An Updated Assessment of Geothermal Direct Heat Use in New Zealand

Prepared by

Brian White, Executive Officer of the NZGA
East Harbour Management Services Ltd

30 June 2009

East Harbour

Photograph 1: Geothermally supplied swimming pools at Waikite, Waikato region. An open channel for heat loss can be seen in the foreground.

Table of Contents

Background

The New Zealand Geothermal Association (NZGA) prepared a report assessing the direct use of geothermal energy in New Zealand in 2006[1]. Since that time there have been further developments coupled with an attempt to assess the historical development of direct use. With national targets for the uptake of renewable energy set by Government, and with an impending World Geothermal Congress (WGC) for which updated information was required, it was timely to produce an update of the direct use report. The updated report was included as an item in the NZGA Action Plan 2008/9 following discussion among NZGA members and approval by the NZGA Board. This report was funded by the Energy Efficiency and Conservation Authority (EECA).

The following report presents an assessment of the direct use of geothermal energy in New Zealand. The New Zealand Geothermal Association has an interest in promoting appropriate use of geothermal energy and so requires market information on this aspect.

This report is being prepared at a key time in New Zealand's geothermal development. Currently there is unprecedented growth in geothermal electricity generation installed capacity, direct use seems to be on a continually increasing trend, while geothermal heat pumps are at the early adoption phase of the product uptake curve. In the near future, a number of Maori Trusts will become cash-rich through Treaty settlements and will be evaluating investment options, some of which could include the labour-intensive direct heat projects such as greenhouses or timber drying kilns. Thus, this report marks an interesting transition time.

[1] Brian White (14 July 2006) *An Assessment of Geothermal Direct Heat Use in New Zealand.* Report prepared for the New Zealand Geothermal Association with funding by the Energy Efficiency and Conservation Authority

Methodology

The methodology used for this report reflects that used in the July 2006 report including:

- Obtaining direct use estimates from various Regional Councils and known major users of geothermal energy,
- Categorising all use into Regional Council areas and into the major geothermal regions as defined in the "Concise Listing of Information on the Thermal Areas and Thermal Springs of New Zealand"[2],
- Updating an initial database of geothermal direct usage, including geothermal heat pumps where known, (for the questionnaire – see Appendix 1), and
- Writing a short report summarising sources of information and providing a conclusion of direct heat usage spread over the categories normally included in the WGC report format, further split out by region.

In addition, attempts were made to try to identify past trends in direct use development and to identify the areas of most recent change. In this regard, it is recognised that databases remain incomplete, so a distinction needed to be made between new discoveries of existing use and new developments.

A further criterion set by EECA was that data should be presented in a manner consistent with the requirements for the World Geothermal Congress country updates. This was done by direct enquiry of John Lund at Oregon Institute of Technology in the areas of debatable application: natural pools and cogeneration situations. Despite John Lund's advice, natural pools where there has been no alteration of fluid flows are still omitted. Energy directed to electricity generation in cogeneration situations are netted off as advised by John Lund and consistent with the previous study. In terms of heat pumps, the WGC practice of netting off the electrical consumption of the heat pump has been followed, as the source of electrical energy is not likely to be geothermal energy (a coefficient of performance of 3.5 has been assumed as a default value).

[2] M. A. Mongillo and L. Clelland (October 1984) *Concise Listing on the Thermal Areas and Thermal Springs of New Zealand.* DSIR Geothermal Report Number 9

Links to Other Studies

Ministry of Economic Development Energy Data File

The Ministry of Economic Development publish regular reports on a wide range of energy supply and consumption through their Energy Data File[3]. It is pleasing to note that their most recent reports for geothermal direct heat use now reference off the NZGA Direct Use Assessment (July 2006) modified by updated figures from major consumers.

Ministry for the Environment

At roughly five yearly intervals the Ministry for the Environment undertakes a national survey of water allocation. The last full report[4] entitled "Information on Water Allocation in New Zealand" was published in April 2000, and was a cooperative study with the Ministry of Agriculture and Forestry as part of a sustainable water management program. An update "snapshot" report was produced in November 2006[5]. While covering a range of water takes, including some geothermal takes, the emphasis of that study was on irrigation. It was evident that the data supplied from Environment Bay of Plenty was incomplete in terms of total geothermal supplies, and this had been evident during the preparation of the previous direct use assessment. However, it was noted that the Aqualinc study did clearly identify some geothermal applications, whereas it appears that originally this had not been intended. Continued development of this MfE water allocation report could see greater capture of data related to direct use. The focus will continue to be on volume flows rather than the more indirect assessment of energy flows.

GNS Science

GNS Science is a Crown Research Institute with interests that include geothermal resources. A continuing component of their research is on both high and low temperature geothermal resources and applications of these.

[3] Ministry of Economic Development (June 2008) *New Zealand Energy Data File.* Report prepared by the Ministry of Economic Development

[4] Lincoln Environmental (April 2000) *Information on Water Allocation in New Zealand.* Report No 4375/1 prepared for Ministry for the Environment

[5] Aqualinc Research Ltd (November 2006) *Snapshot of Water Allocation in New Zealand.* Report ME 782 prepared for Ministry for the Environment

Geothermal Direct Heat Use Covered by this Report

In assessing total geothermal direct heat use, decisions are required on what should or should not be included in the assessment.

Geothermal Resources

Geothermal energy is obviously defined as thermal energy from the earth. There are obvious manifestations of geothermal energy in areas such as those around Rotorua and Taupo, or near Kaikohe at Ngawha. These are associated with high temperature systems. In addition, there are many more thermal springs around the country in both the North and South Islands. The following map shows a compilation of most of the high and low temperature thermal springs.

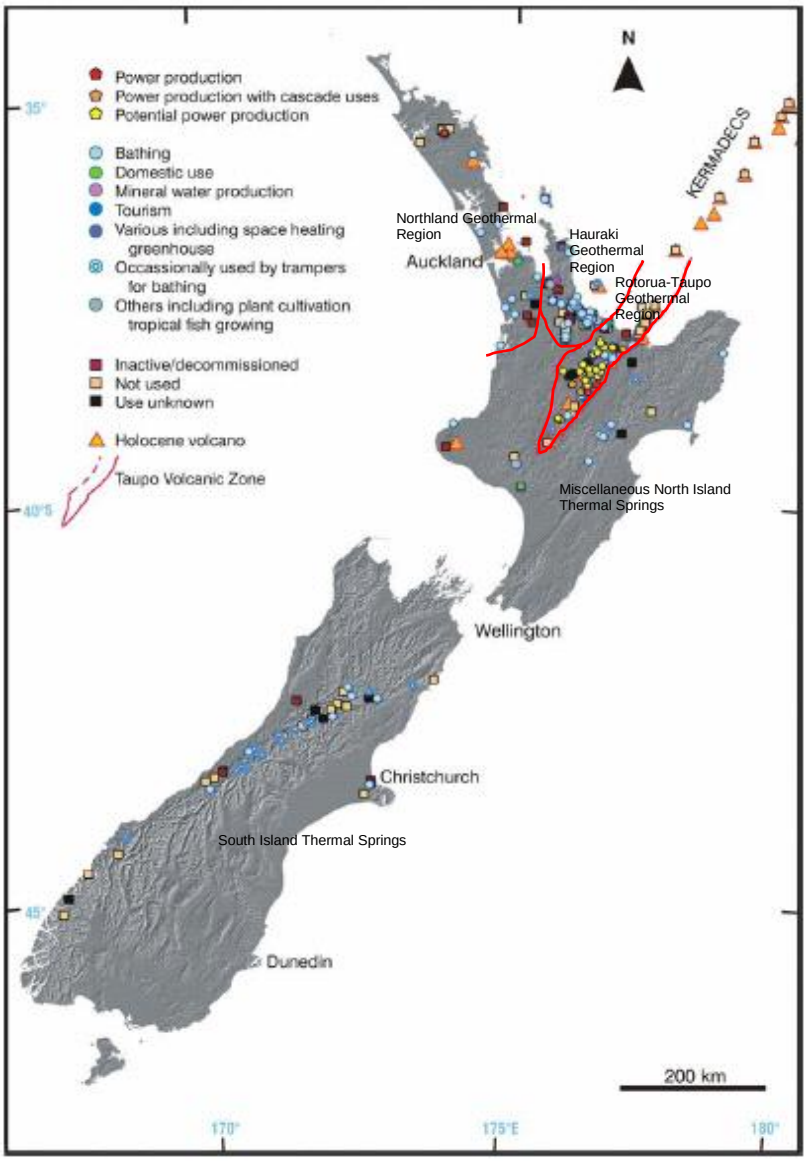

Figure 1: Map showing the main uses of geothermal fluids in New Zealand, and showing the five geothermal regions (based on Thain, Reyes and Hunt 2006)[6]

[6] I Thain, A G Reyes, T Hunt (June 2006) *A practical guide to exploiting low temperature geothermal resources.* GNS Science report 2006/09 (see http://www.gns.cri.nz/geothermal/2006_09_Lw_tmprtr_gthrml_rsrcs.pdf)

Further to these high and low temperature geothermal resources, any place in the world has a natural geothermal gradient, whereby temperature gradually increases with increasing depth. A GNS Science scientist has recently undertaken a survey of temperatures found in oil and gas wells throughout the country. These observed temperatures reinforce the understanding that temperatures increase by about 30°C per kilometre of depth (if not higher) in many places around New Zealand. Because these wells can be drilled to 5km depth, downhole temperatures of 180°C have been measured in wells located in areas not considered to be geothermal areas. One of these abandoned oil and gas wells at New Plymouth has since been converted for use as a heat source for a swimming pool. The existence of abandoned wells makes resources that would have been prohibitively expensive because of drilling costs, potentially available. This type of resource can be accessed through engineered systems (also known as Enhanced Geothermal Systems or EGS). This is still geothermal energy and is an energy resource that is potentially available at any location within the country.

Geothermal heat pumps have opened up a wider resource again. While air temperatures in New Zealand may swing through a range of 30°C between the extremes of summer and winter, ground and water temperatures are far more stable. As a result, there can be thermal and economic justification for using local soils and water as a source or sink for thermal energy in conjunction with geothermal heat pump use. This type of geothermal use can occur at any location in the country.

Table 1: Comparison of potential geothermal applications and associated resource location[7]

	Geothermal Heat Pump Applications	Enhanced Systems for Heat (or Electricity)	Conventional Heat Applications	Electricity Generation
Location				
Comments	• Potential national application • Best areas have not been defined	• Potential national application • Best areas have not been defined • Basic research is required	• Localised application • Data is being collected • Resource size is being assessed under low temperature research funded by FRST	• Narrowly defined resources • Some resources are effectively protected from large scale development

Direct Heat Use Definition

In terms of what constitutes direct use, in keeping with convention this report does not consider generation of electricity as a direct use. Chemical and biota applications are also not considered. Similarly, provision of tourist visitor centres is not included in direct use,

[7] East Harbour Management Services and GNS Science (June 2007) *Assessment of Possible Renewable Energy Targets – Direct Use: Geothermal.* Prepared for the Energy Efficiency and Conservation Authority

despite the commercial opportunities associated with this. This report only considers direct use of thermal properties of geothermally-sourced heat.

At the extreme end of use, there are many thermal springs that may occasionally be visited by trampers in Fiordland National Park, the Southern Alps, the Kawekas or the Ureweras or by local iwi in many other locations, largely in their unmodified state. This report does not consider these as examples of direct use where there has been no significant permanent development and deviation of water from its original course. Thus, the heat from the springs at Hot Water Beach is not included in the assessment despite 130,000 visitors per year who make temporary pools in the sand to bath. Similarly, heat entering the pools at Ngawha has not been counted because the inflow has not been significantly altered, despite development of related bathing facilities.

Where direct heat use has been identified, it has been allocated to one of a number of categories normally identified in World Geothermal Congress surveys. These categories include space heating and cooling, water heating, greenhouse heating, fish and animal farming, agricultural drying, industrial process heat, bathing and swimming, and "other" uses.

Geothermal Energy Supply

In practice, few users of geothermal energy are aware of their full usage. Having invested in the initial development, and secured an adequate heat source for their needs, the very low running costs then means careful monitoring and management is rarely required, unless as a condition of consents. Consequently, there is often more information on geothermal energy supply than on its actual direct use. There are some places where Councils place emphasis on careful measurement. In the case of the Auckland Regional Council resources, users are encouraged to carefully manage the resources available to avoid exceeding their annual allocation measured as a total flow of water.

This energy supply estimate has additional value in that the Ministry of Economic Development maintain an Energy Data File[8] which distinguishes between primary energy supply and consumer energy (the assessment of direct use). Consequently, both assessments (supply and use) will be made for this report, recognising that the primary energy supply estimate is likely to be the more accurate estimate.

For this report all heat supplied is stated relative to $0^{o}C$[9] while all heat used is assessed relative to known (or assumed) discharge temperature.

[8] These reports were published twice a year and are available on the Ministry of Economic Development website http://www.med.govt.nz

[9] There is some debate about the appropriateness of this low figure. Normally the geothermal water would be displacing water at ambient conditions so there is a strong case for using a reference temperature of 15 – 20 ^{o}C. When water is supplied at 25 – 40 ^{o}C a very high proportion of the heat is associated with ambient conditions. However, for energy supply calculations for other fuels, no deductions are mad for ambient conditions so 0 ^{o}C has been retained as the standard for consistent comparability.

Assessment of Direct Heat Use

The process of research has identified a large number of geothermal direct heat applications. While specific information is available in some cases, there are many cases where access to information was limited. As stated previously, direct interviews with users indicate a high level of uncertainty about their own use as a rule, though some operations are carefully monitored. Hence, almost every assessment has required a measure of judgement.

In assessing the total direct heat use, it has been recognised that the greatest percentage of direct usage is concentrated near a few major geothermal developments near Wairakei and Kawerau. As such, some specific discussion on these developments is included in Appendices 2 and 3. Together, these few listed facilities account for around 85% of the national direct heat use. There are still some uncertainties about the details of these operations, but accuracy of these estimates will be relatively high.

All known direct use is summarised in a table in Appendix 4. By far the most common use (though not the largest total energy usage) is for bathing pools. Details on actual use in the main use centres of Tokaanu, Taupo, Rotorua and Tauranga have not been identified at this stage so use for bathing has been selected as the default use in the absence of specific information. In the cases of Tokaanu and Taupo a previous assessment available to Environment Waikato assessed heat split for domestic users only to be 16% space heating, 52% water heating and 42% pool heating, and this has been applied to domestic consumption at those locations.

Accuracy of future reports can be improved by discussions with more individual users. Currently, Bay of Plenty use (particularly in Rotorua, Tauranga, Tikitere and Rotokawa) is based on allocated takes of water as opposed to actual takes. Within this area, more information is required on temperature at which fluid is taken and temperature at which fluid is rejected, along with breakdown of use between heating and bathing.

Within the Waikato region, Environment Waikato has made an assessment of actual use versus consented use, but this will also require some measure of verification at a future time.

Consequently, the accuracy and appropriate allocation of what might be the final 15% of heat use is highly questionable. However, it will be of the right order of magnitude. Given its relative small contribution to the total, the accuracy of the total assessed national heat use should be reasonable.

With these qualifications, the following two tables present the assessed primary energy supply and assessed direct heat use (consumer energy).

Table 2: Assessed Primary Energy Supply for Geothermal Direct Heat Use (TJ/year)

Geothermal and Council Regions	Space Heating	Space Cooling	Water Heating	Greenhouse Heating	Fish and Animal Farming	Agricultural Drying	Indistrial Process Heat	Bathing and Swimming	Other Uses	Total
Northern										
Northland								67		**67**
Auckland	0.4							128		**128**
Waikato	0.4							165		**165**
Hauraki										
Waikato								105	14	**119**
Bay of Plenty	35			79	6			993	11	**1,124**
Rotorua-Taupo										
Waikato	48		85	667	1,503		2,784	1,403	1,263	**7,753**
Bay of Plenty	71		229	21			10,988	1,560		**12,869**
Miscellaneous North Island										
Gisborne								0.4		**0**
Hawkes Bay								16		**16**
Taranaki								0.2		**0**
South Island										
Marlborough	0.4									**0**
Canterbury	15							63		**78**
West Coast								36		**36**
Otago	3	1								**4**
Total	**173**	**1**	**314**	**767**	**1,509**	**0**	**13,772**	**4,537**	**1,288**	**22,362**

Table 3: Assessed Geothermal Direct Heat Use (TJ/year)

Geothermal and Council Regions	Space Heating	Space Cooling	Water Heating	Greenhouse Heating	Fish and Animal Farming	Agricultural Drying	Indistrial Process Heat	Bathing and Swimming	Other Uses	Total
Northern										
Northland								6		**6**
Auckland	0.3							58		**58**
Waikato	0.3							63		**63**
Hauraki										
Waikato								27	14	**41**
Bay of Plenty	14			17	2			274	6	**313**
Rotorua-Taupo										
Waikato	24		40	356	271		880	753	823	**3,146**
Bay of Plenty	24		79	6			5,224	520		**5,854**
Miscellaneous North Island										
Gisborne								0.1		**0**
Hawkes Bay								3		**3**
Taranaki								0.2		**0**
South Island										
Marlborough	0.3									**0**
Canterbury	11							40		**51**
West Coast								14		**14**
Otago	2	1								**3**
Total	**76**	**1**	**119**	**379**	**273**	**0**	**6,103**	**1,759**	**843**	**9,552**

There are small uses for space heating shown in Auckland, Waikato, Marlborough Canterbury and Otago. These represent the initial uptake of geothermal heat pumps which is an industry in its infancy but characterised internationally by exponential growth. In fact the Canterbury applications by the Christchurch City Council are 20 or so years old but did not take off at the time.

The small Taranaki use is associated with an oil and gas well in an otherwise non-geothermal area.

Currently, there is limited indication of space cooling (other than a heat pump application at Dunedin airport). A Rotorua hotel had full geothermal air conditioning at one time but present usage has still to be confirmed.

Currently, no use is indicated for agricultural drying. The lucerne-drying facility at Ohaaki has been decommissioned. There are several major timber drying operations, including those in Taupo and Kawerau which have been assessed as industrial process heat uses for this

report. This treatment appears different to the assessments previously undertaken for the World Geothermal Congress country updates.

Total energy for space heating is shown as a relatively low figure and will be uprated slightly as more surveys are undertaken of actual users, particularly for hotel, motel and hospital heating. However, the final figure is likely to remain fairly low. An assessment in the WGC country update that direct use for space heating in New Zealand might exceed 700TJ/year[10] appears excessive.

Direct use at Kawerau for industrial process heat has been assessed as 5,224TJ/year. This is similar to the assessment in the previous WGC country update (5,500TJ/year), though based on different heat rejection assumptions. This represents continued steady usage rather than a decrease, with any difference due to reassessment.

There are three towns with particularly notable use of geothermal energy: Taupo, Rotorua and Tauranga. With the recent commissioning of the Tenon kiln supply, Taupo now rates as the greatest direct user of geothermal energy (880TJ/year) ahead of Rotorua at 585TJ/year.

When comparing primary energy with consumer energy it can be seen that there is a 43% conversion factor on average. This conversion factor is consistent with International Energy Agency data and their own default assumptions (50%) about geothermal energy conversion for direct heat use applications[11]. In practice, for many low temperature sources, where source and rejection temperatures can be very close, the conversion factor can be as low as 20%.

In addition to energy use, a crude assessment has been made of capacity. For most facilities, capacity is not specified so capacity has been assessed on the basis of the maximum flow rate indicated by consents (commonly expressed on a daily basis). This assessment has been made in compliance with WGC reporting requirements (see Table 4).

[10] M. G. Dunstall (April 2005) *2000 – 2005 New Zealand Country Update.* Proceedings World Geothermal Congress 2005, Antalya, Turkey, 24-29 April 2005

[11] IEA Statistics (2005) *Renewables Information 2005 Edition*

Table 4: Assessed Geothermal Capacity and Utilisation Relationship

Geothermal and Council Regions	Type	Capacity (MWth)	Annual Utilisation		
			Average Flow (kg/s)	Energy (TJ/yr)	Capacity Factor
Northern					
Northland	Bathing/swimming	0.2	22	6	95%
Auckland	Bathing/swimming	2.4	64	58	75%
Waikato	Bathing/swimming	2.8	37	63	71%
Hauraki					
Waikato	Bathing/swimming	1.3	23	27	65%
	Other (irrigation)	1.0	4	14	45%
Bay of Plenty	Space heating	1.5		14	30%
	Greenhouse heating	1.1		17	50%
	Fish farming	0.1		2	50%
	Bathing/swimming	17.4		274	50%
	Other (irrigation)	0.4		6	45%
Rotorua-Taupo					
Waikato	Space heating	2.5		24	30%
	Water heating	4.2		40	30%
	Greenhouse heating	22.6		356	50%
	Fish farming	17.2		271	50%
	Industrial process heat	39.8		880	70%
	Bathing/swimming	30.4		753	78%
	Other (mainly tourist facility)	26.1		823	100%
Bay of Plenty	Space heating	2.6		24	30%
	Water heating	8.4		79	30%
	Greenhouse heating	0.4		6	50%
	Industrial process heat	184.0		5,224	90%
	Bathing/swimming	17.5		520	94%
Miscellaneous North Island					
Gisborne	Bathing/swimming	0.004	0.1	0.1	100%
Hawkes Bay	Bathing/swimming	0.1	2	2.8	100%
Taranaki	Bathing/swimming	0.02	0.1	0.2	49%
South Island					
Canterbury	Bathing/swimming	1.0	8	15	50%
West Coast	Bathing/swimming	0.4	5	14	100%
Subtotal		**385**	**165**	**9,513**	
Heat Pumps	Space heating/cooling, pool heating			39	
Total		**385**	**165**	**9,552**	

Assessment of Historical Changes in Direct Heat Use

An attempt has been made to assess the direct heat use over time. This has been based on:

- Published information on the energy supplied to the Kawerau Mill operation supplemented with advice from the Mills' consultants, which dominates all national use,
- Any information of the commencement or final dates of any particular application, and
- On general information on changes in Rotorua use, coupled with an assumption that this Rotorua uptake or reduction is mirrored for domestic use elsewhere[12] if specific information was not available.

Further refinements of this assessment can be made over time. For many of the smaller developments, their effect is dwarfed by the operations at Kawerau. Hence, errors introduced through crude assumptions will have a second order effect only. The broad growth trends will be correct.

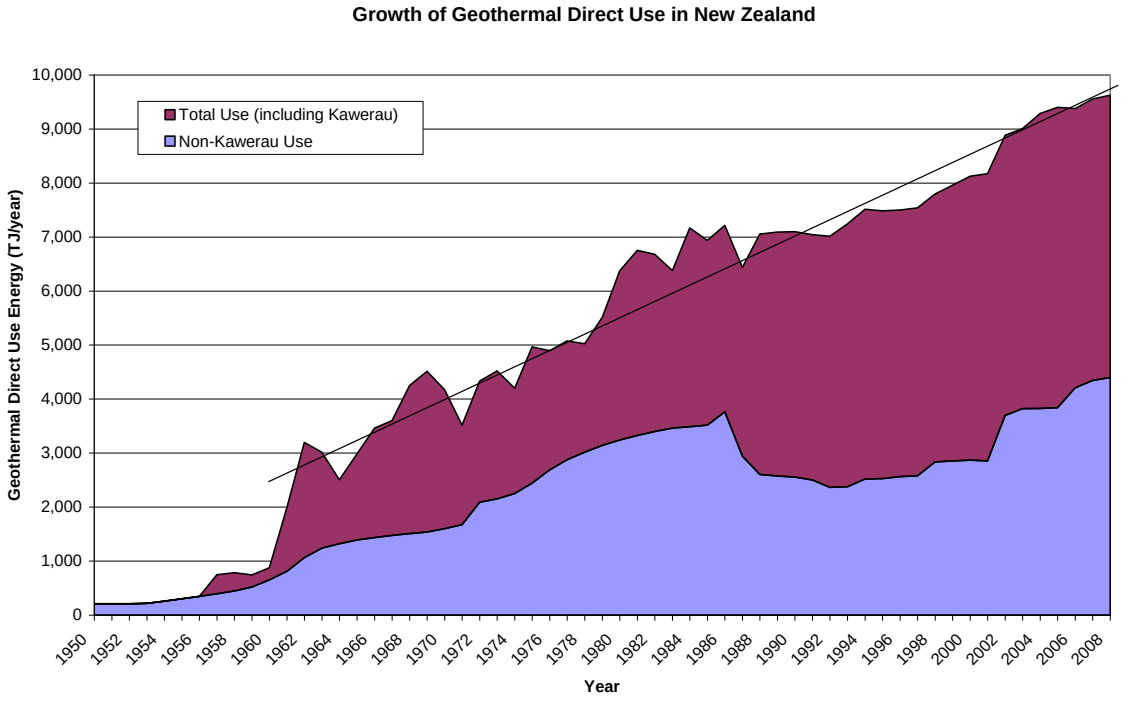

Figure 2: Historical growth of geothermal direct use (consumer energy) in New Zealand

The most remarkable feature of this graph is a fairly steady increase of direct use of geothermal energy continuing to the present. Also striking, is the significance of the Kawerau supply since the 1960's. The linearity of growth hides some significant steps in development at Kawerau which counteracted reductions in the mid-1980s associated with Rotorua bore closures and licensing regimes which discouraged small scale domestic and commercial use through the Taupo Volcanic Zone. Restrictions were also happening in Auckland fields at the time due to previous overuse.

[12] While Taupo or Tokaanu or Tauranga did not have formal bore closure programmes, a licensing regime introduced at the same time did discourage some use.

The following graph compares the total geothermal direct heat use with geothermal electricity generation, simply as a comparison of magnitude. For much of the history of geothermal development in New Zealand, direct use and electricity generation have roughly kept pace with each other. Major investment has commenced in geothermal electricity stations so it will be interesting to see if direct use matches that. In practice, the crudely linear growth for direct heat use has been used in assumptions about future uptake e.g. for the assessment of targets for the National Energy Efficiency and Conservation Strategy.

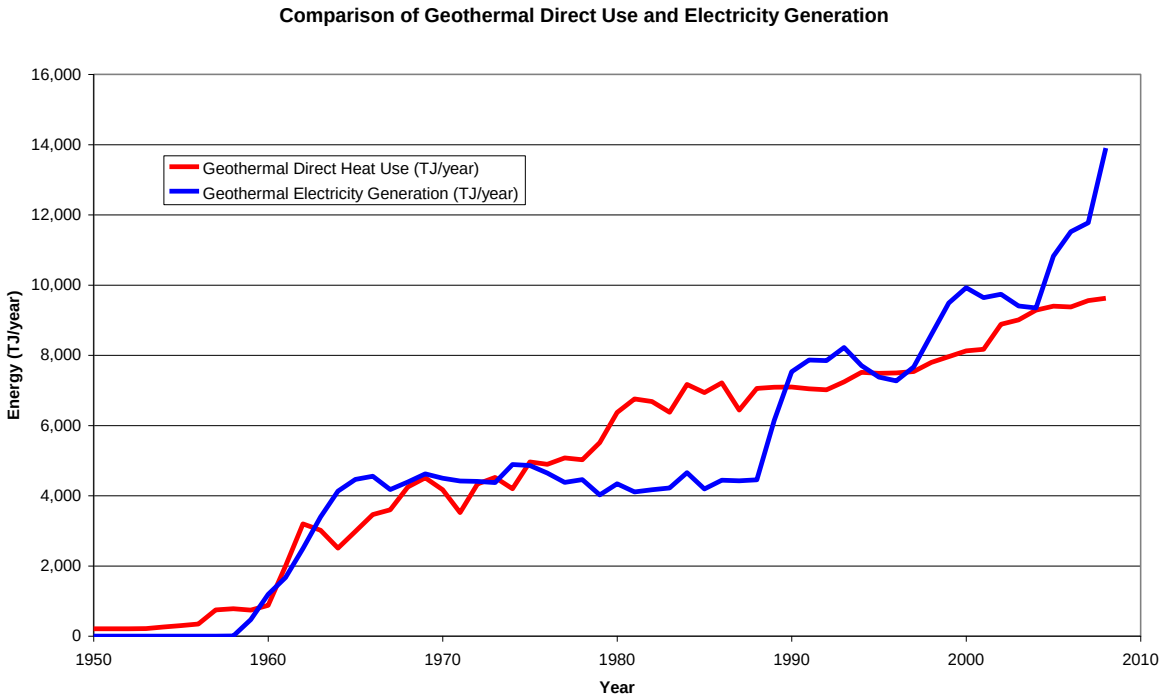

Figure 3: Comparison of geothermal direct heat use with geothermal electricity generation showing these have traditionally been on a similar level.

Description of the Most Recent Changes in Direct Heat Use

The growth trends clearly show some changes in direct heat use. With a survey of this type, some of the apparent change from the previous survey will be associated with refined assessment, some will be associated with capture of information related to pre-existing schemes and some will be associated with new additions or reductions in direct heat use. Primary interest will be on this last aspect i.e. in physical changes to direct heat use.

Significant changes since the 2006 Direct Use Assessment (which was based on 2005 data) included:

- Contact Energy supply of steam to Tenon at Taupo from the Tauhara field – assessed at 430TJ/year for industrial process heat (kiln drying of timber and pellets) commencing 2006.
- The Mokai glass houses have been increased in size from 5 to 11.2 ha in area with a corresponding demand increase of around 174TJ/year and has been treated as effective for the whole of 2008.
- Expansion of the Ohaaki timber kilns operations from mid-2007 to 3 kilns from 2 kilns
- There has been continuing uptake in direct use from shallow bores in the vicinity of Tauranga, though none is at a large scale.
- A number of heat pump applications are now appearing (e.g. Dunedin airport) though this industry is at an early stage of establishment in New Zealand.

The overall impression is that usage has been fairly stable other than some discrete increments.

In discussions with Regional Councils and with developers, it appears that there will be continuing growth:

- Environment Bay of Plenty notes strong interest in development of Rotorua resources once consenting regimes are clarified.
- Heat pump installers note interest in niche markets, though this may be frustrated by the current recession. Geothermal heat pump options are increasingly considered by large commercial developers or for large high heating-load homes.
- Several developers have secured consents for greenhouse expansions and resort developments.
- A major planned expansion of the steam supply at Kawerau has just been made public. At the end of May 2009, the Svenska Cellulosa Aktiebolaget (SCA) tissue mill announced that it was going to be supplied with geothermal steam from Ngati Tuwharetoa Geothermal Assets who currently supply steam to the Norske Skog Tasman mill. This will enable SCA to eliminate use of natural gas. Steam supply is meant to commence in September 2010. As the overall Kawerau site already accounts for half of the total world geothermal industrial heat use, this is significant and will also mean Kawerau will continue to dominate national direct use figures.

In considering future growth, there is an expectation of further investment in industrial/commercial supplies, some of which could be linked to electricity generation developments. There could be opportunities for further greenhouses and timber drying kilns.

Much of the premium geothermal resources are found in the Taupo Volcanic Zone, also occupied by the Te Arawa tribe. Various individuals and Trusts have an interest in the development of geothermal resources, whether for electricity or heat. Shortly they will have access to a cash settlement as part of the overall Crown settlement of Waitangi Treaty claims by Te Arawa, so are actively reviewing options and positioning themselves.

Currently there are no Enhanced Geothermal System (EGS) applications (with the possible exception of the Bonithon pool heat supply in Taranaki). One recent study undertaken with EECA funding has looked at an EGS application at Fonterra's Waitoa dairy factory and found the economics to be quite attractive[13]. On this basis where there are discrete large heat loads in suitable locations then this may also be an area for expansion of direct use.

[13] East Harbour Management Services (April 2009) *Feasibility study report: Geothermal heat and power at Fonterra's Waitoa dairy factory.* Prepared for Fonterra Cooperative Group Ltd with funding assistance from the Energy Efficiency and Conservation Authority

Concluding Remarks

Reviewing the overall direct heat use (and comparing with the 2006 direct heat report):

- Heat use has been steady since the 2006 report of 2005 data other than a few discrete increments such as the Tenon kiln supply and Mokai glasshouse expansions which have helped to maintain the ongoing upward growth trend
- Total direct heat use is now assessed as 9,600TJ/year (c.f. 9,700TJ/year – due to reassessment and some expansion)
- This is from a supply of over 22,000TJ/year
- About 94% of use occurs within the Rotorua-Taupo Geothermal Region (unchanged from the last assessment)
- About 65% of all direct use occurs within the Environment Bay of Plenty region (c.f. 68% - due to reassessment, whereas actual notable increases have been in Environment Waikato's area)
- The combined operations at Kawerau still account for about 55% of all heat use (unchanged from last assessment)
- Significant expansions can be expected in the next few years including activities by new investors and ongoing expansion at Kawerau.
- Larger steps in growth are expected to be focussed on high temperature fields.

There are significant uncertainties in these assessments which can be alleviated by public input and from further direct interviews of users. Recent input by the Regional Councils has been used and adds to the accuracy of the overall assessment.

Appendix 1: Geothermal Database Questionnaire Form

Owner
Phone No.

Date
Call No.

This is a national survey of geothermal direct heat use. It is being undertaken by the New Zealand Geothermal Association with funding by the Energy Efficiency and Conservation Authority.

Are you interested in NZGA membership? Yes/No
If yes you can download information from our website www.nzgeothermal.org.nz

Region	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Manawatu-Wanganui	Taranaki	Wellington	Tasman	Nelson	Marlborough	Canterbury	Otago	Southland	West Coast

Use	Space Heating	Space Cooling (air conditioning)	Water Heating	Greenhouse Heating	Fish and Animal Farming	Agricultural Drying	Industrial Process Heat	Bathing and Swimming	Other Uses

Contact:

Location:

Description of facility (age, how many wells, heat exchangers):

Heat Source	Spring/s	Hot Stream	Hot Ground	Well - Artesian	Well - Pumped	Well – Downhole Heat Exc.	From Adjacent User	Ground Source Heat Pump	Water Source Heat Pump

Waste Disposal	Onto Land	Into Waterway or Drain	Into Shallow Well	Into Deep Well	To Adjacent User	Other

Inlet temp.	Outlet Temp.	Average Flow (water or steam?)

Is your use seasonal? If so when do you use your heat source?

What measures are used to control heat loss/wastage?

Do you have any plans to change your plant? Yes/No
If so what are they?

Energy Output e.g. load factor (annual figure preferred)

Comments:

Do you know of other direct users in the area? Yes/No Contact details:

Appendix 2: Geothermal Direct Use Supplied by Contact Energy

Contact Energy owns and operates geothermal power stations on the Wairakei and the Ohaaki geothermal fields in the Waikato region. In addition, they supply heat to a number of significant direct users at those locations.

Wairakei Supplies
There are two power developments on the Wairakei field and numerous wells.

Geotherm Glasshouses
Alastair McLachlan owns and operates a farm and glasshouses on the western side of the field. He had been the developer of the Poihipi power station now owned by Contact and is preparing to develop a further geothermal power station in the area. His glasshouses were his original inspiration for interest in large scale geothermal development. For many years, an exploration well drilled as part of the original exploration program for the field has been supplying his glasshouses which grow orchids for the Asian market. He now takes steam direct from the supply to Poihipi power station. In 2005, 10,500 tonnes of saturated steam at 3.0bg was supplied by Contact. Condensate from the glasshouses is rejected at about 30 ^{o}C. Heat supplied = 29TJ/year. Heat used = 27TJ/year.

NETCOR
This is a tourism operator with links to local iwi at Wairakei that operates artificial geothermal features as a tourist attraction with a cultural dimension. In 2005 NETCOR was supplied with 2,300,000 tonnes of brine at approximately 130 ^{o}C (546kJ/kg) to recreate silica terraces and the geothermal environment in which local iwi historically lived in, with flow entering the Te Kiriohineki Stream at 40 to 50 ^{o}C (188kJ/kg). Heat supplied = 1,260TJ/year. Heat used = 820TJ/year.[14]

Wairakei Resort
This is a large accommodation facility located on the State Highway at Wairakei that uses heat from the field for space and water heating. The resort was supplied with 7,484 tonnes of saturated steam at 4bg. Heat supplied = 21TJ/year. Heat used = 20TJ/year.

Wairakei Prawn Farm
This farm grows prawns in large ponds on the opposite side of the confluence of the Wairakei Stream and Waikato River for the restaurant on site. Heating requirements are seasonal but the farm operates year round. The prawn farm was supplied with 3,260,000 tonnes of brine at 130 ^{o}C up to the end of June 2005 then at 87 ^{o}C after that following the commissioning of the Wairakei binary plant. Water is rejected to the Waikato River at temperatures between 80-100 ^{o}C. Heat supplied = 1,500TJ/year. Heat used = 270TJ/year.

Tauhara Supplies

Tenon Kilns
Tenon has operated timber drying kilns on their Taupo site for a number of years, previous with natural gas as the fuel. From May 2006, Contact began supplying Tenon with geothermal heat. The process is a batch process so the load is cyclical and kilns are coming in and out of service. They typically run between 12 and 16 MWth with occasional peaks to 20 MWth. Tenon has reported that they are very satisfied with the result which is leading to savings for Tenon while securing a commercial return for Contact. Heat supplied (2008) = 1,796TJ/year. Heat used (2008) = 431TJ/year

[14] Given the definition of direct heat use within this report, it is arguable whether or not the NETCOR application should count as direct heat use. On balance, because of the significant diversion of heat from its course otherwise, the NETCOR application has been counted as an 'other' use.

Photograph 2: Recent kiln supply at Tauhara, Waikato region. (Photo courtesy of Contact Energy)

Taupo Plant Nurseries

A small amount of heat is bled from the Tenon supply to supply the Taupo plant nursery, especially through the winter period. The flows are below the margins of error of the metering. For this report it is assumed that supply and use was similar to Geotherm. Heat supplied = 29TJ/year. Heat used = 27TJ/year.

Ohaaki Supplies

In the past, various supplies were made to a greenhouse, a lucerne drying plant, and another small timber drying plant (all recently closed/relocated).

Ohaaki Timber Kilns

The Ohaaki Timber Kilns expanded their kiln operations from May 2007 now with 3 kilns rather than 2 kilns. In 2008 they received 1052 kilotonnes of brine at 920kJ/kg from Contact. Waste brine is rejected by the kilns through a silencer to an area of land consented as part of the power project for discharge onto land. The temperature of the rejected fluid prior to pressure let down into the silencer ranges between 100 – 140^{o}C (say an average of 120 ^{o}C at 504kJ/kg). There had previously been natural surface discharges (vents) in the area. Brine flows across this and enters the Waikato River. The brine supply is a diversion of 4-5% of the total brine being delivered to reinjection wells from the power station steamfield development.

Heat supplied (2008) = 968TJ/year. Heat used (2008) = 438TJ/year.

Marae

The Ohaaki Marae (the principal marae of Ngati Tahu) has provision for heat supply through heat exchangers from the discharge of well BR22. In addition, some water fed into the Ohaaki Ngawha is diverted through a small bathing pool beside the marae. Use in the last year has not been recorded.

Appendix 3: Kawerau Direct Heat Use

The Kawerau direct heat supply is one of the largest geothermal direct heat applications in the world. The following diagram shows the relatively complex nature of the geothermal supply. It ignores the further complexity within the Norske Skog Tasman (NST) plant due to other competing fuels including wood waste, black liquor, and fossil fuels. In practice, there have been some changes at the mill in recent years. One paper machine has closed down and wood waste is no longer fired, thus enabling NST to be fully dependent on its geothermal supply.

Unusually, while the development could be considered a "cascade" development, it is power generation that receives the low grade heat stream.

The current steamfield wells and fluid collection system are now owned by Ngati Tuwharetoa Geothermal Assets (NTGA), after a transfer and sale through Mighty River Power by the Crown.

The former Tasman Pulp and Paper Mill has experienced ownership changes in recent years. The paper machines and mechanical pulp mill are now owned by Norske Skog Tasman, while the chemical pulp mill is now owned by Carter Holt Harvey Tasman. The former Carter Holt Harvey tissue mill is now owned by Svenska Cellulosa Aktiebolaget (SCA). The former Fletcher Challenge Forests timber mill and kilns are now owned by Carter Holt Harvey Woodproducts.

For the last five years the field has produced about 12Mt[15] of fluid annually at an enthalpy of about 1185kJ/kg (consistent with a resource temperature of 270°C)[16]. Hence, field supply is about 14,200TJ/year from NTGA.

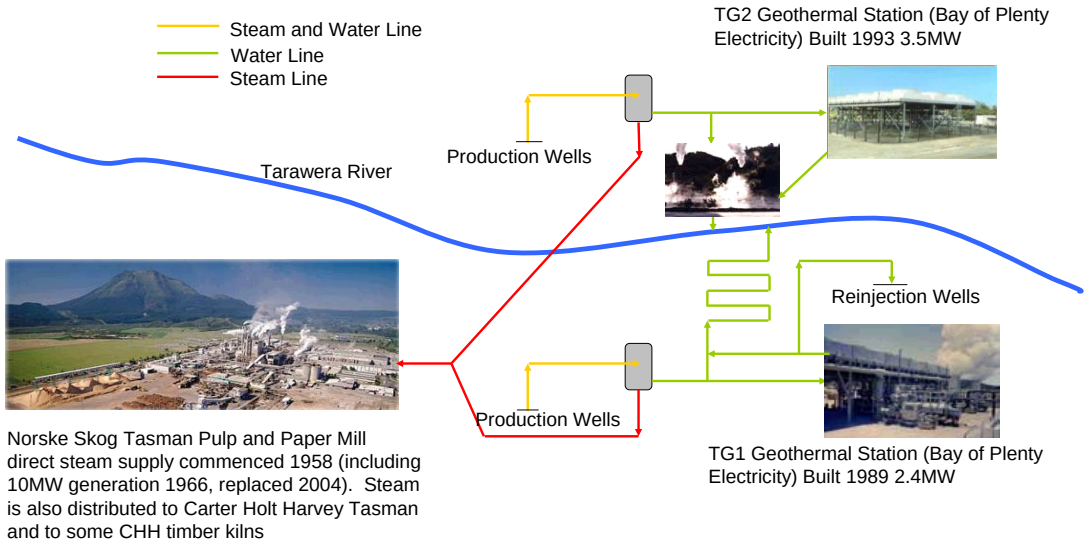

Figure A3.1: Simplified Kawerau Layout

There are separation stations either side of the Tarawera River and the quantity of fluid through each depends on the relative production from the various wells which have required periodic workovers and replacement. However, assuming a separation pressure of 8.5 bara implies a brine flow of 9.33Mt/year or about 1120t/h at 95% load factor. Of this, 266t/h of

[15] Mighty River Power (August 2005) *Kawerau Geothermal Power Station Assessment of Environmental Effects*

[16] For the purposes of these calculations, a 3% gas concentration in the steam has been ignored.

brine is directed to Bay of Plenty Electricity's TG1 station generating 2.56MW and rejecting fluid at 109°C, while between 180 – 325t/h of brine is directed to TG2 station generating 3.8MW and rejecting fluid at 85°C[17]. All brine (including that rejected by the stations) is either reinjected or passed through a cooling lake/channel before being discharged into the Tarawera River. While there may be opportunity for further use of this fluid, none of this existing use for generation (equivalent to a supply of 3,100TJ/year) is recognised as direct heat use. Hence the effective supply for direct heat purposes is 11,000TJ/year.

NST contracts with NTGA for supply of steam. From the separation plants a steam flow of 2.67Mt/year or about 320t/h at 95% load factor is produced, but there may be times when some of this is vented rather than used. Recently NST has received an average of 285t/h of steam. At an enthalpy of 2771kJ/kg this equates to a heat flow of 6,900TJ/year. In turn, NST sells about 15-20t/h of mainly low pressure steam to CHH Woodproducts (for use in timber drying kilns), and the balance of the atmospheric pressure steam[18] vented from their geothermal turbine to CHH Tasman (for pre-evaporators and boiler feed water heating). Generally, these companies will blow through 10-20% of the steam to avoid problems with the non-condensable gas, and return all condensate to NST at about 100°C. NST uses the steam for various processes (normally blowing through about 20% of the steam) and a varying proportion each year (but close to 1/3rd now compared with about ½ in 1980) is directed to its 8 MWe geothermal turboalternator. In practice, this turboalternator largely acts as a pressure reducing valve, reducing pressure for onsale of steam to CHH Tasman. For the direct use calculation, any electricity generated has been deducted from the energy supplied as this is not regarded as direct use. The steam passing through this turbine or condensate produced is reused or onsold so has been left in the calculation of total direct use. As seen in Figure A3.2, across the whole system about 67t/h of steam at 2676kJ/kg and 15.3t/h of condensate at 419kJ/kg is rejected from the system.

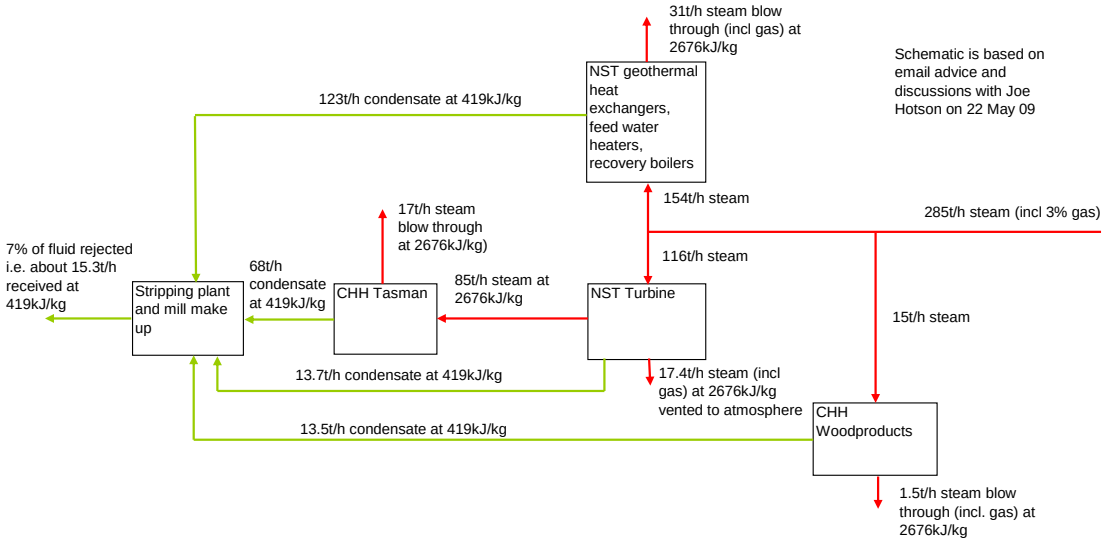

Figure A3.2: Additional Detail Focussed on Rejected Heat within the Mill Complex

In summary for the Mill complex, after deducting flows dedicated to power generation, total supply is 11,000TJ/year. Summing up blow through and condensate rejected in the stripping process, about 1,270TJ/year is rejected. Based on a steam supply of 6,650TJ/year reduced by 155TJ/year for power generation, and reduced by 1,270TJ/year for rejected heat, actual direct use at Kawerau is 5,225TJ/year.

[17] See http://www.bopelec.co.nz/generation/kawerau
[18] Or 70t/h of higher pressure steam if turbine bypass is required.

In addition to these highly connected resources, there are also isolated supplies within Kawerau township. A swimming pool is heated from a geothermal well and there is some other domestic heating. In the past, a greenhouse was supplied with steam from the Tasman supply.

SCA has announced its intention to receive steam from NTGA commencing in 2010. Whether this supply will be integrated with the NST system or kept separate due to differing steam pressure requirements has yet to be seen.

Appendix 4: Geothermal Resources and their Use

The following geothermal resources and their use have been identified through review of the "Concise Listing" report, through direct advice by regional councils, through cross-checks by Agnes Reyes (GNS Science), and by limited interviews with users.

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: 666,000 t/yr (est) at 24 °C (101kJ/kg) = 67TJ 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
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. Consumption is steady	Typically 60-65°C	Take: 174,000 m^3/yr (2008) 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. Consumption is steady (slightly down)	Typically 50-55 °C	Take: 384,000 m^3/yr (2008) at 52 °C (218kJ/kg) = 83TJ Use: reject at 30 °C (126kJ/kg) so use = 35TJ

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
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
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: 404,000 t/yr at 57 °C (239kJ/kg) = 96TJ Use: Reject at 35.3 °C (148kJ/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 t/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 including at the golf course. 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) : 643,000 t/year = 92TJ Use (for pools) = 19TJ Take/Use (for irrigation/frost protection): 119,000 ts/year at 30-35 °C = 15TJ
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. There are no current consents	38-43 °C	Unknown
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

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
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. Consents have been obtained for an equivalent take of 21 TJ/year	51 °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: 33,000 t/y at 95 °C (398kJ/kg) = 13TJ Use: reject at 39 °C (163kJ/kg) = 8TJ
Waitearikiki (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 and a hot house	30-42 °C	Take: 194,000 t/y at 36 °C (151kJ/kg) = 29TJ Use: reject at 25 °C (105kJ/kg) = 9TJ
Mayor Island (Tuhua) Hot Springs	Bay of Plenty	None known, intertidal springs	Warm	None
Omokoroa	Bay of Plenty	Swimming pools	39 °C	Take: 172,000 t/y at 37 °C (153kJ/kg) = 27TJ Use: reject at 23 °C (97kJ/kg) = 10TJ
Oropi Spa Pools	Bay of Plenty	Swimming pools	57 °C	Take: 52,500 t/y at 54 °C (228kJ/kg) = 11TJ Use: reject at 35 °C (147kJ/kg) = 4TJ
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, swimming pools	46 °C	Take: 1,264,000 t/y at 39 °C (163kJ/kg) = 201TJ Use: reject at 30.5 °C (128kJ/kg) = 40TJ

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Sapphire (Katikati) Hot Springs	Bay of Plenty	Swimming pools, greenhouses (16TJ usage) and irrigation (22TJ usage)	39 °C	Take: 796,800 t/y at 43 °C (180kJ/kg) = 142TJ Use: reject at 32 °C (136kJ/kg) = 38TJ
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	Take: 2,237,000 t/y at 44 °C (185kJ/kg) = 413TJ Use: reject at 27 °C (115kJ/kg) = 154TJ
Te Puke Hot Springs	Bay of Plenty	None known	Unknown	None known
Te Puna	Bay of Plenty	Swimming pools, heating and some irrigation	51 °C	Take: 427,300 t/y at 46 °C (136kJ/kg) = 81TJ Use: reject at 35 °C (145kJ/kg) = 24TJ
Welcome Bay	Bay of Plenty	Swimming pools and heating	53 °C	Take: 938,700 t/y at 37 °C (154kJ/kg) = 189TJ Use: reject at 34.5 °C (145kJ/kg) = 32TJ
Woodlands (Athenree) Hot Springs	Bay of Plenty	Swimming pools, heating and irrigation	38 °C	Take: 204,800 t/y at 36.7 °C (154kJ/kg) = 31TJ Use: reject at 34 °C (145kJ/kg) = 2TJ
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 °C springs 165 °C in well	None known

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
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 1,052kilotonnes/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): 1,052,000 t/y at 920kJ/kg = 968TJ Use: 438TJ (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. A further well has been drilled, and consents have been obtained for expanded use	85 ^{o}C	Take: 26,280 t/y at 85 ^{o}C (356kJ/kg) = 9TJ Use: Assuming 50% load factor, reject at 70 ^{o}C (293kJ/kg) = 2TJ
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
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 11.5 ha glasshouse recently expanded from 5.2 ha (growing capsicums and tomatoes) supplied by geothermal heat from dedicated well with waste water added to power station reinjection line (EW consent 930748).	Well temperatures <326 ^{o}C	Take: ~600TJ Use: ~300TJ based on area
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	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

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
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
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 ^{o}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, and process heat requirements (golf course use currently not consented). About 14% of use is domestic (52% water heating, 32% pool heating, 16% space heating). Commercial use is dominated by pool heating. Most recent application = Tenon kilns and Taupo nursery	Various temperatures in springs and wells but assumed to be ~80 ^{o}C for this assessment	Take: 2,797,000t/y at 80 ^{o}C (335kJ/kg) = 937TJ Take for Kilns = 1,796TJ Take for plant nursery = 29TJ Use: reject at ~44 ^{o}C (184kJ/kg) = 423TJ Use for kilns = 431TJ Use for nursery = 27TJ
Te Kopia Geothermal Area	Waikato	Tourism but no direct use (previously mushroom growing)	<241 ^{o}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 ^{o}C in reservoir, one well at 145 ^{o}C, springs up to boiling point	Take: 296,500t/y of fluid from wells at around 107^{o}C (449kJ/kg) = 133TJ Use: reject at 35^{o}C (149kJ/kg) = 89TJ
Tongariro	Waikato/ Manawatu-Wanganui	None. Mainly located in Tongariro National Park	Unknown	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Waikite Geothermal Area	Waikato	Water from flowing springs used in a swimming pool complex. Extensive efforts to lose heat through sprinklers and cascade systems. Also some water used by golf course for irrigation	<99 °C in springs	Take: 1,051,300t/y of water at 98°C (411kJ/kg) = 431TJ Use: reject at 35°C (146kJ/kg) = 278TJ
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 72,400t/y of fluid at 130 °C (547kJ/kg) = 40TJ Use: reject at 60 °C (251kJ/kg) = 21TJ
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: 66,000t/y of fluid at 56 °C (234kJ/kg) = 15TJ Use: reject at 42 °C (176kJ/kg) = 4TJ
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
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. Shallow wells supply heat to a public recreation hall and pool. Previous greenhouses have been removed. There are planned expansions of supply to the tissue mill.	<310 °C in wells	Take: assessed at 11,088TJ Use: assessed at 5,224TJ (see Appendix 3) (also includes 100/23TJ bathing)
Lake Okataina Springs	Bay of Plenty	None - seeps in lake shore beach sands	30-36 °C	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Lake Rotoiti Geothermal Area (includes Manupirua, Maraeroa, Otutarara)	Bay of Plenty	1 well drilled at Moose Lodge to 218m tapping 55 °C water for heating a pool. Possibly other private wells in the area (reassessed downwards)	<130 °C in sediments	Take: about 46,800 t/y at 56 °C (234kJ/kg) = 11TJ Use: reject at 41 °C (173kJ/kg) = 3TJ
Lake Rotokawa Geothermal Area (Rotorua)	Bay of Plenty	8 shallow wells (most < 45m) tap fluids >99 °C. All wells have artesian discharge. These heat a glasshouse, school and swimming pools	>99 °C	Take: 23,600t/y at 102 °C (428kJ/kg) = 10TJ Use: reject at 67 °C (279kJ/kg) = 3TJ
Mangakotukutuku Springs	Bay of Plenty	None	24 °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 °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 °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 °C, fumeroles < 90°C	Take: about 22,200t/y at 38°C (159kJ/kg) = 4TJ Use: reject at 35 °C (147kJ/kg) = 0.5 TJ
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 °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 °C in wells, springs to 100 °C	Take: Approximately 3,658,000t/y at about 458kJ/kg = 1,675TJ plus a further 20TJ from downhole heat exchange Reinject: 3,180,000t/y at around 73 °C (304kJ/kg) = 967TJ Other surface water: 478,000t = 145TJ Use = 1,675 + 20 - 967 - 145 = 585TJ
Taheke Geothermal Area	Bay of Plenty	Springs are used for bathing	<97 °C	None
Tarawera Geothermal Area (includes Te Rata and Humphrey's Bay Springs)	Bay of Plenty	Springs are used for bathing	<90 °C	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
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: 83,200t/y at 130 ^{o}C (546kJ/kg) = 46TJ Use: reject at 100 ^{o}C (419kJ/kg) = 11TJ
Waiaute Springs	Bay of Plenty	None	23 ^{o}C	None
Whale Island (Moutohora) Geothermal Area	Bay of Plenty	None	100 ^{o}C	None
White Island (Whakaari)	Bay of Plenty	Private scenic reserve, formerly used for sulphur mining	<350 ^{o}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 ^{o}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 ^{o}C	Take: ~ 2,000 m^{3}/y at 50 ^{o}C (209kJ/kg) = 0.42TJ Use: reject at 35 ^{o}C (147kJ/kg) = 0.12TJ
Mangatainoka (Mohaka) Hot Spring	Hawke's Bay	Spring feeds two-level DOC trampers baths in Kaweka State Forest	59 ^{o}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 ^{o}C (now 50 ^{o}C)	Take: 77,380 m^{3}/y at 50.2 ^{o}C (210kJ/kg) = 16TJ Use: 66,325 m^{3}/y reject at 40 ^{o}C (168kJ/kg) = 2.8TJ
Ohane Spring	Hawke's Bay	Undeveloped bathing	45 ^{o}C	None
Puketitiri (Mangatutu) Hot Springs	Hawke's Bay	Bathing (spa pool size) facility fed from spring near roadend in Kaweka Forest	52 ^{o}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 ^{o}C	None

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Waipiropiro Hot Spring	Hawke's Bay	None known - in Ruahine Forest Park	40 °C	None
Jerusalem Hot Springs	Manawatu-Wanganui	Plant cultivation	25 °C	Negligible
Pipiriki (Waiora) Hot Springs	Manawatu-Wanganui	None	23 °C	None
Upokongaro	Manawatu-Wanganui	Potable water	21 °C	Negligible
Arawhata Hot Springs	Taranaki	None known	20-29 °C	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 °C	Take and Use: 2,130 m^3/y at 27 °C (113kJ/kg) = 0.24TJ
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 °C	None
Cow Stream Springs	Canterbury	None known	52 °C	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 °C	Take: 129,400m^3/y at 52 °C (218kJ/kg) = 28TJ Use: reject at 24 °C av (100kJ/kg) = 15TJ
Hope River Springs	Canterbury	Natural springs used for bathing	50-54 °C	None
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

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
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/y at 55 °C (230kJ/kg) = 36TJ Use: reject at 36 °C (151kJ/kg) = 14TJ
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: Calculation of Direct Heat Use

Simple Calculation

Calculation of direct heat use is based on a calculation of input heat, and of heat rejected at the end of the process. The difference is assumed to be the heat used. The process application is generally treated as a black box.

Advice on mass or volume flow was received (or assumed), along with advice on source condition temperatures. Steam tables were consulted to determine water or steam density and enthalpy at the source temperature.

Mass flow = volume flow x density

Supplied energy = mass flow x enthalpy

Similarly advice was received on outlet flows and temperatures. The Kawerau assessment in Appendix 3 is the most complex assessment with multiple outlet flows at either steam or condensate conditions. Generally there were simple outlet conditions from the process. Again the steam tables were consulted to determine water or steam enthalpy at exit. An assumption was made that mass loss through evaporation was negligible. Hence, as a rule:

Rejected energy = inlet mass flow x outlet enthalpy

Heat use = supplied energy – rejected energy

Specific Advice

In the case of the Mokai glasshouse very little information on energy flows were available. What was known was the desired internal operating temperature of the glasshouse and a rough assessment of the outside temperature through time. Rough assessments of heat requirements per unit area based on specific outside temperatures were obtained[19]. Heat requirement per unit area was multiplied by total area of the glasshouse to assess total heat use. Based on IEA energy conversion assumptions, and other observation in this report, the energy supplied was assumed to be twice the energy use.

[19] This was personal advice from John Lund, Geo-Heat Center, Oregon Institute of Technology based on OIT data, adjusted for New Zealand conditions.