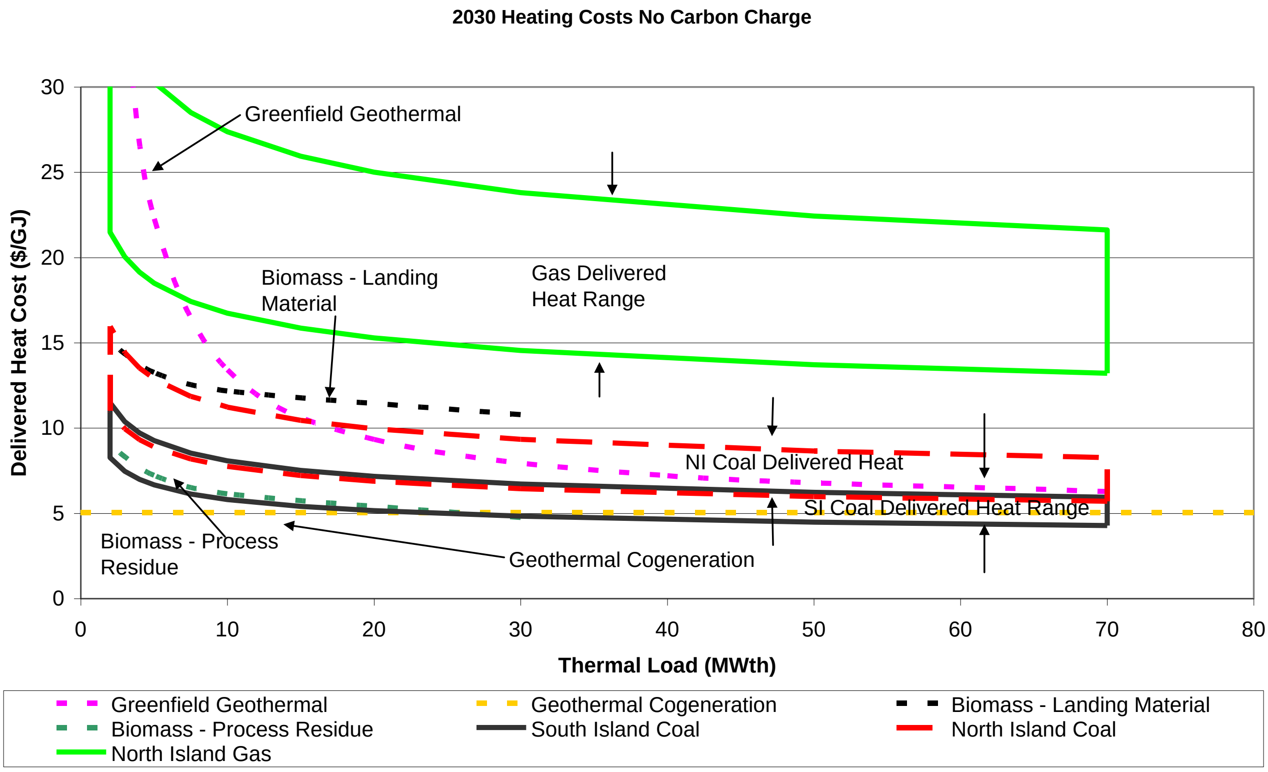


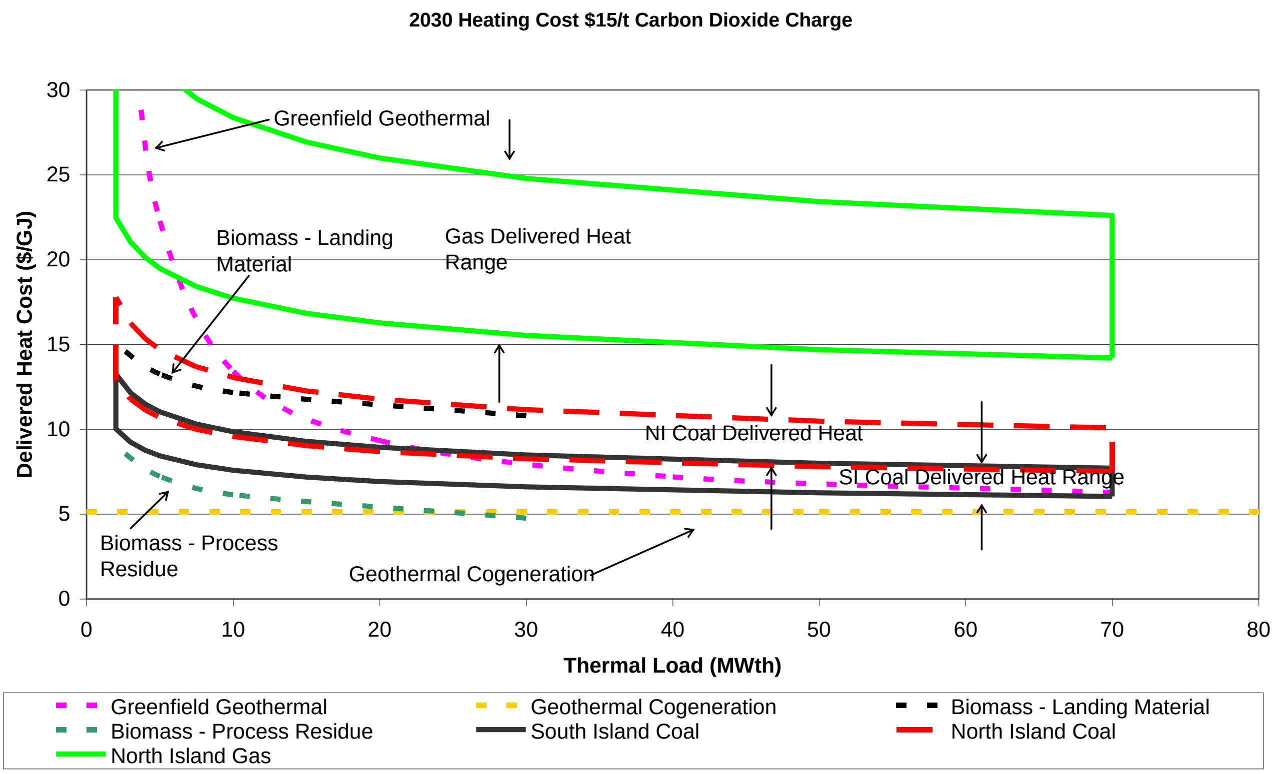
2005 Heating Cost $15/t Carbon Dioxide Charge




2020 Heating Costs No Carbon Charge
Delivered Heat Cost ($/GJ)
Thermal Load (MWth)
Greenfield Geothermal
Biomass - Landing Material
Gas Delivered Heat Range
NI Coal Delivered Heat
SI Coal Delivered Heat Range
Biomass - Process Residue
Geothermal Cogeneration
Greenfield Geothermal
Geothermal Cogeneration
Biomass - Landing Material
Biomass - Process Residue
South Island Coal
North Island Coal
North Island Gas


2020 Heating Cost $15/t Carbon Dioxide Charge
Delivered Heat Cost ($/GJ)
Thermal Load (MWth)
Greenfield Geothermal
Biomass - Landing Material
Gas Delivered Heat Range
NI Coal Delivered Heat
SI Coal Delivered Heat Range
Biomass - Process Residue
Geothermal Cogeneration
Greenfield Geothermal
Geothermal Cogeneration
Biomass - Landing Material
Biomass - Process Residue
South Island Coal
North Island Coal
North Island Gas


2030 Heating Costs No Carbon Charge
Delivered Heat Cost ($/GJ)
30
25
20
15
10
5
0
Greenfield Geothermal
Biomass - Landing Material
Gas Delivered Heat Range
NI Coal Delivered Heat
SI Coal Delivered Heat Range
Biomass - Process Residue
Geothermal Cogeneration
0
10
20
30
40
50
60
70
80
Thermal Load (MWth)
Greenfield Geothermal
Geothermal Cogeneration
Biomass - Landing Material
Biomass - Process Residue
South Island Coal
North Island Coal
North Island Gas


2030 Heating Cost $15/t Carbon Dioxide Charge
Delivered Heat Cost ($/GJ)
30
25
20
15
10
5
0
Greenfield Geothermal
Biomass - Landing Material
Gas Delivered Heat Range
NI Coal Delivered Heat
SI Coal Delivered Heat Range
Biomass - Process Residue
Geothermal Cogeneration
0
10
20
30
40
50
60
70
80
Thermal Load (MWth)
Greenfield Geothermal
Geothermal Cogeneration
Biomass - Landing Material
Biomass - Process Residue
South Island Coal
North Island Coal
North Island Gas

Appendix 6. Specific Data Used in Apportionment between Regions

Region	Population		2006 Census				State Servants	School students	"Hotel" Guest Nights (millions)	Dairy Stock Numbers (thousands)	Greenhouse Heated Area (m^2)
	2006	2021	Dwelling Owned or Partly Owned by Usual Resident(s)	Dwelling Held in a Family Trust by Usual Resident(s)	Dwelling Not Owned by Usual Resident(s)	Not Elsewhere Included[(1)]					
Northland	148,900	157,900	28,359	5,928	15,696	4,470	692	29,730	1.47	277	180,454
Auckland	1,360,000	1,651,700	204,288	52,728	145,857	30,777	6,048	252,427	4.32	99	1,199,276
Waikato	383,800	409,700	69,315	15,132	44,616	9,273	2,515	74,000	2.50	1,415	157,197
Bay of Plenty	267,200	307,700	47,031	12,603	28,977	6,165	817	50,736	2.70	272	75,005
Gisborne	45,000	42,600	7,539	1,362	5,502	1,080	377	9,723	0.31	4	86,964
Hawke's Bay	147,900	145,500	27,975	6,807	16,458	3,375	755	30,326	0.63	62	63,576
Taranaki	104,100	95,400	21,090	5,010	11,262	2,538	629	20,007	0.44	507	83,235
Manawatu-Wanganui	228,900	225,500	43,716	9,183	26,289	4,830	1,415	42,163	0.87	315	53,542
Wellington	455,000	469,200	87,123	17,382	53,583	8,883	12,453	79,684	1.78	76	93,876
Tasman	46,300	50,400	10,002	2,085	3,864	846	157		0.55	53	114,224
Nelson	45,600	50,400	9,279	1,806	5,070	762	314	22,746	0.55		42,778
Marlborough	43,100	45,700	9,276	1,893	4,230	1,035	314		0.55	21	66,780
West Coast	30,400	27,400	7,176	867	3,558	855		5,166	0.86	118	0
Canterbury	517,400	550,200	113,919	20,073	56,409	9,528	3,375	89,767	3.83	485	249,493
Otago	194,400	196,500	37,665	10,599	21,633	3,975	943	30,528	3.35	130	24,260
Southland	90,500	79,400	20,088	4,440	8,862	1,929	629	16,857	0.65	272	24,871

http://www.stats.govt.nz/NR/rdonlyres/3E43463B-4F57-4118-A593-5DFB648CCFED/0/DemTrends2003Table9.xls

http://www.stats.govt.nz/NR/rdonlyres/19D6A4B9-7D98-4AF9-970D-5BBD139794CA/0/RegionalSummaryTablesRegionalCouncil.xls

http://www.ssc.govt.nz/display/document.asp?docid=3939&pageno=10#P283_17449

http://www.educationcounts.edcentre.govt.nz/statistics/schooling/hp-student-numbers.html

http://www.maf.govt.nz/mafnet/rural-nz/statistics-and-forecasts/farm-monitoring/2006/dairy/02overview.htm#Review_of_2005/06
Derived from referenced MAF report

Appendix 7. Specific Results of Modelling by Region and by Sector

		Scenario 2 Base Case Modified – By Year 2020									
Council Region	Current Heat Use (PJ/a)	Housing	Hotels	Schools	Dairy Farms	Hospital	Forestry	Greenhouses	Public service	**Total**	**2020 Increment**
Northland	0.01	0.01	0.00	0.00			0.40	0.07	0.00	**0.49**	**0.48**
Auckland	0.07	0.05	0.00	0.01				0.03	0.00	**0.16**	**0.10**
Waikato	3.59	0.02	0.00	0.00	0.00	0.02	0.40	0.17	0.00	**4.20**	**0.62**
Bay of Plenty	6.95	0.02	0.01	0.01	0.00		0.43	0.07	0.00	**7.47**	**0.53**
Gisborne	0.00	0.00	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Hawke's Bay	0.00	0.01	0.00	0.00				0.00	0.00	**0.02**	**0.01**
Taranaki	0.00	0.01	0.00	0.00	0.00			0.00	0.00	**0.01**	**0.01**
Manawatu-Wanganui		0.01	0.00	0.00				0.00	0.00	**0.02**	**0.02**
Wellington		0.02	0.00	0.00				0.00	0.00	**0.04**	**0.04**
Tasman		0.00	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Nelson		0.00	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Marlborough		0.00	0.00	0.01				0.00	0.00	**0.01**	**0.01**
West Coast	0.01	0.00	0.00	0.00				0.00	0.00	**0.02**	**0.01**
Canterbury	0.03	0.03	0.00	0.00	0.00			0.01	0.00	**0.07**	**0.04**
Otago		0.03	0.01	0.00				0.00	0.00	**0.03**	**0.03**
Southland		0.01	0.00	0.00				0.00	0.00	**0.02**	**0.02**
Totals	**10.65**	**0.22**	**0.04**	**0.04**	**0.00**	**0.02**	**1.23**	**0.37**	**0.01**	**12.58**	**1.93**

		Scenario 3 Carbon Charge – By Year 2020									
Council Region	Current Heat Use (PJ/a)	Housing	Hotels	Schools	Dairy Farms	Hospital	Forestry	Greenhouses	Public service	**Total**	**2020 Increment**
Northland	0.01	0.01	0.00	0.00			0.40	0.07	0.00	**0.49**	**0.48**
Auckland	0.07	0.07	0.00	0.01				0.03	0.00	**0.18**	**0.11**
Waikato	3.59	0.02	0.01	0.01	0.00	0.02	0.40	0.17	0.00	**4.21**	**0.62**
Bay of Plenty	6.95	0.02	0.01	0.01	0.00		0.43	0.07	0.00	**7.48**	**0.53**
Gisborne	0.00	0.00	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Hawke's Bay	0.00	0.01	0.00	0.00				0.00	0.00	**0.02**	**0.02**
Taranaki	0.00	0.01	0.00	0.00	0.00			0.00	0.00	**0.01**	**0.01**
Manawatu-Wanganui		0.02	0.00	0.00				0.00	0.00	**0.02**	**0.02**
Wellington		0.03	0.00	0.00				0.00	0.00	**0.04**	**0.04**
Tasman		0.00	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Nelson		0.00	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Marlborough		0.00	0.00	0.01				0.00	0.00	**0.01**	**0.01**
West Coast	0.01	0.00	0.00	0.00				0.00	0.00	**0.02**	**0.01**
Canterbury	0.03	0.04	0.00	0.00	0.00			0.01	0.00	**0.08**	**0.05**
Otago		0.03	0.01	0.00				0.00	0.00	**0.04**	**0.04**
Southland		0.02	0.00	0.00				0.00	0.00	**0.02**	**0.02**
Totals	**10.65**	**0.29**	**0.04**	**0.05**	**0.00**	**0.02**	**1.23**	**0.37**	**0.01**	**12.65**	**2.00**

		Scenario 2 Base Case Modified – By Year 2030									
Council Region	Current Heat Use (PJ/a)	Housing	Hotels	Schools	Dairy Farms	Hospital	Forestry	Greenhouses	Public service	**Total**	**2030 Increment**
Northland	0.01	0.02	0.00	0.00			0.40	0.07	0.00	**0.50**	**0.49**
Auckland	0.07	0.14	0.00	0.01				0.03	0.00	**0.25**	**0.19**
Waikato	3.59	0.05	0.01	0.01	0.00	0.02	0.40	0.33	0.00	**4.39**	**0.81**
Bay of Plenty	6.95	0.04	0.01	0.01	0.00		0.83	0.20	0.00	**8.03**	**1.08**
Gisborne	0.00	0.01	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Hawke’s Bay	0.00	0.02	0.00	0.00				0.00	0.00	**0.03**	**0.03**
Taranaki	0.00	0.02	0.00	0.00	0.00			0.00	0.00	**0.02**	**0.02**
Manawatu-Wanganui		0.03	0.00	0.00				0.00	0.00	**0.04**	**0.04**
Wellington		0.06	0.00	0.00				0.00	0.00	**0.07**	**0.07**
Tasman		0.01	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Nelson		0.01	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Marlborough		0.01	0.00	0.01				0.00	0.00	**0.02**	**0.02**
West Coast	0.01	0.01	0.00	0.00				0.00	0.00	**0.02**	**0.01**
Canterbury	0.03	0.08	0.00	0.00	0.00			0.01	0.00	**0.12**	**0.09**
Otago		0.07	0.01	0.00				0.00	0.00	**0.08**	**0.08**
Southland		0.03	0.00	0.00				0.00	0.00	**0.04**	**0.04**
Totals	**10.65**	**0.60**	**0.04**	**0.04**	**0.00**	**0.02**	**1.63**	**0.66**	**0.01**	**13.65**	**3.00**

		Scenario 3 Carbon Charge – By Year 2030									
Council Region	Current Heat Use (PJ/a)	Housing	Hotels	Schools	Dairy Farms	Hospital	Forestry	Greenhouses	Public service	**Total**	**2030 Increment**
Northland	0.01	0.02	0.00	0.00			0.40	0.07	0.00	**0.51**	**0.50**
Auckland	0.07	0.18	0.00	0.01				0.03	0.00	**0.29**	**0.23**
Waikato	3.59	0.07	0.01	0.01	0.00	0.02	0.40	0.33	0.00	**4.41**	**0.82**
Bay of Plenty	6.95	0.05	0.01	0.01	0.00		0.83	0.20	0.00	**8.04**	**1.09**
Gisborne	0.00	0.01	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Hawke's Bay	0.00	0.03	0.00	0.00				0.00	0.00	**0.03**	**0.03**
Taranaki	0.00	0.02	0.00	0.00	0.00			0.00	0.00	**0.02**	**0.02**
Manawatu-Wanganui		0.04	0.00	0.00				0.00	0.00	**0.05**	**0.05**
Wellington		0.08	0.00	0.00				0.00	0.00	**0.09**	**0.09**
Tasman		0.01	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Nelson		0.01	0.00	0.00				0.00	0.00	**0.01**	**0.01**
Marlborough		0.01	0.00	0.01				0.00	0.00	**0.02**	**0.02**
West Coast	0.01	0.01	0.00	0.00						**0.03**	**0.01**
Canterbury	0.03	0.10	0.00	0.00	0.00			0.01	0.00	**0.14**	**0.11**
Otago		0.09	0.01	0.00				0.00	0.00	**0.10**	**0.10**
Southland		0.04	0.00	0.00				0.00	0.00	**0.05**	**0.05**
Totals	**10.65**	**0.76**	**0.04**	**0.05**	**0.00**	**0.02**	**1.63**	**0.66**	**0.01**	13.82	3.17

Appendix 8. Replacing or Supplementing Existing Heat Demand versus Encouraging New Demand for Heat

The rationale behind renewable energy promotion is not strongly evident within the draft New Zealand Energy Strategy (NZES) or the draft New Zealand Energy Efficiency and Conservation Strategy (NZEECS). The proportion of energy that comes from our abundant renewable energy sources is to be maximised under the draft New Zealand Energy Strategy (NZES) as a contributing factor to the vision of providing “a reliable and resilient system delivering New Zealand sustainable low emissions energy.” The draft New Zealand Energy Efficiency and Conservation Strategy (NZEECS) is required to consider a renewable energy strategy under the Energy Efficiency and Conservation Act 2000. Under the NZEECS “clean electricity and heat” objective, renewable energy resources are to be maximised to “help New Zealand move to a low-carbon energy supply system whilst improving the sustainability, diversity and security of its electricity and heat supply systems”. A range of policies sit within an “Economic Transformation” or “Growth and Innovation Framework”.

It appears that “renewable energy” has largely become a pseudonym for the concept of sustainable low emissions energy sources. However, a broader review of the rationale for promotion of renewable energy forms such as geothermal energy can give an indication of the acceptability of encouraging new demand versus displacement of fossil fuels.

One useful paper is “The Case for Renewable Energies” (Goldemberg 2004), in which the following rationale for renewable energy promotion is outlined:

- Mitigation of climate change. Renewable energy can substitute for fossil fuels, thus reducing greenhouse gas emissions which have been linked to climate change.

- Generation of innovation, local markets and employment. New Zealand has led the world in some geothermal innovations and has developed a workforce with exportable skills. New innovations (such as heat pumps) are now opening up new markets based on economic benefits passing through to users.

- Diversification of energy supply, energy security and prevention of conflicts about natural resources. There are high, but often hidden expenses (e.g. US military spending) associated with securing energy supplies, while prices for commodities like oil are highly volatile threatening economic and political stability. Renewable energy sources contribute to diversification and increase energy security. They are indigenous resources reducing dependence on outside supplies and the vagaries of exchange rates.

- Reduction of poverty through improved energy access and gender aspects. This is an argument more relevant to developing countries. In future in New Zealand, diverse energy supplies in rural areas could relieve pressure on supply lines to these communities, who will be under increasing pressure to pay the full cost of supply.

- Health related impacts. Human health can be threatened by high levels of pollution from fossil fuel emissions, including particulate matter. Long term regional acidification effects due to fossil fuel emissions impact on crops, man-made structures and potentially on ecosystems. In New Zealand’s case, it is recognised that many homes have been too cold leading to negative health impacts, with renewable energy forms offering a means of increasing energy supply without significantly increasing emissions.

- Spill-over effects.

A review of this rationale, indicates that benefits of renewable energy cover both substitution of fossil fuels and increased energy consumption (associated with improved health or economic growth). Both substitution and increased energy consumption are acceptable end results of a renewable energy promotion initiative, and of the Government's overarching economic goals.