Recommendations to EECA's Renewable Energy Programme

PREPARED BY

NZ Geothermal Association

9 May 2003

Purpose

The following has been prepared for the express purpose of indicating to EECA what assistance the Association considers would better enable it to fulfil its objectives. Accordingly, it identifies proposed key target market activities that aim to increase the uptake of renewable energy produced by the **Geothermal** sector. This will assist EECA in focusing its Renewable Energy Programme (*the Programme*) on priority items.

Association's Key Objectives and Goals

To quote from our by-laws:

> *"The New Zealand Geothermal Association is a scientific, educational and cultural organisation established to operate in New Zealand. It is a non-political, non-governmental, non-profit organisation. It has no political affiliation. Its aim is to encourage, facilitate and, when appropriate, promote co-ordination of activities related to worldwide and national research, development and application of geothermal resources."*

The Association has a diverse membership. It not only includes those whose main interests are in large-scale geothermal energy development, such as developers, consultants and service companies, but also research institutions, universities, regulatory authorities and Maori groups. This means that the Association provides an excellent forum to debate geothermal policy and market issues as well as technical matters - though it can make it difficult to reach a consensus viewpoint in some case !

The Association has an interest in the following markets:

1. Large and small scale electricity generation from geothermal sources.
2. Large and small scale direct use of heat from geothermal sources. The Association acknowledges that this may be more thermodynamically and commercially efficient where a good match between sources and use exists.
3. Non-extractive uses, such as tourism.

The aims of the Association also include education, scientific investigation and conservation of geothermal systems. The Association takes an active role in regulatory issues to do with geothermal matters.

Our priorities and immediate objectives are set out below.

Opportunities and Markets

This is perhaps best addressed in terms of the major markets identified above.

Large and small scale electricity generation of geothermal sources

There is some potential for increases in capacity at some of New Zealand's existing geothermal projects. This includes increases in thermodynamic efficiencies, which would have little impact on the resources or the environment. There are some technical constraints on doing so, as described below.

There are also considerably greater untapped high-temperature geothermal resources available in New Zealand. Many members of the Association believe that a significant proportion of these could be developed without undue environmental effects. Estimates of an additional 1000 MW of electrical energy from geothermal sources with acceptable environmental impact have recently been made. Constraints to doing so are discussed below, but are basically economic and regulatory.

The potential for small-scale development of geothermal energy for electricity generation exists, but is small because of economies of scale especially in terms of the financial implications of risk.

The potential for electricity generation in the medium term at least is limited to the Taupo Volcanic Zone, plus Ngawha in Northland.

Large and small scale direct use of heat from geothermal sources

The *potential* for large-scale direct-heat use of geothermal both by extending existing schemes and developing new opportunities is even greater than for electricity generation, since the energy can be used much more efficiently. However, there are major practical limitations in doing so, in that they require the existence of a suitable, financially viable user in close proximity to the geothermal resource. This is further discussed below.

The potential for widespread small scale use of low-grade geothermal energy, by using ground-source heat pumps, is large and virtually untapped in this country.

Large –scale direct use is limited to the Taupo Volcanic Zone and Ngawha. The potential for small-scale direct use is more widespread.

Non-extractive uses

Tourism related to geothermal activity and heat already makes a major contribution to the economy, especially in Rotorua. There is clearly scope for expansion provided this can be handled in an environmentally sensitive manner. However, we assume that this is outside EECA's brief.

General Issues

Key priorities and emerging technologies are discussed below. They relate to the constraints: cost, regulatory obstacles and environmental effects, information gaps and thermodynamic efficiency.

Barriers to Development

Regulatory Issues

Many members of the Association consider that a major problem for all except the smallest geothermal developers is meeting the procedures of the Resource Management Act. This leads to delays (especially through the protracted appeal process), high costs, risk and uncertainties. The NZGA has previously separately commented on these issues, and we can only re-state our position (see attached paper). The RMA procedures (not its principles, which we support) are considered by most members to be the major obstacle to further large scale geothermal development in this country. They will have the perverse effect of leading on a national scale to environmental degradation, through favouring the development of non-renewable power sources.

Changes to RMA procedures can and should be pursued in the political arena, but presumably this is outside the scope of EECA's current considerations.

There are three areas where EECA could promote pro-active initiatives to lessen RMA constraints:

1. Improvements in our ability to predict and mitigate the environmental effects of geothermal development.
2. Promotion of world's best practice in geothermal environmental management.
3. Education both of the general public and decision makers both in geothermal issues specifically and environmental science generally, to reduce the level of ill-informed objections and decisions.

Environmental Impacts

Geothermal energy development does have real as well as perceived environmental impacts. At least half of New Zealand's high temperature geothermal resources will probably never be developed because of real environmental limitations. There is significant scope to improve methods of predicting, avoiding and mitigating the environmental effects of geothermal development. This inevitably overlaps with the previous item.

Resource Definition and Database

It is not considered necessary for EECA to directly support delineation of individual geothermal resources. There has already been a great deal of basic work done by previous government agencies, and the cost of delineation for individual projects will presumably be covered by the developers.

However, there is a role for EECA in making information widely available. Not all of the data previously collected with public funds is readily publicly available. There is scope for EECA to work collaboratively with the Ministry for Economic Development to produce databases and interpretative compilations of knowledge on geothermal resources, in much the same way that they already do with minerals and petroleum data. Regional councils could also play a valuable role.

Costs

Historically geothermal energy has struggled to compete with other sources of electricity generation and direct use. There are several reasons for this and it is perhaps useful to consider them separately:

1. Cost of other energy sources. There is a widespread viewpoint that historical hydro and gas prices have been set unrealistically low. Apart from promoting renewable energy use through means such as a carbon tax, there is little that EECA can do directly about this, and with the exhaustion of Maui gas the situation is likely to change.
2. Low wholesale electricity prices. There is no doubt that wholesale electricity prices in New Zealand have been a fraction of these in other countries that have geothermal generation. Once again, that should tend to change in the medium term, and other agencies are looking into the problems with the electricity market.
3. Exchange rate. Geothermal projects involve a significant overseas currency component. There is little that EECA can do about the exchange rates. There is possibly some scope for greater substitution with locally-sourced components and services, but the potential to do so is small in view of the small size of the market and the general on–going de-industrialisation of the country. Perhaps all that can be done is for EECA to support New Zealand service and development companies, including in their overseas markets, to ensure that a pool of NZ expertise continues to exist.
4. Compliance costs. These include the direct cost of obtaining resource consents, the cost of the current delays in obtaining resource consents, and the cost of complying with resource consent requirements.

Aversion to Investment, and Market Development

1. Electricity Generation. Large scale geothermal development does not provide a particularly attractive target for international investment in New Zealand, making projects hard to finance. In part this is because of the low power price, about which EECA can do little, But it is also due to the risks, uncertainties and delays imposed by the RMA procedures, which have already been discussed above.

   Direct or indirect subsidies of large geothermal projects, though welcome, are assumed to be outside EECA's project budget. A typical 100 MW development would cost well over NZ $ 200 million, so tens of millions in subsidy would be needed to significantly increase the financial viability of a single project.

2. Direct use projects. Many opportunities have been identified for the direct use of geothermal energy. Many appear technically feasible. However, for a project to proceed on a strictly commercial basis it must be sufficiently financially viable to stand on its own merits. Some apparently attractive opportunities have not been taken up because either:

   (a) The energy cost component of the project is so small in comparison to other financial aspect of the project that the cost advantage of geothermal energy compared the next cheapest, possibly more convenient source make little financial impact on the project as whole.
   (b) The energy component of a direct use project which could be cascaded with a power generation project are so much less than both the energy

and revenue from the power project that they are not considered worth pursuing by the power developer.

(c) Suitable raw materials do not exist close enough to the geothermal resource to justify the transport costs.

(d) There is no market premium for the product, even if, as in the case of geothermally-dried timber or lucerne, it may have superior qualities.

(e) The project involves technology which is new to NZ.

This is where EECA may be able to play a significant role, both in supporting demonstration projects and in market identification.

Plant Efficiencies

The use of geothermal resources for electricity generation is thermodynamically inefficient, and it is better if possible to use the energy directly. Barriers to doing so are identified in the previous section. There is also some potential for improving the efficiency of the conversion of geothermal energy to electricity, as follows:

1. Improvements in steam turbine design, permitting higher inlet and lower exhaust pressures. Turbine manufacturers are steadily improving those parameters in a modest way, and it is not considered practical for development of this type to be undertaken in NZ. Incremental gains will be small.
2. Improvements in binary plant technology. Binary and combined cycle geothermal plants are now a well-established commercially available component. While there is space for improvements, it is unlikely for major developments to be done in NZ. Nevertheless New Zealand operators are cooperating with the manufacturers in incremental design improvements.
3. Retro-fitting of binary plant to existing condensing plants, and lower exhaust temperatures for binary plant heat exchangers. Both of these offer considerable opportunities for additional generation at all geothermal plant in NZ except Ngawha, with virtually zero environmental impact, since they are simply making better use of geothermal fluid that is already available at the plant. The main constraint is silica deposition - the further one drops the temperature of separated geothermal water, the more likely it is that silica will deposit in the pipework, heat exchangers or reinjection wells. A number of technologies for dealing with silica deposition have been developed overseas, and in NZ (though not commercialised to date) which have not been so far applied in NZ. It is however necessary to fine tune the technology to the specific chemistry of NZ geothermal fluids on a case by case basis. This is an area where EECA could very usefully provide support by way of pilot plant trials and/ or a demonstration project at modest cost.

Human Resources

Human resources in geothermal expertise are declining in New Zealand. The recent near-demise of the Geothermal Institute is unfortunate in this regard. Paying the fees of one or more students to attend the GI is a practical step that EECA could take, that is, by making one or two annual scholarships available to suitable New Zealanders.

Once again, maintaining a viable geothermal industry in New Zealand is an important mitigating strategy. In the past the Geothermal Institute has hosted an annual technical conference, in which a great deal of useful material has been presented. It is debatable whether the conference will be able to continue in its present form without some outside support.

Current Research Directions

The Association considers that it is useful to list the current research directions that are already being carried out in New Zealand, and who is responsible. These are presented in an Appendix.

Recommended Priority Activities

Members of the Association have formulated the following projects for inclusion into EECA's Programme. Only some of these projects will seek EECA funding.

Note that these are *not* in order of relative priority.

1. The development of robust methods to predict environmental changes resulting from geothermal development.

The Nature and Scope of the Activity	1. Data collection – type of data, data collection techniques, and data collection locations. 2. Understanding of geothermal processes leading to development of methods for prediction of environmental impacts
Rationale	This will benefit Geothermal Developers and Regional Councils by providing a sound scientific basis to access the impact of geothermal development on the resource and environment.
Timing	Scope for many projects, from periods of several weeks to several years
Parties Involved	University of Auckland, GNS ,SKM and others
Linkages Between Activities and Priorities	High priority, but likely to be broken into a series of sub-tasks some of which are more urgent and achievable than other.
Financial	Present studies supported from a variety of sources, but definitely scope for more support
Outcome Monitoring	Depends on the context, for instance: - Have the existing conditions been quantified? - Has the study increased our understanding of the phenomena? - Has a method of prediction been developed?

2. Greater use of the energy and minerals in separated water,

The Nature and Scope of	The project would need to include mitigating reinjection problems and non-reinjection disposal options.

the Activity	
Rationale	Greater use of geothermal energy to lower exhaust temperatures. Lesser environmental impact of geothermal energy utilisation. Greater financial viability of geothermal projects
Timing	.
Parties Involved	
Linkages Between Activities and Priorities	Moderate priority, but less than item 1
Financial	
Outcome Monitoring	

3. Getting better definitions of field boundaries and connections to nearby fields

The Nature and Scope of the Activity	<u>Nature of activity</u> Surface scientific measurements (predominantly geophysics but including geology, geochemistry, well measurements if available, and other studies). <u>Scope</u> The primary method is magnetotelluric (MT) measurements, followed by 2D and 3D modelling, calibration with other data and integrated assessment.
Rationale	<u>Reason</u> Geothermal systems are characterised by various resistivity structures, broadly corresponding to the fluid and temperature regimes and geological conditions that exist within the system. MT interpretation has now progressed to a stage where the modelling and interpretation of these resistivity structures can be well correlated with the actual geothermal regime, provided sufficient high-quality measurements are made to ensure adequate resolution. <u>Expected achievement</u> The likely boundaries of the high-temperature reservoir can be determined, both horizontally and vertically, to a depth of between 1000 and 2000 m from the surface. This determination can be vastly improved if there are one or more wells in the prospect area which can be used to calibrate and refine the resistivity model. Probable connections between adjacent fields, again within 1000 to 2000 m below the surface, can be reliably determined.

	An MT survey over explored fields with a well-understood geothermal regime and with known connections (e.g. Wairakei-Tauhara) could be carried out to establish proof of concept. Importance of activity To minimise geothermal development costs by eliminating the need for exploration wells outside the productive area. To minimise the possibility of geothermal development in one field from affecting geothermal features in an adjacent field. To determine if fields, at present undeveloped, can be safely developed without affecting nearby fields. Potential Petajoule Contribution A number of geothermal fields are presently undeveloped because of their (unknown) linkages to nearby fields (e.g. Ngatamariki to Orakei Korako, Reporoa to Waiotapu/Waimangu) which could be developed if the linkage was disproven. A conservative 100 MW development at each field would produce 6 PJ per year.
Timing	MT surveys can be carried out at any time over geothermal prospect areas where boundaries or connections to other fields are imperfectly known. Each survey along with interpretation and reporting would take a few months
Parties Involved	This activity can be undertaken by any interested party who desires to know geothermal field boundaries or to determine if connections exist with other geothermal systems. However, it is recommended that the best possible MT subcontractor is used, as the MT method is noise-prone and requires high-quality equipment and skilled filed operators. Interpretation should be carried out by specialised geothermal geophysicists, preferably those with extensive experience in a large number of geothermal systems and with a deep understanding of the physics involved in the MT method.
Linkages Between Activities and Priorities	Low priority
Financial	The cost of an MT survey is primarily dependent on the number of MT soundings that are made. The confident resolution of the modelled resistivity structures at geothermal depths is typically of the same order as the MT sounding spacing at the surface. The determination of field boundaries in an isolated field may require as few as 50 soundings at a cost of perhaps $200,000. The determination of possible connections between adjacent fields, on the other hand, could require as many as 200 soundings at four times the cost.
Outcome Monitoring	The correlation of results (temperatures, alteration, fluid characteristics) from wells drilled into the geothermal system would be used to monitor the

	outcomes of this activity.

4. Public education on geothermal issues

The Nature and Scope of the Activity	Provide materials to improve public perceptions of, and attitudes to, energy development - particularly geothermal
Rationale	Effort spent on determining people's real concerns and educating people to the facts and otherwise addressing the concerns would be well worthwhile and ease the process of obtaining approval for new projects. Long term this could potentially add several hundred MW.
Timing	This is seen as an on-going process, but we propose a first stage to be completed within one year and then reviewed.
Parties Involved	To be carried out by NZGA, by using voluntary input by the Board members to coordinate and direct the programme, and a paid technical writer/editor to do the work. Assistance from EECA would be limited to review (staff time), and assistance with dissemination of information (time plus printing etc. costs)
Linkages Between Activities and Priorities	Priority is high, but the return will be moderately long-term. NZGA has already established a website with some similar information, but it needs updating
Financial	NZ $ 10,000 is sought from EECA to be expended through NZGA on a technical writer/editor. NZGA is prepared to commit time from the members at no cost to facilitate the project. EECA would have to fund printing and distribution, but that cannot be quantified until the concept is refined. It would be of the order of another $10,000, but probably in the following financial year
Outcome Monitoring	1. Have the document(s) been produced ? *2.* Have they been distributed and publicised ?

5. Demonstration direct heat use pilot project

The Nature and Scope of the Activity	Some research into the most practical and efficient process is required, as is some specific market research. Assistance could then be provided to set up the first system, either as a one-off energy supply to a demonstration user, or as utility making hot water or steam available to a cluster of users. This may be in an established industrial area such as Rakaunui Road in Taupo (overlying part of the Tauhara geothermal field) or on an existing operational steamfield, such as Wairakei, Rotokawa, Mokai, Ngawha or Kawerau.
Rationale	A barrier to use in smaller industrial concerns is a lack of knowledge of geothermal energy, but more particularly the high cost of a one-off heating system. There is great potential for energy to be made available to a cluster of users (for example, timber processors/dryers) as a utility. The potential Petajoule contribution is very high. For example one large greenhouse development, currently being developed, alone will require about 0.2 PJ/year – substituting for coal or natural gas
Timing	The sooner it is started the sooner the benefits will accrue.
Parties Involved	Geothermal developers and/or consultants including the Geothermal Institute
Linkages Between Activities and Priorities	Priority: high, but not as high as some of the other activities.
Financial	$20,000 for the initial study $50,000 contribution towards the pilot, once a suitable project is found
Outcome Monitoring	1. Effectiveness of the pilot 2. Number of independent projects started using the knowledge from the pilot

6. Encourage multi-household geothermal use from one source

The Nature and Scope of the Activity	Undertake an analysis of best current practice (specifically in NZ, but also comparing with overseas) and development of a practical system. A demonstration project could be appropriate. Obviously direct use of moderate temperature geothermal energy is restricted to geothermal areas, but ground source heat pumps have much wider application – though the costs may be higher.
Rationale	More efficient use of existing geothermal takes and substitution for non-renewable (gas) or higher value (electricity) resources. 1 PJ per year per 10,000 households connected.

Timing	
Parties Involved	Geothermal developers and/or consultants including the Geothermal Institute
Linkages Between Activities and Priorities	Moderate priority
Financial	$20,000 for the initial study $20,000 contribution towards the pilot, once a suitable project is found
Outcome Monitoring	1. Effectiveness of the pilot (does it provide the householders with the heating system required?) 2. Number of independent projects started using the knowledge from the pilot

7. Encourage geothermal heating use in schools

The Nature and Scope of the Activity	Establish working group with Ministry of Education to confirm economics of geothermal heating in schools
Rationale	Substitution for non-renewable (gas) or higher value (electricity) resources
Timing	
Parties Involved	Geothermal developers and/or consultants including the Geothermal Institute, plus Ministry of Education and specific schools in appropriate areas
Linkages Between Activities and Priorities	
Financial	$20,000
Outcome Monitoring	Uptake of geothermal use in TVZ schools

7. Demonstration project on chemical inhibition of silica deposition

The Nature and Scope of the Activity	Establish a pilot-scale demonstration project at two or three operating geothermal fields (select to provide a range of temperatures and chemical characteristics).

	The project would test a range of acid, alkaline and non-stoichiometric organic chemicals (including the commercially-available product “Geogard”), and at a range of flow and dose rates, with analysis of total and polymeric silica. Analyse the data to produce an outline feasibility study of the economic viability of extracting additional geothermal energy in NZ binary power plants, without adverse silica deposition
Rationale	Current exhaust temperatures at binary power plants are limited by concerns for silica deposition. Technologies to inhibit the deposition of silica have been established overseas, but not trialed in NZ. If these methods can be successfully applied, they would give an immediate benefit in terms of additional generation without additional fluid extraction nor environmental impact. Around 20 -30 MW of additional generation (at over 90% availability) could probably be obtained from existing plants is this way, plus further contributions from future plants by incorporating the findings in the design.
Timing	The activity could commence more or less immediately, and be completed within one year
Parties Involved	A proposal to carry out a programme of this nature was previously put forward to TBG and favourably received but not pursued, by a group composed of SKM and IGNS, with co-operation and contributions in kind from Tuaropaki Power Co. and the Philippines National Oil Co. (who at that time had proprietary rights to some of the chemical concerned, and the leading experience in their application). Revival of this project has not yet been discussed between the parties. It is not appropriate for NZGA to recommend whether this is the most suitable team to undertake the project.
Linkages Between Activities and Priorities	The priority is high as this project could given an immediate, substantial return at low cost and minimal environmental impact.
Financial	Full funding would be sought from EECA. It would be of the order of $100,000. No direct contribution is required from EECA staff. It is considered highly likely that the plant owners would give access to the geothermal facilities at no cost.
Outcome Monitoring	Completion of the study within the specified period

9. Setting out design information to promote direct use applications

The Nature and Scope of the Activity	After discussion with potential heat users, information will be collected to allow preliminary assessments of potential direct use applications, covering both upstream (fluid collection/disposal) and downstream (fluid use) applications.

Rationale	While there is general awareness of the potential use of geothermal energy, investment is hindered by a general lack of knowledge. Direct heat applications could make a significant contribution to the renewable target.
Timing	Information collection can be commenced immediately. Ideally, a database should be established to allow regular updates. Production of an information booklet or design report should be possible within a year.
Parties Involved	A contractor would be employed to assemble the information and produce the report. One Maori Trust has already started to identify information gaps as it attempts to make wider use of an existing development and will be consulted. NZGA Board members would select the contractor and be involved in report review on a voluntary basis. This project would usefully draw on EECA funding.
Linkages Between Activities and Priorities	Medium priority This report can be produced independently of other activities. There could be useful information extracted from activities 5, 6 and 8.
Financial	Cost of this activity is expected to be limited to $25k (ignoring the voluntary contribution from NZGA Board members), spread over one year. The full amount would be sought from EECA. Note that organisations, such as the electricity companies, are not incentivised to fund research that will reduce their sales. At least one Maori Trust is preparing to make financial investments in direct heat applications but is hampered by lack of knowledge.
Outcome Monitoring	The result will be the production of a report. Sales of the report will be one measurable outcome indicating dissemination of information. A further indication will be investment by Tuaropaki Trust and other individuals in direct heat applications.

Appendix: Current Research Directions

IGNS

This a summary of geothermal research undertaken by the Institute of Geological & Nuclear Sciences in the "New and Emerging Energy Technologies Portfolio", funded the Foundation for Research Science and Technology, 2002-2006. Elements of the programme are as follows:

Understanding geothermal heat source environments: To enable a full realisation of NZ's geothermal energy potential, it is necessary to understand better the relationship between the previously explored portions of geothermal systems, and their deeper-seated, magmatic heat sources. In particular, there is a need to clearly identify: (i) the nature and location of the heat sources (i.e., depth, physico-chemical environment, tectonic setting and magma type), and (ii) the mechanisms of heat and mass transfer into the overlying convective hydrothermal environment. This task is an integration and extension of research undertaken separately by GNS and IRL since 1998, which builds conceptual understanding and time-space models (i.e., calibrated numerical simulations), based on geochemical analysis of geothermal fluids and their host reservoir rocks. It is envisioned that in the medium to long term, geothermal developers will look to deeper source regions for a more sustainable geothermal energy supply, and a reduction in the environmental impacts that presently result from shallower production practices.

Increasing the cost-effective utilisation of high-enthalpy geothermal systems: This task develops new surface-based measurement methods for determining the detailed internal architecture of high-enthalpy geothermal fields, without the need for expensive drilling operations. The goal is to apply these advanced geophysical methods to obtain detailed resistivity images of the parameters characterising the geothermal reservoirs, and then to interpret the images in terms of geological structure, permeability and patterns of thermal flow. This will provide the means for identifying the high-temperature, high-permeability up-flow zones, which are suitable targets for drilling and extraction of hot thermal fluids. Future re-measurement will allow accurate monitoring of changes such as groundwater down-flow and other impacts brought about by withdrawal of thermal fluids and re-injection of waste fluids. This research utilises the potential of new-generation magneto-telluric techniques.

Mitigating the physical effects of geothermal development: This research, initiated in 1998 and now incorporating numerical modelling expertise from IRL and geobiological knowledge from Kingett Mitchell, forms part of NZ's contribution to the International Energy Agency (IEA) program on environmental aspects of geothermal development, for which GNS is the Operating Agent. Using mainly geophysical and geotechnical methods, it addresses the following key issues:

(i) Ground subsidence: analysis of mechanical properties and alteration petrology of affected substrate to determine cause and so reduce the likelihood of re-occurrence,

(ii) Greenhouse gas (GHG) emissions: measurement of natural and induced geothermal carbon dioxide emissions, to enable methods for reduction to be devised, and an equitable basis for future carbon taxes on geothermal power generation to be determined,

(iii) Natural thermal features: numerical modelling of long-term monitoring data, to assess the complex physical parameters involved and to provide a basis for mitigation,

(iv) Groundwater levels: numerical modelling of groundwater flow into geothermal aquifers, and development of methods to maximise energy production with minimum detrimental effect on the water table,
(v) Surface water ecosystems: development of a risk assessment model and the tools to reduce negative impacts of geothermal development on aquatic ecosystems, and
(vi) Induced earthquakes: development of stress models and laboratory testing of reservoir rocks, to define the causes and to assist in reducing the detrimental effects of the seismic activity.
In addition, resource valuation models will be developed to provide estimates of the economic cost of environmental remediation options, so that rational RMA decisions for specific geothermal development proposals can be made.

Mitigating the geochemical effects of geothermal development: Geothermal power generation requires extraction and disposal of large volumes of hot fluids and steam, which contain chemical impurities that pose a significant risk of environmental pollution. This can be, in part, mitigated by re-injection, but successful re-injection may require moderately high temperatures, which limits the efficiency of energy extraction and may adversely affect reservoir performance, through degradation of the production aquifers. This task will develop methods to control and/or mitigate the deleterious effects, through understanding the chemistry of geothermal contaminants within power station circuits and effluent streams. Specialised laboratory equipment is being used to inorganic and biochemical transformation of the toxic arsenic (III) and mercury.

NZ geothermal systems host unique thermophilic micro-organisms which have evolved special characteristics allowing them to live in thermal water with high concentrations of toxic trace metals such as arsenic and antimony. Understanding these characteristics opens the way for a wide range of biotechnological innovations, including the treatment of effluents from geothermal power plants. To hasten the development of such technologies and to maximise their benefits, an understanding of the mechanisms responsible for biosequestration of toxic metals is necessary. This task will involve isolation of micro-organisms from NZ geothermal systems, RNA sequencing, laboratory experiments of metal-microbe interactions, and synchrotron infrared analysis of cation binding mechanisms, and in so doing address two key questions: (i) which micro-organisms live in NZ geothermal systems that could provide effective bioremediation of waste water? and (ii) under what physicochemical conditions do they live, and what is the role that trace metals play in their metabolism?

Enhancing the value of low-enthalpy geothermal systems: This research explores the viability of under-utilised low enthalpy geothermal systems as direct sources of energy. More than one hundred of these systems occur throughout NZ, in diverse tectonic settings. From these, geoscientific and ecological data will be obtained to answer the following questions: (i) What are the origins of the anomalous heat? (ii) What are the lateral and vertical extents of thermal aquifers and what limits them? (iii) How do heat flow regimes change with time, and with changes in fluid flow? and (iv) Can the thermal waters trapped in abandoned hydrocarbon wells be successfully used to generate power and/or provide energy for industry? The research is complementary to GNS hydrocarbons research, which looks at heat flow and diagenesis in gas-rich petroleum systems. During the next 6 years of research, NZ’s low-enthalpy systems will be rated on their development potential and efforts made to promote appropriate utilisation.

IRL

Industrial Research Ltd. a CRI, is associated with one objective of the IGNS geothermal research programme. The aims of this objective are, through an integrated and multi-disciplinary research plan, improve the cost-effectiveness of geothermal energy extraction and utilisation. This research concentrates on deep (near-source) geothermal systems and will focus initially on identifying the causes of lost production at Ohaaki, then on providing the necessary knowledge to optimise the target areas for a deep production bore to be drilled.

SKM

Sinclair Knight Merz Limited is a New Zealand geothermal consultancy. They carry out paid R& D work for specific clients, and also internally fund some technology development, with no Government subsidy or contribution. Key areas where SKM is currently developing geothermal technology through internally funded programmes include:

- Modelling of subsidence related to geothermal exploitation
- Well design software
- Measurement of two-phase flow by multiphase tracer dilution techniques
- Process and mechanical design of steamfields, including the cost of pressure drop and pipe stressing methods
- Documentation of geothermal scientific and engineering experience
- Structural geology in relation to well targeting
- A generic financial model for geothermal projects.

PB Power

PB Power, GENZL geothermal division, are geothermal energy consultants.

Both client funded and internally funded research is undertaken with current focus on :-

- Resistivity modelling, calibrated against drilled geothermal reservoirs, to define shallow and deep reservoir boundaries..
- Transient well test modelling to better quantify critical reservoir parameters.
- Geothermal reservoir multi-component chemical tracer modelling to improve understanding of geothermal flow paths and estimation of critical reservoir parameters.
- Well bore 2-phase flow simulation software to optimise drilling costs and to quantify reservoir parameters from wellhead measurements.
- Development of data management software (GDManager & SteamField Manager) aimed at improving resource and environmental management of geothermal projects.
- Integrated steamfield optimisation software.
- Power plant optimisation software.
- Physical steam flow measurement and metering optimisation.

Century Resources

Century keeps abreast of international developments in geothermal drilling, logging and steamfield development. New technologies that are appropriate to New Zealand are adapted for New Zealand conditions in work done for operators in New Zealand.

Further, Century designs and constructs high temperature downhole logging tools to meet the changing needs of operators and to make use of advanced technology. The resulting tools are leading edge and are used in everyday operation to give better information and so enable geothermal resources to be more effectively developed. All research and development is internally funded.

University of Auckland/Geothermal Institute/Geology Department
FRST Funded research:

- Hydrothermal mineralisation and Crustal Fluids. 50% of this research focuses on metal transport and deposition in geothermal systems.
- Tikitere geothermal resources

Marsden Funded Research

- Hot springs and the origin of life

Post graduate geothermal research projects

- Simon Morris, Geology of the Te Puia geothermal area, East Cape, North Island
- Pablo Letelier, Surface manifestations at Tikitere thermal area, Rotorua
- Emma Rudsits, Sulfide mineralogy of submarine hotsprings in East Pacific Rise (co-supervised by Cornel de Ronde, IGNS)
- Kim Handley, Silica deposition in the Champagne Pool, Waiotapu (co-supervised by Bruce Mountain, IGNS)
- Kirsten Nicholson, Silica deposition at Tokaanu thermal area
- Rina Herdianita, Alteration mineralogy and fluid inclusion study at Darajat, West Java, Indonesia
- Suharno, Geophysical and geological assessment of the Ulubelu geothermal area, South Sumatra, Indonesia

University of Auckland, Department of Engineering Science

- Professor M. J. O'Sullivan, Geothermal reservoir modelling of New Zealand and overseas systems.
- Dr David Bullivant, geothermal software development.
- Dr Adrian Croucher, Development of Automatic Well Test Analysis Software (AWTAS)
- Warren Mannington, Large scale numerical modelling of Wairakei and Ohaaki Geothermal Systems using the TOUGH2 numerical simulator
- Juliet Newson, Numerical modelling of shallow geothermal processes, and the effect of production on natural geothermal features (geysers, hot pools, fumaroles, and steaming ground)
- Sadiq Zarrouk, Simulation of complex multiphase, multicomponent, reacting flows in porous media using the TOUGH2 numerical simulator.

Waikato Regional Council:

- The amounts of geothermal water and energy present in the region
- Number of sinter-depositing springs and geysers in the region
- Inventory of geothermal surface waters in the region and their dependent habitats

- Update and expansion of report on geothermal terrestrial vegetation
- Ongoing monitoring of surface geothermal features in undeveloped geothermal fields
- Ongoing monitoring of shallow geothermal wells in Wairakei-Tauhara and Ohaaki
- Geochemical monitoring of geothermal fumaroles and springs
- Monitoring of effects of geothermal take, use, and discharge throughout the region
- Investigations into the landslide hazard caused by the Hipaua steaming cliffs
- Monitoring effects of geothermal inputs to Waikato River

District Councils
Taupo District Council is supporting development of improved methodology for geothermal exploitation-related subsidence prediction and mitigation.

NIWA
Through a FRST-funded project, NIWA is investigating a range of energy supply options for remote Maori communities, including wind, wave and geothermal possibilities.

Generation Companies
The major geothermal electrical generators in New Zealand are Contact Energy (Wairakei-Tauhara, Ohaaki), Mighty River Power (Mokai, Rotokawa, starting on Kawerau), Tuaropaki Power Company (Mokai) and Top Energy (Ngawha). These companies support some commercially-funded R & D by other organisations such as IGNS. They also make a large and often unrecognised contribution to the knowledge of geothermal resources, through their exploration, delineation and resource monitoring programmes. Some of that information is not in the public domain, but a significant part of it is, through the resource consent reporting process.

Private individuals
The NZGA is aware of, and will provide support for, a textbook on geothermal energy being prepared by Dr. Mike Mongillo.

Overseas Research and Technology
We also need to acknowledge that while there is good geothermal technical capability in New Zealand, there are now many specific areas where we once led the world but no longer do so world. This is because of many years of under-funding in research and a slow pace of geothermal development compared to other parts of the world. There are also areas where the New Zealand industry has simply been too small to support major R & D.

These areas include:

- Drilling technologies, including deep directional drilling, mud logging and hydrofracturing
- Down-hole measurement, including measurement while drilling and formation micro-imaging through multi-element resistivity
- 3-D seismic surveys, including the use of micro-seismic surveys to define structural targets.
- Advanced petrological techniques such as SHRIMP analysis of fluid inclusion, or neutron activation analysis. We have recently *lost* the capability for commercial Ar/Ar dating.
- Silica deposition inhibition technologies.
- Hydrogen sulphide abatement technologies

- Advanced steam turbine design
- Kalina cycle power plants
- Ground-source heat pumps

In some cases research or development programmes are under way or are proposed to redress this. However, there are other cases where it is simply not efficient to do so, either because the New Zealand industry and research capabilities are too limited, or because commercially-available technology already exists overseas and it would be pointless to “re-invent the wheel”. Hence the Association considers that a significant part of EECA’s programme should be directed to importation of technology from overseas, where it already exists in an advanced form.