UPCOMING GEOTHERMAL ENERGY DEVELOPMENT IN NEW ZEALAND

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Abstract

This paper looks at the upcoming geothermal developments in New Zealand. Major sustained development is expected in the electricity generation sector for the next 15 to 20 years, possibly with a boom over the next 5 to 10 years. Continued growth is expected in terms of geothermal heat supply and direct use.

This paper attempts to give context to these expectations of growth, pointing out that the growth has already started in terms of major investment by national generators. There is sufficient resource available at readily consentable sites to sustain growth expectations for the period mentioned above.

Geothermal energy is one of the key forms of renewable energy that the Government is now trying to encourage through a range of initiatives. A key role for geothermal energy is recognised within the New Zealand Energy Strategy.

As the potential and current viability of geothermal investment is recognised by others then a greater variety of investors can be expected in the New Zealand context, and is already in evidence.

Manufacturers and suppliers must consider how they can maximise their content within these projects valued in excess of NZ$4 billion over the next 20 years.

Introduction

Geothermal development is happening now because:

- there are consentable geothermal resources available (over 1,200 MW in capacity)
- development of the better (higher temperature, more productive) resources is commercially viable for electricity or heat
- development can be done in stages, which reduces resource risk, and avoids suppression of electricity market prices possible in periods of oversupply
- initial developments on geothermal fields have given investors sufficient confidence to warrant further expanded investment in proven sites
- developers (such as Contact Energy and Mighty River Power) have established teams of sufficient skill and critical size to enable a series of projects to be brought on line progressively, while others (such as Genesis Energy, and possibly Meridian in the heat market) are in the process of doing this
- long term relationship building between landowners (including several Maori Trusts) and developers is leading to resource access
- New Zealand has world-class expertise in geothermal development that is marketed in many parts of the world (and especially in countries like the Philippines and Indonesia, and now Australia)
- much of the technology is proven
- geothermal energy has many attractive characteristics including independence from weather, good baseload generation, low emissions and relative proximity to major load centres like Auckland (say compared to South Island hydro sites).

Some Government Initiatives

The Government released the New Zealand Energy Strategy in October 2007 (Ref. 1), including a target of generating 90% of our electricity from renewable sources by 2025. To assist this goal, a moratorium on the building of new thermal power stations has been imposed (now legislated) unless for security of supply reasons. One figure (Figure 1 below) in that report is highly illustrative of the current drivers for geothermal investment, at least in terms of electricity generation. The fat grey line in Figure 1 shows the effective price of the cheapest thermal generation under the assumptions of the Energy Strategy analysis. Below this line there are cheaper options including about 300MW of hydro (load factor about 50%), between 400 and 1400 MW of wind (load factor about 42%) and about 1000 MW of geothermal (load factor about 93%). If electricity demand growth is about 800 GWh/year (2%/annum increase over current demand), these renewable energy options equate to 1.6 years of growth for hydro development, 1.8-6.4 years for wind and 10.2 years for geothermal i.e. based on the Energy Strategy assumptions on a purely economic basis there could be 14 to 18 years before it is sensible to build new thermal generation[1].

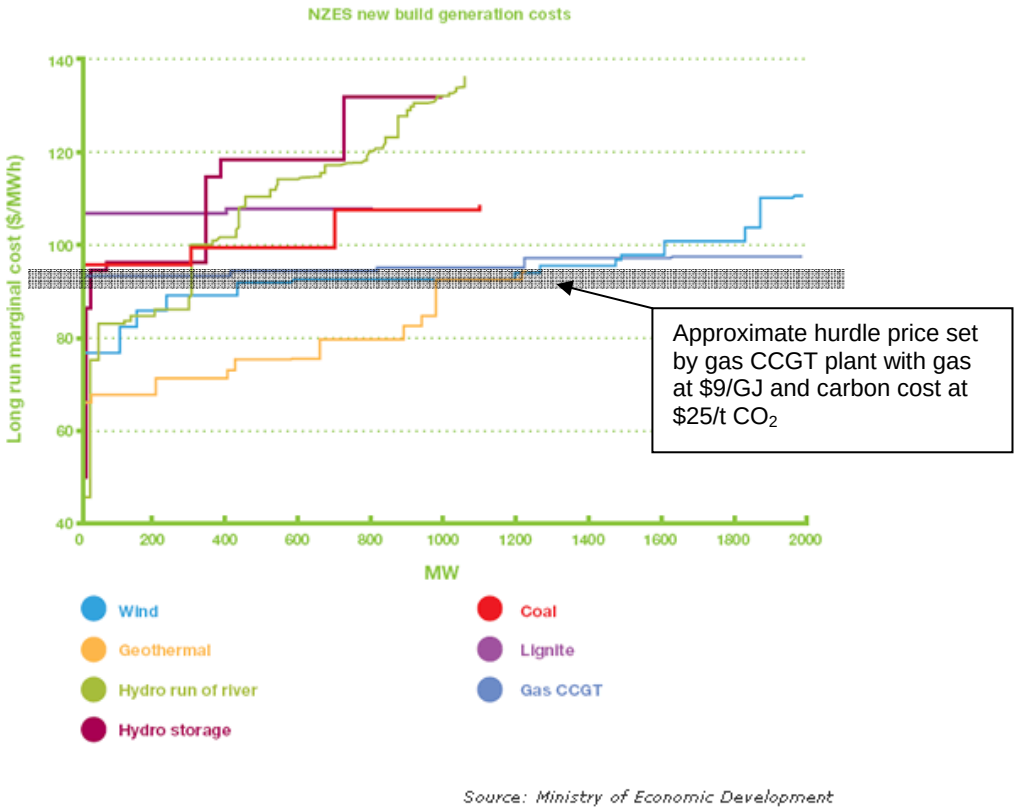

Figure 1: Long Run Costs for a Range of Generation Options (from the New Zealand Energy Strategy)

Beyond broad goals in terms of growth, the Government has initiated a number of other steps that aim to allow a more aggressive approach to development of renewable energy resources. These have included:

- ongoing review of the Resource Management Act with a view to streamlining of processes
- preparation of a National Policy Statement on Renewable Electricity Generation that should ensure that Councils take into account the national significance of renewable electricity generation projects
- submissions by EECA and MED supporting the promotion of renewable energy projects in Regional Plans and Policy Statements and in the resource consent process
- support for distributed generation options through implementation of regulations
- enabling line companies (historical investors in smaller scale generation including geothermal projects) to more easily invest in generation through relaxation of the Electricity Industry Reform Act provisions
- reviews of our transmission system with a view to enabling construction and dispatch of renewable energy projects
- establishment of a pilot feasibility study grant scheme through EECA to encourage new investment
- ongoing funding of research and development through FRST

[1] These are crude assumptions. Estimates could be greatly reduced if old thermal plant was retired.

- and most recently (and possibly most significantly) through carbon pricing/emission trading mechanisms, and a current moratorium on construction of new coal/gas/oil-fired stations (except for security of supply reasons).

One specific government-led project can be used in this paper to illustrate many current and impending developments. The "transmission to enable renewables" studies undertaken by Transpower and the Electricity Commission have included attention on the "Wairakei Ring Main" portion of the national grid (see Figure 2). With the very strong growth of geothermal development in the region of Taupo through to the Bay of Plenty (known as the Taupo Volcanic Zone), the Wairakei Ring does pose a partial blockage in the short to medium term for which plans will be required to address this.

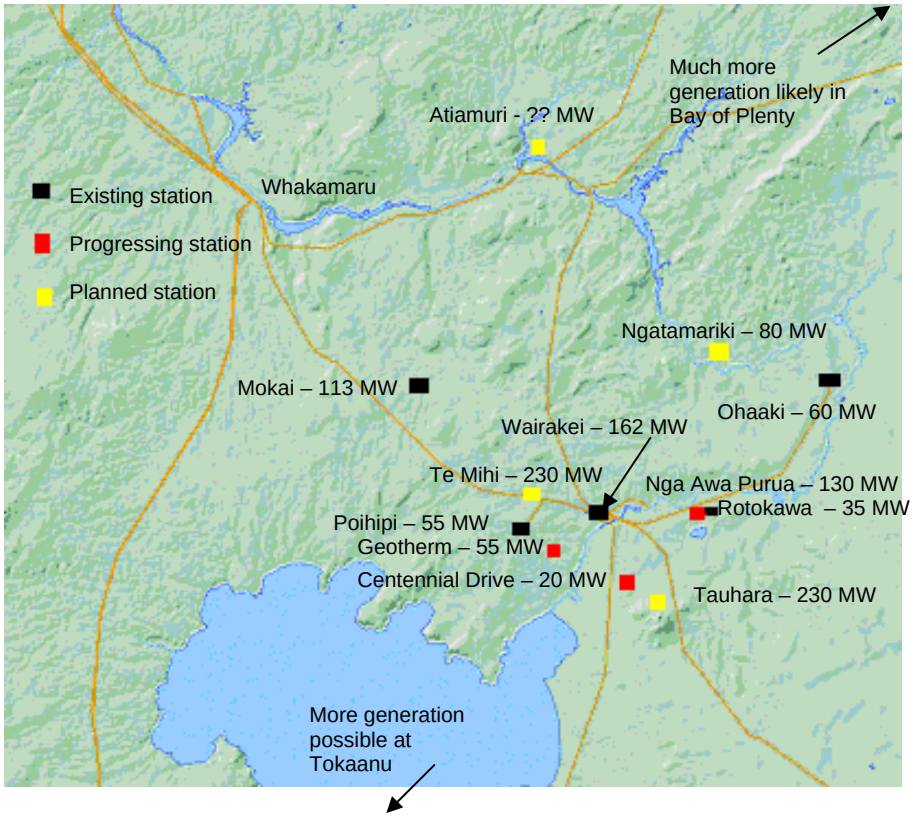

Figure 2: Wairakei Ring Area Between Wairakei and Whakamaru and Associated Geothermal Generation (Basemap from Transpower)

Mighty River Power has pointed out the need for some reinforcement before 2011 to avoid constraints. Transpower is currently aiming for a 2015 completion of Ring redevelopment, this being the earliest that a transmission reinforcement project could be completed by. Transpower's view has been that the Wairakei Ring can handle an additional 150 – 200 MW but with increasing levels of congestion (Ref. 2). Any generation south of the Ring (including from Tokaanu) or reinforcement of the HVDC link will increase constraints. Since 2007, effective geothermal generation in the area has increased by about 75 MW from existing stations at Poihipi and Ohaaki and expansion at Mokai. With over 580 MW of new geothermal generation either under construction or announced and to be constructed by 2013, the system will clearly be stressed.

The Geothermal Technologies

A recent report (Ref. 3)) has outlined a range of energy development options from geothermal heat pumps through heat applications to conventional high temperature electricity generation all with progressively narrower areas of application. These are summarised in Table 1.

Geothermal Heat Pumps

Geothermal heat pumps fall at the extreme end of the range of technologies that might be called "geothermal". The general concept of heat pumps for heating (or cooling) space or water is well known. Geothermal heat pumps (like air-source heat pumps) just extract heat at ambient conditions from rock, soil or groundwater, and do not require elevated temperatures to work successfully. Dunedin International Airport

space heating/cooling system is a recent example of a geothermal heat pump application, for which heat exchange is with groundwater. Several projects have been or are being investigated e.g. for the Supreme Court and for the renovated National Library, pointing to growing national interest.

Many of the New Zealand geothermal heat pump systems extract heat from ground water. They could equally extract heat from seawater as an option. Internationally, the most common method is through use of buried pipes (about 1 m depth) with heat being exchanged with the ground.

Table 1: Comparison of potential geothermal applications and associated resource location (Ref. 3)

	Geothermal Heat Pump Applications	Enhanced Systems for Heat (or Electricity)	Conventional Heat Applications	Electricity Generation
Location				
Comments	• Potential national application • Best areas have not been defined	• Potential national application • Best areas have not been defined • Basic research is required	• Localised application • Data is being collected • Resource size is being assessed under low temperature research funded by FRST	• Narrowly defined resources • Some resources are effectively protected from large scale development

Enhanced/Engineered Geothermal Systems

These systems take advantage of the natural temperature gradient found anywhere. In New Zealand, temperatures generally rise by about 35^{o}C per km of depth. Thus some of our deeper oil and gas wells (drilled to about 5 km) have found temperatures exceeding 150^{o}C which is useful for a range of heating applications and for the generation of electricity. If natural water reservoirs are not found in these systems, then rock can be fractured to create a reservoir, and production and injection wells can be used to flush the heat out from the rock matrix. Surface equipment can be of the type already proven on lower temperature geothermal fields. The challenge with these systems is to create and sustain the artificial reservoir to maximise the extraction of heat from the rock. Potential applications are widespread but some basic research is required at this stage.

The initial developments with this technology may be demonstrations on proven geothermal fields where some relatively impermeable but hot margins may have been identified. If this technology is developed in New Zealand then the resource capacity may increase by orders of magnitude, though much of this will not be currently economic.

Conventional Heat Applications

At a commercial or industrial level geothermal heat supplies are normally based on supplies from wells (as opposed to springs as might be the case for some swimming baths). Steam and water can be separated in a conventional cyclone separator. The steam and/or water can be used directly in some processes. However the steam contains some non-condensable gases (mainly CO_2 and some H_2S), so for condensing processes, some gas extraction (e.g. steam jet ejectors) or further heat exchange will be required. The water/brine contains dissolved minerals, some of which could deposit in pipes and equipment. Thus either conditions are managed to prevent deposits or heat exchangers can be used to isolate the process from the geothermal fluids.

These types of applications are used in conventional geothermal fields. There are many fields around the country (both North and South Islands) where temperatures may be 40 to 70°C. In the Taupo Volcanic Zone (and at Ngawha in Northland), there are high temperature fields where reservoir temperatures can be in the range 230 to 340°C. The process of extracting the fluid from the reservoir involves dropping the pressure which reduces the temperature normally to the 150 to 200°C range to ensure sufficient flow from wells. This is still hot enough for a wide range of applications.

Electricity Generation

Electricity generation can only be undertaken commercially on the high temperature fields currently. The fluid collection and disposal system for these developments is similar to heat applications, consisting of:

- Wells with multiple casings typically drilled to 2 – 3 km deep
- Separators and associated water vessels – large pressure vessels originally of New Zealand design that separate the phases through centrifugal action.
- Pipes of various sizes for taking the steam-water mixture from the wells to the separators, then steam to turbines or heat exchangers, or water to reinjection wells or to other heat exchangers, and condensate to reinjection.

Power station designs are described in many papers, but the broad types of stations include:

- Simple back pressure turbine
- Condensing turbines (potentially receiving steam at up to 3 different pressures)
- Binary cycle plant (these are essentially reverse refrigeration cycles taking advantage of the organic Rankine cycle. A more recent innovation uses a working fluid that is a mix of ammonia and water and is known as the Kalina cycle)

Some research is now being undertaken in New Zealand on use of Stirling engines to generate electricity from geothermal energy or waste heat sources.

Other than the Kalina cycles and Stirling engine research, much of this technology is considered well proven though subject to ongoing development, with some new entry manufacturers getting involved.

Common practice on a number of our high temperature fields is to have a hybrid plant consisting of back pressure turbines discharging at just above atmospheric pressure then using binary cycle plant to condense the steam. Binary plant may also be used to extract heat from brine.

Historical Growth and View Forward

Maori have used geothermal resources from the earliest times. With the European arrivals, formal bathing facilities were developed focused on surface springs and (later on) wells. Early commercial developments included use of geothermal hot water from wells in association with flax treatment. Uptake on a larger scale began with post-World War 2 electricity crises and included development for both direct use and for electricity generation as illustrated in Figure 3 (based on Ref. 4).

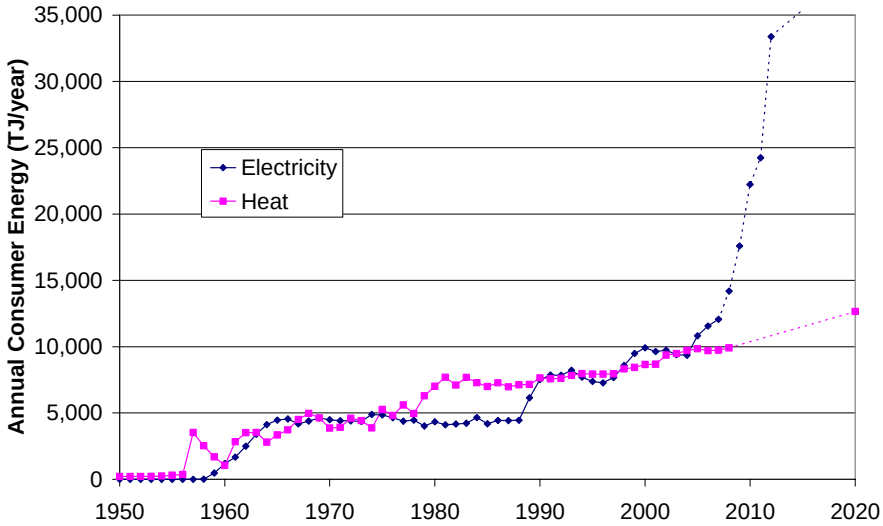

Figure 3 Historical and Projected Growth in Geothermal Direct Use and Electricity Generation

From Figure 3 the overall growth trends are obvious. There are some underlying factors that are worthy of comment.

The direct use trend appears comparatively steady, though this is partly due to the approximate nature of a lot of the domestic data. The initial jump in 1957 was associated with the commissioning of the geothermal steam supply to the Kawerau pulp and paper mill. The Kawerau steam supply has been upgraded and increased on a number of occasions subsequently and still accounts for about half of all New Zealand direct use and half of the total world industrial use of geothermal energy. The steamfield assets associated with Kawerau supply were transferred from Treasury to Ngati Tuwharetoa Geothermal Assets in 2005 marking a new aggressive approach to the development of the Kawerau assets. It is understood that discussions have been held on increased supply of steam for direct use or electricity generation.

Not obvious in the direct use trend is the surge in domestic use through the early 1960s and 1970s associated with energy crises, then subsequent domestic reduction following Rotorua bore closures in 1987 and associated introduction of a royalty regime (now abandoned). The severity of domestic reductions was partly masked in the trend above by another step increase in Kawerau steam supply. Domestic confidence has taken some time to recover, though fresh investment is taking place in areas like Tauranga currently.

Some of the most recent growth in direct use is actually linked to electricity projects or to electricity developers. The Wairakei Prawn Farm is an example where use is made of rejected hot water, as is another timber kiln at Ohaaki. At Mokai, a well otherwise too small to connect to the power station has been used to heat a major glass house (total area is 13 ha). A kiln development by Tenon at Taupo is supplied by steam since 2006 from Contact Energy. Contact is generally looking for other heat supply options on a commercial basis.

Development of electricity generation has clearly been more erratic/stepwise. There was a burst of growth associated with Wairakei 50 years ago, then Ohaaki about 20 years ago, a range of projects in the late 1990s, and the current growth of generation evident over the last 4 or 5 years. Figure 3 projects significant growth over the next 5 years or so, and the specific projects associated with this growth are discussed in the following pages.

Wairakei Geothermal Developments

Wairakei celebrates 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 MW binary cycle plant to make use of water brought down to the area near the station for reinjection purposes. Total effective installed capacity at the original Wairakei site is now 176 MW.

In 1996 a farmer over the field worked with a number of companies to develop the 55 MW 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. However, the original developer has proceeded to secure consents for another “Geotherm” 55 MW 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 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 MW 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 MW using the same resource consents. Consents 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 finalised in September 2008. The plant is expected to be commissioned in 2011.

Tauhara Geothermal Developments

Contact has consents for a limited development on the Tauhara field. A 20 MW_{th} steam supply to the Tenon kiln drying facility has already been developed by Contact in 2005/6. Contact now plans to use the balance of the consent allowance for the construction of the 23 MW Centennial Drive station, for which a contract has already been let to Ormat and which should be commissioned in 2010.

Contact undertook exploration drilling on the Tauhara field in 2005/6 though wells had been drilled in the field for many years before this. These new wells showed the field was hotter and larger than previously expected, thus making public estimates of field capacity into underestimates. Consequently, Contact is in the process of developing concepts for a 225 MW station and has indicated that public consultation will start on this in 2009 with a view to obtaining consents later in the year and commissioning in 2012. The intention is to make this station largely a clone of Te Mihi.

The Tauhara field partly underlies Taupo township. In the past there have been concerns about geothermal-induced subsidence and hydrothermal eruption risks. If the new developments do not appear to result in adverse effects, helping to allay residual concerns, then more development may be possible on the Tauhara field at a later date.

Ohaaki Geothermal Development

Ohaaki was originally developed to 114 MW back in 1989 though has been restricted in output through resource issues. In the last two or three years, Contact has invested in new wells and their connection to bring the station generating capacity up to 60 MW from a low of around 25 MW. Efforts will now be directed at maintaining this new level of operation, rather than any substantial new initiatives at Ohaaki.

Mokai Geothermal Developments (Tuaropaki Power Company)

Historical developments at Mokai have included progressive development up to 112 MW of electricity generation using hybrid binary cycle technology by the largest independent private generator of electricity nationally (Tuaropaki Power Company), and significant supply of heat to a major glass house operation.

Until recently the steamfield management committee included representatives of Tuaropaki Trust, Mighty River Power (as field/station operators) and Contact Energy (who held geothermal development rights over a portion of the field under Pukemoremore). In 2007 Contact sold its interests to Tuaropaki Power Company, 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, but TPC may have interest in some geothermal investment in other areas.

Kawerau Geothermal Developments

Kawerau field has been subject to the longest term commercial development of any field in New Zealand with the initial steam supply to the Kawerau mill commencing in 1957. A small geothermal generator was installed in 1966 and was finally replaced by Norske Skog Tasman in 2006. The initial development has been followed by progressively increasing use with some effect on shallower reservoir zones in terms of drawing in fluids from the surface, but almost negligible effect on the deeper reservoir. A small amount of generation was installed around 1990 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.

Rough indications are that the field can sustain over 400 MW equivalent of generation, though existing wood processing facilities will want a cautious approach to development. The field is hot and has some very productive wells (including some of the world's largest wells at various times) making development particularly attractive economically.

Putauaki Trust, a land owner on the other side of the road from the mill, bid out development rights under their land in 2003, with Mighty River Power winning the bid. Exploration wells were drilled in 2004, but the

greatest potential development wells were still found in the mill vicinity. 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 MW 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 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 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 MW of power from the otherwise unused well. This project was commissioned in September 2008.

Further development on the Kawerau field is possible and could be planned.

Rotokawa Geothermal Developments

Earliest drilling at Rotokawa was undertaken in 1965, but the first development of electricity took place in 1997 with the commissioning of a 29 MW hybrid binary cycle plant, later expanded to 35 MW so that greater use could be made of the changing energy from the wells. It has been known for many years that the Rotokawa field is very large, hot and permeable and could sustain a development of around 300 MW.

Through 2003/4/5 Mighty River Power were active in drilling further exploration wells. Further negotiations took place with local 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. Consents were obtained in December 2007, EPC contracts were let in April 2008 and site foundation work is now well advanced. When the Nga Awa Purua development of 132 MW 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.

Ngatamariki Geothermal Developments

The Crown drilled wells at Ngatamariki in 1985 and the field is recognised as a good prospect. Mighty River has recently obtained consents for exploration drilling and has commenced testing of the original wells. A drilling rig is due on site shortly. Ngatamariki would be developed in partnership with a local trust and may be of the order of 80 MW in size. Commissioning is likely by 2012 if all goes well.

Ngawha Geothermal Developments

Ngawha was first drilled in 1964 but its first development was undertaken by the local electricity lines company Top Energy in association with local Maori Trusts with a 10 MW Ormat binary plant installed in 1998. In October 2008 the Ngawha 15 MW extension was being commissioned. These projects owe much to the dedication of two individuals. With death and retirement of project champions, it is not clear that further development will take place.

Rotoma Geothermal 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 development.

There are some rival interests over the resource and appeals have been lodged.

However, there are several possible developments of this nature in the Rotorua area and these should progressively move forward.

Potential Developers

From the previous discussion, the involvement of Contact Energy and Mighty River Power is clearly evident. Their interests can be seen in comments made in the 2008 Annual Reports of the respective companies. The Executive Officer's report within Contact's Annual Report (Ref. 5) discussed a portfolio of generation investment in which: "*Geothermal generation development remains Contact's number one investment priority and is critical to the development of greater levels of renewable generation in New Zealand. Geothermal is the lowest cost source of new generation in New Zealand, and Contact has an unrivalled set of geothermal opportunities to develop and execute."* Contact identified projects listed earlier as forming the basis for an investment program of $1.2 billion in New Zealand fields. The Mighty River Power report (Ref. 6) included the following comments: "*Mighty River is absolutely committed to developing geothermal resources. We're well on the way to developing a billion dollar geothermal business. … But geothermal does need a lot of risk capital, expertise and courage to explore and get it up and running successfully. We've made that commitment and we are well on track to having over 400MW of geothermal generation operating by 2012."* Both companies have indicated interest in both heat and electricity generation.

Other major developers of geothermal energy in New Zealand include Tuaropaki Power, Bay of Plenty Energy, and Top Energy. Ormat binary cycle plant are marketed in such a way that Ormat can be considered a developer in the New Zealand context though have not been plant owners up until now. Meridian is now investing in some heat projects, though has not built up a geothermal team. Genesis is building up a team and has been in negotiations with a number of land owners with a view to access or partnership in resource developments (including at Tokaanu).

Government rules around electricity generation have changed recently so that in future there may be more lines companies investing in either geothermal generation or energy supply. These traditional investors in distributed generation could potentially invest across the range of geothermal technologies, including heat pumps and heat supplies.

With increasing attention on energy costs, some energy-intensive industries located in suitable areas may start to look at investment in or hosting geothermal heat and electricity supplies.

Maori Trusts with suitable land are now likely to be considering development options including the possibility of full development or partnering with others. It is difficult to see how many developments will be able to proceed without some sort of partnership model. This is already a concept well-established by Mighty River Power.

Development Timeframes and Mechanisms

Figure 4 gives a rough impression of timelines for the development of geothermal projects (Ref. 7). Typically these can take 5 years to develop. Mighty River Power and Contact Energy have differing ideas on the potential duration of the consenting process within this program. However, with the provisions for the call-in of projects, and if land access issues have been addressed at an early stage, then most parties would accept a 5 year period.

There are many projects that are part way down the development path. The Crown has done a lot of preliminary science work on most geothermal fields in New Zealand, though developers may choose to do some of their own work for supplementary project definition.

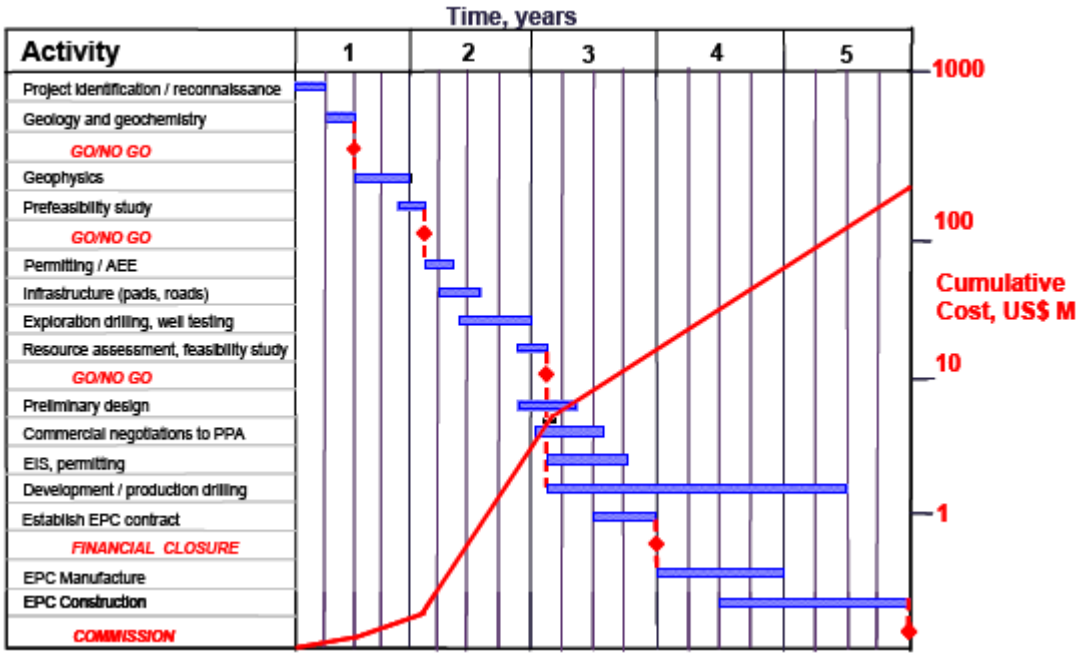

Figure 4: Approximate Schedule for the Development of a Geothermal Power Station (Ref 7)

The costs shown against the schedule are now roughly equivalent to those of a 70 MW geothermal power station.

The schedule above assumes that projects will be developed on a turnkey/ EPC basis. This is still the most common method for developing power projects in New Zealand. There would be separate contracts for the drilling, for some preliminary site preparation and possibly for the upstream (steamfield) costs. Having said that, some developers have observed that it is becoming harder to secure full EPC contracts. These were typically led by the major manufacturers, but they have indicated a desire to avoid some of the risk associated with assembling full projects. For now, the best entry point is likely to be through the major EPC contractors as far as power station developments are concerned.

Heat projects or steamfield contrasts are more likely to be based around mechanical/process plant that can be designed and manufactured in New Zealand. As such there is an opportunity for an NZ Inc approach to development under a lead organisation. Some companies that can be involved in such an approach can be found in the 2005 SKM report or in a HERA Capability register (Ref. 8) found on the New Zealand Geothermal Association website (www.nzgeothermal.org.nz). HERA has indicated a willingness to update this register on a regular basis. Companies can supply relevant information through to HERA if interested.

Existing developers are of the view that necessary skills and equipment can all be sourced internationally if not nationally. Thus, it is up to suppliers to chase opportunities. In the schedule outlined above, the earliest specific project notice in public is likely to be early consultation prior to consenting. At that stage there is a matter of months, if contracts have not been largely predetermined, before contracts are let. The same would apply to heat projects.

Approximate Investment Levels

Each project will have its own peculiarities with respect to concept and cost, the costs being highly dependent on the nature of the reservoir (especially temperature and productivity of wells). Scale of development has a lesser effect on the specific cost (cost/MW installed). The New Zealand Geothermal Association has a document in preparation outlining the cost of geothermal power generation. Figure 5 uses costs derived in that draft report. It gives an impression of the effects of temperature, plant size and well productivity. Given that most future developments will be of a larger scale, typical investment will be of the order of NZ$4/MW installed. With approximately 1,000MW of viable, consentable generation, this indicates upcoming investment of the order of $4 billion.

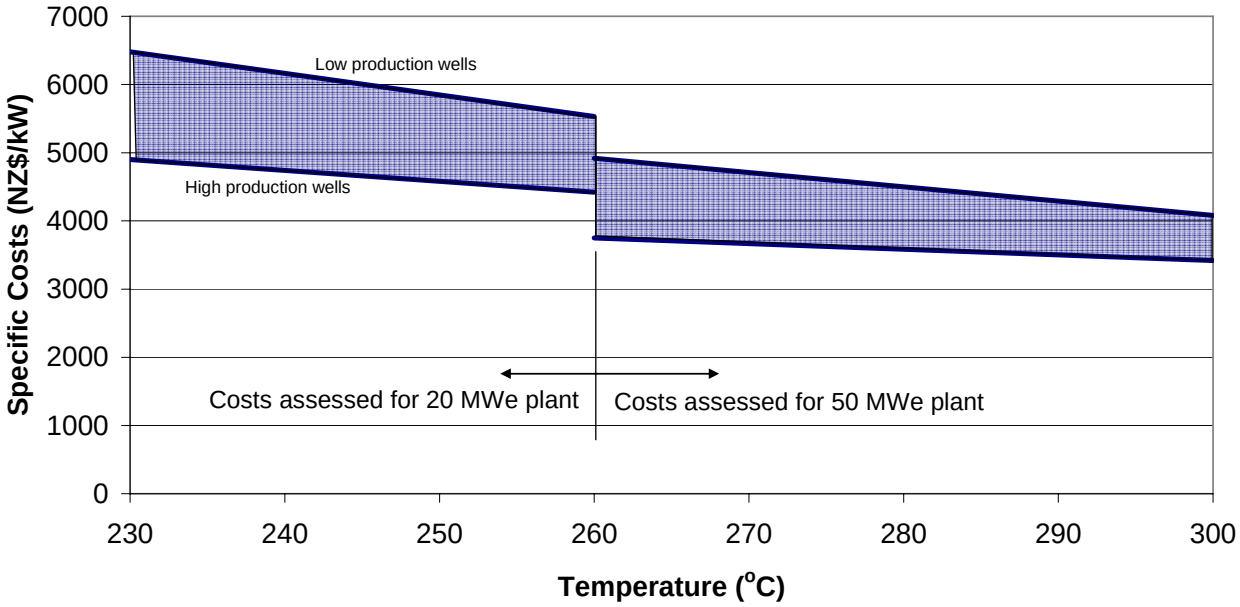

Figure 5: Envelope of Specific Capital Costs for Greenfield Geothermal Electricity Generation Developments

The following table (Table 2) gives an impression of where the capital costs of electricity generation lie in terms of breakdown. The split is indicative only and is reflective of installed cost, but gives some impression of where value might lie.

Table 2: Approximate Split of Installed Costs by Component in a Geothermal Electricity Project

	Subcomponent Split %	Overall Split %
Steamfield		
Elements of EPC Contract		
Site Civil (roads, pads, water supplies, land acquisition)	11%	4%
Mechanical	19%	8%
Control and Instrumentation	1%	0.3%
Steamfield Electrical	1%	0.2%
Elements of a Drilling Contract		
Rig Mobilisation/Demobilisation	3%	1%
Exploration Wells	10%	4%
Production Wells	37%	15%
Injection Wells	8%	3%
Specialist Costs		
Geoscience	1%	0.2%
Environmental	1%	0.4%
Feasibility Studies, Reservoir Engineering	1%	0.4%
Project Management, Engineering and Design	7%	3%
Total Steamfield	**100%**	**40%**
Station		
Elements of the EPC Contract		
Civil and Structural	10%	6%
Mechanical Plant and Equipment	46%	27%
Controls and Instrumentation	6%	4%
Electrical (including Switchyard)	20%	12%
Auxiliaries	6%	3%
Operating Equipment	4%	2%
Specialist Costs		
Environmental and Social	2%	1%
Management, Engineering and Design	7%	4%
Total Station	**100%**	**60%**

Concluding Remarks

This paper has attempted to indicate the active investment environment currently present for geothermal development along with strong projections forward. Some indications of upcoming projects have been given. Timeframes have been presented so potential suppliers of service can identify possible entry points to new projects. Over $4 billion of investment can be expected at current prices and the paper has presented a view on how the associated costs may be roughly broken down. It is up to industry to identify particular niches that can be filled from local sources.

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