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2005 – 2010 New Zealand Country Update

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ABSTRACT

New Zealand is now entering a new and exciting era of geothermal development. Historically, in the 1950's and 60'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 diminished in large part due to the discovery in New Zealand of the large and low cost Maui gas field which provided an alternative source of energy.

With forthcoming depletion of the Maui gas field, few available New Zealand hydro alternatives, commitments under the Kyoto Protocol, and availability of premium geothermal resources, New Zealand is once again recognizing the importance and value of geothermal energy to our national balance of electricity generation and direct use. Currently New Zealand's geothermal power station capacity of 600 MWe generates 10% of total generation, and expansion plans for generation from known fields at standard depths are currently underway to increase this to perhaps 15% of total generation, or even higher. Direct use has been of a similar magnitude to electricity generation in terms of consumer energy, and will continue to grow but at a lesser rate than electricity generation.

To fully utilize our geothermal resources it is essential that we manage the known resources in an environmentally sustainable way. We also need to look afresh at alternatives including deep or lower temperature resources. There also may be yet-to-be discovered resources (with no surface expressions) in the Taupo Volcanic Zone or at greater depths beneath known fields.

After low investment, there is now some growth in research funding, strong participation in research by industry partners, and the reinstatement of a geothermal training course at the University of Auckland.

1. INTRODUCTION

New Zealand is now entering a new and 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, and the anticipated cost and complexity from developing EGS systems.

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. This will be focused 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 (Table 1). A government Energy Strategy (October 2007) aims to increase renewable electricity contribution from around 65% currently to 90% by 2025. The system has a high proportion of hydro generation but with relatively little storage capacity making operation and prices sensitive to weather. Geothermal energy offers baseload energy independent of the weather, close to major load centers and at competitive development cost.

New Zealand electricity demand has been growing almost linearly for the last 30 years by about 660 GWh/year (before transmission and distribution losses of about 7.5%).

Figure 1 is taken from the 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. 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, unless electric vehicles develop at an unprecedented rate.

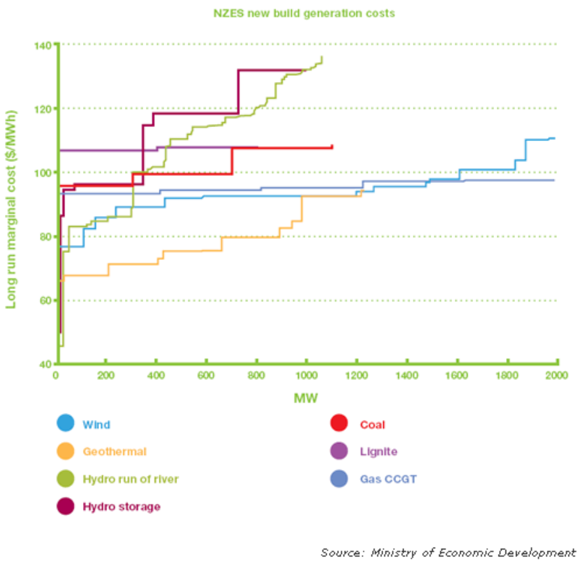

Figure 1: Long run costs for a range of generation options (from the New Zealand Energy Strategy)

The present and planned electricity generating capacity and energy requirements of New Zealand are summarized in Table 1. Information for Table 1 is sourced from the Ministry of Economic Development's Energy Data File Quarterly Updates, and from the Electricity Commission website. The estimate for geothermal installation could be conservative given that several unnamed exploration programs have not been included.

2.2 Geothermal Electricity Generation

Descriptions of geothermal developments are given in Section 4 of this update and are summarized in Table 2 at the end of this report.

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 1,100 MWe available, utilizing existing technology. These projects alone can meet more than a decade of national demand growth. With a capital cost of around NZ$4million/MWe (SKM unpublished), this equates to a $4 billion development program over the next decade or so.

Figure 2 shows historic generation of electricity from geothermal sources, including station names, capacity and commissioning dates. Four significant phases of development can be seen with the latest phase evidenced from 2005 based on earlier preparatory work, and is expected to be the most significant phase.

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 has seen station output returned and maintained above 60 MWe from late 2008. While these steps do not represent increases in installed capacity, they do represent low cost gains in generation.

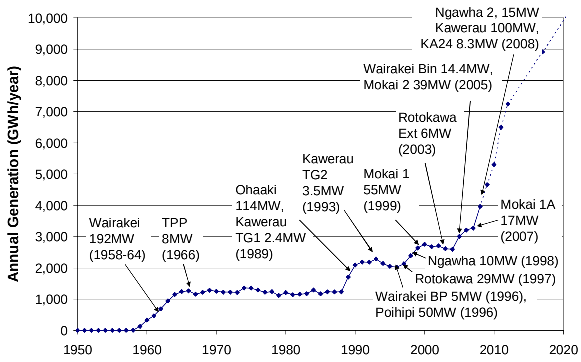

Figure 2: Historical and projected growth in geothermal electricity generation in New Zealand

A wide range of new generation projects have been announced as indicated in Table 2, with principal sources of announced projects being Mighty River Power (a public generator-retailer) and Contact Energy (a private generator-retailer). Both of these companies have announced billion dollar investment programs.

There are also several developments outside of these companies including Maori Land Trusts e.g. Tuaropaki, Tauhara North No 2 and Geothermal Developments Ltd.

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. The proposed Te Mihi development not only replaces the old Wairakei plant but is expected to provide a further 65 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 time of the previous country update it was difficult to find one company that could competently install a heat pump system, but there are now multiple companies that can provide these services as part of a wider suite of home or commercial energy services. The majority of applications appear to be water-sourced.

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 must now start to work together, especially in ensuring that the quality of advice and installation is adequate so the industry is not negatively impacted at its outset.

3.2 Other Geothermal Direct Use

Direct use in high temperature fields is outlined in the following section, while all national direct use is summarized in Tables 3 and 5 at the end of this paper, as reported in 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, glasshouse heating, 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 56% of national geothermal direct energy use. This remains the largest single geothermal industrial use in the world (at the time of writing), and the supply is set to expand further to adjacent industrial users.

The following graph shows that direct use growth has been of a similar magnitude in terms of consumer energy over the last 50 years.

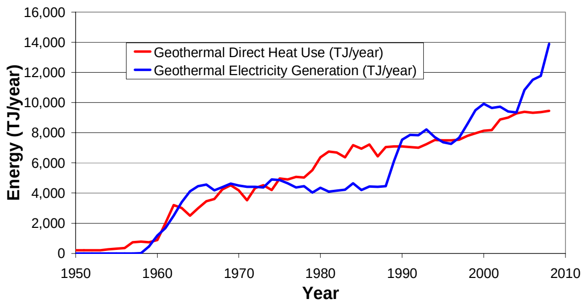

Figure 3: Historical comparison of electricity generation and direct use in New Zealand

The most noticeable areas of growth are associated with the Kawerau, Wairakei, Mokai and Tauhara fields frequently linked to existing or planned electricity developments. There is ongoing domestic/commercial installation in Tauranga and renewed interest in Rotorua as the Plan related to resource allocation is revised by local authorities.

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 has proceeded to secure consents for another “Geotherm” 50 MWe station. Development plans, the consents and an associated drilling operation were all offered on the market by receivers in 2008. Bids closed on 1st September 2008 and a decision is still pending.

The next major development associated with Wairakei is likely to be 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 225 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 65 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 was expected to be commissioned in 2011, but Contact has since announced a delay in key project decisions at the time of writing.

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 has consents for a limited development on the Tauhara field. A 20 MW_{th} steam supply to the direct use Tenon kiln drying facility has already been developed by Contact in 2005/6. Contact is now proceeding with the 23 MWe Centennial Drive station, for which construction of the Ormat units is well advanced and which should be commissioned in 2010.

Contact undertook new exploration drilling on the Tauhara field in 2005/6 and continued through to 2009 though 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. Consequently, Contact is in the process of developing concepts for a 225 MWe station and has started public consultation with a view to obtaining consents later in 2009 and commissioning in 2012.

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. Such concerns may be an impediment to more Tauhara development, but the initial small-scale Centennial Drive project may help to allay residual concerns, enabling more development on the Tauhara field. 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 to 114 MWe in 1989 though has been restricted in output through resource issues. Beginning in 2006, Contact has invested in new wells and their connection to bring the station generating capacity up to 65 MWe from a low of around 25 MWe. Efforts will now be directed at maintaining this new level of operation, including reviews of alternative production and injection strategies to minimize concerns over subsidence affecting flood-sensitive properties by the Waikato River.

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.

Until recently the steamfield management committee included representatives of Tuaropaki Trust, Mighty River Power (MRP) (as field/station operators and minority shareholder in TPC) and Contact Energy (who held geothermal development rights over a portion of the field under Pukemoremore Dome in the east). In 2007 Contact sold its interests to TPC, enabling TPC to commence active drilling and testing with a view to further expansion. Two wells were drilled in the vicinity of Pukemoremore in 2008. It is understood that TPC is currently considering its development options.

4.5 Kawerau Developments

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 is hot and has some very productive wells (including some of the world's most productive wells at various times) making development particularly attractive economically.

Putauaki Trust, a land owner to the east of the mill, reached agreement with Mighty River Power for the exploration of the eastern part of the field for electricity development. Four exploration wells were drilled in 2004, but the largest output wells were still found near the mill. Following further negotiations with Putauaki Trust, mill interests, government and Ngati Tuwharetoa Geothermal Assets, Mighty River Power obtained consents for the development of a 90 - 100 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 is the single largest step in New Zealand's geothermal generation since Ohaaki in 1989.

At an early stage in this process the Crown's stake in the wells and steamfield assets supplying the Kawerau mill were transferred to Ngati Tuwharetoa Geothermal Assets (NTGA). NTGA has already indicated a desire to be an active developer, having discussed expanded steam supply options with parties in the Kawerau area.

At the time of asset transfer from the Crown, 3 wells were separated out for different treatment. One of these was KA24. In a very low key development, the KA24 land owners have secured benefits under the now defunct Projects to Reduce Emissions scheme, secured resource consents, and signed a turnkey contract with Ormat to develop a further 8.3 MWe of power from the otherwise unused well. This project was commissioned in September 2008.

Further development on the Kawerau field was announced in May 2009. NTGA will supply a large Svenska Cellulosa Aktiebolaget tissue mill adjacent to the Norske Skog Tasman mill with steam from late 2010.

4.6 Rotokawa Developments

It has been known for many years that the Rotokawa field is very large, hot and permeable and has significant potential for large scale development. 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 resulting in a decision to proceed with a major new power development through a joint venture. Consents were obtained in December 2007, EPC contracts were let in April 2008 and construction work is now well advanced. When the Nga Awa Purua triple flash, single Fuji unit development of 132 MWe at Rotokawa is commissioned in May 2010 it will be the largest development in New Zealand after the initial development of Wairakei 50 years ago, and the largest single geothermal turbine in the world.

4.7 Ngatamariki Development

The Crown drilled 4 wells at Ngatamariki in 1985 and the field is recognized as a good prospect. Mighty River Power recently obtained consents for exploration drilling and has commenced testing of the original wells. Three new wells were drilled and tested in 2009 with encouraging results.

Applications for consents for a 100-130 MWe development have been lodged through a joint venture.

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 the Ngawha 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 one other 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). Rotoma No 1 Trust has now submitted a resource consent application for a 35 MW geothermal power station development.

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 (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 but is thought to have lesser growth potential than the electricity market.

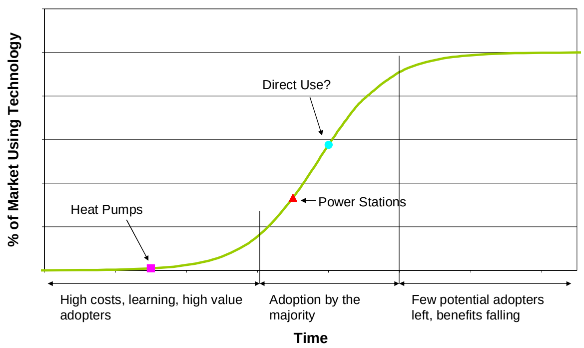

Figure 4: Generic cumulative adoption paths for a range of geothermal technologies in New Zealand

6. PERSONNEL

The New Zealand Geothermal Association has undertaken personnel surveys at the beginning (Barnett (2005)) and end of this period (Brotheridge (2009)), and these figures have been entered into Table 7. There are indications that personnel numbers leveled at 320 people across the various sectors in 2009 from 280 people in 2005. About 60 of the current geothermal professional personnel work directly for the two major developers (Contact Energy and Mighty River Power). What is not obvious in this table is the step increase in numbers prior to 2005 from a base of less than 100 full time equivalents across New Zealand (Dunstall (2005)) as all companies prepared for the major domestic investment projects in planning.

Within the total number of people employed, there are currently about 250 consultants including university staff and the combined research/commercial consulting “Crown Research Institutes” which have consulting duties split between New Zealand and international work. An estimated 40% to 50% of the consultancy work is on international projects in both science and engineering. The larger developers have built up their own in-house expertise 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 the expected EGS and Hot Sedimentary Aquifer (HAS) developments in Australia, then the workload of these consultants will increase.

The increasing workload has meant that consultancies previously without geothermal experience have also entered the scene, particularly focused on civil aspects, but also in terms of piping and process design, under the direction of experienced geothermal engineering personnel.

Within the consultancies are cores of senior staff with broad geothermal skills. Many of these are nearing retirement age raising the issue of succession and ongoing training requirements. Similar succession issues are being faced by the major developers. At the tertiary education level, specialist geothermal training courses have now been re-introduced by the University of Auckland. In the past, such courses attracted international students, partly due to the support of New Zealand government aid funding. The current courses are now attracting increasing numbers of New Zealanders.

7. INVESTMENT

Table 8 shows the step increase in investment from the previous half decades. Five year investment has lifted to around US$1billion from previous levels of around US$140million. This is still weighted in favor of public (government) investment (through Mighty River Power), but a further increase in investment level and a swing towards private investment is expected as Contact Energy proceeds with Wairakei replacement and the new Tauhara project. Maori Trusts may also increase their involvement in the investment scene.

Another indication of investment activity has been well drilling activity. Expenditure on wells is summarized in Table 6. The following graph shows that numbers of wells drilled is also now up to previous record levels. The wells being drilled now tend to be of greater depth and diameter than the earlier New Zealand wells.

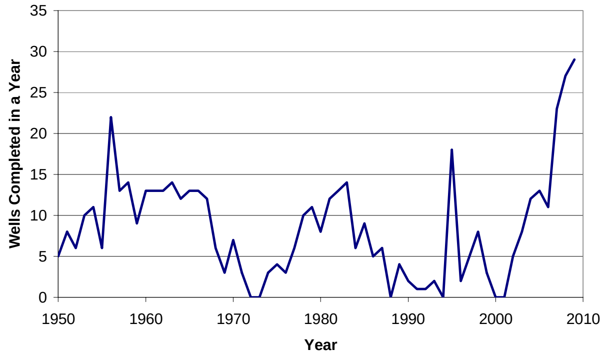

Figure 5: Historical record of wells drilled (for electricity, investigation or Kawerau direct use)

8. 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.

Any discussion of Government initiatives to encourage renewables (and therefore geothermal) development is complicated by a change of Government at the end of 2008. The new National Party-led coalition Government is reviewing a number of past initiatives and putting greater emphasis on economic growth, especially in the face of global recession, and security of supply.

8.1 A New Zealand Energy Strategy

In 2007 the "New Zealand Energy Strategy to 2050" (NZES) and the "New Zealand Energy Efficiency and Conservation Strategy" (NZEECS) 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 new Government has announced that the NZES will be updated 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.

8.2 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 the last five years efforts have been made to improve the quality of decisions and associated processes, as well as reduce the time required to obtain consents. The new National-led Government is taking further steps to improve the process.

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. In this context an NPS on Electricity Transmission was developed in 2008. This gives clear direction to the Regional Councils under the Resource Management Act requiring these decision makers to consider the national significance of a reliable and secure electricity supply when assessing transmission proposals. Transmission constraints can impact on the rate of generation development.

Similarly, an NPS on Renewable Electricity Generation is being developed to direct councils to take account of the national significance of renewable electricity generation when considering consent applications. This is continuing under the new Government.

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.

8.3 Local Authority Initiatives

At local government level, Environment Waikato's (EW's) Regional Policy Statement and its Regional Plan with respect to geothermal development has been revised. These are key regional planning documents under the Resource Management Act. About 80% of New Zealand's high temperature geothermal resources are thought to lie in EW's region. These documents enable developers to identify resources that can be readily developed and target their attention accordingly. Environment Bay of Plenty (which is responsible for almost all of the other high temperature resources, and which currently has 66% of direct use by energy in its area) is now looking at revision of their planning documents and may partly model these on EW's documents.

8.4 Bringing a Cost of Carbon to the Market

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

The Government recognized Kyoto Protocol obligations through the Climate Change Response Act 2002. As an interim measure this Act introduced a scheme known as Projects to Reduce Emissions in which carbon credits could be tendered for. There have been several geothermal projects, including the Kawerau KA 24 development that benefitted from this, though the scheme was subsequently effectively scrapped.

In 2008 Parliament passed the Climate Change (Emissions Trading) Response Bill which amended the earlier Act to establish an emissions trading scheme (ETS). However, under the new Government, the ETS is being reviewed by a Special Select Committee to ensure appropriate design.

8.5 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.

8.6 Treaty Settlements and the Role of Indigenous People in Future Development

A central document in the establishment of New Zealand as a nation was the Treaty of Waitangi signed in 1840 between the British Crown and representatives of many of the indigenous Maori tribes. In recent decades the Government has addressed restitution for past actions which were not in the spirit of this Treaty through Treaty Settlements and the Waitangi Tribunal. A number of settlements have recently been reached that relate to tribes with geothermal interests. The outworking of these settlements has already seen former government-owned steamfield assets at Kawerau pass to one company representing Maori interests (Ngati Tuwharetoa Geothermal Assets).

Maori-owned land is often held on a collective basis by internally managed Trusts. The various Trusts have diverse interests but, where they own land over geothermal resources, frequently have a strong interest in geothermal development whether for tourism, heat supply, electricity generation or thermophylic organisms. They already have a kaitiakitanga (or guardianship) role.

8.7 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.

9. 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.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in January 2009	570	4,050	3,360	14,630	5,480	22,090	0	0	wind 360 biogas 30 wood 45	1,050 200 320	9,845	42,340
Under construction in January 2009	150	1,400	200	90	20	80	0	0	wind 170	640	540	2,210
Funds committed, but not yet under construction in January 2009												
Total projected use by 2015	1,200	8,900	3,600	10,200	5,600	22,600	0	0	wind 1,500 biogas 40 wood 55 marine 2	5,200 300 400 5	11,995	47,600

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2008

1) N = Not operating (temporary), R = Retired. 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) Data for 2008.

4) Totals exclude retired plant

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe	Annual Energy Produced 2008[3)] GWh/yr	Total under Constr. or Planned MWe
Wairakei	Wairakei	1958-63	4	R	4 HP - BP	36		
			9	Op	2 IP - BP 4 LP - C 3 MP - C	157	1216	
		1996	1		1 LP - BP	5		
	Wairakei Binary	2005	3		B	14.4	128	
	Poihipi	1996	1		D	55	349	
	Te Mihi (replacement for Wairakei)							220
	Geotherm							55
Kawerau	Tasman BP	1966	1	R	1 BP	10		
	Tasman BP	2004	1	Op	1 BP	8	43	
	TG1	1989	2		B	2.4	8	
	TG2	1993	1		B	3.5	26	
	KA24	2008	1		B	8.3	30	
	Kawerau	2008	1		2F	100	366	
Reporoa	Ohaaki	1989	2	R	1 HP - BP (ex-Wairakei)	11		
				Op	1 HP - BP (ex-Wairakei)	11	549	
		1989	2	Op	1F	92		
Rotokawa	Rotokawa	1997	4		H (1F, B)	29	273	
	Rotokawa Extension	2003	1		B	6		
	Nga Awa Purua				3 F			130
Northland	Ngawha	1998	2		B	10	140	
	Ngawha 2	2008	1		B	15		
Mokai	Mokai 1	1999	6		H (1F, B)	55		
	Mokai 2	2005	5		H (1F, B)	39	927	
	Mokai 1A	2007	1		B	17		
Tauhara	Centennial Drive				B			23
	Tauhara							220
Ngatamariki	Ngatamariki							80
Rotoma	Rotoma							35
Total[4)]			42			628	4,055	763

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2009 (other than heat pumps)

[1] 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)

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

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

[4] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] 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

[5] 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 (^{o}C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity Factor[5]
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	
Northland	B		24	22			0.2	22	6	0.95
Auckland	B		50-65	30			2.45	64	58	0.75
Waikato	B, O, H, D, G, I, F						148		3,250	0.70
Bay of Plenty (misc)	B, O, H, D, G						49		943	0.61
Bay of Plenty (Kawerau)	I						184		5,224	0.90
Gisborne	B		50-100	35			0.004	0.1	0.12	1.00
Hawke's Bay	B		50-62	40			0.09	2	2.8	1.00
Taranaki	B		27				0.016	0.1	0.24	0.49
Canterbury	B		52	24			0.95	8	15	0.50
West Coast	B		55-60	36			0.44	5	14	1.00
TOTAL							385		9,513	0.78

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184
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. (^{o}C) - outlet temp. (^{o}C)] 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]	19	181	0.30
Air Conditioning (Cooling)	-	-	-
Greenhouse Heating	24	379	0.50
Fish Farming	17	273	0.50
Animal Farming	-	-	-
Agricultural Drying[5]	-	-	-
Industrial Process Heat[6]	224	6,104	0.86
Snow Melting	-	-	-
Bathing and Swimming[7]	74	1,733	0.74
Other Uses (irrigation, frost protection, geoth. tourist park)	28	843	0.97
Subtotal	386	9,513	0.78
Geothermal Heat Pumps		39	
TOTAL		9,552	

[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 FROM JANUARY 1, 2005 TO DECEMBER 31, 2009 (excluding heat pump wells)

[1] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)					
Production	>150° C					
	150-100° C	-				
	<100° C	-				
Injection	(all)					
Total				103		

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)
2005	37	15	13			216
2006	38	20	20			217
2007	40	21	27			217
2008	41	30	33			218
2009	41	30	33			218
Total	197	116	126	0	0	1086

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) 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$	%	%
1995-1999	4	30		120	70	30
2000-2004	13	40		80	20	80
2005-2009	88	483		577	42	58