The geothermal heat pump opportunities in New Zealand

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Abstract: The New Zealand Geothermal Heat Pump (GHP) market is in its infancy compared to international trends, but recent developments seek to accelerate growth in this area.

A small research project, started in 2008, has grown into a consultative, multi-agency collaboration for research, advocacy and market development. In 2012, the Geothermal Heat-pump Association of New Zealand (GHANZ) was established. This group, comprising suppliers, installers, designers, government agencies and private organisations, is working together to encourage growth and quality in the New Zealand GHP market.

This paper will present an update on the market opportunities in New Zealand, identified barriers and initiatives underway to accelerate technology transfer. These include: modelling ground temperatures and shallow rock properties; understanding heating and cooling practices; consultation with architects and engineers; encouraging quality assurance; developing promotional and educational material; improving the regulatory regime; economic modelling; enabling sector collaboration and improving communication.

Key Words: Geothermal heat pumps, New Zealand, Australia, Barriers, Market, Opportunities

1 INTRODUCTION

Geothermal Heat Pumps (GHPs), also known as ground-source heat pumps or geo-exchange systems, harness the stored, renewable thermal energy at relatively shallow depths in soil, rock, surface water or groundwater. The GHP technology transfers the heat energy from lower-temperature sources to useable higher grade energy, by using a small amount of electrical energy, making it available for heating and cooling purposes.

Applications include space heating and cooling in buildings, heating swimming pools, heating domestic hot water systems and supporting some industrial heat use applications. The utilisation of GHPs is common place in the northern hemisphere; however in the southern hemisphere they are a comparatively under-utilised technology and there is an evident potential for their increased use.

2 NEW ZEALAND CLIMATE

New Zealand is located in the south Pacific and stretches 1600 km from top to bottom, crossing 13 lines of latitude. The New Zealand climate varies from warm subtropical in the north to cool temperate in the south. Average annual temperatures range from 16ºC in the northern regions to 8ºC in the southern, with some average alpine temperatures reaching as low as 2ºC (Figure 1; NIWA 2012). Ambient air temperatures can fluctuate up to 20ºC between seasons in many places around New Zealand.

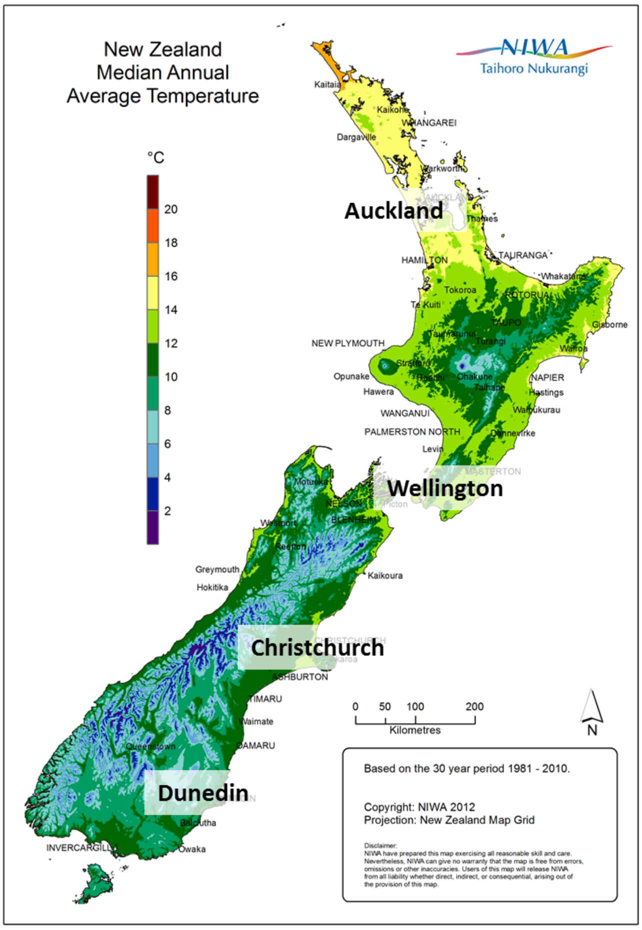

Figure 1: Mean annual ambient temperatures (NIWA 2003)

Ground temperatures remain relatively constant throughout the year. While they are site specific and best obtained from local water well logs or ground temperature surveys, New Zealand ground temperatures generally average between 12°C and 16°C, depending on location.

2.1 Monitoring of New Zealand soils temperatures

The National Institute for Water and Atmosphere (NIWA) monitors and maintains a network of climate stations around New Zealand. Many of these climate stations include shallow (1 m deep) boreholes measuring in-ground temperatures. GNS Science is co-locating deeper temperature monitoring boreholes (10 m) at several of these climate stations, to research the climatic effects on the thermal properties of differing soils types around New Zealand. Understanding the thermal properties of soils is a critical design consideration for GHP installations.

Variations in daily ambient temperatures generally affect ground/soil temperatures to depths of approx. 50 cm, while seasonal temperature variations can propagate to depths of 7 – 9 m

(Figure 2). Below about 10 m depth the ground temperature is fairly stable, and a temperature profile can be approximated by adding 2°C to the average annual air temperature for a specific location. Average ground temperatures recorded in some New Zealand locations are: Auckland 16.1°C; Wellington 14.3°C; Christchurch 13.2°C and Dunedin 12.2°C (from www.niwa.co.nz).

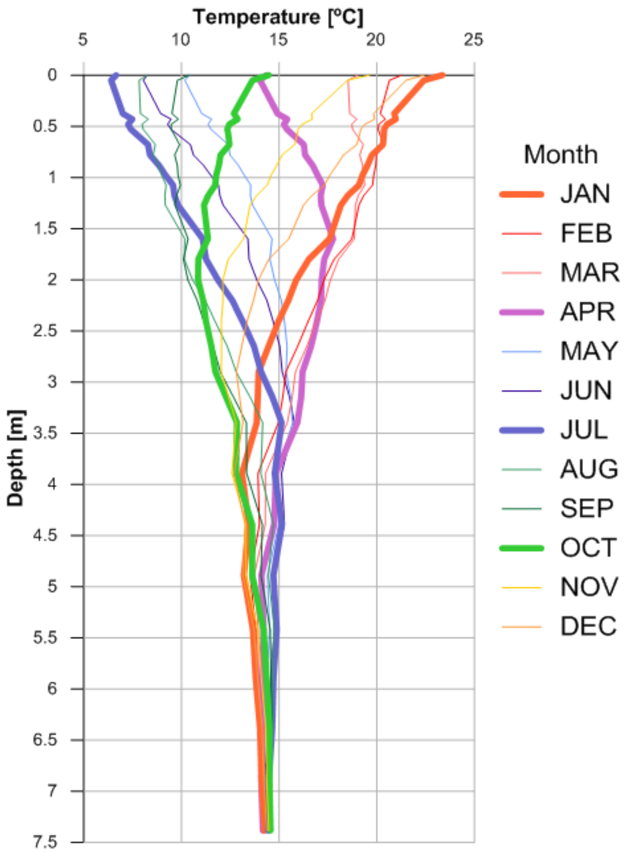

Figure 2: Annual ground temperatures measured at Wairakei, near Taupo, New Zealand (Seward *et al*, 2013).

By continuously monitoring *in-situ* ground temperatures, thermal properties such as thermal diffusivity, thermal conductivity and volumetric heat capacity can be determined. In the development of low enthalpy geothermal resources, these parameters are particularly important for efficient and cost-effective heat recovery using GHPs. The effects of rainfall and moisture content on the propagation of heat through varying soils can also be observed.

3 GEOTHERMAL HEAT PUMP INSTALLATIONS

Globally, GHPs have been gaining in popularity, with utilisation increasing over 2.5 times across ca. 30 countries between 2005 and 2010 (Lund et al 2010). In New Zealand, the GHP market is less developed with approximately 200 installations nationwide. The 2010 estimated net use from GHPs in New Zealand was ca. 11 GWh/yr (0.04 PJ) (Bromley and White 2010). The majority of installations are domestic, with several larger-scale commercial installations, including two airport terminals, public swimming pools, town-halls, library, conference facility and hotels. Domestic installations are predominately located in the South Island where the largest variations in seasonal temperatures occur.

Systematic tracking of new installations began in 2013, with the initiation of a New Zealand GHP database. This database collects information on locations, installers, installation type, loop type, configuration, distribution system, and capacity. An interactive web-based map is being developed to provide information on the uses of New Zealand's geothermal resources, including the GHP industry (http://data.gns.cri.nz/geothermal) (Figure 3).

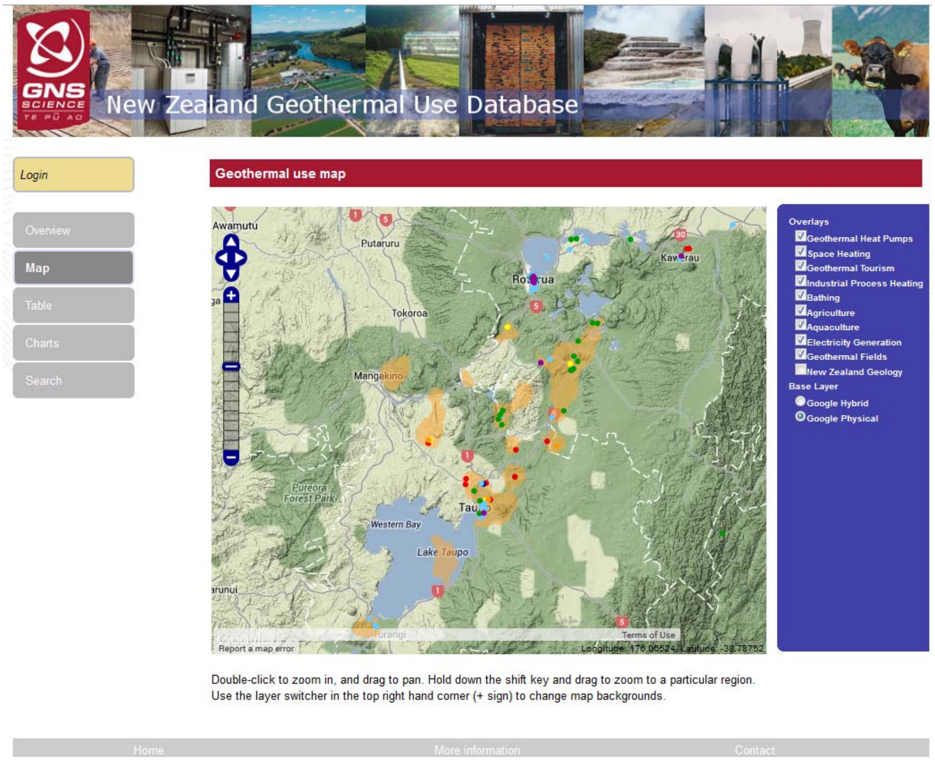

Figure 3: Example screen shot of GHP database web-based map.

3.1 Installation Case Studies

3.1.1 Christchurch International Airport

Figure 4: Aerial view of Christchurch International Airport.

Christchurch city airport (Figure 4) accommodates almost six million passengers a year and is forecast to increase to 1.5 million by 2020. In 2007, Christchurch airport commenced a Terminal Development Project, in which it aimed to achieve carbon neutral status. In 2008, Christchurch International Airport Limited became the first airport company in the Southern Hemisphere to achieve that goal.

The airport terminal building is heated and cooled via an open loop groundwater GHP system. Groundwater (12°C) is extracted from the underlying aquifer via a series of boreholes and is pumped to heat exchangers before being discharged back through soak pits to the ground.

The system is based on 3.6MW water-cooled chillers and variable speed pumps that direct thermal energy around the building. The chillers work in combination with the ground water. In summer the groundwater can be used for cooling directly, however when demand is high the groundwater can be further cooled using the chillers. By reversing the chillers (i.e. using them as heat pumps), groundwater becomes the source of heat and the buildings can be heated through 40°C heating loops.

3.1.2 Manuka Point Lodge

Figure 5: Manuka Point Lodge.

Located in the Rakaia Valley in the Southern Alps, Manuka Point Lodge (Figure 5) experiences some of the most extreme climatic conditions in New Zealand. Winter temperatures can reach as low as -15ºC and as warm as 40ºC in the summer. The lodge was built in 2008, with the owners keen to “create a premium trophy lodge that was sensitive to the environment, while ensuring that clients were warm and comfortable”. A horizontal ground loop coupled to a 19.9 kW heat pump provides water at 30 - 35ºC which is pumped through underfloor pipes to heat the lodge.

3.1.3 Queenstown Family Home

Figure 6: Queenstown family home

Queenstown is located in the central Southern Alps and is prone to cold temperatures (-5ºC) in winter and warm (~28ºC) temperatures in summer. In designing their family home (Figure 6), architect Ian Adamson considered comfort, sustainability and environmental considerations as key factors. The family home has been designed to be as energy efficient as possible and is heated / cooled through the use of two 120 m (vertical depth) boreholes, each encasing “U-shaped” ground exchangers and an 11 kW heat pump.

4 POTENTIAL FOR MARKET GROWTH

The New Zealand Government is committed to reducing fossil fuel consumption and increasing the nation's use of renewable energy. The Government has targeted 90% renewable electricity generation by 2025 and, of relevance to GHPs, an additional 9.5 PJ/year of direct-use geothermal or biomass over 2005 levels (MED 2007; MED 2011; NZEECS 2011).

As New Zealand's population grows and attitudes change, energy demand for space heating and cooling is predicted to increase. In the residential sector, New Zealand has a history of minimal investment in home heating, energy efficient design and construction techniques. Single room heating is common, and there are generally lower expectations of indoor comfort levels in winter compared with many other similar countries where central heating / air conditioning, double glazing and good insulation are the norm. This attitude is changing in New Zealand; adequate home heating is increasingly being seen as important for improved health. Energy demand modelling predicts an 11% increase in heating and cooling energy demand over 2007 levels (49.3 PJ/year) by 2025 (Rossouw and Lind 2010).

In the commercial sector (i.e. non-residential buildings such as schools, hospitals, office buildings, airports, factories and warehouses) with large facilities to heat or cool, energy consumption is greater, and small improvements in energy efficiency can achieve significant cost savings. Modelling (Rossouw and Lind 2010) predicts a 40% increase in heating and cooling energy demand over 2007 levels (24 PJ/year) by 2025 in the commercial sector.

4.1 Barriers and Success Factors

There are several barriers that need to be overcome for the industry to thrive, including:

(1) lack of consumer awareness,
(2) limited consumer confidence,
(3) high capital installation cost, and
(2) absence of market infrastructure.

Consumer awareness is a significant market barrier. A study of New Zealanders' perceptions of geothermal energy use showed that generating power was the most commonly understood use of geothermal resources, but less was known of the direct heat use or GHP opportunities (Doody and Becker 2011). Consequently, consumer confidence is difficult to gauge given the limited knowledge of the technology.

However, substantial information on the perceived barriers for GHPs has also been collected in a series of focus groups with architects, engineers and energy/facilities managers; those who advise the consumers in their decision making. This study aimed to gain an understanding of perceived risks and benefits of direct geothermal heat use and GHPs, and to identify the barriers that prevent the adoption of these technologies (Coyle 2014). Identified barriers include natural phenomena, such as seismicity and lack of extreme climate, as well as lack of awareness and a need for consumer confidence, and the culture of "living in a cold house.

Development and dissemination of educational, marketing and accurate technical information is required to address these issues of awareness and confidence, and to support informed decision making amongst consumers and those groups (e.g. engineers, architects) who advise consumers (Climo and Carey 2011).

At present, the capital installation costs of GHPs in New Zealand are relatively high, compared to more conventional heating options such as natural gas and electricity. Factors contributing to higher capital costs include:

- lack of sufficient experienced installers and designers;
- low volume of installations;
- current drilling practices;
- poor availability of materials;
- the need to import GHP systems; and
- the tendency to overdesign systems based on European or North American design standards.

These higher costs can mean longer pay back periods, and as such GHP's are generally utilised in the higher end residential market and in commercial buildings where energy savings can be more significant. Costs are expected to reduce as the market matures, opening up a wider market and higher uptake. Likewise, the market infrastructure (e.g. manufacturers, suppliers, installer training, industry regulation etc) will also develop as the market matures.

To assist in the development of the New Zealand GHP market and infrastructure, the Geothermal Heat-pump Association of New Zealand (GHANZ) was established in 2012. This industry group is working collaboratively to promote and monitor the development of the GHP market in New Zealand. Members include suppliers, installers, designers, government agencies and other private organisations. GHANZ seeks to develop this sector as a quality, renewable energy source for New Zealand homes, businesses and institutions, by:

- Expanding the market in New Zealand for GHP technologies and services;
- Promoting GHP technology to government / industry / consumers;
- Maintaining a website for information and promotional purposes (www.ghanz.org.nz);
- Providing a forum for members to collaborate and discuss common interests;
- Serving as a point of contact for anyone seeking advice and information about GHPs;
- Engaging with equivalent organisations overseas to share information and develop knowledge that will benefit the development of the New Zealand market;
- Working closely with industry to promote top quality products and professional standards of design and installation across the industry; and
- Facilitating the development of internationally recognised training and standards for installers and designers.

In 2013 the Australasian chapter of IGSHPA (International Ground Source Heat Pump Association) was also formed, in an effort to improve training, standards and collaboration opportunities in Australia and New Zealand.

5 THE AUSTRALIAN PERSPECTIVE

The first GHP systems were installed in Australia in the early 1990s. Over this twenty year period the industry has seen successful installations in landmark buildings as well as long periods of inactivity. Closed vertical loops have been the most common application across both the residential and commercial sectors.

Interest in the technology has increased over the past 8-10 years as a result of new companies in the market, increased power costs and a general trend towards energy efficiency in the building sector.

The industry is still in its nascent stage and has both great opportunity and great challenges ahead of it. The main challenge for the industry is to ensure its sustained growth through high quality installations that deliver on the expectations of the client and provide the predicted energy savings. The on-going development of industry training programmes and standards will contribute significantly towards achieving the desired sustainable uptake of the technology.

6 ONGOING RESEARCH AND WORK

There are numerous groups undertaking research into GHP technology and how the North American and European standards and designs can be utilised and applied to Southern Hemisphere conditions. Most research is focussed on reducing the upfront cost of installation, for example:

- by modelling effects of energy piles on the ground (Melbourne University (e.g. Johnston et al 2011, Johnston 2012, Bidarmaghz et al 2014); Monash University (http://www.eng.monash.edu.au/civil/research/centres/ggrg/));
- understanding local soils and effect of climate on ground thermal properties (Van Manen and Wallin 2012; Seward et al 2013); and
- retrofitting for resilient and sustainable buildings (Wollongong University (www.sbrc.uow.edu.au)).

Collaboration between the Australian and New Zealand industries and research groups will aid in developing GHP markets.

7 SUMMARY

Geothermal heat pumps offer a mature, proven, energy efficient technology using a renewable, nationally available resource. The utilisation of this technology is still in its infancy in New Zealand and Australia. Increased use of GHPs can contribute to meeting expected growth in heating and cooling demand.

On-going research in both Australia and New Zealand aims to increase our understanding of local conditions that are key to designing efficient ground loops and GHP systems in the southern hemisphere. The formation of the Australasian chapter of IGSHPA in 2013 endeavours to produce a common industry standard between Australia and New Zealand, as well as provide a means to share knowledge and training.

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