Geothermal Energy: Summary of emerging technologies and barriers to development

Ministry of Economic Development
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Aim: To consider barriers to the development and use of geothermal resources in New Zealand, particularly for emerging technologies, and discuss ways to reduce the impact of these barriers.

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1. Introduction

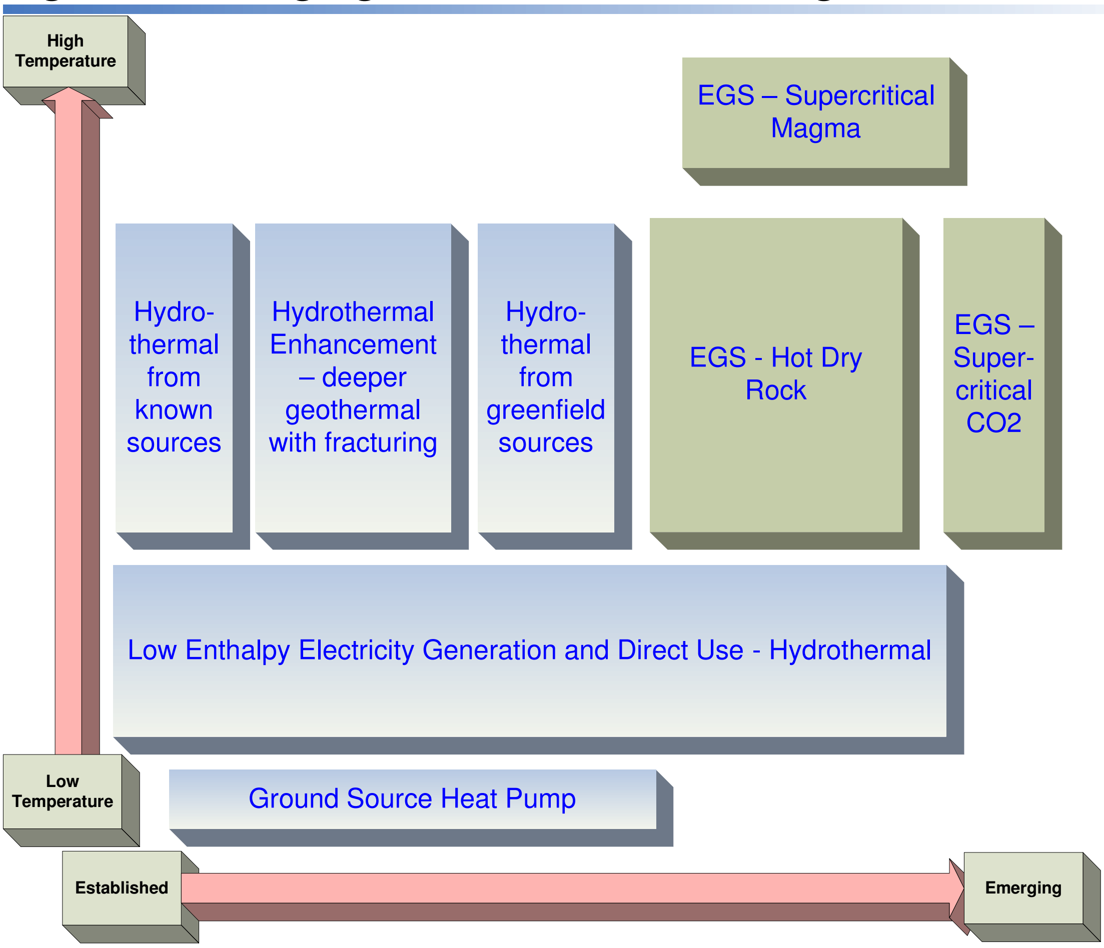
1.1 Context

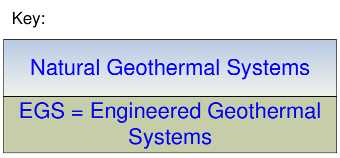
The review of the Resource Management Act (RMA) and the Electricity Review provide an opportunity to look at the state of play and future of geothermal in New Zealand. The aim of this paper is to look at developments in geothermal technologies and at how geothermal energy is developed, to identify barriers or opportunities in the development of geothermal resources in New Zealand.

1.2 Scope

In order to take a wide view of the topic and to identify synergies between different technologies, this paper looks at geothermal energy across a range of technologies: from ground source heat pumps through conventional hydrothermal, to engineered geothermal systems (EGS). It also considers the use of geothermal energy for both electricity generation and direct heat use.

Figure 1: Emerging Geothermal Technologies in NZ





1.3 Background of geothermal in New Zealand

Like many other countries with a significant landmass situated on the Pacific Rim, New Zealand has an easily accessible and large geothermal energy resource. The first use of geothermal energy in New Zealand was by central North Island Maori as a heat source for cooking, bathing and ceremonial purposes.

Historically most industrial use has been centred on the Taupo and Kawerau regions within the Taupo Volcanic Zone (TVZ) with large scale electricity and direct use applications existing since the late 1950's. The use of geothermal resources for domestic use purposes and as a tourist attraction have occurred throughout the TVZ.

Today New Zealand is home to the world's oldest operating geothermal power station at Wairakei and around 700 MW of electricity is supplied from geothermal sources. In addition to this, the direct use of geothermal energy has provided heat for various applications such as wood processing, with large scale use since the early 1950s.

1.4 Economic value of geothermal energy in New Zealand

Geothermal energy adds value to the New Zealand economy, however it is challenging to quantify this and compare it to other sectors such as the minerals and petroleum sector.

Noting that there are many other uses of geothermal resources in New Zealand from which we derive economic value such as cultural needs, tourism, direct use and the value of the ecosystems that geothermal resources support, the easiest way to put a monetary value on geothermal resources is to look at the main output of geothermal energy in New Zealand - clean renewable electricity - and put a value on this to compare with the value obtained from other resources. It is recognised, however, that this does not take account of the significant tourism related revenue associated with geothermal resources.

Using recent production and price information[1] it can be shown that around $0.5 billion worth of coal, over $2 billion worth of oil and over $1 billion worth of gas is produced in New Zealand each year.

Geothermal energy as a product is not sold on a large scale basis, but the electricity produced from it is. Based on an average wholesale electricity price we can estimate that over $0.35 Billion dollars worth of electricity was generated from geothermal energy[2] in 2009.

MED's recently published Energy Outlook[3] forecasts show that geothermal energy is likely to be one of the cheapest sources of new electricity generation over the next 20 years. Geothermal capacity from traditional hydrothermal sources could increase to nearly 1500 MW by 2025 and at current prices this indicates a potential

[1] Primarily from 2008
[2] Taking an average wholesale electricity price of $77/MWh and that nearly 4 Million MWh were generated from geothermal in 2008
[3] http://www.med.govt.nz/energyoutlook

contribution of nearly $1 billion per annum from electricity generated from geothermal energy[4].

2. Emerging geothermal technologies

Until recently thinking about geothermal energy in New Zealand has largely been limited to the traditional high temperature hydrothermal resources predominantly found in the Taupo Volcanic Zone (TVZ). As a consequence all references to geothermal energy in law and regulation in New Zealand has solely focused on this traditional resource, albeit across a range of temperatures.

Over the last 10 years research into alternative geothermal technologies has expanded rapidly as global warming has led people around the world to look for cleaner renewable technologies to supply energy into the future. Some of the following developments, such as ground source heat pumps, are mature technologies, and others such as Hot Dry Rock are still in the early stages of research and development.

This section summarises the main geothermal technologies currently being developed globally and analyses the potential of each technology in a New Zealand context and considers whether the current regulatory regime is sufficient to deal with future technological developments and deployment. These technologies are not mutually exclusive, with the potential for overlaps and combination applications, particularly in relation to direct use.

[4] This does not take account of any emissions related costs associated with geothermal developments, although geothermal developments compare well with many electricity generation options.

Figure 2a: Geothermal Technologies Summary Matrix

	Resource Extent	Regulations	Economic Potential
2.1: Direct Use - Hydrothermal	Centred on TVZ but possible in other geologically active areas around NZ	Covered by RMA	Wide potential for expansion of use – tourism, timber and food processing, space heating etc.
2.2: Ground Source Heat Pumps	Nationwide	Covered by RMA unless too small to trigger significant adverse effects	Proven technology - more economic in areas with extreme seasonal temperature variations.
2.3: Hydrothermal Enhancement – deep geothermal with fracturing	TVZ	Covered under existing RMA legislation	Expensive to drill to depth – but has good potential - could be used to lengthen and enhance use of existing capital
2.4: Low Enthalpy Binary Hydrothermal systems	Centred on TVZ but possible in other hot spots around NZ	Covered under existing RMA legislation	Power from stand alone plants is currently more expensive than steam flash plants – however it opens up a wider range of resource temperatures and is a proven technology.
2.5: EGS - Hot Dry Rock	Potentially nationwide, although more promising around geologically active areas.	RMA covers geothermal fluid and energy, take and injection of fluids	Not yet viable commercially. Likely to be expensive compared with most hydrothermal resources
2.6: EGS - Supercritical CO_2	Requires a large and continuous carbon dioxide source e.g. thermal power plant, large industrial source.	RMA covers geothermal fluid and energy, take and injection of fluids	Still physically and economically unproven – early research phase. Could be a form of Carbon Capture and Storage (CCS)
2.7: EGS - Supercritical Magma	Probably in TVZ and other areas of high volcanic activity	RMA covers geothermal fluid and energy	Early research phase. Potential unknown.

2.1 Direct use – hydrothermal

Technology: Direct use of geothermal energy for commercial applications in New Zealand has existed since the early 1950s, however only a few major direct use applications exist such as the Kawerau Pulp and Paper Mill which makes up half of New Zealand's direct use demand and the glasshouse operation at Mokai. Small scale and domestic direct use has also been relatively common in the TVZ.

Consent requirements: For large scale users the consent requirements are similar to those for the use of hydrothermal for electricity generation. Smaller users may be exempt from requiring resource consent depending on the depth of bore and amount of energy extracted.

Risks of Development: In the late 1980s over extraction of the geothermal resource around Pohutu Geyser in Rotorua led to the closure of most bores in the surrounding area. These bores were all for direct use applications and due to their small size were not managed as closely as for large extractors, but in combination they had the same level of impact as a large extractor. Most commercial scale direct use applications to use geothermal energy would need to apply for resource consent[5]. If not managed holistically, there is the potential that the cumulative effect of direct use could endanger the potential of the resource for electricity production.

Barriers to development of direct use

Identifying Barriers: Direct use can be overlooked when deciding how to use a geothermal resource with the direction often going in favour of electricity generation. Electricity generation may not always be the most efficient or economic use of the resource. Individuals and organisations looking to invest in geothermal developments may be unaware of the different potential uses of a geothermal resource. The proximity of potential users to geothermal resources can also be a barrier to uptake, relocating may be problematic when it comes to accessing raw materials. Lack of access to local skills and knowledge can also be an issue.

Breaking Barriers: Locations where both geothermal resources and large heat demands exist should be considered for their direct use potential as well as their electricity generation potential. This may involve mapping of where geothermal resources are located compared to large industry or potential for large industry. This additional information for developers and investors could lead to better investment choices, and lower energy costs.

2.2 Ground source heat pumps (GSHP)

Technology: Relatively new to New Zealand but widely deployed in northern Europe, this technology is relatively mature and the economics in New Zealand are currently considered marginal at the domestic level but with greater potential at commercial loads e.g. hotels and schools. The deployment potential in New Zealand

[5] The RMA does exempt the taking or use of geothermal surface water (>30 degrees Celsius) in accordance with tikanga Maori for the communal benefit of the tangata whenua of the area and that does not have any adverse effects on the environment.

is substantial (though less than for air sourced heat pumps), for both heating and cooling applications. There is the potential for rapid deployment, the main barriers being lack of customer awareness and the availability of skilled installers.

Consent Requirements: If an open circuit GSHP system is being considered then this will require consent to extract the fluid (water). If the fluid is greater than 30 degrees Celsius it is classified as geothermal water and requires consents as such.

A closed circuit GSHP system using heat exchange to transfer heat from the ground or an underground aquifer would be unlikely to require resource consent in relation to geothermal energy as long as the ground or aquifer below were no greater than 30 degrees Celsius. It may require resource consent to do the earthworks required to install the system. If geothermal energy was being extracted from a source greater than 30°C, then resource consent to extract geothermal energy would be required.

Risks from Development: There are environmental risks that would need to be managed for a GSHP. If uptake is significant then the resource may need to be more closely managed to prevent excessive soil heating or cooling. Where a system uses refrigerant as opposed to water there could be a risk of soil contamination if an underground closed loop were to leak into aquifers or waterways. There is also a risk that an operating or abandoned system could be damaged by earthworks causing refrigerant to contaminate water and soil. Monitoring refrigerant levels could be a necessary part of gaining a resource consent to undertake the works. At the end of life of a GSHP, all refrigerant should be removed or the entire system should be removed to ensure no leaching takes place in the future.

Barriers to Development of GSHP

Identifying Barriers: Barriers to the uptake of GSHPs in New Zealand include high initial capital cost to realise the long-term benefits, lack of awareness of the technology amongst customers, competition from other energy sources, and the possible difficulty in retrofitting particularly where land is scarce such as in urban environments. Elsewhere GSHPs have been installed on a community basis and this approach is generally lacking in New Zealand.

Breaking Barriers: End user grants such as those that exist for air source heat pumps could be considered to foster the market and drive a reduction in capital costs over time, although it is questionable whether or not this would be cost effective for one off domestic retrofit installations. A strategy to increase public awareness (e.g. through the Energy Efficiency and Conservation Authority) of GSHPs as an option to be considered when building a new home or commercial building, that has low running cost compared with other forms of heating, could be developed. There is also a role for industry to address issues around the availability of trained installers.

2.3 Hydrothermal enhancement – deep geothermal with fracturing

Technology: The techniques associated with hot dry rock technology could be applied to the impermeable fringes (lateral and vertical) of existing high temperature resources to increase their assessed capacity. Deep drilling (below 3km) can be a means of extending the proven resource in existing high temperature fields as assessed reserves require proof of high temperatures to be booked for development purposes.

Areas in existing production fields have been abandoned because of no permeability e.g. in the south of the Kawerau field. Fracturing techniques and associated injection could bring these currently abandoned areas into production, either linked to existing stations or for dedicated developments, although there is still debate about the long term effectiveness of this technique for enhancing existing fields. Exploitation of these impermeable areas will be cheaper than most deep hot dry rock projects because the drilling for these resources will be at conventional geothermal depths. The end result is that there can be significant value in bringing either deep drilling or reservoir fracturing techniques from petroleum exploration and hot dry rock research into the areas associated with New Zealand's high temperature hydrothermal fields.

Consent Requirements: All the enhancement methods mentioned are able to be covered by the Resource Management Act. At an existing operation any change in the nature of the geothermal fluid or the amount of geothermal energy being extracted may require a revised consent to extract the geothermal fluid, energy and water.

Risks from Development: As with HDR resources, concerns exist that fracturing could induce seismic activity. Australian experience suggests the risk of induced seismicity is low compared with natural earthquakes. Research into this continues. If chemicals are used during the process there would also be concerns about their behaviour in the subsurface and any potential for groundwater contamination.

Barriers to Development of resource enhancement

Identifying Barriers: As wells get deeper the cost of drilling may become prohibitive and many investors may consider deep drilling too risky. Such developments may require assistance to prove the resource. In addition to the financial barriers, there are also likely to be geophysical and geographical limits to where these techniques can be applied. For instance they may not be suitable for use on a fault line due to concerns over induced seismicity.

Breaking Barriers: Providing grants to help prove a deep resource could enable more deep drilling to take place and could make financing traditional resource developments easier by providing more information on reserves. Any such proposal would need to weigh up the costs of such a grant against any positive economic impacts of development. Currently there is no intention to offer any grants in this area.

2.4 Low enthalpy binary hydrothermal systems

Technology: Low enthalpy geothermal plants based on a number of enabling technologies can generate electricity from a heat source considerably lower in temperature than traditional flash steam plants. Instead of the geothermal fluid itself passing through the generating turbine, heat exchangers are used to heat a working fluid (binary fluid) which has a lower boiling point than that of water and so can be evaporated and expanded through the turbine at a lower temperature.

This is not a new technology and in some cases is based on mass produced technology for the heating and air conditioning market. New Zealand currently has five locations with operational geothermal binary cycles – Wairakei, Mokai, Rotokawa, Ngawha and Kawerau. Wairakei, Mokai and Rotokawa binary cycles extract further heat from expanded steam or hot water that cannot be expanded though a turbine. This increases the overall electrical conversion efficiency at these plants.

Both Ngawha plants and the new Kawerau KA24 plants (this is an independent plant in addition to Mighty River Power's recent Kawerau development) are stand alone binary plants, however these still use relatively high temperature geothermal fluid (Ngawha averages 220 degrees Celsius). Standalone binary plants can be used on lower temperature resources, for example, Raser Technologies have installed a 10 MW plant in Anaheim California which uses geothermal fluid in the range of only 90 – 150 degrees Celsius. The use of standalone low enthalpy binary plants could clearly increase the potential geothermal resource for the generation of electricity in New Zealand.

Consent Requirement: Low enthalpy geothermal resources are already managed by the Resource Management Act in the same way as higher temperature resources.

Risks from Development: There appears to be a tendency for developers to assume electricity generation is the best utilisation of the resource, where as direct use of heat may be a better option in some instances.

Barriers to Development of Low Enthalpy

Identifying Barriers: Typically the small plant size (around 10 MW) erodes the economies of scale making it a more expensive option for standalone electricity generation than for large scale high temperature resources (over 100 MW). The cost of consenting and exploration could be similar to that of a larger plant with productive output much less.

Breaking Barriers: Binary cycles are widely deployed for geothermal energy in New Zealand in combination with initial steam flash technology and stand-alone plants on high temperature resources, but no truly low temperature resources have been developed this way to date. Although there is little scope for government intervention in this area, there is publically funded research going on, and the geothermal sector has conducted research into how to develop low enthalpy opportunities. More information on potential resources for developers and users could be helpful.

2.5 Engineered geothermal systems – hot dry rock

Technology: The subject of significant research programs worldwide, including in Australia, Hot Dry Rock (HDR) technology involves drilling (often very deep) combined with the injection of a heat transfer fluid (most proposals focus on water, however carbon dioxide has also been proposed), deep within the Earth's surface to extract heat from areas which have no traditional hydrothermal resource but have considerable available heat.

Due to the site-specific influence on costs it is difficult to estimate delivered costs of energy produced by HDR techniques but high drilling costs lead to an assessment that costs will be considerably greater than the other more immediate geothermal opportunities available in New Zealand[6].

Hot dry rock exploration can start from a review of elevated temperatures in existing oil and gas wells and other boreholes to identify areas with greater potential, from which new hot dry rock developments could be considered. Hot dry rock development normally involves an array of production and injection wells linked to a geothermal power station designed for a relatively low temperature resource. A reservoir is formed by drilling into the hot rock and then fracturing it at targeted depths normally through injection of water at high pressure, possibly with propping agents to retain permeability. Other wells are then drilled to intersect the newly created reservoir, and a circuit of flowing fluid is created by injecting water in one well and producing from the other. The fluid flow through the fractured rock flushes out heat which can be used for power generation.

Hot dry rock wells are commonly deeper than conventional geothermal wells (greater than 3 km versus 1.5 to 3 km deep) and so are consequently expensive.

Consent Requirements: The consenting process for HDR would have to deal with the physical changes being proposed beneath the surface, the injection of a heat transfer fluid and also the extraction of geothermal energy, even though no natural geothermal fluid is being extracted. It is considered that HDR technology is covered within the existing RMA regime given that it deals not only with the resource management of geothermal fluid but of the geothermal energy.

Risks of Development: An HDR development would be at depths traditionally associated with oil and gas reserves. Potential for conflict between a geothermal resource at one level and an oil and gas reserve at another level is a possibility. MED is considering the issue of conflicting access to underground resources. Also concerns exist that the fracturing technique used in HDR could induce seismic activity (earthquakes). According to Australian experience the risk of induced seismicity is low compared with natural earthquakes. Research in this area continues.

Barriers to Development of HDR

Identifying Barriers: HDR technology is commercially unproven with projects existing worldwide solely through government and private research assistance. There may be limited available information on the potential resource as very few actual data points (from drilling) exist at the depths necessary for HDR in New Zealand. The available information will be dispersed, making it difficult to find and obtain, especially for interested parties outside New Zealand.

[6] HDR wells are currently around 3-4 times the cost of standard hydrothermal wells.

Breaking Barriers: Over time this technology is likely to reduce in cost and may become commercially economic in countries with no hydrothermal resource. New Zealand has a large hydrothermal resource so it seems unlikely that higher cost HDR projects will attract investment ahead of hydrothermal options. At present there is no need for Government intervention in this area, although thought is being given to how New Zealand retains and makes information on its underground resources available. The geothermal industry in New Zealand should keep track of the development of HDR technology and its potential deployment in New Zealand.

2.6 Engineered geothermal systems - supercritical CO_2

Technology: Supercritical Carbon Dioxide[7] (CO_2) has been proposed as a possible alternative to water as the heat transfer medium used in HDR systems. Supercritical fluids are able to diffuse through solids like a gas (seep into the pores of rocks) whilst dissolving materials like a liquid. For EGS supercritical CO_2 could lead to reduced scaling, larger heat extraction rates (due to it being considerably more mobile than water – which should compensate for its lower heat capacity) and could also be a possible means of removing CO_2 from the atmosphere and storing it underground (Carbon Capture and Storage (CCS)). However, there are concerns around the corrosiveness of CO2 in water.

At this stage, supercritical CO_2 systems are only a concept and have not been tested anywhere meaning that the cost is uncertain, though likely to be very high.

Consent requirements: A supercritical CO_2 system would have similar consenting requirements to any other HDR technology. In addition, an applicant would be likely to have to show this untested technology is unlikely to have any unforeseen impact on the natural and built environment. To be a viable CCS technique it would need to be shown that the CO_2 would remain stored underground indefinitely.

Risks of Development

The biggest risk with this technology surrounds responsibilities and liabilities if CO_2 migrates from the intended reservoir.

Barriers to Development of supercritical CO_2

Identifying Barriers: This technology is still in the research and development stage and consequently will not be widely deployed until it has been demonstrated to work reliably at the commercial scale.

Breaking Barriers: New Zealand could contribute to international research in this field. There are currently no specific government activities in this area.

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[7] Under normal temperatures and pressures a substance is likely to be a solid, liquid or gas. Carbon dioxide is naturally a gas at standard atmospheric pressures and temperatures. If both the temperature and pressure exceed the critical point - 27 degrees Celsius and 73 times standard atmospheric pressure - then carbon dioxide will cease to be either a liquid or gas and become a supercritical fluid.

2.7 Engineered geothermal systems - supercritical magma

Technology: Drilling deep into magna is being researched around the world, predominantly in Iceland and Hawai'i. This would involve extracting heat directly from magma rather than geothermal brine and is in the very early developmental phases.

Consent requirements: A supercritical magma system would have to overcome serious safety concerns, chemical issues and high temperatures which melt all but the toughest of materials. It would certainly be testing for a Regional Council to allocate consent in this instance.

Risks from Development: As this deals with very high temperature geothermal resources (magma) there would be safety concerns which could be dealt with under health and safety regulation.

Barriers to Development of supercritical magma

Identifying Barriers: This technology is in the research and development stage and consequently will not be deployed until it has been demonstrated to work reliably at the commercial scale. The high temperatures involved will require the use of expensive engineering materials.

Breaking Barriers: New Zealand could contribute to international research in this field. There are currently no specific government activities in this area

2.8 Other uses of geothermal resources

In addition to the use of geothermal resources for energy, there are other potential uses for these resources.

Mineral extraction from hydrothermal resources

The extraction from geothermal fluid of minerals in solution including gold, silver, copper, arsenic and lithium could be a major use of geothermal resources in the future. This activity would require both RMA and CMA consenting and permitting and there would be requirements to control any hazards associated with the process.

Carbon capture and storage (CCS)

Low temperature geothermal reservoirs could be potential sites for the underground storage of CO_2 for atmospheric emissions reduction. Warm saline aquifers are already being considered as suitable storage sites in Australia.

Thermophile cultivation

There are opportunities to use lower temperature geothermal resources and fluid that has already been through a generation plant in the cultivation of organisms that can benefit from increased temperature environments.

Figure 2b: Barriers to emerging geothermal technologies in NZ

Short Term → Long Term

Technology	Immediate NZ Potential	Identifying Barriers	Options for Breaking Barriers
Direct Use – Hydrothermal Potential for heat intensive industries – Wood and dairy processing, increased tourism...	Very strong potential – often ignored as possibility	Perception that geothermal energy is only good for electricity. Requirement for end use to be near resource as difficult to distribute (relative to electricity). Limited potential uses and area (TVZ)	Awareness raising amongst potential customers and resource developers
Ground Source Heat Pumps Mature technology, high capital cost, small & medium heat demand...	Already in place, e.g. Dunedin Airport. Best for climates with large annual temperature swings	High capital cost Low public awareness Difficulty in retrofitting Requires space (difficult in urban environments?)	End user grants like those for air source heat pumps to foster market and drive reduction in capital cost over time Public awareness campaign (EECA) – highlight as renewable, low running cost, best installed in new buildings
Hydrothermal Enhancement – deep geothermal with fracturing Enhancement of existing resources, more heat deeper, fracture rock increasing permeability...	Already being considered. Lengthen operational lifespan or capacity of existing plants.	Deeper wells are more costly Concerns over fracturing and induced seismicity (earthquakes caused by man)	Drilling grants an option
Low Enthalpy Binary Hydrothermal Systems Heat exchangers – secondary fluid to generate, traditional resource, low temperatures...	Technology is widely used for NZ geothermal. No low enthalpy (temperature) binary use yet.	Typically small plant size may erode economies of scale. Consenting and exploration costs may be same as for larger flash steam plants	Binary cycles are widely deployed for geothermal in New Zealand. However no stand- alone, low temperature resources have been harnessed to date.
EGS – Hot Dry Rock High temperature rocks at great depth, inject water to transfer heat...	Not yet fully commercial – significant research funding in US/Australia.	Not operating at commercial scale Limited resource information	Over time, cost will reduce through economies of scale but will likely remain more expensive than hydrothermal in New Zealand.
EGS – Supercritical CO_2 Hot dry rock, carbon dioxide as fluid, carbon capture and storage...	Theoretical and unproven. Of interest primarily due to CCS possibilities.	The technology has high risk of never becoming commercial.	New Zealand could contribute to international research.
EGS – Supercritical Magma Drilling to magma, heat exchange, very high temperature...	Very early research in Hawaii and Iceland. Far from commercial – safety concerns	Early research phase High temperatures require specialist materials to drill	New Zealand could contribute to international research.

3. Barriers to the use of geothermal energy in New Zealand

3.1 Introduction

This section breaks down the development and use of a geothermal resource into five key phases, and looks at what barriers may exist to progressing to the next phase of a geothermal development.

The five phases are: Resource study; initial site exploration; Exploratory drilling and reservoir modelling; consenting and operating; and decommissioning.

3.2 Phase 1: Resource study – prospecting

Phase includes

Desk Study: Research of publically available information where possible geothermal resources may be cited.

Accessing data: Some data may need to be negotiated for and purchased.

Remote Sensing: Research on geothermal resources without the requirement of a land access agreement – e.g. a flyover of property using electromagnetic resonance to define the potential extent of the resource.

Barriers to progression

Information/data availability: Information such as drilling records and maps indicating the extent of geothermal fields, the location of geothermal resources such as geysers, hot springs and even areas of higher than normal subsurface temperatures are currently available from a range of sources, including central and local government and Crown research institutions such as GNS Sciences and the University of Auckland. However there are inconsistencies in how this information can be accessed and it has been argued that it is sometimes difficult to gain access to information even when it is meant to already be public. There are a range of sources of data on land ownership.

Regional Councils collect data on operations on existing fields, but there are protections applied to this information to prevent other parties gaining a commercial advantage from the release of this information. For example, Environment Waikato is trying to make the information that they collect more accessible, but by contrast Environment Bay of Plenty currently treats the majority of the information they receive as commercially confidential. This reflects the current situation where Environment Bay of Plenty is regulating in an environment where there are multiple operators on a field, a situation that does not currently exist for any Environment Waikato consents.

In addition to Regional Council held data, information from other sources exists, such as past Crown drilling programmes and temperature data for other drilling operations, but is kept by a variety of organisations and has a range of access requirements. This makes it difficult to get a clear overview of all of the existing data available for a particular site. This problem is greater for new market entrants who may be unfamiliar with past exploration activities in New Zealand.

In contrast, for Crown owned petroleum and mineral resources, which are permitted under the Crown Minerals Act 1991, information generated during exploration must be provided to the Crown, which then maintains the information collected, making most of it public after a period of time.

Without access to the raw data on potential geothermal resources, it is not possible for subsequent analysis to take place efficiently, and be of benefit to a wide range of explorers rather than just be of relevance to one particular project, field or technology. Access provisions such as the time for which the data remains confidential, need to reflect the costs associated with obtaining and interpreting the data in the first place. It is important that the value of data on underground resources is recognised across a range of resources.

A resource may have been explored but been considered to be uneconomic for the project requirements at the time. Currently this information is unlikely to be available to other potential users who may be able to find an alternative use for the energy which may be economically viable now. This could lead to extended timeframes and higher risks in the development of a project or the opportunity to develop being lost altogether.

Potential actions to address barriers

Stocktake of existing information on New Zealand's geothermal resources: Large amounts of high level information on New Zealand's geothermal resources exist, much of it being held by Regional Councils. However, there is no national coordination of this information, making it difficult for potential investors, particularly foreign investors to find and access this information. In addition to the data held by Regional Councils, some resource information, resulting from drilling by the Ministry of Works from the 1950's to 1980's is held by the New Zealand Treasury and there may also be some merit in co-ordinating underground temperature information obtained as a result of oil and gas exploration, for example. For low temperature resources other information such as soil conductivity and air temperature variations might also be helpful.

Conducting a stocktake of the existing information on New Zealand's geothermal resources could provide investors with information on what data is available, where it is available from and what the access requirements are e.g. if there is a charge.

As part of any stock take, consideration needs to be given to the long term management of information on geothermal resources into the future.

Establishing a national data set on New Zealand's geothermal resources: Following a stocktake, a national geothermal data repository could be formed. This would enable all existing geothermal data to be accessed through the same process, with clear access requirements. There would need to be clarity over what would be available within this data set and for how long access to specific data would remain restricted due to commercially sensitivity.

Establishing a national geothermal data set would have implications for the information provided under the RMA by existing operators and for those providing underground temperature data from other sources, such as information from petroleum exploration and production provided to Crown Minerals.

If such a data set existed, the Crown would need to consider how to make available this information to potential investors, without placing a disproportionate burden on those providing the information.

Crown undertaking speculative surveys: As has happened in the petroleum sector, the Crown could chose to undertake speculative surveys of the geothermal resource in New Zealand, to better understand the locations for potential geothermal energy applications. The logical focus of this activity would be on greenfield sites where there is no surface expression of a geothermal resource. The economic case for conducting speculative surveys is much less substantial for geothermal than for petroleum. However, there could be merit in government and Regional Councils working together to improve knowledge about geothermal resources.

3.3 Phase 2: Initial site exploration

Phase includes:

Land access: To conduct certain geophysical surveys or to drill on a geothermal field a developer must first have access to land under which the field is sited. This can be obtained through purchasing land outright, or negotiating access and usage rights with the landowner. Although the exploration of a geothermal field may not require all land owners above a field to sign an access agreement, a developer is best placed for the future development of the field if they find agreements with all potentially affected land owners at this early stage. Access agreements are not a guarantee that the resource will be developed and in some cases they can 'lock up' resources.

Most major plants (>50MW) since 2000 have been built in varying degrees of partnership between the land (and resource) owner and the operating company. For example, Mighty River Power has successfully worked with local iwi to negotiate terms of access to drill, build and operate on various geothermal fields, in most cases leaving a large proportion of plant ownership with the local iwi through Joint partnerships, or other arrangements, all of which leave the land owner as an active business partner as opposed to a landlord.

Many landowners are aware of the geothermal resources under their land due to surface expressions such as hot springs. However, in the future greenfield sites with no surface expression and emerging technologies will mean that landowners who are new to the geothermal space will become increasingly involved.

Consent to drill: To do on-site exploration, resource consent under the RMA must be obtained to drill/explore for geothermal fluid. In most cases this will depend on the classification of the geothermal field being targeted and there are likely to be data reporting requirements attached.

There is currently a lack of certainty over how to allocate and consent possible offshore geothermal resources beyond the 12 nautical miles limit of the application of the RMA.

Securing funding: Geothermal wells for power generation are typically deeper than 1km and as a result are expensive to drill. To undertake onsite research an operator must secure investors willing to wait for any return and an affinity to high risk investment.

Barriers to progression

Lack of clear process to gain land access and rights of explorer to use resource: The current system of geothermal management under the RMA requires a developer to negotiate formal contracts with all land owners where access is required, defining what rights each party have in respect to accessing the geothermal resource. This lack of certainty can be a deterrent to investors, particularly from overseas. There is no formal process of arbitration and no legislative guarantee that the explorer will be given the first right to extract the resource. In contrast, for oil and gas (covered by the Crown Minerals permitting regime), arbitration is an option for land access negotiations, although arbitration has never been required to date.

It has been argued that geothermal explorers do not have enough certainty to explore because someone else can come in and apply for resource consent after the explorer has invested in exploration in a particular area. However, it is not clear that the lack of a legislative guarantee over the right to develop is necessarily of concern. An application for resource consent to develop a resource requires the provision of considerable information. Hence, the ability of a new party to gazump an existing explorer to develop for the same use may not be as easy as some assume or suggest, but there is considerable potential that such a situation could delay or even terminate the development of a resource, or that there could be conflict between those seeking to use the same resource for different types of development.

High cost and risk of failure at initial site exploration phase: There is a significant risk of failure at this initial onsite phase if resource consent to explore is not granted and funding to drill cannot be obtained. There are many reasons a site may not be consented, even though the resource may be potentially of high value, for example, depending on the level of protection of the resource and on existing allocations. The consent process can take a long time to progress which can be costly, particularly if there are any objections to the development.

Obtaining funding to drill once consent is obtained may prove equally as difficult given the high risk that an insufficient resource may be obtained (much like in the risk in the petroleum sector). These costs may prohibit smaller private developers from progressing geothermal developments. There is a role for the development of technologies in reducing these risks.

Access to sea bed outside 12 nautical mile zone: The RMA does not apply outside 12 nautical miles, and even within the 12 nautical miles ownership is often less than clear. Between 12 nautical miles and the edge of New Zealand’s Exclusive

Economic Zone (EEZ) is covered by the Continental Shelf Act. Offshore there is currently no equivalent to the sustainable management of geothermal resources under the RMA so it is not clear what the basis for permitting offshore geothermal developments would be at present. In the future EEZ legislation could address this.

Potential actions to address barriers

Giving explorers more certainty: There is a risk that a geothermal explorer may be blocked from using a resource that they have explored at great cost because another developer applies for resource consent first and they are considered on a first come first served basis. In reality the competing developer is unlikely to have sufficient information to be granted resource consent. Regional and District Councils have improved their processing of multiple applications and it is hoped that this will reduce delays.

In 2005 the RMA was amended to consider a similar issue: the potential for the value of existing investment to be undercut by new resource consent applications that would affect the operation of that investment. There is a need to balance this with the desire to allow new entrants and to see that resources are not tied up in perpetuity.

The efficacy of the current system and the effects of the RMA review will continue to be monitored by MED .

Financial incentives: An option to encourage exploration; particularly on high risk greenfield sites, may be for the government to offer tax breaks or grants. There does not appear to be a sufficient economic case to consider such measures at this time.

3.4 Phase 3: Drilling and reservoir modelling

Phase includes

Drilling and reservoir modelling: Wells must be drilled to enable measurements on which to base detailed reservoir modelling to be undertaken. This is to build up a picture of the resource to understand: how the geothermal fluid behaves, the extent of the resource and to identify optimal sites for production and injection wells.

In the Waikato and Bay of Plenty region, strict criteria have been set on the level of information required, so a large amount of data is being collected by these organisations. This could be of value to future explorers if development of the field does not go ahead, but only if the information held is not kept confidential indefinitely.

Barriers to progression

Availability of equipment, skills and personnel: Drilling wells is not only expensive, but can be technically challenging especially when dealing with high temperature fluids at depth. As is the case in the petroleum sector, gaining access to rigs and staff with the expertise to operate them can be problematic.

A developer may also struggle to find and retain the suitably qualified people to undertake the complex reservoir modelling required when developing a geothermal field. This is a particular concern with the growing global uptake of geothermal energy and the associated demand for skilled people.

Potential actions to address barriers

Increased co-operation between developments: A factor leading to the success of Mighty River Power's recent geothermal developments has been a continuous phase of geothermal development with three large scale plants being constructed in succession.

Staggered development has the advantage that expertise can be retained in New Zealand. In the MRP example, whilst Kawerau was being built, drilling and reservoir modelling was underway for Nga Awa Purua, and as Nga Awa Purua is now nearing completion, drilling and reservoir modelling are being undertaken at the third site, Ngatamariki.

Staging of developments like this is a very good way to retain skills in New Zealand which are internationally in high demand. However, it relies on the fact that a very operator needs a continuous string of new projects to retain demand for the equipment and expertise. Smaller operators with no plans for successive plants will still find it difficult to access the appropriate equipment, skills and expertise from within New Zealand and overseas. The New Zealand geothermal industry as a whole could look at ways of co-operating between projects.

Promote international linkages for domestic energy companies: Although at present geothermal development is moving at a relatively fast pace, there is likely to be time in the future when our equipment, skills and expertise will be underutilised. A recent report undertaken by the National Energy Research Institute (NERI) on behalf of the Ministry for Research, Science and Technology discusses the potential of New Zealand energy companies and consultants to build on being international exporters of skills and knowledge, particularly at times when domestic demand for such is low. It suggests New Zealand Trade and Enterprise may have a role in fostering these relationships and possibly play a marketing role, with the energy companies driving the process. There is also a role for New Zealand based consultants operating globally to foster connections between New Zealand and international companies.

Continued government funding to support building geothermal capability: The NERI report suggests that to maintain a geothermal skills base with knowledge succession, the government must give a clear continued commitment to support geothermal research, however, it is unclear how large a skills base New Zealand should maintain.

3.5 Phase 4: Consenting and operating

Phase includes:

Gaining and maintaining resource consent: Resource consents are granted with specific requirements on the developer. To maintain a resource consent and the ability to extract fluid in the long term, conditions are likely to include that ongoing reservoir modelling and data collection takes place, and environmental impacts must be monitored, measured and mitigated.

Although most large scale geothermal projects are of national significance the consent process can seem more concerned with local impacts rather than national benefits. Recent changes to the RMA have seen the instigation of a 'fast track' process for nationally significant projects to be conducted through the new Environmental Protection Agency (EPA).

Barriers to progression

Consent conditions: As resource consent conditions are set by Regional Councils, the ongoing requirements put on operators can vary around New Zealand. Recently with the commencement of new regional plans in Waikato and Bay of Plenty, the consent requirements in these areas have become more closely aligned. This may not be the case for possible future greenfield or HDR developments outside these areas. Regional Councils have expressed concern about the limited pool of peer reviewers available to them to aid in the consideration of consent applications.

Maintaining resource consents and the reconsenting process can be costly and raises levels of uncertainty among investors.

Alternative uses and effects over time: There is continued uncertainty regarding the amount of information that applicants need to provide about potential alternative uses for a resource. There are also concerns that increased uptake of lower temperature applications could, in combination, have an effect on the future allocation of higher temperature resource use and may not encourage the best use of the resource overall.

Potential actions to address barriers

Permit efficiency: The efficiency of current permitting process for geothermal developments and the effects of the changes to the RMA will continue to be assessed by MED.

Geographical experience: Local Authorities throughout New Zealand need to be increasingly aware and prepared to manage potential geothermal developments in their areas. The development of a National Policy Statement (NPS) for renewable electricity will go some way to addressing this.

Figure 3: Barriers to developing geothermal in NZ

Phase	Identifying Barriers	Options for Breaking Barriers
Phase 1	**Resource Study – Prospecting** Desk study, remote sensing, accessing data...	
	◦ Access to geothermal resource information is fragmented and difficult to obtain, especially for new market entrants. ◦ Information which may be useful for alternative uses (e.g. low enthalpy) is often linked to operational data and is unavailable.	◦ Information stock take ◦ Creation of national data depository ◦ Crown undertaking speculative surveys to gather new information
Phase 2	**Initial Site Exploration** Getting land access, funding, consent to drill...	
	◦ No formal process to enable land access (oil and gas on the other hand have such a system) ◦ Explorer not automatically given 'right to mine'. This may deter investment. ◦ Lack of understanding of partnership opportunities and processes, especially for new entrants. ◦ Drilling is expensive and the risk of failure is high – funding may be difficult to obtain	◦ Maintain current system of contracting with land owners to ensure access during and after exploration ◦ Resource Management Act (RMA) amendments to give explorer first right (with limitations) to apply to extract resource. ◦ Standalone geothermal permitting regime. The regime could: centralise control (one initial point of contact for prospectors), enable land access, guarantee right to mine to explorers. ◦ Tax breaks/grants could be offered to encourage exploration
Phase 3	**Drilling and Reservoir Modelling** Detailed site investigations, preparing for consent...	
	◦ Access to drilling equipment – Rigs etc. ◦ Access to drilling expertise ◦ Access to reservoir modellers ◦ Large cost of drilling and reservoir modelling	◦ Increased cooperation between developers and planning of successive projects to retain equipment and opportunities. ◦ Promotion of NZ capability so it's not lost during down times. ◦ Continued capability funding to grow and strengthen NZ knowledge base.
Phase 4	**Consenting and Operating** Gaining consent, maintaining consent...	
	◦ Resource consents come with many conditions, which may be costly to comply with. ◦ The process itself can take many years as it is first considered by regional councils at which stage it may be appealed to the environment court.	◦ Access the ongoing efficiency of geothermal permitting.
Phase 5	**Decommissioning** Site closure, well capping, ongoing monitoring...	
	◦ Lack of experience of decommissioning	◦ Use regional plans and consent conditions to actively manage

3.6 Phase 5: Decommissioning

Phase includes:

Field recovery: Ceasing or stepping down operations to allow resource temperatures to recover.

Site closure/cleanup: Leaving the site in same or better condition as before development

Well capping: Ensuring wells are sealed so pressure in the field can recover.

Ongoing monitoring: Ongoing monitoring and maintenance may be required.

Barriers to progression

Lack of experience of decommissioning: Although many direct use sites have been closed or decommissioned, no geothermal electricity plant has been decommissioned in New Zealand as of yet, so the exact process and requirements may be unclear.

Potential Solutions

Regional planning: Within the current legislative and regulatory framework both Environment Bay of Plenty and Environment Waikato have looked at the abandonment of geothermal wells and set requirements within the well permit conditions. Environment Bay of Plenty's recently released draft policy statement includes a requirement to "require provision to be made on the expiry and non renewal of consents associated with the development activity, for site remediation, abandonment of wells, removal of buildings and structures, including pipe work."

4. Conclusions

Geothermal energy has been, is and will continue to be an important resource for New Zealand. The technologies being used to exploit geothermal resources are developing apace and there is likely to be increasing competition for these resources for energy and other uses.

On the whole, the current regulatory system is flexible enough to deal with many recent technological developments. Issues that have arisen in the past around the process for acquiring and retaining permits have been addressed through changes to the RMA and the approaches of both Environment Waikato and Environment Bay of Plenty. All Local Authorities in New Zealand need to be increasingly aware and prepared to manage potential geothermal developments.

Access to and availability of comprehensive data on New Zealand's geothermal resources is an issue that could be addressed in a relatively rapid and cost efficient manner by means of a stocktake of existing data and identifying areas where new data could be of value.

A wider policy question that needs to be considered across all of New Zealand's underground resources is how to assess and reconcile applications for competing use of the same resource or compromising access to other resources.