A COUNTRY UPDATE OF NEW ZEALAND GEOTHERMAL: LEADING THE WORLD IN GENERATION GROWTH SINCE 2005

Colin C. Harvey and Brian R. White

GNS Science, Private Bag 2000, Taupo and East Harbour Energy, PO Box 11 595, Wellington, New Zealand

c.harvey@gns.cri.nz, brian.white@eastharb.co.nz

Keywords: geothermal energy, New Zealand, electricity generation, direct use, development

ABSTRACT

New Zealand is experiencing an exciting era of expanded geothermal development with the commissioning over 300 MWe of new generation in the past five years. Historically, in the 1950's and 1960's New Zealand led the world in the research and development of water-dominated geothermal systems. In the latter part of the 20th century the pace of development decreased because of the discovery in New Zealand of the large and low cost Maui gas field which provided a readily exploitable source of energy.

With the current depletion of the Maui gas field and limited additional New Zealand hydro alternatives, New Zealand is once again recognizing the importance and value of its abundant high temperature geothermal resources for both electricity generation and direct use. Currently New Zealand's geothermal power station capacity of over 700 MWe generates between 12 and 15% of total generation depending on time of year. Construction of further generation is currently underway to increase this to around 1000 MWe of total generation by 2013. Direct use has been of a similar magnitude to electricity generation in terms of consumer energy until 2007, and continues to grow. Research also is underway to tap into deeper higher temperature resources at deeper than 3km, and to make better use of low temperature resources.

After low investment and limited research during the final years of the 20th Century, there is now some growth in research funding, strong participation in research by industry partners, and the re-instatement of geothermal training courses at the University of Auckland.

1. INTRODUCTION

Over the past seven years New Zealand has experienced an exciting era of geothermal development. Stimulation for the current growth in geothermal development is due to several factors which include:

- Declining gas reserves in the large, low-priced Maui gas field and renegotiation of prices,
- Concerns around the future cost and supply of imported fossil fuels (as an alternative generation fuel), coupled with rising domestic prices for these fuels,
- Availability of premium geothermal resources that represent the best practical option of all available generation options,
- Expansion opportunities on existing operations that provide attractive economics in the current domestic market,
- Readiness of developers to invest in resources through established staff bases and experience, coupled with availability of skills,
- Climate change concerns linked to the Kyoto Protocol and national requirement to reduce greenhouse gas emissions, and
- Government reforms to reduce investment barriers.

This has resulted in increased development for both electricity generation and direct heat using high temperature resources especially. It is interesting to note that enhanced geothermal systems (EGS) developments still do not feature in New Zealand developer or regulator thinking, largely because of the abundance of premium high temperature fields with further development potential.

Future development will be led by a mix of private and public electricity generators (supplying heat and electricity), electricity lines companies, Maori Trusts (and possibly other land holding interests) and some major industries with heat and electricity needs. The focus will still be on high temperature resources, but there will be ongoing investment at domestic level for direct use across the full range of resources.

2. CURRENT AND FUTURE PRODUCTION OF ELECTRICITY: ALL SOURCES

2.1 General Description

New Zealand has an electricity generation system that is already dominated by renewable electricity sources (hydro, geothermal and wind), with renewable energy accounting for 77% of all electricity generation in 2011. A government Energy Strategy (August 2011) confirmed a renewable electricity target of 90% by 2025. The New Zealand generation system has a high proportion of hydro generation (around 50 to 60% of total generation) but limited lake storage capacity has meant that hydro generation is always sensitive to weather. In contrast, geothermal energy offers baseload energy independent of the weather. Its location close to major load centers and at competitive development cost has been the major factor in encouraging greater utilization of geothermal.

New Zealand electricity demand grew almost linearly between the mid 1970's and 2007 by about 660 GWh/year (before transmission and distribution losses of about 7.5%). Since 2007 this has stalled due to the slow down in the World economies. However despite this slowdown in demand growth, geothermal has continued to be the preferred generation technology for new generation because of its cost competitiveness.

Figure 1 is taken from an earlier NZ Energy Strategy and shows quantities and long run costs (NZ$) associated with various energy sources. The striking thing about this graph, for which inputs were developed in consultation with industry, is that there are significant quantities of low cost geothermal and wind generation that should reasonably compete with fossil-fuelled generation options. Hence wind and geothermal generation are expected to dominate new capacity for at least the next 1000MWe of new generation. The most competitive fossil-fuelled option is gas-fired combined cycle plant with gas at NZ$9/GJ and with CO_2 valued at NZ$25/t of CO_2. In a national context, the quantities of renewable energy options available are sufficient to satisfy 20 or so years of demand growth (on the original trend), unless electric vehicles develop at an unprecedented rate.

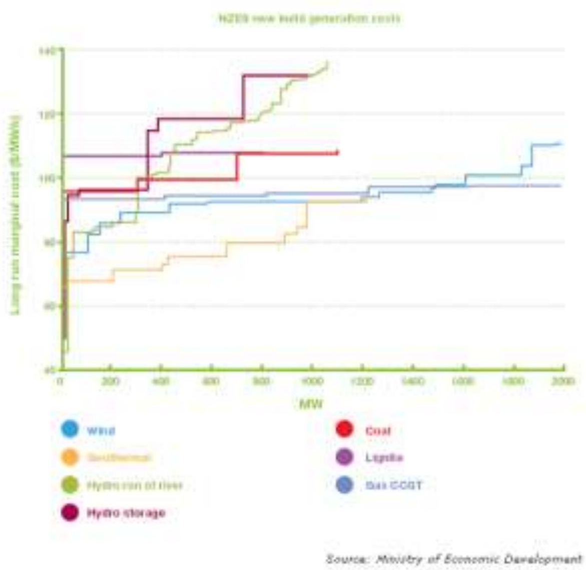

Figure 1: Long run costs for a range of generation options (from the New Zealand Energy Strategy)

Table 1 provides details of the recent and proposed geothermal development program although the future installation estimates will be conservative given that several exploration/development projects have not been listed pending restoration of demand growth.

2.2 Geothermal Electricity Generation

Descriptions of geothermal developments are given in Section 4 of this update.

Only considering the readily available, high temperature geothermal resources, after deleting protected fields from consideration and derating fields that are close to population centers, there is the equivalent of around an additional 1,000 MWe available, utilizing existing technology. These projects alone can meet more than a decade of national demand growth based on traditional demand patterns. With a capital cost of around NZ$4million/MWe (SKM 2009), this equates to a $4 billion development program over the next ten or fifteen years.

Figure 2 shows historic generation of electricity from geothermal sources up to 2010. It includes station names, capacity and commissioning dates. Not shown on the graph are ongoing efforts to maintain or increase generation from existing facilities. Very active engineering has been necessary throughout the history of Wairakei's steam supply. Steam winning in the Te Mihi area has recently provided sufficient steam to load Wairakei and Poihipi stations. Ohaaki's output dropped dramatically after commissioning, though a small measure of this decline was planned for. Ohaaki's output reached a low of 25 MWe in 2007 but a steam winning project resulted in station output returning to above 60 MWe in late 2008 (but back to 40 MWe now). While these steps do not represent increases in installed capacity, they do represent low cost gains in generation.

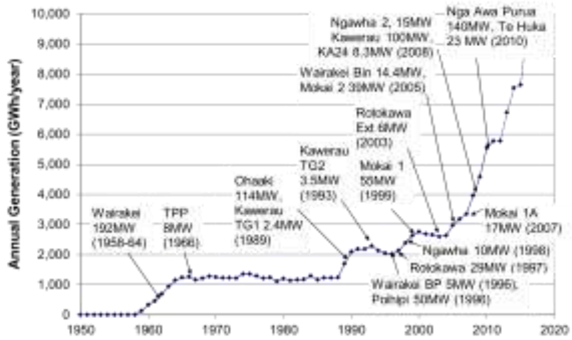

Figure 2: Historical and projected growth in geothermal electricity generation in New Zealand

A wide range of new generation projects have been announced as indicated in Table 1, with principal sources of announced projects being Mighty River Power (a public generator-retailer for which a portion of shares are planned for private sale shortly) and Contact Energy (a private generator-retailer).

With some developments now reaching 50 years of age, retirement and replacement are growing features. The original back pressure turbine installed at the Norske Skog Tasman mill was replaced in 2004 and a further expansion is currently under way. The Te Mihi development also currently under way not only replaces part of the old Wairakei plant but is expected to provide a further 114 MWe from the consented take with improved efficiency.

3. DIRECT USE UPDATE

3.1 Geothermal Heat Pumps

Geothermal heat pumps (whether ground-source or water-source) are making a significant contribution to direct use internationally, but are only just taking off domestically. This accelerating uptake may be partially frustrated by the recession which has the effect of suppressing new building in which heat pump uptake is focused.

At the domestic level, installations are reported in colder parts of the South Island e.g. in Queenstown through to larger homes in the warmer north e.g. in Auckland. These domestic heat pumps fit into the luxury housing market as a rule. At the larger commercial scale, an increasing number of companies are recognizing that geothermal heat pumps should be considered as an energy supply option, and forerunning projects such as the Dunedin airport have been implemented.

All developments are part of an infant industry that has now started to work together with the establishment of the Geothermal Heat-pump Association of New Zealand (GHANZ) in 2012 as an interest group within the New Zealand Geothermal Association.

3.2 Other Geothermal Direct Use

Direct use in high temperature fields is outlined in the following section with data from White (2009).

Direct use applications are found in both the North and South Islands. The most common application is for bathing, with space and water heating to a lesser extent, and occasional direct use for frost protection and irrigation. Diversity and magnitude of use increases for higher temperature resources found in the Taupo Volcanic Zone, including greenhouse heating, prawn farming, milk powder drying, kiln drying and a special tourism development. Geothermal direct use in New Zealand is dominated by the major industrial supply at Kawerau now accounting for over 50% of national geothermal direct energy use. This remains the largest single geothermal industrial use in the world and the supply has expanded recently to adjacent industrial users.

The following graph shows that direct use growth has been steady and of a similar magnitude to electricity generation in terms of consumer energy over at least 50 years, but has been left behind by the recent electricity generation growth.

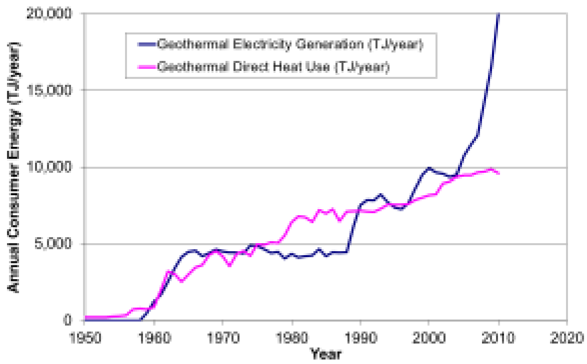

Figure 3: Historical comparison of electricity generation and direct use in New Zealand

The most noticeable areas of growth are associated with the high temperature fields of Kawerau, Wairakei, Mokai and Tauhara. Large scale direct use has almost always been linked to existing or planned electricity developments. There is increased domestic/commercial installation in Tauranga and renewed interest in Rotorua.

Field developers are now securing commercial rates for new direct use supply contracts and this is driving interest in identifying and encouraging new direct use supplies. It is thought that timber drying kilns and greenhouse heating will be key areas of expansion, partly driven by surrounding land use (East Harbour and GNS Science (June 2007)). Where there is industry located close to a resource then this may also take up direct use to avoid exposure to future fossil fuel prices.

4. NEW ZEALAND GEOTHERMAL DEVELOPMENT

4.1 Wairakei Developments

Wairakei celebrated the 50th anniversary of the commissioning of its first turbo-generator in November 2008. Many modifications have been made to the plant over the years, the latest being the installation of a 14 MWe net Ormat binary cycle plant (commissioned in 2005) to make use of some of the hot separated water brought down to the area near the station for reinjection purposes. Total effective installed capacity at the original Wairakei site is now 176 MWe, with the plant owned by Contact Energy.

In 1996 a local landowner over the field worked with a number of companies to develop the 50 MWe Geotherm plant, now known as Poihipi Road station on the western edge of the field. This was subsequently taken over by Contact Energy, which has invested in consents and wells to fully load the station from a previous 50% loading. However, the original developer Alistair McLachlan proceeded to secure consents for another “Geotherm” 50 MWe station. This faced further difficulties with receivers. Alistair McLachlan passed away this year so his personal drive will be a loss to the industry.

The next major development associated with Wairakei is the Te Mihi development, effectively the replacement plant for the aging Wairakei plant. It is expected that much of the old plant will be retired. However the new binary plant will continue operation and perhaps some LP turbines. The new 166 MWe Te Mihi plant is expected to be more efficient so that commissioning of Te Mihi/retirement of Wairakei will result in a net generation gain of 114 MWe using the same resource consents. Consents for the replacement plant were obtained through a special Board of Inquiry resulting from the Minister for the Environment calling-in the consent application (at Contact’s request) and were finalized in September 2008. The plant, based around Toshiba turbines is expected to be commissioned in 2013.

The future use of the current power station site is not yet determined, but given that Wairakei station was of global significance in opening wet steamfields to commercial development, Contact Energy has been considering options for possible preservation.

4.2 Tauhara Developments

Contact currently has a limited development on the Tauhara field, but is preparing for major expansion. A 20 MW_{th} steam supply to the direct use Tenon kiln drying facility was developed by Contact in 2005/6. A 23 MWe Ormat binary plant known as Te Huka was commissioned in 2010.

Some exploration drilling on the Tauhara field was undertaken in the 20th Century but it was extended in 2005/6 to other parts of the field. These new wells confirmed the field was hotter and larger than previously thought. Consequently, consents have now been obtained for a 250 MWe development with a view to commissioning in the next few years.

The Tauhara field partly underlies Taupo township. There have been concerns about geothermal-induced subsidence and hydrothermal eruption effects possibly linked to Wairakei operations, Wairakei being hydrologically connected to Tauhara. Contact Energy has also undertaken an extensive core drilling program over the Wairakei-Tauhara area to gain new information on subsidence mechanisms.

4.3 Ohaaki Development

Ohaaki was originally developed as 114 MWe generating station in 1989. However drawdown of the resource has restricted output significantly. Beginning in 2006, Contact invested in new wells with the aim of maintaining production at 50 to 60 MWe. This has been relaxed and generation has been allowed to fall back to 40 MWe.

4.4 Mokai Developments (Tuaropaki Power Company)

Historical developments at Mokai have included progressive development up to 112 MWe of electricity generation using hybrid binary cycle technology by the largest independent private generator of electricity nationally, Tuaropaki Power Company (TPC), and significant supply of heat to a major glass house operation. Mokai station has been developed in three stages: 55 MWe in 1999, a further 39 MWe in 2005 and re-engineering of the first stage with another 17 MWe in 2007. In 2011 a milk treatment plant using geothermal steam was commissioned and is believed to be the first of its kind in the world.

4.5 Kawerau Developments

The Kawerau field has been subject to the longest commercial development of any field in New Zealand with the initial steam supply to the Kawerau mill for direct use commencing in 1957. A small embedded geothermal generator was installed in 1966 and was finally replaced by Norske Skog Tasman in 2005. The initial direct use development has been followed by progressively increasing use. This had some effect on shallower reservoir zones in terms of drawing in fluids from the surface, but almost negligible effect on the deeper reservoir showing the field capacity is much greater than was being utilized. A small amount of grid generation was installed around 1990 (TG1 – 2.4 MWe installed in 1989, TG2 – 3.5 MWe installed 1993) using a portion of the rejected brine and this proved the applicability of Ormat binary cycle technology in New Zealand with several other examples following. The TG1 and TG2 plants are now owned and operated by Bay of Plenty Energy. The field has some very productive wells making development particularly attractive economically.

Mighty River Power in collaboration with Ngati Tuwharetoa Geothermal Assets (NTGA) obtained consents for the development of a 100 - 110 MWe double flash geothermal power station on the mill property. An EPC contract was let to Sumitomo Corporation (with major partners including Fuji Electric and Hawkins Construction) for the construction and commissioning of the plant. Commissioning was completed and plant handed over by the end of August 2008. This project constituted the single largest increase in New Zealand's geothermal generation since Ohaaki was commissioned in 1989. Other land owners developed 8.3 MWe of geothermal power from and otherwise unused well which was commissioned in September 2008. There are similar plans for another large unused well.

NTGA has supplied a large Svenska Cellulosa Aktiebolaget tissue mill adjacent to the Norske Skog Tasman mill with process steam since late 2010.

Kawerau is now the site of further construction. A 25 MWe power station using Ormat plant is being built by Norske Skog Tasman and will result in retirement of the 8 MWe plant and a net gain of 16 MWe on commissioning late in 2012.

4.6 Rotokawa Developments

Earliest drilling at Rotokawa was undertaken in 1965, but the first development for electricity generation took place in 1997 with the commissioning of a 29 MWe hybrid binary cycle plant, later expanded to 35 MWe so that greater use could be made of the changing enthalpy from the wells.

Through 2003/4/5 Mighty River Power were active in drilling further exploration wells. Further negotiations took place with local landowning Maori Trusts (especially with Tauhara North No 2 Trust), and environmental studies were undertaken leading to consents in December 2007 for a 130-140 MWe development. EPC contracts were let in April 2008 and commissioning took place in May 2010 of the Nga Awa Purua triple flash, single Fuji unit. This has been the largest development in New Zealand after the initial development of Wairakei 50 years ago, while the 130 MWe Fuji turbine is the largest single geothermal turbine in the world.

4.7 Ngatamariki Development

The NZ Government drilled 4 wells at Ngatamariki in 1985 and the field is recognized as a good prospect. Mighty River Power obtained consents for exploration drilling and for development. Contracts have been let, drilling is continuing (with an Iceland rig) and construction is underway for an 80 MWe Ormat plant scheduled for commissioning in 2013 in partnership with a local Maori Land Trust.

4.8 Ngawha Developments

Ngawha was first drilled in 1964 but the first development was undertaken by the local electricity lines company Top Energy in association with local Maori Trusts with a 10 MWe Ormat binary plant installed in 1998. In October 2008 a 15 MWe extension was commissioned, predicated on the use of a novel supplementary injection concept to avoid effects on the surface springs. This required the drilling of three new reinjection wells (one had been partially completed decades earlier under the Crown drilling program) and adaption of another old well as an injector. Previous estimates have indicated that the field capacity is much larger than the currently installed plants, but it is not clear when further development will take place.

4.9 Rotoma Development

This proposal may be typical of many developments in future. The proposer is a Maori Trust, likely working in with a developer or equipment supplier (in this case Ormat).

4.10 Taheke Development

The Taheke field has drawn the attention of both major developers working with different land-owning groups. Contact has drilled 3 wells with apparently good results. Mighty River Power is expected to start exploration drilling shortly.

5. COMPARISON ACROSS TECHNOLOGIES (A VIEW ON FUTURE GROWTH)

There are various economic models for the diffusion and adoption of technologies and it is useful to consider a continuous adoption model in comparing the various technologies already described in this paper. A generic qualitative cumulative adoption path is shown in Figure 4 after White (2007).

The curve, as shown, assists in outlining expected future growth across the three technologies:

- The geothermal heat pump industry in New Zealand is in its infancy, with a very small current contribution, but an expectation of significant growth.
- The electricity market is established but with considerable growth possible from an increasing pool of interested players.
- The direct use market is established and has good growth potential.

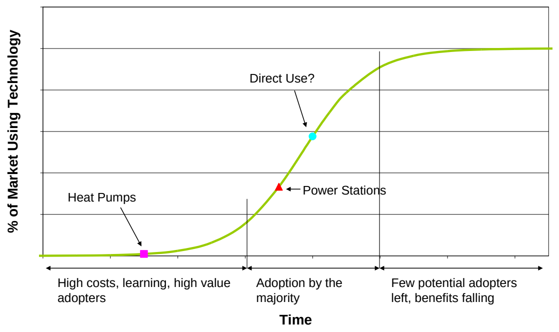

Figure 4: Generic cumulative adoption paths for a range of geothermal technologies in New Zealand

6. PERSONNEL AND INVESTMENT

The New Zealand Geothermal Association has undertaken personnel surveys in (Barnett (2005)) and 2009 (Brotheridge (2009). There were indications that geothermal professional personnel numbers leveled at 320 people across the various sectors in 2009 from 280 people in 2005 with about 60 of the geothermal professional personnel working directly for the two major developers (Contact Energy and Mighty River Power). This had risen from a base of less than 100 full time equivalents across New Zealand prior to 2005 (Dunstall (2005). The growth since 2005 reflected the general optimism as all companies planned for the anticipated growth in major domestic investment projects.

Although no updated surveys have been undertaken we believe that the total number of people employed, there are currently in excess of 400 consultants including university staff and the commercially orientated "Crown Research Institutes" which have consulting duties split between New Zealand and international work, with possibly 150 of those people heavily weighted towards international consultancy. The larger developers have also continued to build up their own in-house expertise (though numbers have leveled off recently) recognizing that the consultants will continue to service the international client base they have already established. If expansion projects in South East Asia, East Africa, Central and South America proceed coupled with possible EGS and Hot Sedimentary Aquifer (HSA) developments in Australia, then the staff numbers and workload of these consultants are projected to increase.

The increasing workload has meant that some consultancies previously without geothermal experience have entered the scene, particularly focused on civil aspects, piping and process plant design, under the direction of experienced geothermal personnel. Engineering services required to build and install the recent and planned developments at Kawerau, Nga Awa Purua, Te Mihi and Tauhara have also expanded and there is current interest in marketing these construction skills internationally for overseas geothermal developments.

Within the consultancies are cores of senior staff with broad geothermal skills. Many of these are nearing retirement age raising succession and ongoing training as issues. Similar succession issues are being faced by the major developers. At the tertiary level, specialist geothermal training courses have now been recommenced by the University of Auckland.

Another indication of investment activity has been well drilling activity. Figure 6 shows the number of wells drilled between 1960 and 2010. Drilling has continued at this level since 2010 with the wells being to greater depth and of larger diameter than the earlier New Zealand wells.

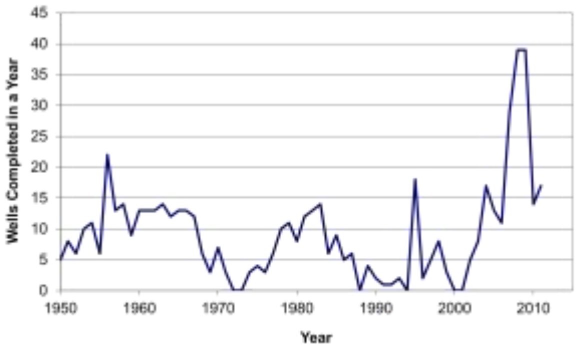

Figure 5: Historical record of wells drilled (for electricity, investigation or Kawerau direct use)

7. GOVERNMENT POLICIES AND INITIATIVES TO ENCOURAGE RENEWABLES

New Zealand Governments have a strong aversion to subsidy and trade barriers and only looked at interventions where there was some evidence for a market failure or where there are natural monopolies.

7.1 New Zealand Energy Strategy

In 2007 the Labour-led Government introduced the "New Zealand Energy Strategy to 2050" (NZES 2007) and the "New Zealand Energy Efficiency and Conservation Strategy" (NZEECS 2007) were issued. These documents and other linked infrastructure documents set out a coordinated energy strategy. Among wide-ranging initiatives, targets were set for renewables in electricity generation (90% renewable by 2025) and targets have been set in terms of direct use of renewables including of geothermal resources. The Energy Strategy clearly identifies the significant part that geothermal energy will play in achieving the renewables targets, because it presents an attractive investment opportunity. The current National-led Government has replaced the NZES with an emphasis on maximizing economic growth while maintaining appropriate focus on energy security and environmental responsibility. However the 90% renewables target remains government policy. Similarly there is a target for an additional 9.5 PJ/year from biofuel and direct use geothermal above 2005 levels by 2025 (NZES and NZEECS 2011).

7.2 Resource Allocation Procedures

Resource allocation and the management of effects of development in New Zealand are handled through the Resource Management Act 1991 by local Government or the Environment Court. Over recent years efforts have been made to improve the quality of decisions and associated processes, as well as reduce the time required to obtain consents.

Within the planning environment there is provision for what is termed a National Policy Statement (NPS) established by Government to direct the local councils in deciding on consent applications. An NPS on Renewable Electricity Generation was also developed to direct councils to take account of the national significance of renewable electricity generation when considering consent applications. At the project level, central government has made submissions in support of consent applications by developers to local authorities when renewable energy projects start the resource allocation process.

7.3 Initiatives to Enable Investment

Some of the smaller geothermal electricity generation stations could be classed as distributed generation. In 2007 regulations were introduced around the connection of distributed generation to facilitate its uptake, where connection is of appropriate standards.

Like many countries, New Zealand had previously legislated splits in the electricity industry between monopoly elements (lines functions) and market elements such as electricity generation and retail, through the Electricity Industry Reform Act 1998. This effectively removed some potential geothermal investors from the market. In December 2007 the Electricity Industry Reform Amendment Bill relaxed a number of aspects in terms of:

- Allowing lines companies to more easily sell the output of generation they were permitted to own;
- Allowing lines companies to be involved in generation and retailing without limits outside their lines area, and
- Amending the definition of renewables to include geothermal and hydro (previously excluded), to allow the lines companies to freely invest in this type of renewable development.

One specific initiative to encourage geothermal investment relates to Crown wells. The Crown owned around 100 geothermal wells drilled in the 1960s, 70s and 80s under previous government exploration policies. These assets were managed by the Treasury in a caretaking role, but the existing exploration wells and the information associated with these could give potential developers greater confidence than would normally be possible with a greenfield development. Some of these wells and related assets at Kawerau have now been transferred to developers through the state-owned Mighty River Power, in what could be a model for other fields.

7.4 Bringing a Cost of Carbon to the Market

Any value placed on carbon emission has the effect of encouraging low emissions technology such as geothermal energy (for heat or electricity generation).

New Zealand Governments have brought in an emissions trading scheme which applies to electricity industry and major heat plant. While there are small costs associated with geothermally-sourced CO_2 or methane, these are minor compared to the cost penalties for fossil fuels which are the main competitors. Average CO_2-e emissions from a New Zealand geothermal station are around 30% of a combined cycle gas turbine plant or 18% of a modern coal-fired plant.

7.5 Government-Funded Research and Development

Prior to the depletion of the Maui gas field, New Zealand Government funding for geothermal research was in decline. The anticipated depletion of Maui plus the recognition of the role of geothermal as a renewable, indigenous, low carbon source for electricity generation and heat led to an increase in funding since 2006. Current funding for the Crown Research Institute (GNS Science was formerly the DSIR) is close to NZ$3 million annually with some further industry support. The University of Auckland receives approximately NZ$1 million per year from Government and industry sources. These funds are applied to research in conventional systems, low temperature resources and deep geothermal exploration.

8. CONCLUSIONS

New Zealand is currently experiencing renewed growth in terms of installed geothermal electricity generation. Direct heat use continues to grow, especially at the industrial level, with users now prepared to pay commercial rates for the supply of geothermal heat. The geothermal heat pump industry is in its infancy, but is now entering a rapid uptake phase.

This growth is generally happening without subsidies, though the costing of carbon through possible future government initiatives is providing an added incentive for businesses and individuals to invest in geothermal energy. Government continues to look at ways to encourage infrastructure investment (including in geothermal energy options) as a means to economic growth.

Consultancies that built up international portfolios of customers based on their experience in New Zealand geothermal development are splitting their services between domestic and international work. Some of the larger developers have built up considerable in-house expertise thus leaving consultants to continue to follow international opportunities. However the level of domestic service required has meant that some new consultancies have entered the geothermal arena, particularly from a civil/structural and piping/process background.

Further growth in investment is expected in coming years, but elements of the industry appear to be at sustainable levels. Training and replacement of an aging workforce remain an area for attention.

REFERENCES

____ *New Zealand Energy Strategy to 2050 – Powering our Future: Towards a sustainable low emissions energy System,* New Zealand Government (October 2007)

____ *New Zealand Energy Efficiency and Conservation Strategy: Making it Happen. Action plan to maximise energy efficiency and renewable energy.* New Zealand Government (October 2007)

____ *Developing our Energy Potential: New Zealand Energy Strategy 2011-2021 and the New Zealand Energy Efficiency and Conservation Strategy 2011-2016.* New Zealand Government (August 2011)

Barnett, P.: *Review of Current and Future Personnel Capability Requirements of the NZ Geothermal Industry.* Report prepared for New Zealand Geothermal Association by Sinclair Knight Merz (October 2005)

Brotheridge, J.: *Skills Issues in the Geothermal Industry.* Report prepared for New Zealand Geothermal Association (June 2009)

Dunstall, M.G.: 2000 – 2005 New Zealand Country Update, *Proceedings,* World Geothermal Congress 2005, Antalya, Turkey (April 2005)

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

Sinclair Knight Merz: *Assessment of Current Costs of Geothermal Power Generation*, Report prepared for New Zealand Geothermal Association (October 2009)

White, B.: Growth in the New Zealand Geothermal Industry, *Proceedings*, New Zealand Geothermal Association Seminar, Auckland (November 2007)

White, B.: *An Updated Assessment of Geothermal Direct Use in New Zealand.* Report prepared for New Zealand Geothermal Association (June 2009)

Table 1 Summary of New Zealand's Current and Future Use of Geothermal Energy for Generation and Direct Use

New Zealand Geothermal Energy Use in Generation (March 2012)	Start Date	Installed Before 2008	Installed Since 2008	Projected 2013	Planned by 2015?	Annual Direct Use
System		**MWe**	**MWe**	**MWe**	**MWe**	**TJ (net)**
Wairakei	1958	162				1120
Wairakei (Poihipi)	1996	55				
Wairakei (Te Mihi)				114		
Wairakei Binary	2008		14			
Tauhara (Te Huka) Binary	2009		23			500
Tauhara					240	
Kawerau Mills	1958	14		16		5600
Kawerau MRP and NTGA	2008		108			
Ohaaki	1986	105				400
Rotokawa and Nga Awa Purua	1997	36	139			
Mokai 1 and 2	1999	112				150
Ngawha	1998	10	15			
Ngatamariki				82		
Rotoma						
Tiketere						
Taheke						
Direct use in spas etc						1950
Total Installed Capacity (MWe)	Before 2008	494	299	212	240	9720
	By 2012		793			
	By 2013			1005		
	By 2015				1245	