IS Kawerau – Direct Heat Background Study

1. Background

The original development of the Kawerau geothermal field was undertaken to supply steam to the Tasman Pulp and Paper mill built in the early 1950s. The field has been in production since 1957 and was the first major direct industrial use of geothermal energy in the world [1].

The expansion of direct heat use from the geothermal field was limited throughout the 1960s and 1970s, although in 1966 the mill installed a 10 MW embedded generator to produce electricity from a portion of its geothermal steam supply. From the mid 1970s through to mid 1980s the New Zealand Government had an active drilling program focused on maintaining supply to the mill, but also investigating the potential expansion of power generation and steam for direct use.

In 1989 a partially embedded 2.4 MW Ormat binary turbine (the first in NZ) was installed utilising lower grade separated brine from the industrial supply. An additional 3.5 MW Ormat plant was installed in 1993, utilising further separated brine. Owned and operated by Bay of Plenty Energy (BOPE) they, along with the mill's generator (since upgraded), demonstrate the cascading use of geothermal steam and brine for energy and direct use.

In July 2005 the New Zealand Government (the Crown) negotiated a Treaty of Waitangi settlement with Ngati Tuwharetoa Ki Kawerau, a prominent local Maori tribe. This settlement resulted in a contemporaneous transaction taking place between the Crown, Mighty River Power (MRP - a state owned energy company) and Ngati Tuwharetoa (BOP) Settlement Trust (NTST), whereby the Crown transferred its Kawerau geothermal assets to MRP (at market value) in order for MRP to develop the field. The sale covered physical assets (47 wells), commercial contracts, applicable land, resource consents, intellectual property related to the field, and all associated liabilities and obligations [2]. MRP then on-sold the majority of the geothermal assets, including the Crown's direct heat business and steam supply agreements to NTST. The assets are managed by Ngati Tuwharetoa Geothermal Assets Limited (NTGA), a wholly owned commercial entity of NTST [3].

Figure 1 offers a simplified illustration of the geothermal relationship between NTGA, the Norske Skog Tasman (NST) pulp and paper mill, and BOPE's geothermal plants.

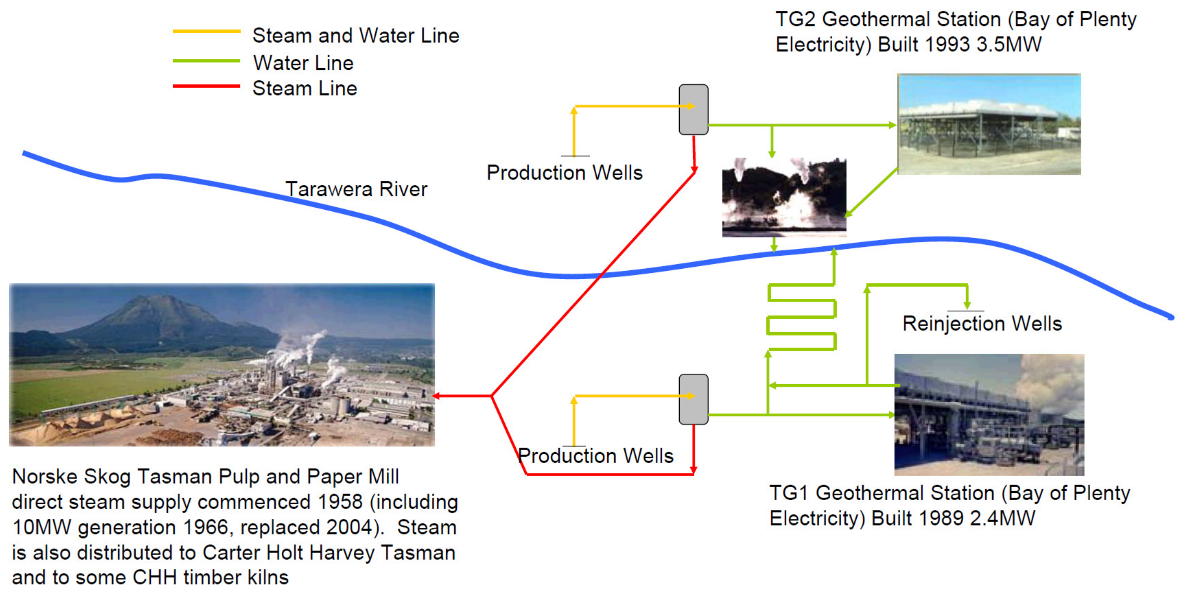

Figure 1: Simplified layout of the geothermal relationship between NTGA, NST and BOPE [4]

2. Providers of geothermal steam for direct use

NTGA is the field's pre-eminent supplier of geothermal steam for industrial use, sourcing geothermal brine from five wells [5]. Four provide steam for direct use, while the fifth provides steam for direct use and top up brine to MRP's 106 MW geothermal power plant commissioned in 2008. NTGA, under its current consent, has permission to extract 44,600 tonnes of geothermal brine per day [6].

In addition to NTGA, both MRP and Eastland Group hold separate consents to extract brine (45,000 and 5,500 tonnes per day respectively) [6]. These companies both generate electricity, MRP through the plant described above and Eastland through an embedded 8.3 MW Ormat binary plant, also commissioned in 2008. Together they hold a little over half the consented extraction from the field.

Although electricity generation is the primary use for the brine under these consents, it is still possible to extract heat for direct use from the spent brine prior to reinjection. Activities would need to be suited to the temperatures of the discarded brine and then utilised in an ever reducing heat profile before disposal. This could potentially make both MRP and Eastland suppliers of brine for direct use, but it could also create issues around the disposal of brine at lower temperatures.

3. Levels available for distribution

Since 1957 brine extraction for direct heat use has expanded inline with growing demand for process heat from the industrial site. The three initial power plants developed at Kawerau use low grade heat from the industrial supply, after it has been separated from high grade heat for industrial use.

Between 2004 and 2008 the Kawerau field produced approximately 12 million tonnes [4] of brine annually at an enthalpy of about 1185kJ/kg. These figures relate to the extraction of brine by NTGA, prior to construction of the two power plants commissioned in 2008, and are consistent with a resource temperature of 270℃. Multiplying the amount of brine extracted by the enthalpy we get a total energy supply from NTGA of about 14,200TJ per year [4].

As demonstrated in Figure 1, there are separation stations either side of the Tarawera River. After allocating a portion of the separated brine to the two binary power plants owned by BOPE, the effective supply from NTGA for direct use is 11,000 TJ per year [4]. The brine used in the binary plants, equivalent to 3,100 TJ per year [4], could potentially be further utilised directly but currently is not. Table 1 below illustrates the primary energy supply for geothermal direct heat use across New Zealand, as at 2009. Kawerau is represented under 'Industrial Process Heat' and 'Bay of Plenty'.

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 1: Assessed primary energy supply for geothermal direct heat use (TJ/year) [4]

4. Current levels utilised

Historically NTGA has supplied raw geothermal steam to NST and CHH Woodproducts, with NST contracting to NTGA for the majority of overall supply to the industrial site.

From the separation plants a steam flow averaging 305 tonnes per hour (2.67 million tonnes per year) is produced [7]. NST receives an average of 285 tonnes of steam per hour, which at an enthalpy of 2771kJ/kg equates to a heat flow of 6,900TJ per year [4]. NST on-sells about 26 tonnes [7] of high pressure steam to CHH Woodproducts for use in its high temperature timber drying kilns. Of the remaining 259 tonnes (235 tonnes low pressure, 24 tonnes high pressure) [7] approximately half is used directly in NST's industrial processes, while the other half is used to generate electricity through NST's 10 MW embedded generator [8]. This generator, which NST upgraded in 2004, also acts as a pressure reducing valve for the on-sale of spent steam to the CHH Tasman pulp mill [4].

Total supply to the industrial complex is 11,000TJ per year, which after process losses leaves about 6,650TJ available for use. This is reduced by 155TJ for power generation and a further 1,270TJ from rejected heat, giving actual direct use at the industrial complex of 5,225TJ per year [4]. This is displayed in Table 2, which assesses the geothermal capacity and utilisation relationship for direct heat use across New Zealand.

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**	

Table 2: Assessed geothermal direct heat use (TJ/year) [4]

Figure 2, sourced from East Harbour Energy's 2009 review of direct heat use in New Zealand, displays the distribution of steam through NST's operation and the interactions between the parties that utilise steam from this source. It includes a focus on waste streams and rejected heat. Although the allocation of resources doesn't necessarily reflect what is detailed in this document, it does demonstrate the flow of geothermal resources and lost energy.

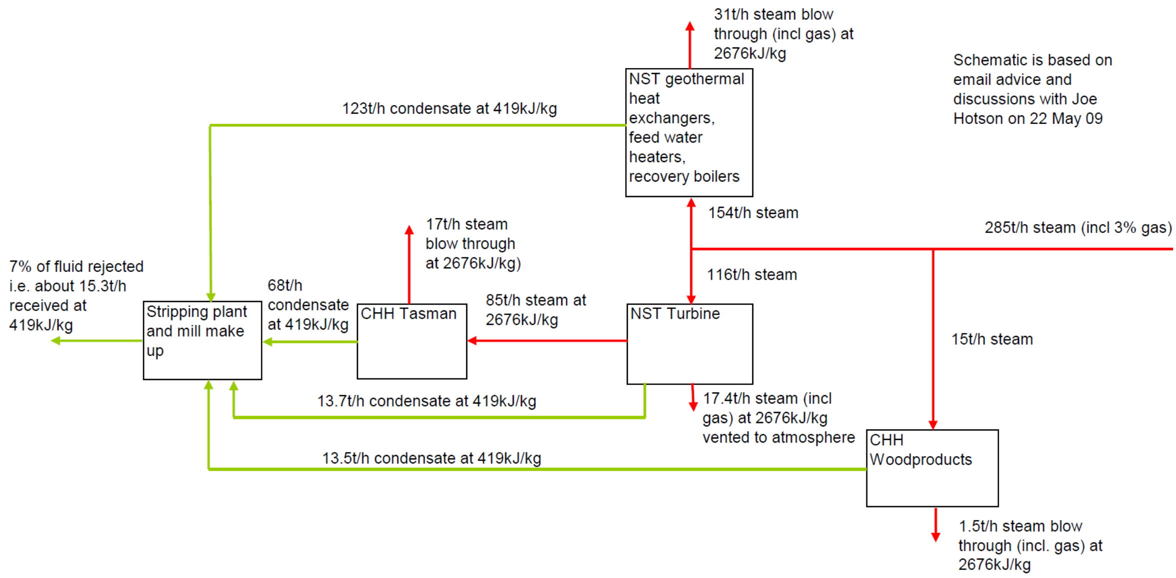

Figure 2: Additional detail focused on rejected heat within the Kawerau mill complex [4]

In addition to supplying steam to the industrial complex, in May 2009 NTGA agreed to supply the SCA Hygiene Australasia (SCA HA) tissue mill with steam for direct use. The installed plant features two 16 MW, 55 tonne steam generating heat exchangers [9] delivering up to 26 tonnes of clean steam per hour. Commissioned in September 2010, the new plant replaced SCA HA's two natural gas boilers [9] and is critical to SCA HA's operation [10]. SCA HA research shows this is the world's first tissue manufacturing plant to use geothermal energy for production and estimates geothermal steam adoption will reduce CO_2 emissions from SCA HA's Kawerau plant by up to 39% [11].

SCA HA's supply is separate to that of NST, with its peak demand of 26 tonnes of clean steam per hour requiring 34 tonnes of raw geothermal steam. However, typical demand is 18 tonnes of clean steam per hour, from 23 tonnes of raw steam [7].

Combined typical demand from all NTGA customers is 328 tonnes of raw steam per hour [7]. All steam provided by NTGA is done so through its current consent to extract up to 44,600 tonnes of brine per day [6].

5. Current uses of direct heat at Kawerau

NTGA's industrial direct heat supply is understood to be the largest geothermal supply for direct industrial use in the world. It directly supplies three core customers in NST, CHH Woodproducts and SCA HA, but a further customer indirectly through NST - the CHH Tasman pulp mill.

Geothermal steam at NST's mill is used in clean steam heat exchangers to provide process steam to the mill's operations [1]. Change within the mill over recent years has seen a greater uptake of geothermal for both electricity and direct heat supply. The NST mill now operates on 100% geothermal steam for direct heat, having replaced other fuel sources including wood waste, black liquor, and fossil fuels [4]. NST's impending 25 MW power plant will also see it sourcing over 90% of its electricity from geothermal, through a mix of internal generation and long term contracted supply [8].

As depicted in Figure 3, NTGA supplies both high and low pressure steam to NST, with NST on-selling high pressure steam to CHH Woodproducts. In addition, NST supplies the CHH Tasman pulp mill with spent steam for direct use from NST's 10 MW embedded generator. This produces electricity for the mill, but also balances load and smoothes out steam demand [12].

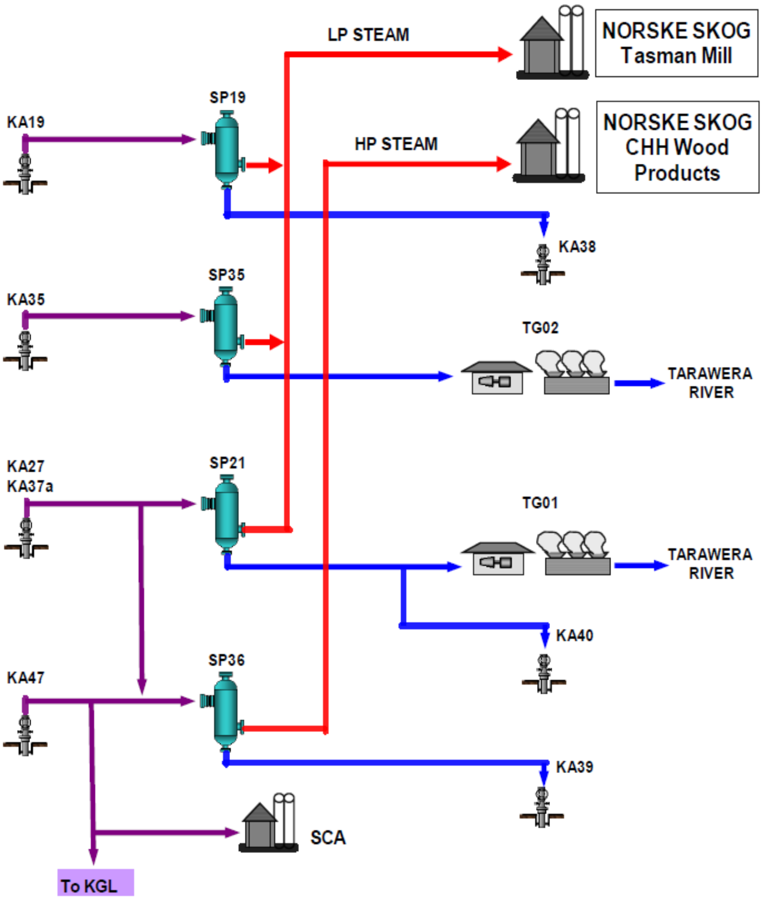

Figure 3: The NTGA direct heat system [7]

Although not consumers of direct heat for industrial use, the two Ormat binary power stations owned by BOPE were installed to utilise the separated brine from the industrial site. This brine was initially supplied from separator plant 21 on the east side of the Tarawera river and then separator plant 35 on the western side, once the second Ormat plant was installed in 1993 [13].

SCA HA's decision to replace steam from natural gas boilers with geothermal derived steam was made to minimise SCA HA's carbon footprint and reduce costs [14]. Brine is sourced from the same well that supplies top up brine to MRP's 106 MW power station, while the steam cleaning process takes place at the geothermal field before being distributed to SCA HA's plant.

6. Replacing other industrial heat sources with geothermal

There are various reasons why parties may seek to replace traditional fuels such as coal, oil, natural gas or wood residues with geothermal steam for industrial process heat. These include:

1. Long term and secure supply from a baseload energy source
2. High availability of the resource, offering consistency in delivery
3. Cost savings to the user in comparison with other fuel sources
4. Improved performance and increased reliability
5. Reduction in CO_2 emissions. Replacing coal or oil with geothermal could reduce emissions by up to 75%, while reductions from replacing natural gas could be up to 45%.

In the Central North Island, further adoption of geothermal in the wood processing industry would conserve biomass residues typically burned for process heat, allowing biomass resources to be put to higher value uses, such as bio-fuel or bio-chemical production.

SCA HA had the following to say about their move to geothermal for process heat: "There were a number of additional appliance safety checks and maintenance requirements in place when we were using our natural gas boilers but these are no longer necessary which has reduced our workload. The machine operators are also very impressed with the reliability of the geothermal supply. We're making use of a sustainable earth energy that is right under our feet while being able to significantly reduce our carbon footprint. This major outcome is totally aligned with the values of SCA and the Government's objectives with the introduction of the emissions trading scheme." [14]

It is possible for any person or entity to seek to utilise the geothermal resource for industrial use or electricity generation. This may be achieved in one of two ways:

1. Negotiate with a geothermal consent holder to secure supply under a commercial arrangement, in much the same way as achieved between NTGA and SCA HA in 2009.
2. File for a separate consent to extract brine from the geothermal field.

Under the second method the party would become the holder of the consent for the quantity sought. However, there is a process that must be followed. If the party seeking consent is not the landowner of the property from which they wish to secure the geothermal brine, they must conclude an access / lease agreement with the land owner.

With land access secured, the party can apply to the Bay of Plenty Regional Council (BOPRC) for consent to extract the brine. BOPRC will deal with a range of stakeholders and effected parties, including NTGA, NST and MRP (as parties to the Kawerau geothermal steamfield management agreement), in order to progress the consent. Consent from consulted parties cannot be unreasonably withheld, but the longevity and productivity of the field as a whole should be the main concern when judging the affect of additional consents on stakeholders and the field itself.

7. Plans for expansion of geothermal direct heat use

Regarding immediate development of the field, three entities are moving forward with plans to further utilise the resource, however only one of these parties potentially relates to the expansion of direct use. NTGA is seeking permission to extract an additional 45,000 tonnes of brine per day, having lodged resource consent with BOPRC. This application has been supported by the Kawerau District Council and other entities, and will provide NTGA with the capacity to expand supply to both current and new customers. The increased steam supply will most likely require upgrades and modifications to existing infrastructure, which as a result would be made more cost and environmentally efficient. This additional supply could be used for electricity generation and/or direct heat use.

NTGA has stated the reason for this new resource consent application is that customers want more geothermal for increased renewable energy and processing of logs domestically [7]. It has also been stated there are no particular projects to which this volume has been applied, but the consent will enable NTGA to meet increased demand from projects as they develop.

Also worth mentioning is the 25 MW Ormat binary power plant to be developed by NST in 2012. Although not direct use, NTGA will supply NST with brine out of its current consent, re-routing spent brine from other activities to the plant. This agreement benefits both NST and NTGA, in that NST gets the brine it requires while NTGA receives an additional use for its brine and simultaneously diverts spent brine from disposal into the Tarawera River – assisting with consent scenarios in this regard.

Currently a little over 700 tonnes of separated brine is discharged into the Tarawera River per hour [7]. A condition related to NTGA's consent requires that all separated brine from the industrial part of the Kawerau operation is to be re-injected prior to the expiry of the consent in December 2012 [1]. A new consent will need to be negotiated to supersede the expiring consent.

With such a mass of geothermal use in close proximity (electricity generation and direct use) there will be opportunities for expansion through utilising spent brine from existing users. Such opportunities will likely relate to the cascading use of heat in various applications. This may include lower temperature resources used for binary power production which can then be cascaded for direct use, making efficient use of the resource and improving economics across multiple operations.

Figure 4 below outlines the growth of geothermal direct use in New Zealand and demonstrates the significance of Kawerau in the national landscape. With a resurgence of interest in geothermal direct use both domestically and internationally, growth is expected to continue. This is likely to be buoyed by the fact that geothermal is a low carbon fuel source and that the wood processing industry will likely view biomass residues, once combusted for process heat, as simply too valuable to burn.

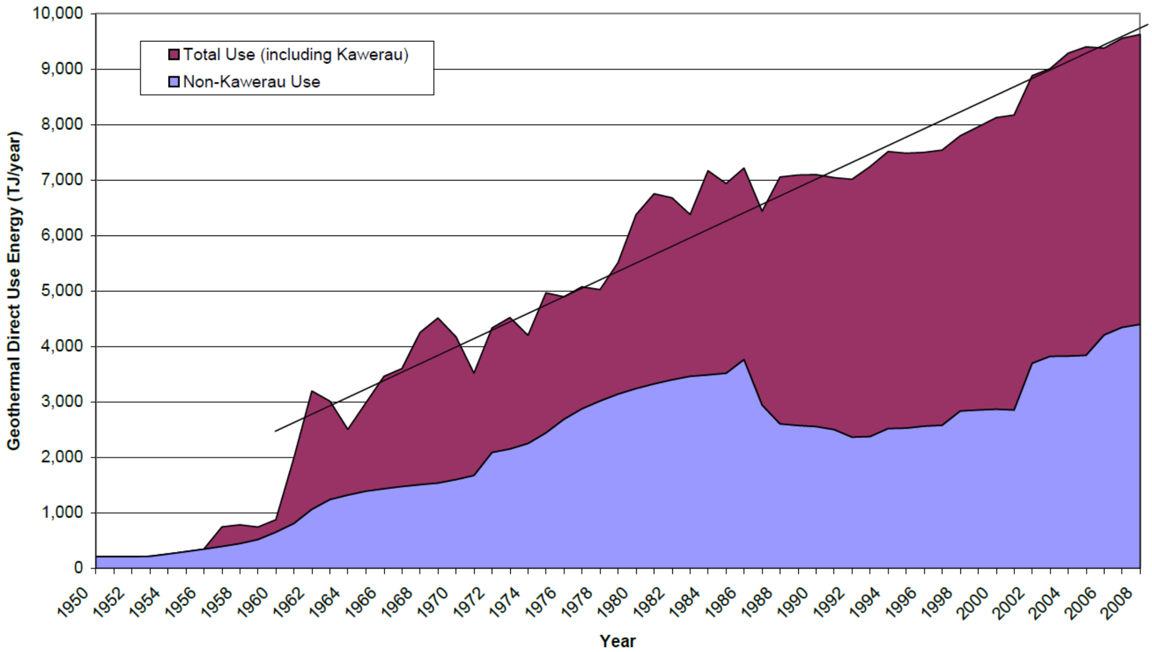

Figure 4: Historical growth of geothermal direct use (consumer energy) in New Zealand [4]

8. Activities suited to geothermal direct use

The direct use of geothermal applies to either heating or cooling. Typical direct uses for commercial purposes include:

- Agricultural applications, such as greenhouse heating
- Aquaculture applications, such as prawn farms or fish ponds
- Industrial processes, such as paper, food or grain drying

The suitability and economics of any potential activity is relatively dependent on site location and the cost of raw materials with regard to the site. Due to this, various activities will be site or location-centric and the geographic location of any one site may in itself be the driving force behind the viability of any one activity.

The diagram in Figure 5 displays a range of geothermal energy uses, including activities suited to direct use, at various temperatures.

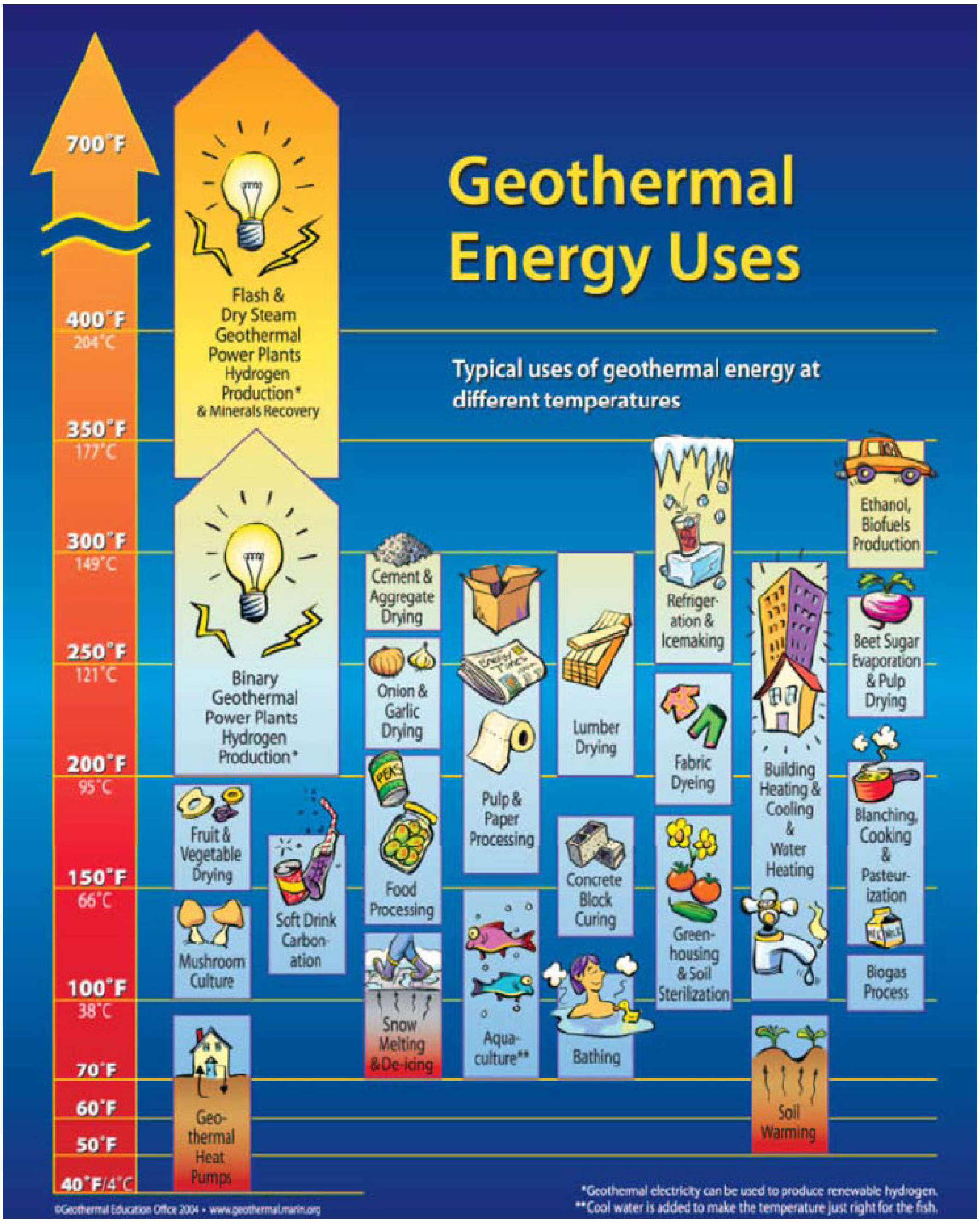

Figure 5: Geothermal energy uses [15]

9. Geothermal and carbon emissions

Placing value on carbon emissions acts as an incentive to adopt low emissions technologies such as geothermal. Although low emission, geothermal is not emission free as it releases small elements of gas when discharged. This gas is mostly CO_2 but includes small amounts of hydrogen sulphide and methane. It is discharged naturally through the surface of the field but can also be carried in the brine extracted by commercial operations [16].

The emissions profile of geothermal alters when used in different circumstances. CO_2 emissions from electricity and direct heat facilities vary from plant to plant depending on the characteristics of the

geothermal field and the end use of the steam. Atmospheric emissions from geothermal plants average about 10% of those from equivalent sized fossil fuel plants [16].

The Kawerau field produces approximately 59,000 tonnes of CO_2 per year, emitted at a rate of about 226 grams per kWh. This is higher than the average 100 g/kWh for geothermal plants across New Zealand, but is approximately ¼ of the emissions from oil or coal fired plants, and ½ the emissions from gas-fired combined cycle plants [16].

10. Geothermal and the New Zealand Emissions Trading Scheme

The New Zealand Emissions Trading Scheme (ETS) applies to geothermal brine used for generating electricity or industrial heat, where the emissions of CO_2-equivalent (CO_2-e) exceed 4,000 tonnes per year from a single installation [16].

All facilities have a prescribed emissions factor which when multiplied by the annual fluid production calculates their reportable annual emissions [16]. It is possible for individual producers to gauge their production process and apply for a unique emissions factor specific to their facility.

The ETS effectively taxes industries for their carbon emissions. This assists industrial companies that adopt low emissions technologies and sources, such as geothermal, as it increases their economic performance when compared to higher emitting fuels used for process heat or electricity generation - such as coal, oil or gas [16].

References

[1] Review of Carbon Emission Factors in Draft Stationary Engine and Industrial Process Regulations: Using Geothermal Fluid. Ian Thain, Geothermal & Energy Technical Services Ltd, May 2009.

[2] New Zealand Government media statement, 'Crown agrees to Kawerau Geothermal Assets Deal', 13 July 2005.

[3] Mighty River Power's resource and development strategy at Kawerau geothermal field, New Zealand. Spinks et al, 2010.

[4] An Updated Assessment of Geothermal Direct Heat Use in New Zealand, East Harbour Management Services Ltd, 30 June 2009.

[5] New Zealand Geothermal Association – www.nzgeothermal.org.nz/nz_geo_fields.html#Kawerau – depicted in diagram illustrating geothermal activities at the field.

[6] Industrial Research Limited, Consent Scenarios for the Kawerau Geothermal Field, July 2005.

[7] Ngati Tuwharetoa Geothermal Assets Limited, 2011 Update. NZ Geothermal Workshop, 23rd November 2011.

[8] Industrial Direct Use: Examples from Kawerau. Geothermal energy and paper making presentation - Mike Gommans, Norske Skog, October 2011.

[9] Dobbie Engineers, annual newsletter 2009.

[10] Dobbie Engineers, annual newsletter 2010.

[11] SCA Hygiene Australasia website. www.tork.co.nz

[12] Long term use of geothermal resources at the Tasman Pulp and Paper Co Ltd's Mill, Kawerau, NZ. GW Hotson, 1994.

[13] Small power plants: Recent developments in geothermal in New Zealand. Michael Dunstall, 1999.

[14] Geothermal solution for SCA's Kawerau Paper Plant, GNS case study. Lisa Lind, Libby O'Brien and Jo Bell.

[15] Direct heat utilization of geothermal energy, John W Lund. Oregon Institute of Technology, Oregon, USA.

[16] New Zealand Geothermal Association – www.nzgeothermal.org.nz

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