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2015 New Zealand Country Update

Brian Carey[1], Mike Dunstall[2], Spence McClintock[3], Brian White[4], Greg Bignall[1], Katherine Luketina[5], Bridget Robson[6], Sadiq Zarrouk[7], Anya Seward[1].

1 GNS Science, Private Bag 2000, Taupo, 3350, New Zealand

2 Contact Energy Limited, Private Bag 2001, Taupo, 3350, New Zealand

3 Mighty River Power, PO Box 245, Rotorua 3040, New Zealand

4 East Harbour Energy Limited, PO Box 11-595, Manners Street, Wellington 6142, New Zealand

5 Waikato Regional Council, Private Bag 3038, Waikato Mail Centre, Hamilton 3240, New Zealand

6 Bay of Plenty Regional Council, P O Box 364, Whakatane 3158, New Zealand

7 University of Auckland, Private Bag 92019, Symonds Street, Auckland 1142, New Zealand

b.carey@gns.cri.nz, Mike.Dunstall@contactenergy.co.nz, spence.mcclintock@mightyriver.co.nz, brian.white@eastharbour.co.nz, g.bignall@gns.cri.nz, Katherine.Luketina@waikatoregion.govt.nz, bridget.robson@boprc.govt.nz, s.zarrouk@auckland.ac.nz, a.seward@gns.cri.nz

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ABSTRACT

New Zealand has seen a period of rapid growth in the utilization of geothermal energy over the last 10 years, particularly for electricity generation. The availability of high temperature, productive geothermal resources has seen geothermal development being the lowest cost electricity generation facilities to construct and operate (on an energy unit cost basis) compared to other renewable energy or fossil-fuelled options. The increment in geothermal electricity generation from 2010 to 2014 of about 1500 GWh is significant, being greater than a 20% per annum increase in the level of geothermal generation over this four year period. There is a total of over 1000 MWe of installed geothermal electricity generation capacity which is typically contributing about 16% of national electricity generation (c.f. 13% in 2010) in an electricity system dominated by renewable generation. New Zealand currently produces about 75% of its electricity from renewable energy sources and is strategically targeting 90% renewable electricity by 2025.

Post 2013 there has been a hiatus in construction of geothermal power generation capacity in New Zealand due to flat electricity demand growth. The New Zealand geothermal operators are focusing on sustaining and maintaining existing developments, looking to share experience partnering in international developments and investigating some new prospects.

Several New Zealand companies have invested significantly in large scale industrial direct geothermal energy applications in the last five years including; Ngati Tuwharetoa Geothermal Assets Limited supplying the Svenska Cellulosa Aktiebolaget tissue mill at Kawerau, and Tuaropaki supplying clean steam generated from geothermal energy to the Miraka milk powder processing plant at Mokai. Despite these new developments, there has been a reduction in geothermal direct use overall since 2010, primarily a consequence of Norske Skog Tasman closing one of the paper production lines at its Kawerau facility in January 2013. There is more that needs to be done in New Zealand to further foster direct geothermal heat use, and the uptake of geothermal heat pumps, and these are discussed in the paper.

With the significant development that has gone on in New Zealand over the last decade the science and engineering around geothermal resource development is at the leading edge of geothermal technology and its implementation. This paper identifies Geothermal New Zealand as a connector to this pool of quality expertise.

This paper discusses the developments in the New Zealand geothermal sector since the New Zealand update paper was presented at the 2010 World Geothermal Congress in Bali, Indonesia (Harvey et al 2010). The text discusses direct heat utilisation, electricity generation, environmental and regulatory aspects, personnel, training and investment. The paper includes the tables requested by the International Geothermal Association for inclusion in the country update papers.

1. INTRODUCTION

This paper has contributions from across the New Zealand Geothermal sector with the authors contributions providing valuable content to the paper and insight into the New Zealand geothermal sector since 2010.

The data tables requested by the International Geothermal Association numerically quantifying various aspects of geothermal energy and other energy use in New Zealand in the period 2010 to 2014 are included in the appendices to the paper.

The tables in the appendices are numbered while the tables in the body of the paper use alphabetical identifiers.

Growth in the geothermal electricity sector in the last decade has seen the most significant increase in geothermal electricity energy production that has been experienced in the history of New Zealand. Geothermal electricity in 2014 contributed approximately 7000 GWh of a total of 43,000 GWh of electricity produced, roughly 16%.

Figure : 1 plots annual geothermal electricity production with time. The data in Figure 1 is recorded data with the exception of the 2014 year data point which is a prediction. The increase in annual geothermal energy generation since the last World Geothermal Congress in 2010 (Harvey et al 2010) is quite evident in Figure 1 showing an increase of over 20%.

Since 2010 there has been over 270 MWe of geothermal electricity generation capacity constructed in New Zealand. This has included the construction of the 23 MWe TOPP 1 plant, at the Kawerau Geothermal Field, that has been operational since early 2013, the 82 MWe (net) Ngatamariki geothermal power plant that was fully operational in June 2013 and was officially opened on 3 October 2013, and the 166 MWe Te Mihi facility, at Wairakei, that was officially opened on 14 August 2014. All these plants are contributing to the 1500 GWh per annum increase in geothermal electricity production since 2010 shown in Figure 1.

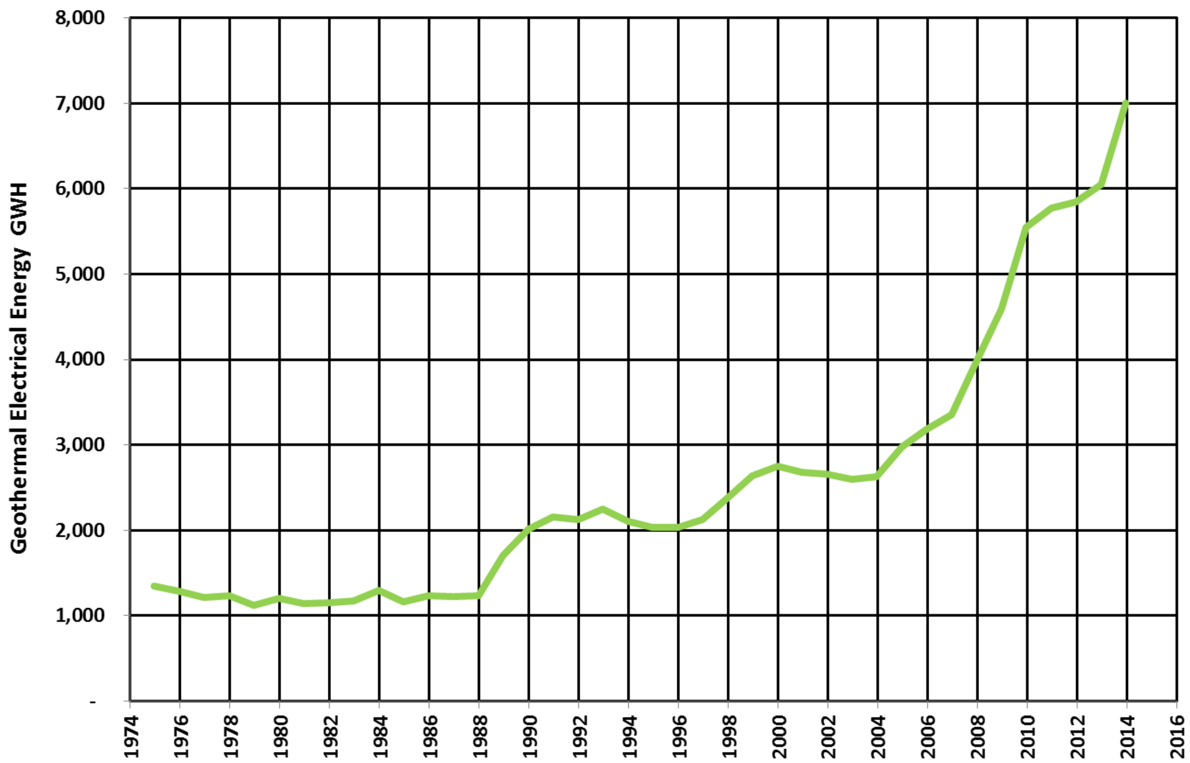

Figure : 1 : Annual Geothermal Electricity Production in GWh 1975 to 2013. The 2014 data point is a prediction.

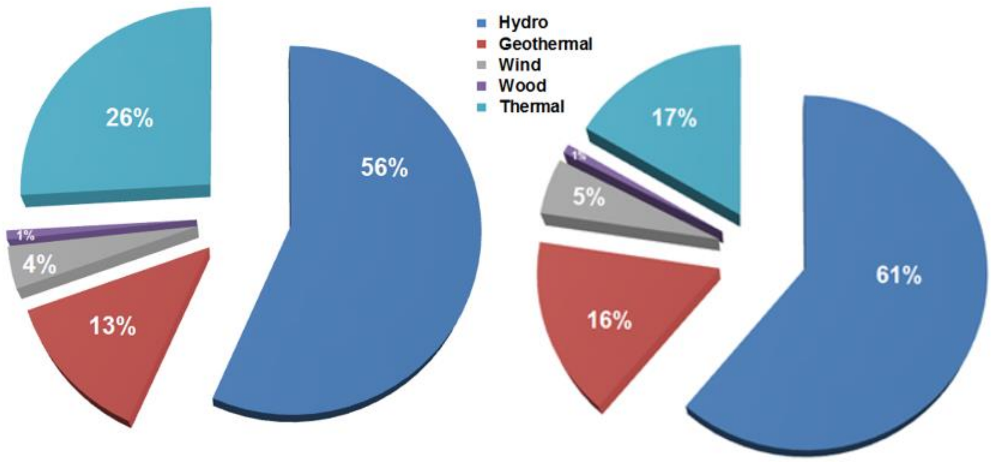

Figure 2 : Percentage Fuel Type Contributions to New Zealand's Annual Electricity Production - 2010 (left) and 2014 (right).

Figure 2 shows, in pie-chart format, the percentage of fuel type contributions to New Zealand's annual electricity production for the 2010 and 2014 calendar years. Depending on the prevailing hydrological conditions in any given year the renewable energy contribution to electricity generation varies from 70% to 85%. The 2025 New Zealand government strategic target is for 90% renewable electricity (MED 2011). Figure 3 plots the percentage contribution that geothermal electricity has made to total electricity production in New Zealand since 1958 which was the year that geothermal electricity generation commenced at Wairakei.

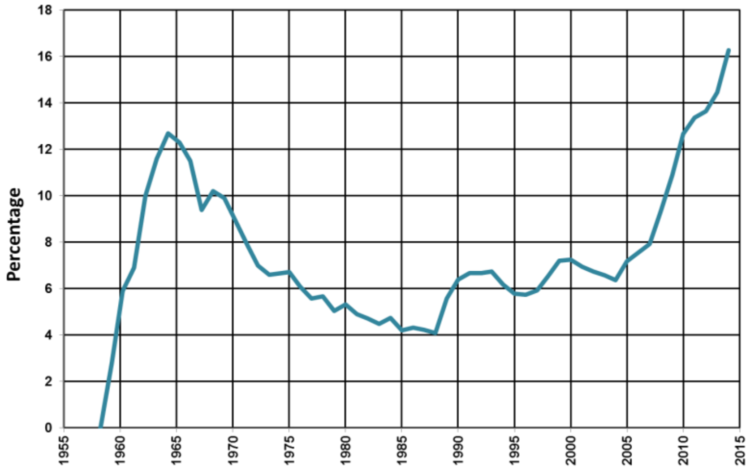

Figure 3 : Percentage geothermal electricity of New Zealand's total annual electricity generation since 1958

Figure 4 plots the seven day rolling electricity demand for 2011 (orange line), 2012 (green line), through to 2013 (blue line). The static or reducing growth in demand is evident as the 2011 seven day demand is generally greater than 2012 or 2013. There is some indication of this changing in 2014 (not shown) where up to end of October 2014 demand has been about 4% greater overall than the 2013 demand over the August - October period (Transpower 2014a). In terms of annual electricity produced this has been relatively static over the last four year period, declining from 43,470 GWh in 2010 to 41,900 in 2013, and increasing to an estimated 43,000 in 2014 (Table A).

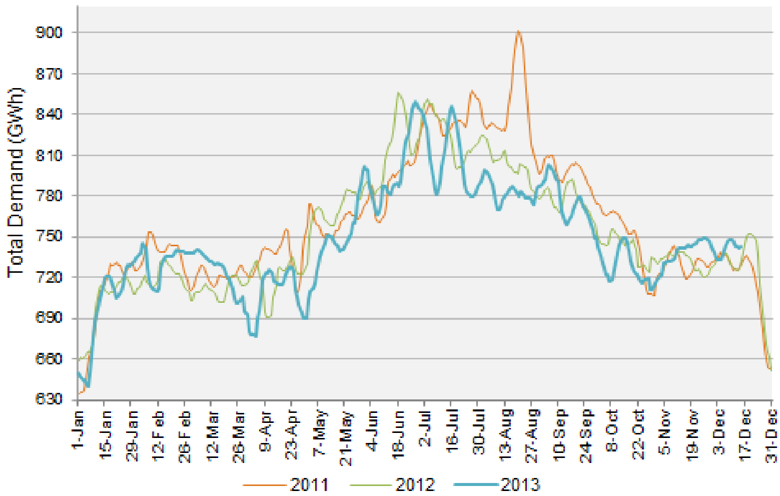

Figure 4 : Seven day rolling electricity demand for 2011, 2012 and 2013 for New Zealand (Transpower 2013)

Table A : Total New Zealand Annual Electricity Production for the years 2010 to 2014.

Year	Electricity Production (GWh)
2010	43400
2011	43100
2012	42800
2013	41900
2014	43000[1]

[1] - Estimated

Domestic geothermal electricity capacity construction is for the moment paused, awaiting further demand growth. There are permits in place for development but development activity is occurring only at a low level.

Mighty River Power, Contact Energy Limited (Contact Energy) and Maori Trusts have been the key entities in the geothermal development space over the last 10 years, supplemented with investment by Norske Skog Tasman and line companies. Both Contact Energy and Mighty River Power have had billion dollar geothermal investment programmes in the last decade and geothermal expenditure in total has topped NZ $2.4 billion.

The most significant change in ownership since the last World Geothermal Congress (2010) has been for Mighty River Power who in 2010 was a State Owned Enterprise with a Board of Directors reporting to two Crown ministers. The company was floated in May 2013 by way of a partial market sale float with the Crown retaining 51% of the company whilst 49% is now held by other shareholders. Mighty River Power was asked to provide for this paper its view of the New Zealand Market, and its position and approach to geothermal development:

> "Mighty River Power has been one of the largest geothermal developers globally in recent years, investing more than NZ$1.4 billion and successfully completing three geothermal power plants domestically since 2008, in addition to interests outside of New Zealand.
>
> A major strategic milestone for Mighty River Power was the addition of the Ngatamariki Geothermal Power Station, completed in September 2013. The development was more than 10 years in the making since the development rights for the reservoir were jointly secured with Maori landowners Tauhara North No.2 Trust in 2000.
>
> Ngatamariki represents the final chapter in Mighty River Power's current programme of geothermal development, which began with Kawerau in 2008, progressed to Nga Awa Purua in 2010 – a programme of development which has made the Company one of the world's leading developers of geothermal power generation in the last 10 years, and one of the world's largest geothermal power station owners (by installed capacity).
>
> The Ngatamariki project and the other investments in renewable generation have influenced a positive change in New Zealand's energy mix – with Mighty River Power's annual geothermal generation saving the country more than three million tonnes of carbon emissions every year by displacing coal-fired generation.
>
> Geothermal has been key to the evolution of Mighty River Power from its beginning as a hydro generator - diversifying and strengthening the Company's production base with 2,800 GWh now coming from geothermal, making up more than 40% of Mighty River Power annual production.
>
> A key foundation of Mighty River Power's successful track record of geothermal development has been the long-term partnerships with Maori Trust land owners, and the establishment of business models that enables their equity involvement and ensures direct and aligned economic participation. This allows the Company's partners to generate long-term value related to their land and its resources – and to invest the returns for the benefit and well-being of their people.
>
> Offshore, Mighty River Power is now applying its geothermal expertise in Chile and in the United States through Energy Source."

Mighty River Power's position in moving into the international space is because of the static domestic electricity demand, which is reflected in a number of other New Zealand geothermal businesses.

With the significant development that has gone on in New Zealand over the last decade the science and engineering around geothermal resource development is at the leading edge of geothermal technology and implementation. Geothermal New Zealand (www.geothermalnewzealand.com) was established as a focus and connector for making these advances available in the international market. Geothermal New Zealand can connect you to experts able to apply international best practice in exploration, resource confirmation, feasibility, design, procurement, construction, commissioning and operation of geothermal energy facilities.

The track record for New Zealand expertise is recognised globally and the quality and success of the recently commissioned plants in New Zealand have set new standards. The global geothermal market and the entry of a range of new players into this market demand these standards be replicated wherever possible. Geothermal New Zealand, led by Dr Mike Allen (mike.allen@xtra.co.nz) is providing innovative solutions in this new era of geothermal development (NZTE 2011).

2 CHANGES IN DIRECT HEAT USE

This section of the paper discusses both direct heat use and geothermal heat pumps. GNS Science has developed a web based application that seeks to capture and identify where geothermal energy is being used in New Zealand. The data includes direct heat and geothermal heat pump information which can be accessed via the web http://data.gns.cri.nz/geothermal/index.html.

Geothermal Heat Pumps

Interest and use of geothermal heat pumps (both ground- and water-sourced) is accelerating in New Zealand. The Geothermal Heat-pump Association of New Zealand (GHANZ www.ghanz.org.nz) was formed in 2012. It was formed under the auspice of and as an interest group of the New Zealand Geothermal Association (NZGA). Membership currently stands at about 30 members which represents about 10% of the total NZGA membership. GHANZ is associated with the Climate Control Companies Association and the Institute of Refrigeration, Heating and Air Conditioning Engineers. The geothermal heat pump industry is in its infancy but is finding niche markets in areas of high end housing or facilities where there is greater demand for heating and cooling such as airports, libraries, swimming pools, residential care facilities and hospitals.

One of the significant areas where geothermal heat pump development is occurring is in Christchurch which suffered major damage in the September 2010 and February 2011 earthquakes. These quakes destroyed much of the central business district and rebuilding is underway. This rebuilding of the central business district has enabled distributed energy nodes (district energy hubs) to be established. Some of these will use open source geothermal groundwater based energy technologies to supply about 90% of the energy load to a node with the peak 10% topped up from other sources.

Other Geothermal Direct Use

Direct geothermal energy use in New Zealand is dominated by the Norske Skog Tasman (NST) pulp and paper mill at Kawerau. Prior to 2013 this one site accounted for half of the total New Zealand direct geothermal heat use. This site used half of the world's total direct geothermal industrial energy use. With the reducing global consumption of newsprint, one of the two paper production lines was closed at the beginning of 2013. In an effort to diversify, NST constructed a power station (TOPP1) to use some of the steam previously used directly by the mill. NST are also researching liquid fuel production from timber with geothermal energy as an input into that process. With the paper machine closure there has been a not insignificant reduction in the NST (and therefore the New Zealand) geothermal direct heat energy use.

Several new industrial developments are using geothermal energy directly. In 2010 a tissue mill owned by Svenska Cellulosa Aktiebolaget at Kawerau converted from natural gas steam production, to clean steam production using geothermal steam and energy to run its reboiler steam generation equipment. The Miraka milk drying factory, located on land above the Mokai geothermal field, commenced operating in August 2011. The plant also uses reboiler technology to produce clean process steam from geothermal steam (www.miraka.co.nz/about-miraka.html).

The data in Figure 5 is the annual assessed direct geothermal heat use plotted since 1950.

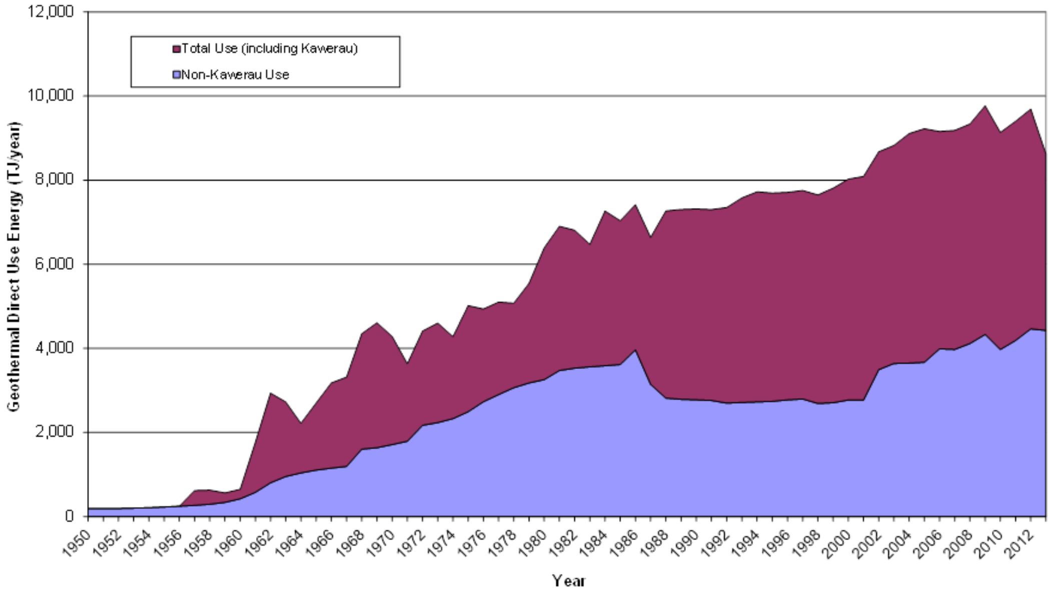

Figure 5 : Growth in geothermal direct heat energy use. Total is the purple plus the blue data. The blue data excludes the contribution from Kawerau.

The direct geothermal use and geothermal electricity generation data are plotted in Figure 6, the different trends over the last decade are quite evident.

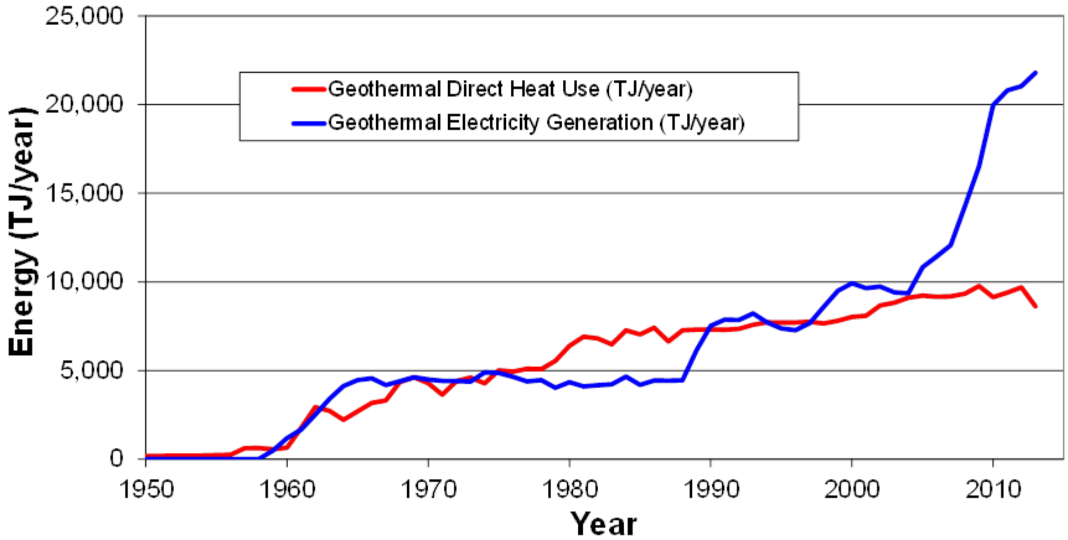

Figure 6 : Comparative data showing growth in geothermal direct use (red) relative to geothermal electricity use (blue).

There are regional and district development agencies in New Zealand that are building parts of their development strategies on direct geothermal energy use. How to leverage direct geothermal use in an area that is endowed with geothermal resources is a key to these strategies. Studies have shown that in New Zealand larger scale direct heat use can be commercially attractive when of an adequate size (10-20MWth). Moving the geothermal direct heat sector forward in New Zealand requires, amongst other aspects, aspirational leadership. Climo et al (2015) provides interesting insight into future development of geothermal direct heat utilisation in New Zealand.

3 NEW ZEALAND GEOTHERMAL DEVELOPMENT - FIELD BY FIELD

3.1 Wairakei Developments

The geothermal resource at Wairakei is now used in four separate plants; the original Wairakei power station (commissioned 1958-1962), the Wairakei binary plant added in 2005, the Poihipi power station built in 1996 and purchased by Contact Energy in 2000, and the recently commissioned Te Mihi plant (2014). Total effective installed capacity of the combined Wairakei stations as of the end of 2014 is 333 MWe, with all the plants owned by Contact Energy and operated off an integrated steam supply and reinjection system.

Wairakei Power Station, now in operation for over 55 years, continues to develop and adapt to modern requirements. Two recent changes are that steam flows through the original station have been reduced to the equivalent of about 112 MWe (from 157 MWe) in favour of the new more efficient 166 MWe Te Mihi plant. A novel and unique bioreactor (Figure 7) has been added to the Wairakei cooling water discharge channel. The process was designed from research and concepts developed in New Zealand. The facility reduces the hydrogen sulphide load in the discharge to the Waikato River by about 95%. The bioreactor consists of a network of parallel HDPE pipes, buried underground, through which the mixed condensate and cooling water from the power station flows before re-entering the river. The tubes provide a surface and habitat for naturally occurring bacteria to grow on. The bacteria consume the hydrogen sulphide present in the condensate, converting it to sulphate in a four minute transit time through the bioreactor. These changes, along with much greater use of reinjection, which are being phased in over a ten year period allow Wairakei to meet environmental standards set in the resource consent renewal process of 2007. The station is expected to operate until at least 2026, when the current consents expire. The binary plant at Wairakei continues in operation, utilising geothermal water sourced predominantly from within the western bore field.

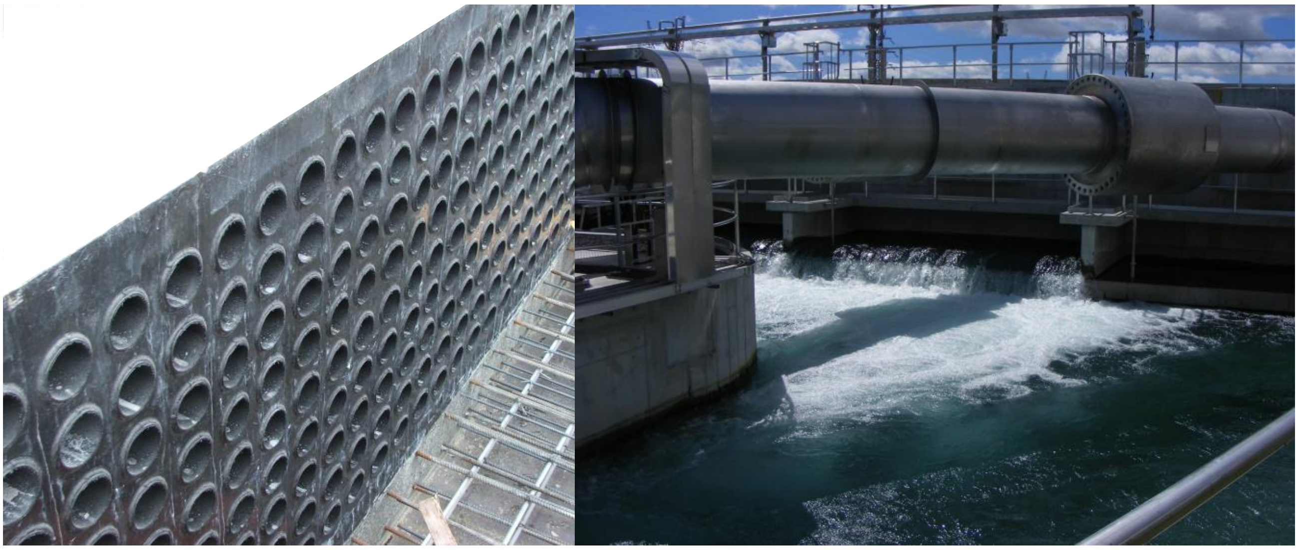

Figure 7 : Wairakei cooling water bioreactor tube bank (left) and treated water discharge from the reactor (right)

The Poihipi Power Station, originally established in 1996 as an independent venture located on the western edge of the Wairakei field, has been fully loaded after Contact Energy took ownership in 2000 and subsequently it has been integrated with the rest of the Wairakei steam supply system. With the development of the Te Mihi plant the steam field system has been further developed to ensure flexible and reliable supply of steam to the Poihipi station. The original developer of the Poihipi station secured consents for another plant near the western edge of the field and drilled a deep well as part of this development. However, a power plant was not built, the main take and reinjection consents have lapsed, and the project has been sold. The new owners have expressed an intention to re-establish the project but by late 2014 have not drilled wells or sought new consents for fluid take.

The completion of the Te Mihi plant is the most recent development at Wairakei consisting of two 83 MWe Toshiba mixed pressure units, it began generating in 2013. Te Mihi was constructed in the period from 2011-2013 and is located near the centre of the current Wairakei production field, at high elevation which assists reinjection, gas dispersion and improves cooling tower performance. Originally conceived as a three unit replacement for Wairakei, the Te Mihi plant has been built as a two unit plant with space for a third unit at a later time. Steam that was originally conceived for use in the third Te Mihi unit is supplied to Wairakei, which remains in service albeit operating at a lower than previous load. This development strategy has met the required environmental performance improvements at lower cost than full replacement and offers a future potential path for renewal as the original Wairakei assets will have seen over 65 years operational service by 2026.

Integration of the steam gathering and reinjection system to supply all of the interconnected plants in a flexible way, along with incorporation of the bioreactor to reduce environmental impact on the Waikato River, have been key to the recent phase of Wairakei development. Two additional reinjection areas at Karapiti and Poihipi West have been developed as reinjection on the Wairakei field has been greatly increased under the new arrangements. In total Contact Energy has drilled over fifty wells at

Wairakei since 2006 including three production wells in the western bore field, which is the first new well drilling in that area for over forty years.

3.2 Tauhara Developments

Contact Energy has two existing developments on the Tauhara field and in 2010 was granted consent for further development up to approximately 250 MW for a large geothermal power station. The first of the existing operations to be established was a 20 MWth direct use geothermal heat supply to the Tenon kiln timber drying facility which was developed by Contact Energy in 2005/6.

At about the same time as the Tenon direct use operation was established a period of further exploration drilling on Tauhara commenced and continued through to 2009, although wells had been drilled in other parts of the field many years earlier. These new wells confirmed the field was hotter and larger than previously thought and Contact Energy obtained resource consents sufficient for a 250 MWe power development through a Board of Inquiry process in 2010. During this period several new wells were also drilled close to the Tenon mill for the Te Huka power plant, which is a two unit Ormat binary plant of 23 MWe capacity. The Te Huka plant was commissioned in 2010 and was later uprated to 26 MWe capacity in 2011when increased fluid volumes became available under the Tauhara geothermal fluid take consents that were issued at that time.

The Tauhara field partly underlies Taupo township and there have been expressed concerns about geothermal-induced subsidence and hydrothermal eruption effects possibly linked to Wairakei operations. As part of Contact Energy's application for consent to develop Tauhara it undertook an extensive scientific investigation and drilling programme to understand these effects. The programmes included an extensive core drilling program over the Wairakei-Tauhara area to gain new information on subsidence mechanisms. Over 4000m of core was cut from relatively shallow wells and laboratory material strength testing was performed. Tauhara is hydrologically connected to Wairakei and greater use of reinjection at Wairakei has assisted in supporting pressures in Tauhara, relieving some of the concern about development. Successful development of the smaller Te Huka power plant, with no undesired or unexpected effects to date may also assist in allaying any residual concerns.

3.3 Ohaaki Development

Ohaaki was originally developed to 116 MWe in 1989 and after an initial period at full output through to 1993 became restricted in output through resource issues. Beginning in 2006, Contact Energy has invested in a number of new wells and the running regime of the station has stabilised around a single unit fully loaded configuration. Resource consents for Ohaaki were renewed in 2013 for a further 35 years, which is the maximum time allowable under New Zealand law. In the long term it is expected that Ohaaki will continue to operate with a single unit at intermediate pressure. The high pressure turbines, originally refurbished and relocated from Wairakei, had been expected to be retired within the first decade of station operation at Ohaaki but well drilling has maintained a steady supply of high pressure steam and one high pressure turbine is expected to operate for some time. As part of the renewal of the resource consents Contact Energy has committed to extensive flood protection works for flood-sensitive properties near the Waikato River.

3.4 Mokai

Tuaropaki are guided by their stated intent - "We will act as a beacon of hope and prosperity for our people" and have established an integrated business with farming, telecommunications, power generation, horticulture, and milk processing at Mokai.

At Mokai geothermal drilling was undertaken by the Ministry of Works and Development over the period 1982 to 1984 with six geothermal wells drilled. The Tuaropaki Power Company (TPC) was formed in 1984 progressively developing over 110 MWe of installed electricity generation capacity (55 MWe in 2000, 39 MWe in 2005, 17 MWe in 2007). Geothermal heat is supplied to a large glasshouse facility established in 2002 that initially covered 5.5 hectares. In 2007 this was extended by the addition of a further 6.2 hectares. In 2010 a geothermal to clean steam generation process was established to provide process steam to the Miraka Milk processing facility that was established by Tuaropaki and JV partners near to the Mokai geothermal power development.

Mighty River Power have a 25% holding in the power development and provide operations and maintenance services under contract to TPC.

3.5 Kawerau Developments

Direct geothermal energy use commenced at Kawerau in 1957 with a geothermal steam supply to the Tasman Pulp and Paper mill. A small embedded geothermal generator was installed in 1966 which was replaced by Norske Skog Tasman (NST) in 2005. The initial direct use development has been followed by progressively increasing use of the geothermal resource. A small amount of grid connected generation was installed around 1990, with the 2.4 MWe TG1 plant installed in 1989 and the TG2 3.5 MWe plant installed in 1993, using energy otherwise discharged with the brine. TG1 has recently been retired from service.

Putauaki Trust, with land to the east of the mill, reached agreement with Mighty River Power for some exploration of the eastern part of the Kawerau field for larger scale electricity development. Four exploration wells were drilled in 2004. Following negotiations with Putauaki Trust, mill interests, government and Ngati Tuwharetoa Geothermal Assets Limited (NTGA), Mighty River Power obtained consents for the development of a 100 MWe double flash geothermal power plant. A contract was let to Sumitomo Corporation to construct the plant and commissioning was completed with the plant handed over to Mighty River Power by the end of August 2008.

In 2005 the Crown's Kawerau wells and steamfield assets were transferred to NTGA as part of a negotiated Treaty of Waitangi settlement. NTGA is progressive, seeking opportunities that wisely use the Kawerau resource whilst seeking to facilitate additional geothermal energy utilization.

A further development has seen an 8.3 MWe binary power plant established using well KA24. The power plant development was undertaken by Geothermal Developments Limited and the plant was commissioned in September 2008.

Subsequent development has seen NTGA develop a 25 tonne per hour clean process steam production plant, using geothermal steam as the primary fluid supply and the energy to power the process, supplying clean steam to the Svenska Cellulosa Aktiebolaget tissue mill. This geothermal supply uses reboiler technology and since September 2010 has replaced the natural gas fired steam generation process that had been used by the tissue mill.

In early 2013 NST commissioned the 23 MWe (gross) TOPP 1 binary power plant using steam and brine supplied by NTGA.

There have been a range of consenting activities undertaken on the Kawerau resource by NTGA, Mighty River Power and an Eastland Group / A8D Ahuwhenua Trust venture (Te Ahi O Maui Limited Partnership). In March 2014 consents were granted to the Te Ahi O Maui Limited Partnership for a nominal 15 MWe power plant development.

3.6 Rotokawa Developments

Scientific investigations began in the 1960's and were followed by the drilling of three investigation wells (RK1x, RK1 and RK2) in 1965-67. The temperature measured in RK1 reached 307°C, the highest temperature encountered in a geothermal well in New Zealand at that time. Investigations continued into the 1970's, with RK3 drilled in 1976. A drilling programme was undertaken between 1984 and 1986 (RK4 to RK8), drilling deeper than had earlier been undertaken. Electricity generation commenced from the Rotokawa power plant in 1997 with the commissioning of a 29 MWe hybrid binary cycle plant which was expanded to 35 MWe in 2002.

Through 2003 to 2005 further well drilling for both production and exploration was undertaken. A joint venture between the Tauhara North No 2 Trust and Mighty River Power embarked upon environmental studies with consent applications being lodged and granted in 2007 that would support the development of a nominally 150 MWe power plant. Construction contracts were let in April 2008 and the Nga Awa Purua Power plant was commissioned in May 2010. It is a triple flash arrangement supplying steam to a Fuji 140 MWe turbine generator. Acid dosing is used for silica deposition management in the reinjected brine.

3.7 Ngatamariki Development

The New Zealand government drilled four wells at Ngatamariki in the mid 1980's following which interest in the field languished somewhat. In 2004 Mighty River Power and the Tauhara North Number 2 Trust embarked upon a range of geoscientific and reservoir assessments to update and extend the resource information that had been derived from the earlier investigation work.

Figure 8 : Ngatamariki separation plant (left) and one unit of the power plant (right)

Detailed environmental assessments supported the consent applications lodged in November 2009. The consents were granted in May 2010 for a 100 MWe nominal development. There was a period of internal and peer review with the notice to proceed with construction given in June 2011 for an 82 MWe (net), four unit binary power plant facility (Figure 8). Additional drilling was undertaken and construction completed, with commissioning of two of the units occurring in the second quarter of 2013 and all units operational by the end of June 2013. The plant was officially opened on 3 October 2013 by the Prime Minister of New Zealand, John Key.

3.8 Ngawha Developments

Ngawha well NG1 was drilled in 1964 followed by investigation drilling of 13 wells in the period 1977 to 1983. Power development was undertaken by a joint venture between the local electricity lines company Top Energy and the Tai Tokerau Maori Trust Board with a 10 MWe binary power plant installed in 1998. A further 15 MWe binary plant was commissioned in 2008. Further exploration work is being contemplated for the Ngawha resource. Top Energy chief executive Russell Shaw identified in February 2014 that the company had been carrying out research and modelling to better understand how much geothermal resource might be available for generating electricity or heat for an industrial process. "Although we will not know exactly what we have until we explore through test drilling, we believe there could be enough resource for an additional 100 MW of energy," Mr Shaw said. The 25 MWe facility operates reliably producing about 70% of the electricity demand of the far north.

3.9 Taheke Exploration

In 2008 Contact Energy embarked on a programme of surface exploration and slim hole drilling at Taheke. Results were sufficiently encouraging for the drilling of a deep exploration well in 2013, but market electricity conditions in New Zealand softened significantly over that period and remain flat. Development at Taheke, like other green fields geothermal areas will take longer than was anticipated in 2010.

4.0 ENVIRONMENTAL MANAGEMENT

Environmental management in New Zealand is devolved to Regional Councils, with the Waikato and Bay of Plenty Regional Councils responsible for the Taupo Volcanic Zone (TVZ), which between them covers 90% of the nation’s high temperature geothermal resource. These two councils collaborate in managing the TVZ geothermal resources, and work with the major research organisations in investigating the resource’s extent and characteristics, and with the Department of Conservation. Since 2007, there has been a 550 MWe increase in installed geothermal electricity capacity across six projects in the TVZ, with most consent applications for large projects (e.g. Kawerau, Ngatamariki) being processed by the Regional Councils within six months.

Regional Council geothermal policy and rules provide resource users with an enabling framework for sustainable management of the Geothermal Resource, giving reasonable certainty to developers while also protecting valued geothermal features and recognising the social and economic benefits of direct uses and tourism.

4.1 Waikato Regional Council Geothermal Policy and Plans

The Waikato Regional Geothermal Policy has been operative since 2007-2008. The overarching policy framework for sustainable management of the region’s natural and physical resources has recently been reconfirmed almost unchanged after a comprehensive review (Regional Policy Statement). The document that sets out the rules and other methods that implement the policy (Regional Plan) will be reviewed from 2017. Planning is already underway for that review. Changes likely to be explored include setting limits on the development potential for individual geothermal systems, clarifying policies and rules around reinjection, and specifying in greater detail the monitoring and reporting requirements of consent holders. A change in focus to regional governance will see much of statutory decision-making by the Waikato Regional Council done in collaboration with Maori Tribal Authorities.

4.2 Bay of Plenty Regional Council Policy and Plans

The Bay of Plenty Regional Policy has been in place since 1999 (Regional Policy Statement) along with the 1999 and 2008 Regional Plans. A review of the Regional Policy Statement was completed in 2013 and review of the 2008 Plan commenced in February 2014. Changes in the Plan will include emphasis on system management plans for multi-user systems, identification of geothermal features (of which there are over 2000 in the Bay of Plenty region), mapping of significant geothermal features, and a consolidation of investigation, modelling and monitoring, especially for the Rotorua geothermal system.

5.0 PERSONNEL

Data for Table 7 requested by the International Geothermal Association has been collected through interviews with representatives of New Zealand companies. There has been major growth in the industry since the 2010 country update with 320 professionals in 2009 growing to just over 720 professionals in 2012 and tapering off somewhat since then.

This growth has come from a number of sources. There has now been 10 years of solid geothermal investment growth and this has encouraged science and engineering graduates or those in early careers into the industry. Companies have recruited personnel on the national and international markets to build up required levels of staff expertise. Many of the companies have been able to move staff from other sectors of their business to cover peak workloads e.g. minerals staff to support geoscience or wider engineering experience to support geothermal engineering. Some specific projects have been resourced through internal seconding of general engineering personnel from Australia under the lead of New Zealand experts. The two major developers (Contact Energy and Mighty River Power) have both built up internal resources of similar size and together employ about 35% of the professional geothermal workforce in New Zealand.

New Zealand construction companies have been active on projects, largely operating within Engineer, Procure and Construct (EPC) contracts and have played a role in bringing projects in on time and under budget.

The flat domestic electricity demand since 2011 has resulted in some winding back of staffing levels through and since 2013.

A number of the New Zealand companies are active internationally. Mighty River Power has investments in the US and Chile. Contact Energy staff have assisted Origin Energy with geothermal projects in Australia and Indonesia. New Zealand consultants and academics work in many parts of the world. Companies are interested in bringing the range of skills to the international market, ideally in integrated packages. New Zealand is well endowed with expertise across the geothermal sector.

6.0 PROFESSIONAL TRAINING - GEOTHERMAL INSTITUTE

The two-semester geothermal Post Graduate Diploma in Geothermal Energy Technology (PGDip Geotherm Tech) course at the Geothermal Institute (GI), University of Auckland, ran from 1979 until 2002 when funding ceased.

A one-semester Post Graduate Certificate course in Geothermal Energy Technology (PGCert Geotherm Tech) was established in 2007 as a response to the increasing demand for training for engineers and scientists with the growth in geothermal exploration and development occurring in a number of nations around the world. The course also provides for Masters and PhD studies for students interested in researching aspects of geothermal energy in greater depth.

210 students have completed the PGCert course from 28 countries since 2007. Course numbers have varied through the years with 2014 seeing the greatest number of enrolments at 48 students in total attending (Figure 9). Of the 210 students trained the largest percentage has come from the Philippines and Indonesia, comprising 23.8% each, followed by New Zealand (11.9%) and Kenya (10.5 %). The course is providing training for the international geothermal geosciences and engineering sectors.

Understanding the challenges of running the course and with the lessons learned from the Diploma course assisted staff to structure the PGCert course seeking to ensure sustainability:

- The course was structured as a one-semester (19 week) course, which made it easier for employers to send employees to New Zealand.
- The course was divided into separate blocks, each of about six weeks in duration. This meant that students can complete the PGCert course over two years, in six week long blocks and with a one month short project. This is attractive to some company-sponsored students.
- For the first four years, the course was run by two part time (50 %) academic staff. Currently one full time academic staff member runs the course, with other lecturers donating their time or contracted on short-term contracts.

In the 2007 inaugural year there were nine students taking the course and numbers have steadily grown (Figure 9). In the first three years of the course some of the papers were structured as open entry short courses. This was aimed at increasing student numbers and improving the course funding. There were some negative aspects of this arrangement and the open entry short courses have not been offered since 2009.

There have been more male than female students attending the course, with an average overall composition of 24% female through the 2007 to 2014 period. This gender distribution is similar to that of other engineering courses at the University of Auckland were female attendance from 2007 to 2014 is 22%.

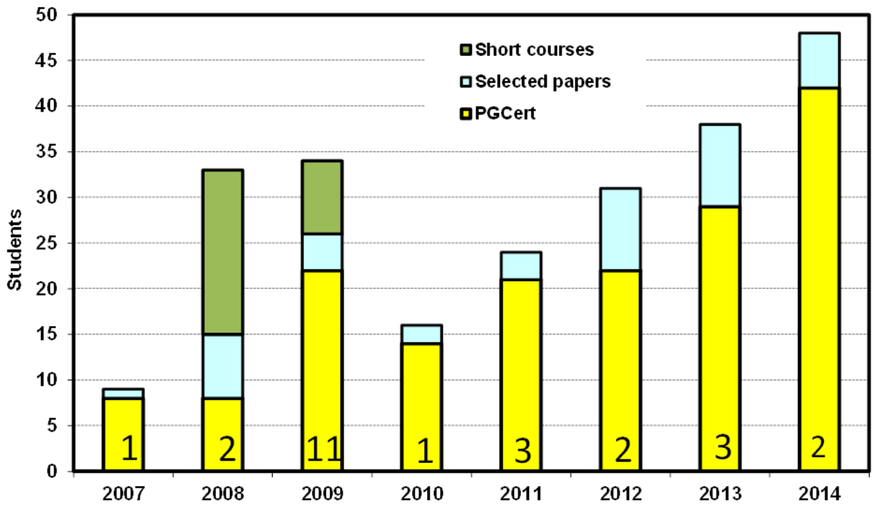

Figure : 9 Student enrolment in the PGCert Geotherm Tech, selected papers and short courses. The numbers at the base of the columns indicate the number of New Zealand students attending the PGCert Geotherm Tech course.

7.0 INVESTMENT

In the appendices, Table 8 identifies a steep increase in geothermal investment that took place in New Zealand about 10 years ago and that has been sustained until the middle of 2014. Investment in the last 5 years has been similar to the previous 5 years, but has seen a shift from investment dominated by the state-owned Mighty River Power to that dominated by the publicly listed Contact Energy, although both companies and a range of other companies have been active throughout the 10 year period.

Table 8 also shows the investment in large industrial direct heat projects in the last five years. In practice, there has also been some investment in previous years which has not been able to be captured in the data. These direct use applications have been discussed in section 2 of this country update paper.

The data on geothermal heat pumps and smaller direct heat applications continues to be firmed up. This data is difficult to obtain with any degree of accuracy.

Another indication of investment activity is well drilling, with well costs being a substantial (and growing) portion of total project costs, whether for electricity generation or heat. Figures 10 and 11 show the number of wells and fields drilled in the period compared with previous years. It is interesting to compare efforts in earlier decades (when drilling, exploration and development were controlled by the government), with the last decade (when these efforts have been driven by market conditions and a combination of public and private investment). The recent drilling efforts have exceeded those of the former years in both the number of wells drilled annually and in the diversity of fields in which well drilling has been undertaken. Recent wells are generally deeper and larger in diameter than the early wells and so are greater in real cost. There have been reports of significant cost increases in drilling out running inflation but data is not available in this paper to distinguish between inflation and changes in well design and construction methods. What has occurred is that investment has been enabled on fields that were previously investigated by the New Zealand Government, and the heritage exploration data has provided enough information to facilitate proceeding with additional investigation activities, leading in some cases to further drilling and field development.

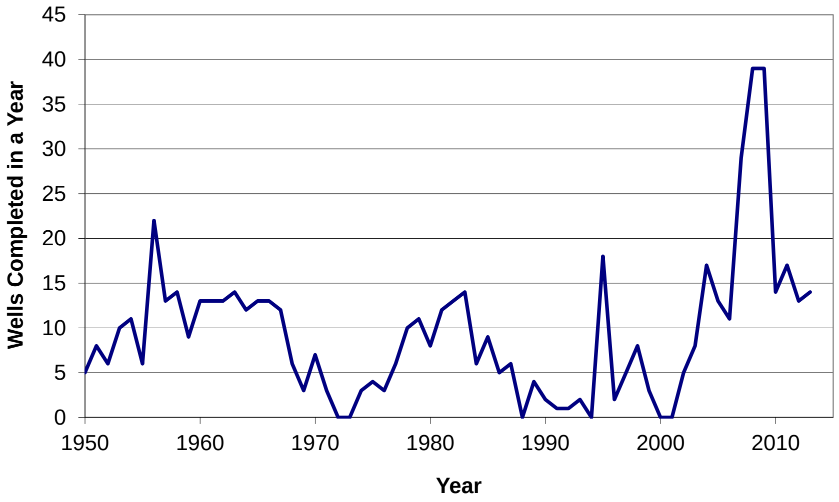

Figure 10 : Well drilling activity with time

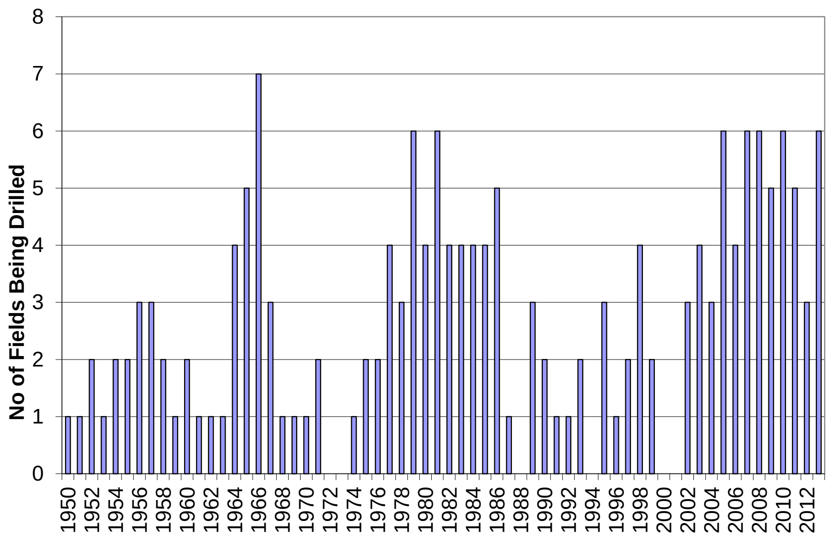

Figure 11 : Number of geothermal fields with in which drilling has been undertaken in a given year.

6.0 CONCLUSION

New Zealand has seen a period of rapid growth in the utilization of geothermal energy over the last 10 years. The anticipated increase in geothermal electricity generation from 2010 to 2014 of about 1500 GWh is a significant increment being an increase of over 20% of the total geothermal generation through the period.

The availability of high temperature, productive geothermal resources has seen geothermal developments being the least cost generation option (on an energy unit cost basis) compared to other renewable energy or fossil-fuelled options. There is a total of over 1000MW of installed geothermal capacity which is typically contributing about 16% of total electricity generation (c.f. 13% in 2010) in an electricity system dominated by renewable generation. New Zealand currently produces about 75% of its electricity from renewable sources and is strategically targeting 90% renewable generation by 2025.

Post 2013 there has been a hiatus in geothermal electricity generation construction in New Zealand due to a period of low / no electricity demand growth with the New Zealand geothermal operators focusing on sustaining and maintaining developments, looking to share experience partnering in international developments and investigating new prospects.

Several New Zealand companies have invested significantly in large scale industrial direct geothermal energy applications in the last five years including; Ngati Tuwharetoa Geothermal Assets Limited supplying the Svenska Cellulosa Aktiebolaget tissue mill at Kawerau and Tuaropaki supplying the Miraka milk powder processing plant at Mokai. There has overall been a reduction in geothermal direct heat use as a consequence of Norske Skog Tasman closing down one of the paper production lines at its Kawerau facility in January 2013.

With the significant development that has gone on in New Zealand over the last decade the science and engineering around geothermal resource development is at the leading edge of the technology and its implementation. Geothermal New Zealand is a connector to this quality expertise.

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APPENDIX – DATA TABLES REQUESTED BY THE INTERNATIONAL GEOTHERMAL ASSOCIATION

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

In the New Zealand context there are scenarios that are developed for Electricity planning purposes. Table 1 has been replaced with a figure from one of the scenarios. There are five planning scenarios currently being considered by Transpower, the grid operator :

- Sustainable Path,
- South Island Renewables,
- Medium Renewables,
- Coal, and
- High Gas Discovery.

Additional information can be obtained from Transpower (2014b), Appendix G.

The Figure A.12 below identifies the medium renewables scenario taken from Transpower (2014b) from 2015 to 2029.

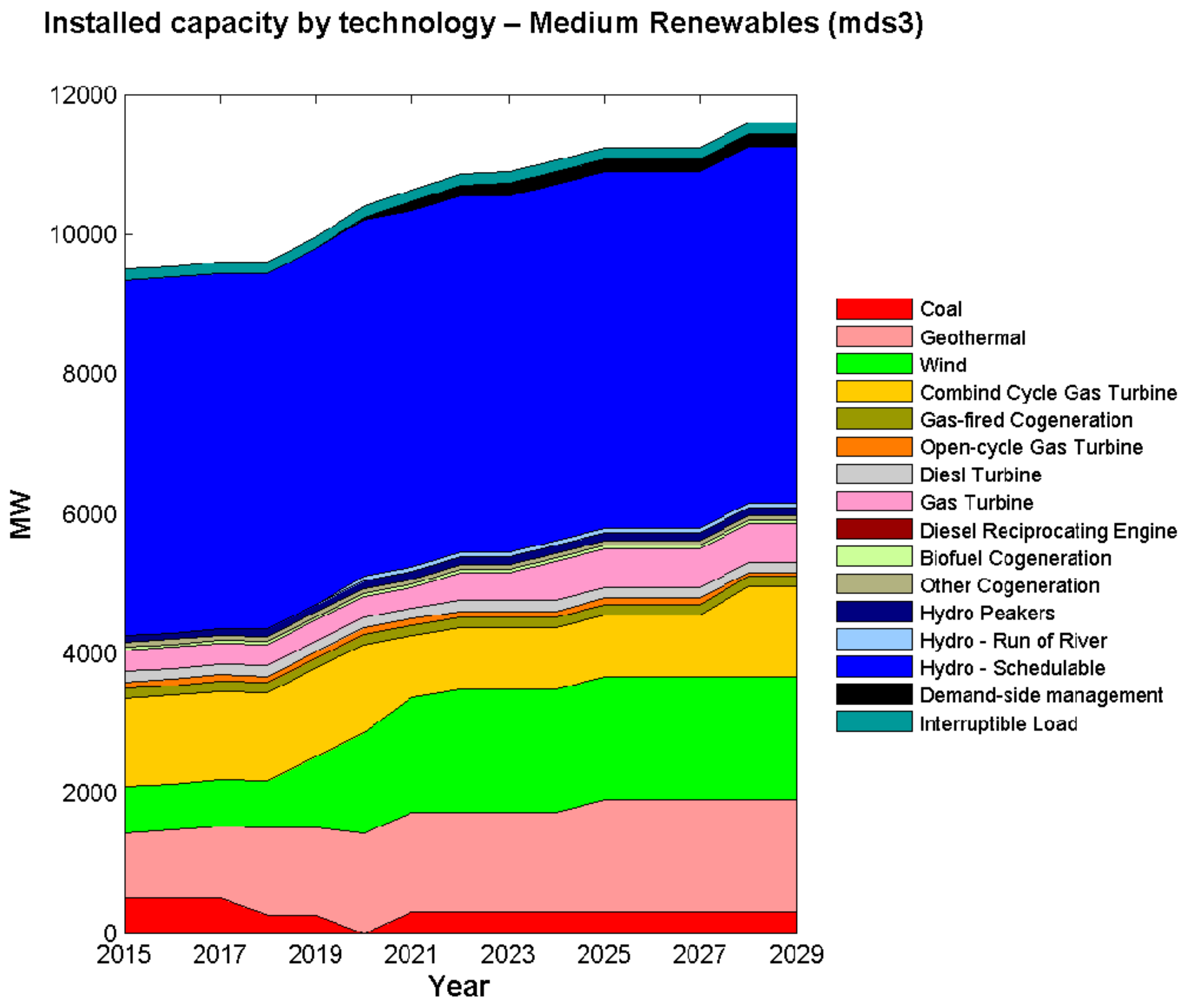

Figure A.12 : Medium Renewables scenario – installed capacity by technology.

The component of the medium renewables path has a geothermal capacity increase of about 630MWe from 2015 up to 2029.

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION PREDICTED AS OF 31 DECEMBER 2014

1) N = Not operating (temporary), R = Retired, C = consented, I = investigations. Otherwise leave blank if presently operating.

2) 1F = Single Flash; B = Binary (Rankine Cycle)
2F = Double Flash; H = Hybrid (explain)
3F = Triple Flash; O = Other (please specify)
D = Dry Steam

3) Estimated data for 2014

4) Totals exclude retired plant

Locality	Power Plant Name	Year Commissioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe	Annual Energy Produced 2014[3)] GWh/yr	Total under Constr. or Planned MWe
Wairakei	Wairakei	1958-63	4	R	4 HP - BP	34		
			9		2 IP - BP			
					4 LP - C	157	970	
					3 MP - C			
		1996	1		1 LP - BP	2		
	Wairakei Binary	2005	2		B	14	120	
	Poihipi	1996	1		D	55	420	
	Te Mihi	2014	2		2F	166	920	
Kawerau	Tasman BP	1966	1	R	1 BP	10		
	Tasman BP	2004	1		1 BP	5	44	
	TG1	1989	2	R	B	2.4		
	TG2	1993	1		B	3.5	26	
	KA24	2008	1		B	8.3	30	
	Kawerau	2008	1		2F	100	800	
	TOPP1	2013	1		B	23	180	
	Te Ahi O Maui	?		C				15
Reporoa	Ohaaki	1989	2	R	1 HP - BP (ex-Wairakei)	11		
				R	1F	47		
		1989	2		1 HP - BP (ex-Wairakei)	11		
					1F	47	300	
Rotokawa	Rotokawa	1997	4		H (1F, B)	29	270	
	Rotokawa Extension	2003	1		B	5		
	Nga Awa Purua	2010	1		3F	140	1000	
Northland	Ngawha	1998	2		B	10	140	
	Ngawha 2	2008	1		B	15		
	Ngawha 3	?		I				50
Mokai	Mokai 1	1999	6		H (1F, B)	55		
	Mokai 2	2005	5		H (1F, B)	39	930	
	Mokai 1A	2007	1		B	17		
Tauhara	Te Huka	2010	2		B	26	200	
	Tauhara II	?		C				250
Ngatamariki	Ngatamariki	2013	4		B	82	650	
Rotoma	Rotoma-Tikorangi	?		I				35
Rotoiti	Tikitere-Taheke	?		I				40
Total[4)]			51			1,010	7,000	390

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2013 (other than heat pumps)

I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting

H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

Enthalpy information is given only if there is steam or two-phase flow

Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 ($MW = 10^6$ W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 ($TJ = 10^{12}$ J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Northland	B		24	22			0.2	22	6	0.95
Auckland	B, H		50-65	30			2.6	17	57	0.69
Waikato	B, O, H, D, G, I, F						148		3,039	0.65
Bay of Plenty (misc)	B, O, H, D, G, F						65		1,239	0.60
Bay of Plenty (Kawerau)	I						184	400	4,196	0.72
Gisborne	B		40-50	30-35			0.004	0.1	0.14	1.00
Hawke's Bay	B		50-62	40			0.1	2	3	1.00
Taranaki	B, O		27				0.004	0.07	0.11	1.00
Canterbury	B		52	24			0.5	4	8	0.50
West Coast	B		55-60	36			0.4	5	6	0.50
TOTAL							401		8,553	0.68

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2014

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to rejected to the ground in the cooling mode as this reduces the effect of global warming.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or Water Temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Canterbury		11.5	53	H				
		10	4	V				
	12	32.3	8	W				
Marlborough		28.7	3	H				
Otago		13.7	24	H				
		60.5	2	V				
Southland		15.7	1	W				
		6	6	H				
Wellington		7.7	3	H				
West Coast		4.3	2	H				
Commercial installations								
Southland		10.7	1	H				
Otago		19.6	1	H				
Manapouri		14.2	1	H				
Wanaka		23.6	1	W				
Canterbury		23.1	1	W				
Canterbury hunting lodge		19.6	1	H				
Christchurch Airport	12	3600	2	W				
Dunedin Airport	12	240	2	W	typically > 5		0.8	
Jellie Park Complex	12			W	3		25.9	
Pioneer pool complex	12			W	3		25.4	
Christchurch South Library	12			W	3		2.7	
TOTAL			116				54.9	

* Typical Heat Pump rating or Capacity is the average of the capacity of the installed units

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2013

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)]x0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% capacity all year

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4] / District Heating[4]	62	578	0.30
Air Conditioning (Cooling)	-	-	-
Greenhouse Heating	24	366	0.48
Fish Farming	17	196	0.36
Animal Farming	0	2	0.50
Agricultural Drying[5]	-	-	-
Industrial Process Heat[6]	284	5,043	0.56
Snow Melting	-	-	-
Bathing and Swimming[7]	58	1,375	0.75
Other Uses (irrigation, frost protection, geoth. tourist park)	33	992	0.95
Subtotal	479	8,552	0.57
Geothermal Heat Pumps	>9.3	69	
TOTAL	487	8,621	

[4] Other than heat pumps, includes water heating
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology

Table 6. Wells Drilled for Electrical, Direct and combined use of Geothermal Resources in New Zealand from January 1, 2010 to December 31, 2014 (excluding heat pump wells)

		No. of wells drilled				
Purpose	**Wellhead temp**	**Electric po**	**Direct use**	**Combined**	**Other (specify)**	**Total depth (km)**
Exploration	(all)	9				7.75
Production	>150°C	21		5		49.57
	150-100°C		9			0.79
	<100°		18		5	7.06
Injection	(all)	21	11	1		45.92
Total		51	38	6	5	111.09

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010	55	102	42.5			371.5
2011	62.5	116	43.5			482
2012	65	131	42.5			488.5
2013	62	127	42.5			473
2014	59	128	40.5			410.5
Total	303.5	604	211.5	0	0	2225.5

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
2000-2004	14	44		88	20	80
2005-2009	97	533		638	42	58
2010-2014	66	543	17	639	61	39