An Assessment of Geothermal Direct Heat Use in New Zealand

Prepared by

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Photograph 1: Geothermally heated 5 ha glasshouse at Mokai, Waikato region (Mokai power station in the background)

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Background

The following report presents an assessment of the direct use of geothermal energy in New Zealand. Internationally, geothermal direct heat use has been increasing at nearly twice the rate of electricity generation[1], and there is considerable potential for growth here. The New Zealand Geothermal Association has an interest in promoting appropriate use of geothermal energy and so requires market information on this aspect.

This task was first outlined in the New Zealand Geothermal Association (NZGA) Action Plan (April 2006) and has been progressed with sponsorship from the Energy Efficiency and Conservation Authority (EECA).

Assessments of direct heat use have been prepared by various authors for country updates at World Geothermal Congresses (WGCs) arranged by the International Geothermal Association every five years[2]. The country reports have been useful summaries but the surveys have been incomplete. Statistics New Zealand collects geothermal direct heat use statistics on a quarterly basis, but its data is based on direct heat use in the Environment Bay of Plenty region only (coupled with some other known industrial uses) so is again incomplete. The Statistics New Zealand data feeds directly into the Ministry of Economic Development's "Energy Data File", which is therefore incomplete.

A more complete and accurate data set is needed, especially given that a measure of changed use will be required in future in assessing effectiveness of a new National Energy Efficiency and Conservation Strategy (NEECS).

In preparing this report it was recognised that even rudimentary attempts to itemise current usage would have the effect of putting NZGA in touch with current users, and give greater understanding of usage.

There are a range of potential follow up activities to this report that can further extend knowledge and application, including

- a comprehensive database of direct use,
- a report on resource potential,
- a report on practices (and costs) in New Zealand (and possibly some recommendations for improvements e.g. rationalisation of developments in mini-district heating schemes),
- use of source material for case studies to encourage further use and best practice, and
- comparison of the New Zealand and overseas situations, to identify why the uptake of geothermal direct heat use in this country is slow.

[1] J. W. Lund, J. Koenig, O. Mertoglu and V. Stefansson (2006) "World Geothermal Congress 2005 Findings and Recommendations" (see http://www.nzgeothermal.org.nz/publications/Reports/2005IntPanel_WorldGeothermal.pdf)
[2] M. G. Dunstall (April 2005) "2000-2005 New Zealand Country Update" Proceedings World Geothermal Congress 2005, Antalya, Turkey, 24-29 April 2005

Methodology

Key elements of this report include:

- Obtaining direct use estimates from various Regional Councils and known major users of geothermal energy,
- Reviewing "Concise Listing of Information on the Thermal Areas and Thermal Springs of New Zealand"[3] to ensure that known usage in all thermal areas is covered,
- Commencing an initial database of geothermal direct usage, including geothermal heat pumps where known, (after development of a direct use 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.

As a further step in assessment of use, GNS Science scientist Agnes Reyes has been involved in projects looking at low temperature geothermal resources around New Zealand and so has visited many sites. Consequently, Agnes was approached to review and update the relevant material extracted from the 1984 Concise Listing report.

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

Links To Other Studies

Statistics New Zealand

Statistic New Zealand does undertake a quarterly assessment of geothermal direct heat use. As mentioned earlier this SNZ assessment has been incomplete. During the course of this NZGA study, discussions were held with the SNZ project manager who was open to improvement of the database. She was advised of particularly helpful Regional Council contacts.

In the process of undertaking this NZGA study, it was identified that there was a significant error in the information provided by Environment Bay of Plenty, and this will be corrected in future.

Ministry for the Environment

At roughly five yearly intervals the Ministry for the Environment undertakes a national survey of water allocation. The last 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. While covering a range of water takes, including some geothermal takes, the emphasis of that study was on irrigation.

During the course of this NZGA study, Regional Councils were in the process of submitting full summaries of water takes for the updated study being undertaken for MfE by Aqualinc. The water allocation study is now being undertaken under the Water Programme of Action, which covers a wider range of interest in water application. As a rule, this study does not isolate water takes for geothermal applications (with exceptions such as takes in the Waiwera and Parakai areas near Auckland where all takes are for geothermal applications)[5]. This study will still be useful to people interested in geothermal developments as it will give summaries of the current consenting environment in every region.

It has been pointed out to the MfE project manager that the Water Programme of Action does cover a range of interests in water use, including for energy purposes. As such, it will be useful to identify energy use in future as a component of the reporting.

GNS Science

GNS Science is a Crown Research Institute with interests that include geothermal resources. As a component of their research, they have been researching both high and low temperature geothermal resources and applications of these. Research areas are diverse, but while this NZGA direct use study has been carried out GNS Science has published "A Practical Guide to Exploiting Low Temperature Geothermal Resources".[6] This useful report does give practical advice on direct heat use, and also provides brief information on all known hot springs and geothermal areas in New Zealand. This GNS Science report has been drawn on for this NZGA study.

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

[5] In fact, specific heat references for the Environment Bay of Plenty area have now been deleted at the request of EBOP, after being submitted initially.

[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/research/geothermal/2006_09_Lw_tmprtr_gthrml_rsrcs.pdf)

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.

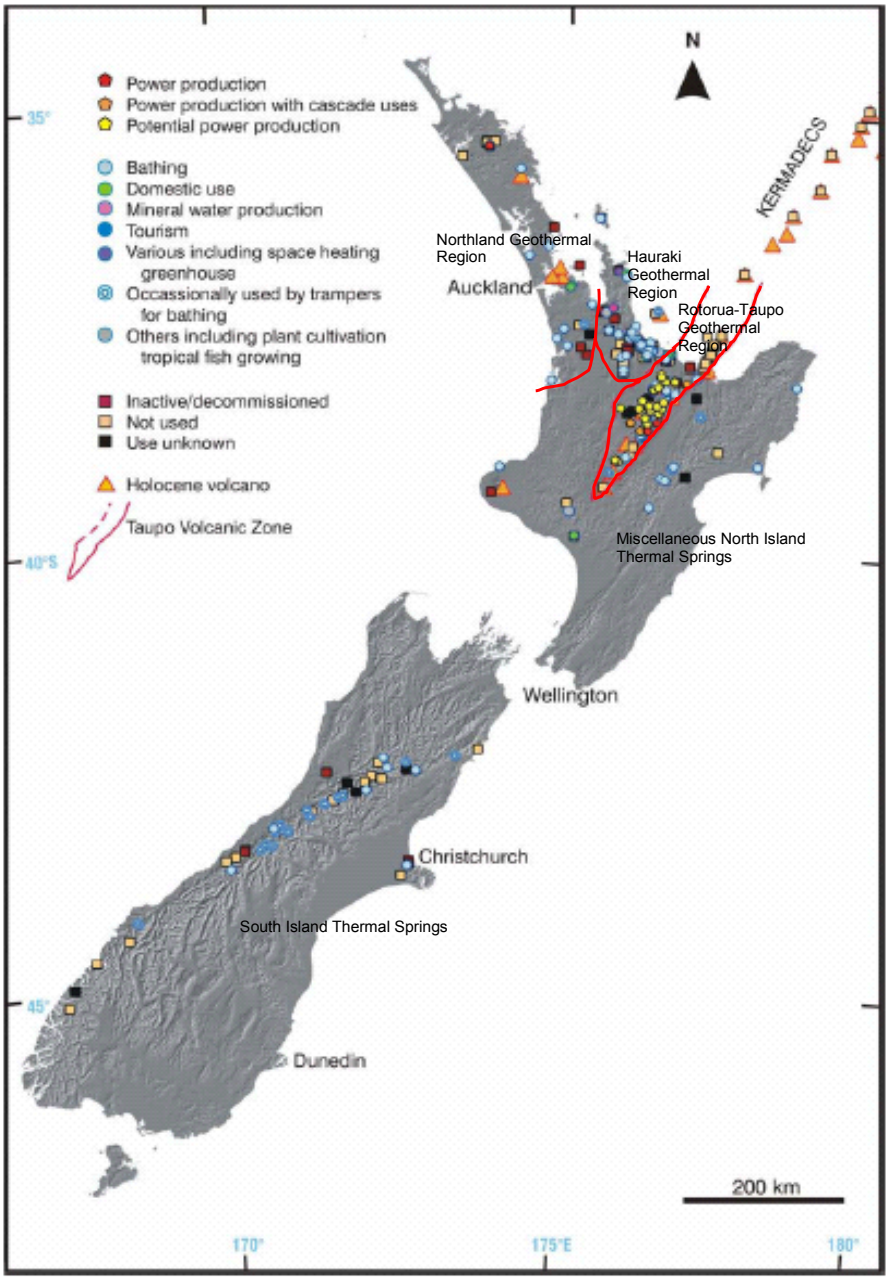

Figure 1: Map showing the main uses of geothermal fluids in New Zealand, and showing the five geothermal regions (based on Thain, Reyes and Hunt 2006)

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 28°C per kilometre of depth. 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 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 where oil/gas wells have been or will be drilled.

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

Photograph 2: Trampers in the Copland River (Welcome Flat) springs, West Coast region, South Island. This type of use is not counted in the assessment of direct heat use.

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.[7]

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.

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°C[9] while all heat used is assessed relative to known (or assumed) discharge temperature.

[7] Note that this report does list all fields or springs where bathing is known in Appendix 4, including those where there is no technical assessment of direct heat use.

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

[9] There is some debate around 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 °C. When water is being supplied at 25 – 40 °C a very high proportion of the heat is associated with ambient conditions. However, for energy supply calculations for other fuels, no deductions are made for ambient conditions so 0 °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 other cases, particularly in the Bay of Plenty region 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 at 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 use) 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 small allowances have been made for space heating based on the limited number of homes that might be heated.

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 1: 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	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 2: 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	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**

Note that although space heating is indicated as zero for the Northern Geothermal Region (Waikato) and South Island Geothermal Region (Marlborough), these represent the first specifically identified recent installations of geothermal heat pumps (space heating load is probably close to 0.007TJ/year each). These are domestic installations located in Hamilton and Blenheim. While other geothermal heat pumps have been reported, including another now-decommissioned system in Hamilton, no specific information is known.

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

Currently no use is indicated against space cooling. 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. However, the final figure is likely to remain fairly low. The total number of homes with geothermal heating is probably of the order of 1000. Other studies indicate that average homes consume about 8,000kWh/year of electricity of which about 30% is used for space heating[10]. If that need for energy for space heating was fully met for those 1000 homes then direct heat use would be 8TJ/year. There will be similar amounts for hotel/motel heating, and possibly similar quantities again for Rotorua hospital. An assessment in the WGC country update that direct use for space heating in New Zealand might exceed 700TJ/year appears excessive.

Direct use at Kawerau for industrial process heat has been assessed as 5,315TJ/year. This is very similar to the assessment in the WGC country update, though based on different heat rejection assumptions.

When comparing primary energy with consumer energy it can be seen that there is roughly a 50% conversion factor on average. This conversion factor is consistent with International Energy Agency data and their own default assumptions about geothermal energy conversion for direct heat use applications[11].

For comparison purposes, MED's Energy Data File records that total New Zealand electricity generation from geothermal energy for the year ended September 2005 equated to 9,520TJ/year[12]. Hence, it appears that geothermal energy makes equal contributions to electricity generation and direct heat use after conversion efficiencies are taken account of.

[10] BRANZ (2004) *Energy Use in New Zealand Households Report on the Year 8 Analysis for the Household Energy End-use Project (HEEP).* Study Report No SR 133 (2004)
[11] IEA Statistics (2005) *Renewables Information 2005 Edition*
[12] Ministry of Economic Development (January 2006) *New Zealand Energy Data File*

Concluding Remarks

Reviewing the overall direct heat use:

- total direct heat use is about 9,700TJ/year (a figure currently about equal to that of recorded geothermal electricity generation in New Zealand),
- this is from a supply of over 20,000TJ/year,
- about 94% of use occurs within the Rotorua-Taupo Geothermal Region,
- about 68% of all direct use occurs within the Environment Bay of Plenty region,
- the combined operations at Kawerau account for about 55% of all heat use, and
- about two-thirds of all New Zealand thermal springs or thermal areas have had no development at all.

There are significant uncertainties in these assessments which can be alleviated by public input and from further direct interviews of users. Reviews will be required of actual usage for category allocation purposes within Tokaanu, Taupo, Rotorua and Tauranga.

Photograph 3: Kawerau mill site, Bay of Plenty region. This is one of the largest geothermal direct heat uses in the world (5,316TJ/year), though use is now spread over three separate owners with supply from a fourth party.

Appendix 1: Geothermal Database Questionnaire Form

Owner
Phone No.

Date
Call No.

This is the first 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. Last year 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.[13]

Wairakei Resort
This is a large accommodation facility located on the State Highway at Wairakei that uses heat from the field for 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 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.

[13] 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.

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 currently operates two timber drying kilns and received 931,500 tonnes 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°C (say an average of 120 °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 = 857TJ/year. Heat used = 390TJ/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 supply (while ignoring the further complexity within the Norske Skog Tasman (NST) plant due to other competing fuels including wood waste, black liquor, and fossil fuels).

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. 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[14] of fluid annually at an enthalpy of about 1185kJ/kg (consistent with a resource temperature of 270°C)[15]. Hence, field supply is about 14,200TJ/year from NTGA.

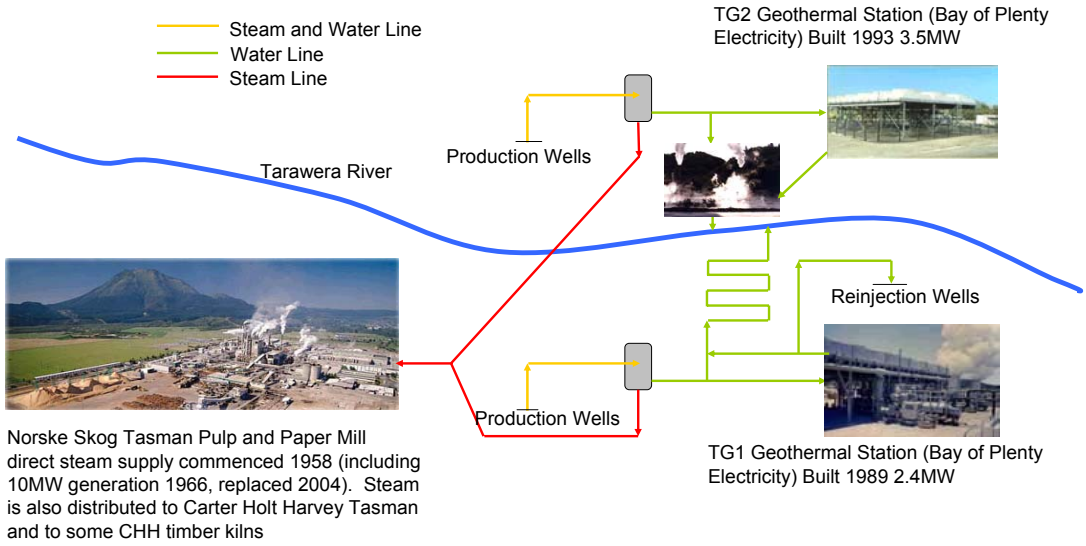

Figure A3.1: Simplified Kawerau Layout

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 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

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

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

3.8MW and rejecting fluid at 85°C[16]. 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 3,200TJ/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 NST will receive a steam flow of 2.67Mt/year or about 320t/h at 95% load factor. At an enthalpy of 2771kJ/kg this equates to a heat flow of 7,400TJ/year. In turn, NST onsells about 20t/h of mainly low pressure steam to CHH Woodproducts (for use in timber drying kilns), and 72.5t/h of atmospheric pressure steam[17] 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) 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. However, about 18% of the flow will be dedicated to power generation, with the non-condensed portion of this steam being vented to atmosphere. This is equivalent to 415TJ/year which needs to be deducted from both the supply and use assessment because it is not direct use. The remaining steam passing through this turbine is reused or onsold so has been left in the calculation of total direct use. As seen in Figure A3.2, about 72t/h of steam at 2676kJ/kg and 17.5t/h of condensate at 419kJ/kg is rejected from the system.

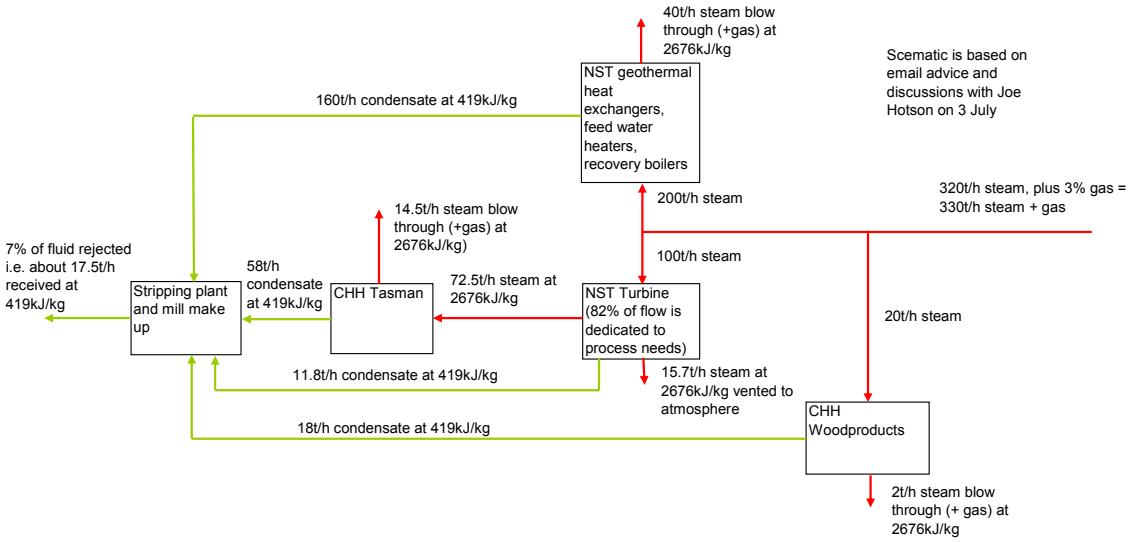

Figure A3.2: Additional Detail Focussed on Rejected Heat within the Mill Complex

In summary for the Mill complex, after deducting flows dedicated to power generation, total supply is 10,585TJ/year. Summing blow through and condensate rejected in the stripping process, about 1,670TJ/year is rejected. Based on a steam supply of 7,400TJ/year reduced by 415TJ/year for power generation, and reduced by 1,670TJ/year for rejected heat, actual direct use at Kawerau is 5,315TJ/year.

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.

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

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: 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
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

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: 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
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	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
Waitearikl (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
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

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
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
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
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 °C	Take (from Ohaaki waste): 931,500tonnes at 920kJ/kg = 857TJ Use: 390TJ (see Appendix 2)
Crater Lake (Ruapehu)	Waikato	None	~50 °C	None
Golden Springs	Waikato	Bathing in springs	50 °C	None
Horohoro (includes Haparangi) Geothermal Field	Waikato	Private well drilled tapping 87 °C water but no known use. Esendam family takes 72t/d of fluid at 95 °C for their glasshouses with shallow reinjection	95 °C	Take: 26,280 m^3 at 92 °C (385kJ/kg) = 10TJ Use: Assuming 50% load factor, with 8 °C temperature drop = 0.4TJ
Horomatangi	Waikato	None - discharges under Lake Taupo. System is protected from development.	>44 °C	None
Ketetahi Geothermal Area	Waikato	Scenic attraction surrounded by Tongariro National Park, warm springs for use by Tuwharetoa guests	91 °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 °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 °C	Use: ~140TJ based on area Take: ~280TJ

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
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
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 °C in reservoir, springs up to 100 °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 °C in reservoir, springs up to 97 °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 °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

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
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
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
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 °C in wells	Take: assessed at 10,585TJ Use: assessed at 5,315TJ (see Appendix 3)

Area or Spring	Region	Known Usage	Temperature	Heat Assessment
Lake Okataina Springs	Bay of Plenty	None - seeps in lake shore beach sands	30-36 °C	None
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	<130 °C in sediments	Take: about 850,000 m^3/year at 55 °C (230kJ/kg) = 193TJ Use: reject at 32 °C = 80TJ
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	Allocated take: 127,000t/year but other details are unknown
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 94,600t at 38°C (159kJ/kg) = 15TJ Use: reject at 35 °C (147kJ/kg)
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 3,540,000tonnes/year at about 540kJ/kg = 1,900TJ plus a further 20TJ from downhole heat exchange Reinject: 3,180,000t/ year at around 85 °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 °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 °C assume 130 °C for wells	Allocated take: 154,000t/year at 130 °C (546kJ/kg) = 84TJ Use: reject at 100 °C (419kJ/kg) = 20TJ
Waiaute Springs	Bay of Plenty	None	23 °C	None
Whale Island (Moutohora) Geothermal Area	Bay of Plenty	None	100 °C	None
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 °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/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 °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: 260,000m^3/year at 52 °C (218kJ/kg) = 56TJ Use: reject at 24 °C av (100kJ/kg) = 30TJ
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 per year 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 Rotorua, Environment Bay of Plenty had commissioned the development of a reservoir model by Industrial Research Limited[18]. The modelled conditions at discharge from the field, total mass flow, specific assumptions around heat from downhole heat exchangers, and assumed reinjection and surface disposal conditions[19] were all obtained and used in a field-wide black box calculation.

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[20]. 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.

[18] For more information on this model – Environment Bay of Plenty (June 2005) *Rotorua Geothermal Field Management Monitoring Update: 2005.* A report compiled and edited by D A Gordon, B J Scott and E K Mroczek, Environmental Publication 2005/12

[19] Disposal conditions were later modified to reflect conditions specifically advised by Environment Bay of Plenty (temperatures of 80 – 90^{o}C).

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