SMALL POWER PLANTS: RECENT DEVELOPMENTS IN GEOTHERMAL POWER GENERATION IN NEW ZEALAND

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WHAT IS SMALL SCALE?

None of the recent New Zealand power plant developments truly qualify as "small" on a field wide basis. The size of the individual units in these projects is however, quite small. Over the last four years fourteen geothermal generation units have been installed in New Zealand, eleven of these having a capacity of less than 5MWe. Prior to the recent period of activity three small units were installed at Kawerau; each of these units were also less than 5MWe in output.

All the recent construction has been undertaken by individuals, local power companies, or by trustees of local Maori tribes, often as joint venture projects. New Zealand's first two geothermal power stations, Wairakei and Ohaaki, were both large. They were built using NZ Government money in 1958 and 1989 respectively.

RECENT NEW ZEALAND DEVELOPMENTS

Four new geothermal stations have been erected in New Zealand since 1996. One plant (Poihipi) uses conventional steam turbine technology, while the three smaller plants (Rotokawa, Ngawha and Mokai) use binary cycle technology. Two older binary cycle plants also operate at Kawerau.

Poihipi: Mercury-Geothermal (July 1996)

This 55-MW power station was imported to New Zealand as a second hand unit, having been built for the Geysers geothermal field but never run. The complete power plant was reconfigured to generate at 50Hz (60Hz is used in the USA) and has been erected in the western part of the Wairakei geothermal field, tapping a shallow steam zone. Electricity output is restricted by a resource consent that does not allow the plant enough steam to run fully loaded 24 hours per day. To get the maximum possible revenue it is run at high load 14 hours per day, when electricity tariffs are high, and runs at very low output (~3MW) during the night. It is New Zealand's only non-base load geothermal station.

Rotokawa: Transalta (September 1997)

The Rotokawa geothermal field is located in the Taupo Volcanic Zone (TVZ) and contains wells with some of the hottest downhole temperatures (>320EC) recorded in New Zealand. Wellhead pressures at Rotokawa are also very high, with some wells showing over 70 bar when shut in. The field is bisected by the Waikato River and covers a wide area, estimated at somewhere between 17 and 30 km^2. The field is thought to be one of the largest in New Zealand, containing an estimated 2700PJ of useable heat (Hunt, 1998).

Fracture permeability is the main means of fluid movement at Rotokawa as the andesitic reservoir rocks are relatively impermeable. The wells are generally good producers providing high temperature fluids with high enthalpy. Because of the high enthalpy, the power station installed at Rotokawa has an output double that of the Ngawha plant, while processing about the same mass flow.

Silica content at Rotokawa is high so the fluid separation pressure is maintained at 20-25 barg to prevent scaling problems. The non-condensable gas contains a considerable quantity of H_2S, but due to the relatively small size of the development this does not produce an odour nuisance when the gas is vented to atmosphere.

The Rotokawa power station (Fig.1) utilises a 16MW steam turbine which exhausts at just over 1 barg to two air-cooled ORMAT binary cycle units. The hot brine from the separator is used in a third ORMAT binary cycle unit. Total output of the plant is 24MWe. The plant is supplied by two production wells, about 1000m deep. After two-phase transmission the steam and water are separated at the power plant, passing separately through the units, and are then recombined before reinjection. Three shallow reinjection wells are used (~400m); a relatively impermeable layer exists between the production and reinjection horizons preventing cold fluid returns.

Figure 1. Rotokawa Power Station (24 MW) .

Several of the wells in use at Rotokawa were drilled by the New Zealand Government during the early eighties and have since been sold to the project. Some new wells have also been drilled. Three other Government funded wells remain unused at Rotokawa, because they are unsuitable for producton or reinjection, or because they are too far away from the plant to be viable.

Rotokawa field also has three abandoned exploration wells that were drilled by the Crown. These wells were cemented after corrosion of the casing by acid fluids at shallow level. This region of acid fluids has now been delineated and covers only a small area of the field, near steam heated surface features. This type of corrosion is not expected to cause problems in the remaining wells.

Ngawha: Top Energy (July 1998)

The Ngawha geothermal field is the only high temperature geothermal field in Northland New Zealand. Compared to high temperature fields in the Taupo Volcanic Zone (TVZ) the Ngawha field has a number of differences. Reservoir pressures are somewhat higher due to a confining layer near the surface. The reservoir is also mainly greywacke rocks, which are often found as low permeability basement rocks in the TVZ fields. At Ngawha these rocks are extensively fractured, providing very good permeability in wells which intersect fractures and very poor permeability in others.

High boron, high non condensable gas and high mercury levels characterize the fluids at Ngawha, which are also at relatively low temperature (230EC) and enthalpy (~ 970kJ/kg). The low enthalpy means that while the wells produce high mass flow rates the electrical potential per well is lower than is typical in the TVZ. Calcite scaling was observed during early production tests at Ngawha and is expected to be an ongoing concern during development of this resource. The resource area is approximately 15km^2, and the stored heat has been quoted as 1400PJ (similar in size to Ohaaki) (Hunt, 1998).

The current development at Ngawha consists of two air-cooled ORMAT binary cycle units, with a combined output of just under 10 Mwe (Fig. 2). The units are supplied with steam and hot water from two production wells, about 1000m deep. Steam and water are separated at the wellpad before transmission because of the steep terrain that must be traversed. Separation pressure floats between 10 and 17 barg.

The steam and hot brine are passed through separate heat exchangers in the power plant. Flows are then recombined before being pumped to disposal in two reinjection wells with depths of about 1300m. Non-condensable gases are vented to the atmosphere.

All the wells in use at Ngawha were drilled by the New Zealand Government during the early 1980s. A further ten unused wells drilled to depths up to 2300m and one abandoned well exist at Ngawha. This early drilling program reduced the economic risk of development considerably. However, the existing wells were drilled for exploration and are quite widely spaced. This meant that approximately 7000 m of steam-field piping was needed to connect the system (Fig.3).

Figure 3. ***Long pipelines were needed to connect the widely spaced wells at Ngawha.***

One of the wells used for fluid production at Ngawha was completed in an unusual manner. Up until its recent removal, NG9 (Fig.4) was New Zealand's only "dual-

Figure 2. Ngawha Power Station (10 MW).

completion" well. The upper feed zone discharged through the annulus between the $8^5/_8$" production casing and an inner $5^1/_2$" casing. The lower feed discharged through the $5^1/_2$" casing. Although the two zones could feed to the surface separately they were combined before phase separation when the Ngawha development commenced. The dual-completion has since been removed, increasing the well output.

Figure 4. NG9 wellpad - a "dual completion."

Mokai: Tuaropaki Trust (October 1999)

The Mokai resource has many similarities to the Rotokawa resource. The power development is also similar. Mokai was confirmed by drilling in the 1980's after geophysical measurements suggested the presence of a large geothermal reservoir. The wells drilled at that time were some of New Zealand's largest producers, with MK5 having sufficient output for about 25MW of electric power. The resource area is estimated to be 12-16km^2, containing stored heat of 2700PJ (the same figure attributed to Rotokawa) (Hunt, 1998). The wells are high temperature (over 300EC), have high wellhead pressure (>50bar), and produce high silica fluids. Gas levels at Mokai are however quite low compared to other fields in the Taupo Volcanic Zone.

The current development at Mokai uses four production wells with depths between 1000 and 1500m. Three shallower reinjection wells (<800m), drilled in the outflow tongue of the reservoir, are used for fluid disposal. Two further wells were drilled during the exploration of Mokai in the 1980s, but these are not used in the current project.

The hybrid power plant at Mokai (Figs. 5 and 6) is similar in concept to the Rotokawa plant. Steam separated at 21 barg is used in a 29 MW steam turbine that exhausts at about 1 barg to four ORMAT binary plants, where the steam is condensed. A further two ORMAT binary plants make use of hot brine from the separators, which are located on the power plant site. The brine and condensate mix before being pumped to the reinjection wells. The ORMAT units are air-cooled and, as with other developments in New Zealand, the non-condensable gas is vented to atmosphere.

Figure 6. Overview of Mokai Power Plant - 50 MW.

Figure 5. Mokai Power Plant (50 MW).

Kawerau: BOP Electricity (1989, 19991)

The Kawerau geothermal field is the only geothermal field still operated on a commercial basis by the New Zealand Government, with day-to-day operation by Century Drilling and Energy Services Ltd. The primary use of steam from the Kawerau field is for direct use at the Tasman Pulp and Paper Company mill. Geothermal steam is used in clean steam heat exchangers to provide mill process steam. It is also used for timber drying in high temperature kilns in the nearby Tasman Lumber plant and a small quantity is used to heat a greenhouse located in the steamfield (see Vol. 19, No. 3, 1998). An 8 MWe atmospheric back-pressure turbine at the mill is used for load balancing to smooth out the mill steam demand, allowing well output to be changed gradually (Hotson, 1994).

Development of the Kawerau field began in the early 1950's with steam production for use in the mill predating electricity generation at Wairakei. The resource area is estimated to be 19-35km^2, containing stored heat of 1300PJ (about the same figure attributed to Wairakei). The field poses no special difficulties for utilisation, having a moderately high temperature of about 270EC. Some very productive wells have been drilled at Kawerau and these have generally had a long life. Today there are five production wells operating, with an average depth of about 1000m. Some wells tend to produce calcite scale but this is controlled by injection of inhibitor chemicals or cleaned out in periodic work overs (Bloomer, 1998). Non-condensable gas levels are moderate, and variable venting of these gases provides a convenient method of control in the clean steam heat exchangers.

Up until the late 1980s, water from the separator plants was flashed to atmospheric pressure and dumped in the Tarawera River. Steam condensate from the mill heat exchangers was also dumped to the river.

In 1989, two 1.3MWe ORMAT units were installed to make use of the separated water supply from separator plant 21 on the east side of the river, and reinjection of some waste brine was started. This first ORMAT plant was named TOI (Tarawera ORMAT Installation) (Fig 7) and was capable of cooling the brine from 180EC to 108EC. After some initial teething problems these units proved reliable and the decision was made to install another unit (TG2) on the western side of the river, utilizing fluid from separation plant 35. TG2 is larger than TO1, with 3.5 MWe output from a single unit. This plant is also a newer design than the TO1 units and includes a recuperator between the turbine and the condenser. The outlet temperature of brine from TG2 is 95ºC. All three plants use air-cooled condensers and run unattended.

Figure 7. Tarawera ORMAT Installation 2.6 MW (Kawerau field - east side of Tarawera River).

Three reinjection wells are currently in use at Kawerau, accepting about 25% of the water produced in the field; the remainder flows to the river. All the condensate from the mill heat exchangers is now collected and, after stripping the non-condensable gases, is used as a source of clean feed water for all of the mills boilers. The field has 23 unused wells of varying age and 12 abandoned wells.

LOW EXPLORATION RISK FOR DEVELOPERS

The four recent power developments in New Zealand, and the older Tarawera ORMAT plants, have all presented a relatively low exploration risk for the developers.

In three cases, Ngawha, Rotokawa and Mokai, a number of productive wells already existed and the New Zealand Government had carried out a substantial amount of scientific work from the early 1960s until the 1980s. Most of the scientific information about these fields was in the public domain and available free to the developers. The wells themselves were also sold to the developers at a reduced cost. While this sounds simple enough the well ownership issue was very complex and involved considerable legal wrangling.

In the case of the Poihipi development the plant was built in the western area of the Wairakei steam field so quite a lot was already known about this resource.

At Kawerau, the hot water resource used in the ORMAT power plants had been pouring into the Tarawera River for 35 years.

Despite the scientific and drilling work which had already been done some developers chose to reduce exploration risk even further by using “No steam - No reward” contracts when drilling new wells.

WHY THE RECENT SURGE IN DEVELOPMENT?

There have been many regulatory changes in the past ten years in New Zealand which have had an impact on geothermal development (Fig 8). Changes in resource management and electricity industry regulations have had the main impact.

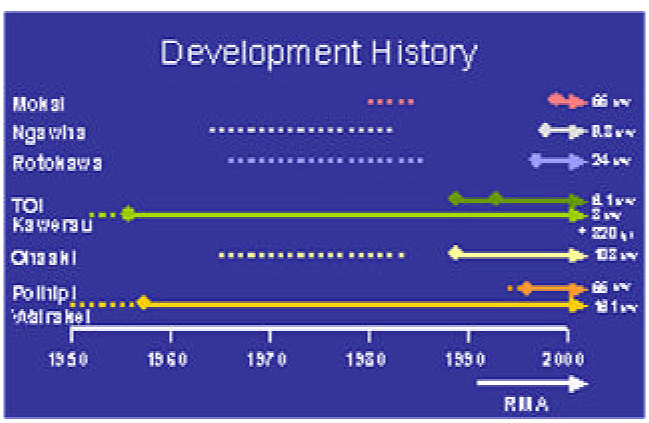

Figure 8. ***Geothermal exploration and field development 1950-1999.***

Through these rapid changes a number of new interested parties have emerged.

New Zealand has quickly shifted from a position where one Government owned company controlled power generation and distribution, to a competitive system for generation and retailing of electrical energy.

Some background to these regulatory changes is needed to understand the circumstances that led to the recent activity in geothermal power plant construction.

NEW ZEALAND ELECTRICITY SYSTEM

New Zealand’s electricity network is highly interconnected through a national grid of high voltage power lines and an undersea DC cable linking the North and South Islands. However, the grid has a limited capacity to carry power north, where most of the demand exists. Over 50% of New Zealand's population live north of an East-West line through Lake Taupo (Fig. 9).

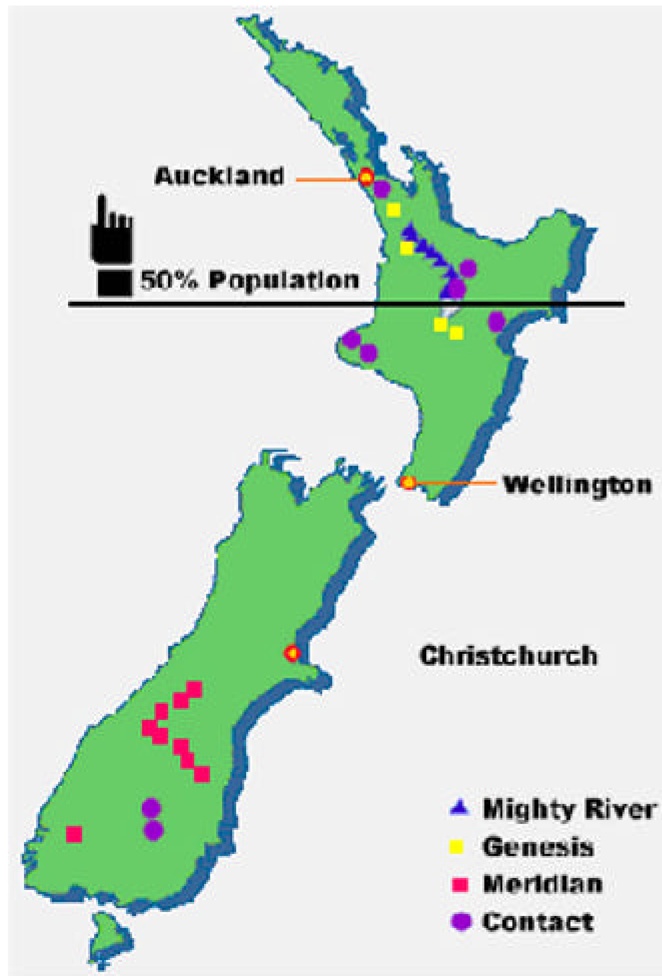

Figure 9. ***Location of major power stations and population (load center) in New Zealand).***

The system has a high reliance on hydro stations (which generate 60 -70% of the power), many of which lie on the South Island, well away from load centres. Traditionally, thermal generation has been used to meet peak loads and this has been at high marginal cost. This situation is now changing somewhat with the proliferation of high efficiency gas turbine combine cycle and co-generation plants.

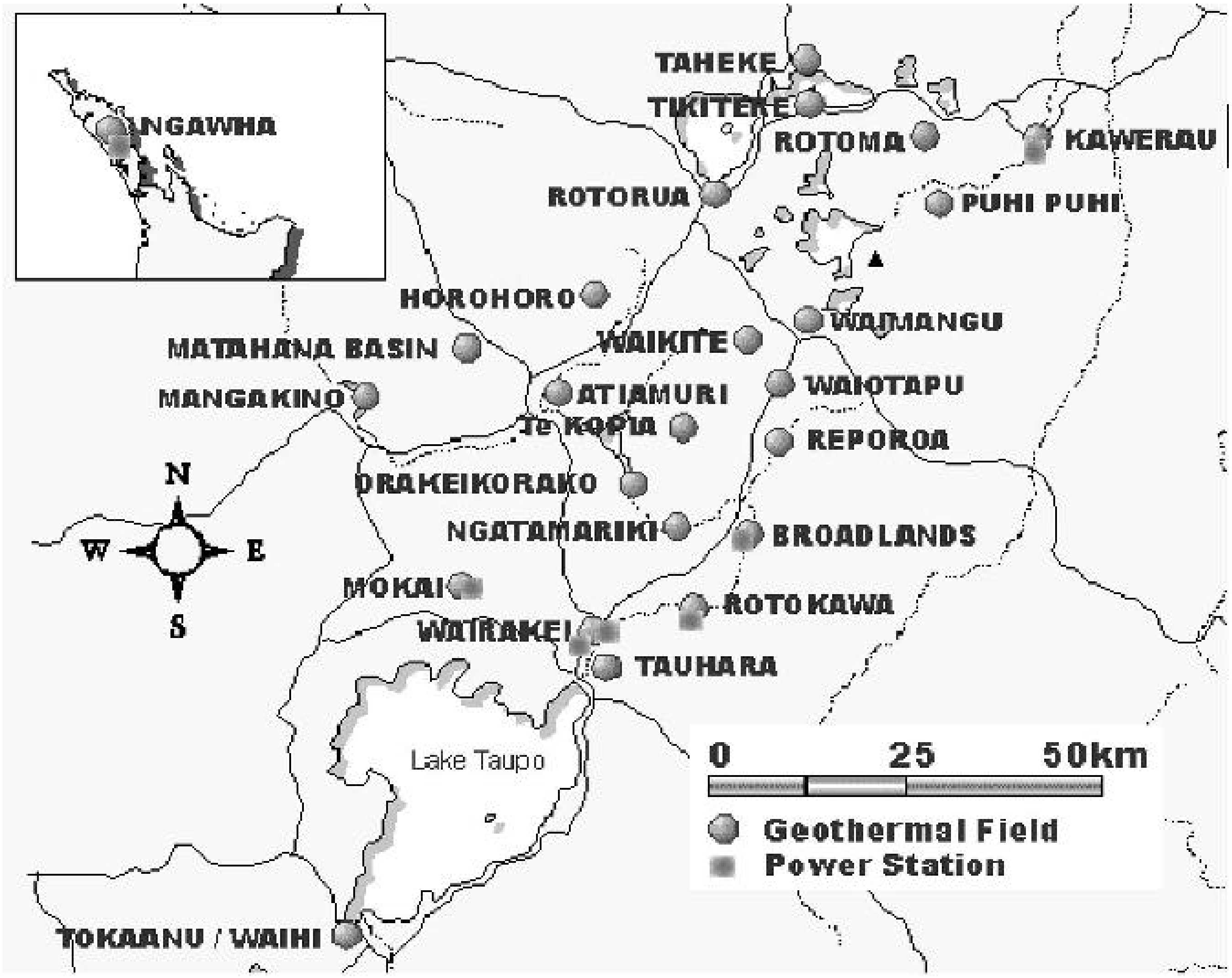

Figure 10. High temperature geothermal fields.

New Zealand's high temperature geothermal fields are in a strategically good location, near load centres on the North Island (Fig 10). Ngawha is the exception to this, lying in Northland, but is relatively strategic to that area, which has no major power stations following the closure of the Marsden Point oil fired stations.

NEW ZEALAND ELECTRICITY MARKET

New Zealand's electricity market has also undergone a period of rapid change while continuing to show about 3% annual demand growth. Electricity is now sold 1/2 hourly on a wholesale market, where competitive retail and generation sectors bid for the supply and purchase of electricity.

In theory, an electricity retailer can now make electricity sales in any part of the country, but in practice retailers have mainly stuck with their traditional local customers. Distribution of electricity on a national level is handled by TransPower, the grid operator, and at a local level by smaller distribution (lines) companies.

RESOURCE MANAGEMENT AND ELECTRICITY REFORM

Up until 1988, the Geothermal Energy Act 1953 was the main legislation controlling the development of geothermal resources for electricity. It was set up to allow development at Wairakei and gave the Minister of Energy, through the Ministry of Works and the New Zealand Electricity Department, quite sweeping powers. The "Minister may authorise search for geothermal energy and give power to enter land". The Public Works Act also gave the Government power to take land needed for geothermal development, although this was never used.

The Geothermal Energy Act was amended in 1988 when the Ministries were converted into State Owned Enterprises (Government owned companies). The regulations covering safe use of geothermal passed to the Health and Safety in Employment Act 1992 and allocation of geothermal resources for utilisation fell under the newly created Resource Management Act 1991 (RMA). The purpose of the RMA was "to promote the sustainable management of natural and physical resources" and required resource managers to "have regard to efficient use and development of natural and physical resources" and to "have regard to any finite characteristics of natural and physical resources" (Bloomer, 1994). Mineral resources were specifically excluded from the RMA but geothermal was included.

Geothermal resources now have to be managed in a sustainable and efficient way. This had never been a requirement in New Zealand before.

Sustainable Management is defined as "...managing the (use of) resources in a way, or at a rate, which enables … social, economic, and cultural well being ... while; meeting the reasonably foreseeable needs of future generations; safeguarding the life-supporting capacity of air, water, soil and ecosystems; and avoiding, remedying or mitigating any adverse effects of activities on the environment.

Electricity Industry reform has also had a major impact. In 1996 part of the Electricity Corporation of New Zealand (ECNZ) was split off to form a competitor in the generation market. The new company was called Contact Energy. Rules were also put in place to ensure that the dominant players could not shut independent power producers out of the market. This year the Electricity Reforms Act (April 1999) has had a major impact. The remaining ECNZ assets were split into three competing state owned enterprises (Meridian Energy, Genesis Power, Mighty River Power) and Contact Energy was sold.

Local power companies were also forced to split into energy companies (retailers) or distribution companies (lines companies). It is no longer possible to own a substantial share of a generating company and a lines company in New Zealand. The national grid operator (TransPower) is at present untouched and still owned by the New Zealand Government.

PREVIOUS INVESTMENT BY THE GOVERNMENT

The historical investment in geothermal exploration made by the New Zealand Government during the 1950-1986 period is now coming to fruition. Excluding those wells drilled at Wairakei and Ohaaki, 124 investigation wells were drilled over this time. In many fields these wells proved the resource. The scientific effort that was put into these fields was also substantial and almost all of the information is in the public domain. Of the 124 wells drilled between 1950 and 1986 82 remain, and the Crown has an ongoing commitment to maintenance of these wells and abandonment where necessary (Koorey, 1999).

A few of the exploration wells were drilled into fields which are now classified as "protected" for their scientific, cultural, heritage or tourism values (Luketina, 1999). However, most of the effort was placed in fields recognised early on as good candidates for development (see Table 1). The existence of these wells has been a boon to developers. Several of the highest producing wells ever drilled in New Zealand have since been sold to developers at a low price. Wells drilled by the Crown have been sold to developers at Mokai, Ngawha, Tikitere, Tauhara, and Rotokawa.

WHERE TO FROM HERE?

Geothermal energy in New Zealand continues to face stiff competition from natural gas, which has been chosen as the fuel source in a number of new power plants. The low price of natural gas in New Zealand is expected to continue for some years to come, as it results from historical "take or pay" contracts inherited by Contact Energy during its formation.

The impact of targeted CO_2 reductions, which New Zealand has committed to in the international Kyoto protocol agreement, may yet have an effect on the price of competing fuels. Although all New Zealand geothermal stations emit CO_2 they do so at a much lower rate than natural gas stations, which are their main competition. This issue remains open, since the mechanism by which New Zealand will set out to achieve CO_2 emission reductions has not yet been decided.

Although the New Zealand Government no longer provides money for new geothermal exploration programs the benefits of the earlier work will continue to flow for some time. Several as yet undeveloped fields have proven potential.

As electricity demand rises new geothermal power plants will be built in New Zealand. In the short-to-medium term, the most likely scenario is small incremental developments and expansions in the recently developed fields. Efficiency improvements planned for long established fields like Wairakei are also expected to result in some new construction.

ACKNOWLEDGEMENT

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Table 1. Government funded wells drilled into systems now classified as "Development Systems."

Field	Production	Injection	Shut-in	Abandoned
Horohoro	-	-	5	-
Kawerau	5	3	23	12
Mokai	4	1	-	1
Ngawha	2	2	10	1
Rotokawa	1	1	3	3
Tauhara	-	-	14	1

Source: Koorey (1999)

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