THE RISE AND RISE OF GEOTHERMAL HEAT PUMPS IN NEW ZEALAND

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ABSTRACT

Geothermal heat pumps (GHPs) are an established technology capable of delivering energy efficient heating and cooling utilising renewable geothermal energy from the ground, groundwater and surface water.

GHPs have been gaining popularity globally with utilisation increasing over 2.5 times across about 30 countries between 2005 and 2010 (Lund et al, 2010). In New Zealand, the GHP market is in its infancy, but recent developments seek to accelerate growth in this area.

The Geothermal Heat-pump Association of New Zealand (GHANZ) was established in 2012 under the New Zealand Geothermal Association. This industry group, comprising GHP suppliers, installers, designers, government agencies and private organisations, is working collaboratively to encourage growth and quality in the GHP market in New Zealand. Current initiatives include identifying barriers to uptake, encouraging quality assurance, development of promotional material, identifying improvements in the regulatory regime, involvement in the development of a joint Australia / New Zealand standard, enabling sector collaboration and improved communication.

This paper details the nationwide availability of geothermal energy in New Zealand, as well as the expected growth in demand for residential and commercial heating and cooling. An overview of GHP technology is provided, with a summary of the barriers and success factors to increased uptake identified in New Zealand and from the successful Swedish experience. An overview of GHANZ is also presented, including current and future activities.

1. SOURCES OF GEOTHERMAL ENERGY

Geothermal energy is heat energy stored in the Earth. It is a renewable, earth-friendly resource that is accessible nationwide.

In New Zealand, geothermal energy systems have three main sources (Figure 1):

1. Stored solar energy - About half of the solar energy that reaches the Earth's surface is absorbed and stored by the land and the oceans. This keeps the Earth's surface at an average temperature of 14°C (Somerville et al, 2007; Goldstein et al, 2011). The total solar radiation is usually between 100-170 W/m^2 per year depending on the location.

2. Conductive, geothermal gradient - Heat is generated in the Earth's interior, mainly by the decay of radioactive elements in rocks. Away from localised areas of volcanic or geothermal activity, this conducted heat moves slowly through to the surface along a ground temperature gradient of about 30°C for every 1000 metres depth. The average heat flow is 65 mW/m^2 over continental crust and 101 mW/m^2 over oceanic crust (Davies and Davies, 2012; Goldstein et al, 2011).

3. Convective, hydrothermal systems - Localised areas of higher heat flow (e.g. over 200 mW/m^2 (Pandey, 1981)) are typically associated with recent volcanic activity, and occur near plate tectonic boundaries, or at crustal and mantle hot spot anomalies. Temperatures above 1,000°C can occur at less than 10 km depth (Goldstein et al, 2011). Magma typically emits mineralised liquids and gases, which then mix with deeply circulating groundwater. Faults, fractures and permeable paths channel heat to the surface.

1.1 Using geothermal energy in New Zealand

Geothermal energy use in New Zealand for electricity generation and direct heat use applications is mostly using the convective hydrothermal systems in the Taupo Volcanic Zone and at Ngawha in Northland. These geothermal areas are New Zealand's most recognised geothermal energy resources (Doody and Becker, 2011).

Geothermal energy currently provides 13% (19 PJ) of New Zealand's annual electricity supply (144 PJ) from a 2012 installed capacity of ca. 760 MW.

In 2010, direct heat use applications in New Zealand used 10 PJ/yr (Bromley and White, 2010). Approximately 55% of this is industrial uses in Kawerau (i.e. timber drying and paper processing). The balance is in bathing and space heating facilities, milk drying, kiln drying facilities, geothermal tourism businesses, horticulture and aquaculture.

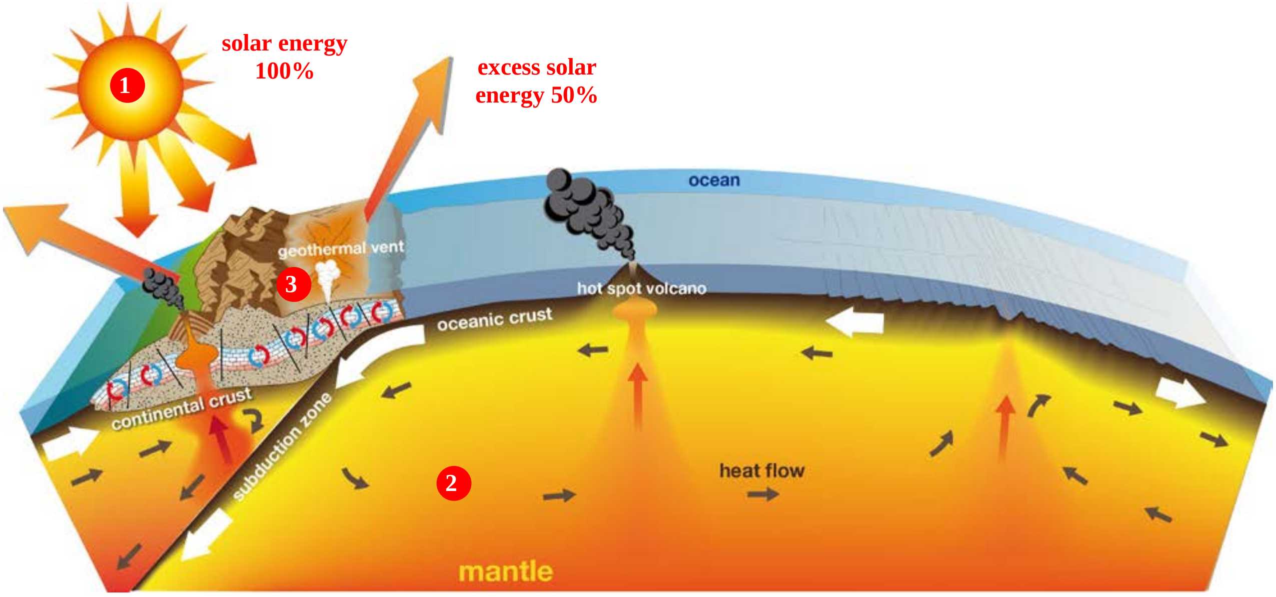

Figure 1. Geothermal energy sources: (1) stored solar energy; (2) conductive, geothermal gradient; (3) localised convective, hydrothermal systems.

New Zealand currently has no projects underway to utilise the heat stored in deep conductive zones (>3 km depth). Typically this resource constitutes low permeability and low porosity prospects, and possibly deeper aquifers where temperatures might be expected to exceed 100°C. Some parties are assessing prospective sites in New Zealand. Accessing these geothermal resources may require the use of enhanced or engineered geothermal system (EGS) technologies, which seek to create fluid connectivity adequate for operation if the natural connectivity is insufficient.

Conductive and solar energy stored in the ground, groundwater or surface water can be accessed for heating and cooling using GHPs. GHPs are gradually becoming established in New Zealand, especially in colder climate regions in the South Island. They amount to some 100 domestic installations to date, plus a number of large-scale commercial installations, including two airports, a swimming pool, a town-hall, a library, a conference facility and a hotel. Systematic tracking of new installations is yet to occur, so these numbers may be higher. The 2010 estimated net use from GHPs in New Zealand was ca. 11 GWh/yr (0.04 PJ) (Bromley and White, 2010).

The New Zealand Government is committed to accelerating the use of renewable low-emission energy (including geothermal energy) and reducing fossil fuel consumption. The major energy targets are to achieve 90% renewable electricity by 2025 and 9.5 PJ/year of additional direct-use geothermal or biomass over 2005 levels by 2025 (MED, 2007; MED, 2011; NZEECS, 2011).

GHPs represent an opportunity to meet direct use targets, yet have achieved little recognition or awareness to date in government, industrial or public sectors.

2. HEATING AND COOLING DEMAND

New Zealand's climate varies from warm subtropical in the north to cool temperate climates in the south, with severe alpine conditions in mountainous areas.

The largest users of energy for heating and cooling (0-100ºC), historically and in the future, are the residential and commercial sectors.

New Zealand's energy demand for heating and cooling in 2007 was 84.7 PJ/year in the 0-100ºC temperature range, being 20% of the total energy demand of 426.7 PJ/year. Future total energy demand is predicted to increase by 19% by 2025 to 507.8 PJ/year. Geographically, growth in energy demand is correlated with population density and is concentrated in the Auckland Region, followed by Waikato, Canterbury and Wellington.

This forecasted growth in heating and cooling energy demand highlights opportunities for the increased use of geothermal energy.

Some of the energy demand growth in the commercial and manufacturing sectors (10 PJ per year and 4 PJ per year respectively) can directly be met through the use of GHPs.

A 40% increase over 2007 levels in heating and cooling energy demand is predicted by 2025 in the commercial sector (Rossouw and Lind, 2010). In commercial buildings (e.g. schools, hospitals, office buildings, airports, factories and warehouses), there are certain levels of indoor comfort that are provided for clients, customers and employees. As these are typically large spaces to heat / cool, energy consumption is high, and even small improvements in energy efficiency can achieve significant cost savings. There are opportunities here for GHPs.

In the residential sector, an 11% increase over 2007 levels in heating and cooling energy demand is predicted by 2025 (Rossouw and Lind, 2010). New Zealand has a history of winter time, single room heating, minimal investment in home heating and a low level of energy efficient design and construction techniques. New Zealanders generally have lower expectations of indoor comfort levels in winter compared with a number of other countries. However, this is changing. In many countries, central heating / air conditioning, double glazing and good insulation are considered basic necessities and this attitude is becoming more common in New Zealand. Further, home heating during winter is increasingly being seen as an important health issue.

GHPs, while generally more expensive to install than other domestic heating solutions, are one of the most efficient and low-running cost, whole-home heating and/or cooling solutions.

With predicted increases in energy costs, growing energy demand and social changes towards energy, a drive towards climate-friendly renewable energies presents a sound opportunity for increasing the use of GHPs in parts of the New Zealand energy space.

3. GEOTHERMAL HEAT PUMPS

Geothermal Heat Pumps (also known as ground-source heat pumps) harness the stored geothermal energy in soil, rock, surface water or groundwater to heat and cool buildings of almost any size. GHP technology takes advantage of the relatively constant year round temperature of these energy sources to provide efficient space heating and cooling by transferring heat from lower temperature sources to useful higher grade energy (to heat the buildings), using a small amount of electrical energy.

3.1 GHP technology

A GHP has three key components; the ground loop, the heat pump unit and the building's distribution system (Figure 2).

The ground loop is a network of pipes installed vertically, horizontally or in a series of coils (slinkies) in the ground, groundwater or surface water. The primary function of the ground loop is to collect or dispose heat. This is achieved by circulating a working fluid (water and antifreeze solution) through buried or submerged pipes (closed loop systems) or using groundwater or surface water directly (open loop systems). Direct exchange systems circulate a refrigerant in a closed copper tubing loop in the ground, exchanging heat directly from the soil to the refrigerant across the ground loop.

The heat pump transfers heat collected from the ground loop into the building when in heating mode. In cooling mode, the process is reversed and heat from the building is transferred to the ground loop for disposal. A heat pump works by circulating a refrigerant through a loop with two heat exchangers; one exchanger to gain heat, one to lose it (Figure 2). When circulated, the refrigerant gains heat from one exchanger and turns into a gas. The gas is compressed and then passes through the second exchanger where it loses heat, before being expanded, returning to a liquid to begin the cycle again. In a GHP, the first heat exchanger is placed in the circuit with the group loop, the second in the circuit with the building. The refrigerant can gain heat from the ground loop and lose it to the building, or can operate in reverse; heating or cooling the building respectively.

The building's distribution system delivers or removes heat to / from the building. Methods include under floor heating loops, radiators and forced air systems.

GHPs can be tailored to suit the characteristics of a particular site. For example, if the site has access to a lake or river, a submerged coil or surface water installation could be considered. If space is limited, a vertical installation may be preferred. Other factors to be considered include the building's heating/cooling demand, aquifer/groundwater temperature, availability and characteristics, soil type and temperature, and the heat capacity and thermal conductivity of the ground. Table 1 summarises common GHP configurations and typical uses for each type of installation.

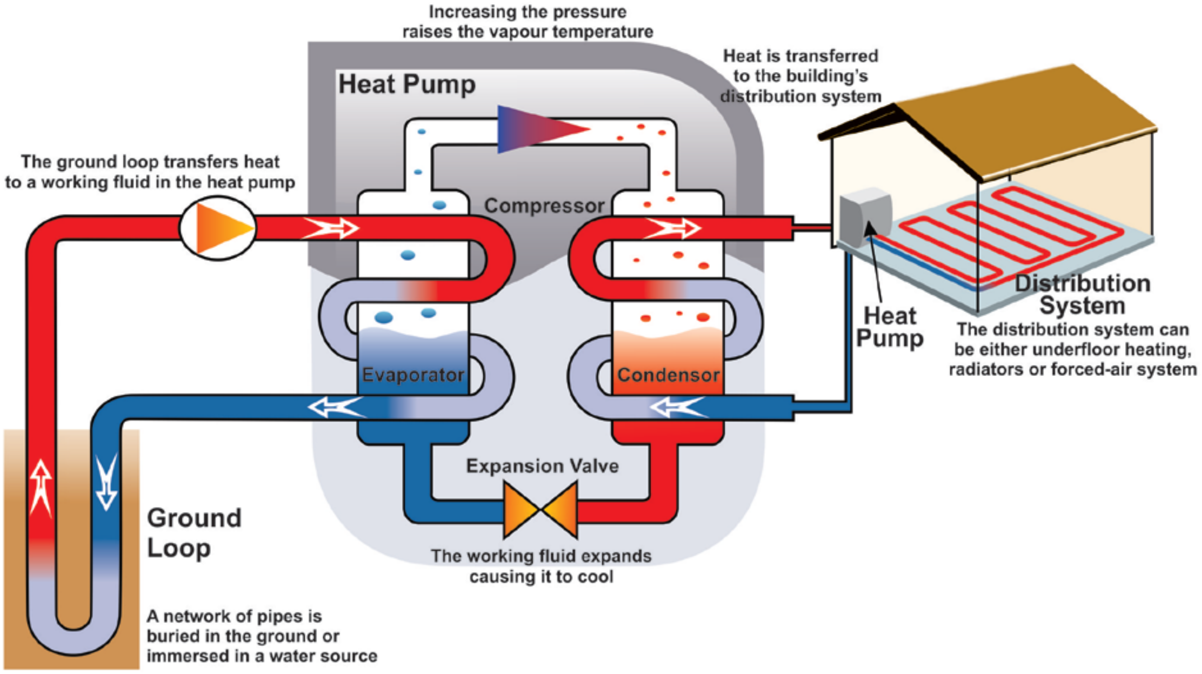

Figure 2. Geothermal heat pump schematic (in heating mode).

Table 1. GHP configurations and typical uses.

Type	Configuration	Description	Typical Use
Closed Loop	Horizontal (straight or "slinky" pipe)	Network of pipes laid in ground, 0.5 m to 2 m deep.	Residential with larger lot sizes / access to land.
Closed Loop	Vertical	Straight pipes inserted in bore holes to approx. 100 m.	Commercial or high energy demand applications.
Closed Loop	Submerged coil	Coil of pipe placed into river or lake.	Any site; must have access to pond, lake or river.
Closed Loop	Direct Exchange (DX)	Copper pipes laid in a network and filled with a circulating refrigerant (instead of water / antifreeze).	Residential or small commercial.
Open Loop	Groundwater (single well and drainage field, double well or standing column well).	Well drilled to access groundwater directly, water is discharged at surface or back into aquifer.	May support smaller applications but due to drilling costs, often used for commercial or high energy demand applications.
Open Loop	Surface water	Direct take of surface water from fresh water source (lake, river etc) or sea water. Discharge water returned to source.	Commercial or high energy demand applications, often used for cooling. Requires access to large volume of surface water.

3.2 Geothermal energy storage

While natural processes generate the geothermal energy accessed by GHP systems, ground temperatures can also be artificially managed to benefit the function of a GHP system and increase overall system efficiency. This is achieved using geothermal energy storage. An example of this is where heat energy is discharged to the ground/aquifer in summer in such a way that it can be accessed during winter for heating. Seasonal storage of heat can be considered by larger scale energy users that require both heating and cooling, such as hospitals, nursing homes, all types of office buildings and shopping centres. While system design and operation can be more complex, energy savings can be substantial.

3.3 Advantages and disadvantages

There are a number of benefits of using GHP technology for residential and commercial heating and cooling.

They are an environmentally friendly technology that does not burn fossil fuels, which, in addition to providing environmental benefits, can be a competitive advantage for business through the promotion of their environmental credentials.

GHPs also assist consumers by providing an efficient form of heating and cooling. Typically, about one unit of electricity is used to move three or four units of heat energy. Since the ground or water source remains at a relatively constant temperature throughout the year, warmer than the air above it during winter and cooler in the summer, they are more energy efficient than air-sourced heat pumps. Compared to conventional electrical heating devices GHPs are highly energy efficient, with over 70% of the energy coming from the ground (Curtis et al, 2005). They can also be designed and operated to take advantage of off-peak electricity rates.

GHPs support healthier homes and buildings through the provision of a whole of building conditioning system (heating and cooling) for year-round comfort. They are suitable for use in a range of applications and energy loads; current technology already allows practical implementation from small buildings (i.e. 3 to 10 kW) to large buildings and district heating schemes (100 to 1000 kW or more).

GHPs are low maintenance, durable and reliable. Ground loop components overseas often carry warranties for over 50 years. They are quiet and can be installed with no external unit, allowing improved integration with architectural considerations.

However, while GHPs offer significant benefits, the key disadvantage is higher capital installation costs. This can result in longer pay back periods, particularly for lower level energy users. Additionally, in New Zealand there may be costs associated with resource consent requirements for installing a GHP system (EMS, 2011).

3.4 Barriers and success factors

The New Zealand GHP market is in its infancy, and barriers to increased uptake are multifaceted. Common to other countries, primary New Zealand market barriers are 1) high capital installation cost, 2) lack of market infrastructure, 3) lack of widespread consumer awareness, and 4) consumer confidence.

This technology is however mature, being the standard solution in Sweden and Switzerland. The Swedish experience in embracing GHP technology over the last 25 years highlights a number of success factors. In 2008, space heating using GHP accounted for 17% of the market share in Sweden, with a peak of 40,000 units installed in 2006 (Lind, 2010). The most popular use is in small residential buildings (ca. 10kW demand), but they are also used for larger 600-900 kW systems, supporting district heating networks.

Success factors in Sweden included (Lind, 2010):

- Government support and incentives - Subsidies for research and development of GHP systems were offered to improve operation and efficiency, and reduce cost. This established the market credibility of GHP and led to more installations. Additionally, government subsidies were available for GHP installations to replace oil-burners at a time when the oil price was high.

- Quality standards – GHP quality markings were established to grade factors including energy efficiency, safety and construction, documentation, manufacturing quality. For vertical in well arrangements in Sweden, a Swedish national energy well standard (Normbrunn-97) sets requirements on the installation of the geothermal system, the borehole, equipment and competence of the driller.

- Certified installers - A voluntary certification scheme for drillers and installers was initiated by the Swedish Institute for Technical Approval in Construction. In 2004, a European certified GHP installer campaign was initiated. These accreditation systems seek to improve customer confidence by identifying competent specialists, who can design and install reliable and efficient GHP systems.

- Independent association - An independent association including manufacturer and installer members was established to act on issues such as lobbying, promotion, technical and quality aspects.

- Environmental benefits - GHPs provide significant environmental benefits over oil-burners which were at one time common in Sweden. The fluctuating cost and reliance on imported oil was also a defining factor in changing to an indigenous fuel.

- Awareness – Promotion initiatives were undertaken to increase the awareness of GHPs.

Currently in New Zealand there are no NZ quality standards, installation guidelines or accredited training certification programmes for installers.

Prior to 2012, there was no independent GHP association.

A recent review of the planning and regulatory framework of New Zealand as it relates to GHP's (EMS, 2011) highlighted the implications for geothermal direct heat use and GHP technologies. Positively, the legislative and environmental policies are supportive at national and regional levels, and generally there are permissive requirements for closed loop systems. The installation and operation of GHPs are regulated by the Resource Management Act and the Building Act. A building consent is unlikely to be required for a GHP installation but a resource consent is required in some areas, for certain types of installations. Some regional frameworks are not well suited to GHP systems, and there is inconsistency in consenting approaches between regions and districts.

A focus is needed on the development and dissemination of educational, marketing and accurate technical information to raise awareness and support informed decision making amongst consumers (Climo and Carey, 2011).

4. GEOTHERMAL HEAT-PUMP ASSOCIATION OF NEW ZEALAND (GHANZ)

The Geothermal Heat-pump Association of New Zealand (GHANZ) was established in 2012 as an industry group working collaboratively across the GHP industry in New Zealand. GHANZ seeks to develop the GHP sector as a quality, renewable energy source for New Zealand homes, businesses and institutions. Members include GHP suppliers, installers and designers, government agencies and other private organisations.

GHANZ is working to overcome the barriers to increased uptake of GHPs in New Zealand 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.

GHANZ was established under the New Zealand Geothermal Association (NZGA). Members have access to the activities and resources of the NZGA, the affiliated Climate Control Companies Association (CCCA) and the Institute of Refrigeration, Heating & Air Conditioning Engineers in New Zealand (IRHACE). To join GHANZ, individual need to join the NZGA and indicate that they wish to become a member of GHANZ on the NZGA membership application.

GHANZ is engaging with equivalent organisations overseas to share information and develop knowledge that will benefit the development of the New Zealand market. These overseas models are being used to develop GHANZ activities and the New Zealand GHP market. Overseas equivalents include the International Ground Source Heat Pump Association (IGSHPA – based in the USA), the Canadian GeoExchange Coalition and the European Heat Pump Association. Some of these organisations offer technical conferences, installer training, a range of publications, and business directories to accredited designers, trainers and installers.

4.1 Quality standards

GHP installations require specialist knowledge to ensure reliable operation and the full realisation of benefits achievable with GHP technology. An improperly installed or specified system will not function effectively or efficiently, and can be very expensive to repair. Such failures can be hugely damaging to consumer confidence, and overseas experience has shown that this can hinder market growth.

There are many quality installers and system designers in New Zealand today, yet negative media coverage from one poor installation by an unqualified or unscrupulous individual could present a setback for New Zealand's budding GHP industry.

Promotion of quality products and professional standards of design and installation across the industry are therefore required to ensure that the reputation of the technology is protected. Two initiatives are underway to address the current lack of standards in New Zealand.

A joint Australian / New Zealand Standard is under development for the minimum requirements for design, installation, testing, verification, and decommissioning for GHP systems. The Standard will cover closed-loop GHP systems and apply to domestic, commercial, and industrial applications. It is aimed at the designers and installers of GHP systems, architects and engineers specifying GHP systems, and main and sub-contractors involved with specialist installer companies supplying GHP systems, designs, or components. The Standard is expected to cover drilled, horizontal, and pond-based systems for both water-based and direct exchange systems. The content in the Standard is being developed by an expert committee. The committee is made up of volunteers nominated by organisations (public and private) that have an interest in the subject covered by the Standard. GHANZ is represented by one of its members on the GHP standard committee. Once the content for the Standard is written a draft will be made publically available for comment before finalisation. This GHP standard is expected to be finalised early in 2014.

Additionally, GNS Science, the Energy Efficiency and Conservation Authority (EECA) and Environmental Management Services Limited (EMS) are developing an introductory guide to GHPs. This provides an overview of the installation and operation of GHPs in New Zealand. It is intended to assist a range of stakeholders by providing information on geothermal energy, general technical information on the operation and installation of GHPs, and the relevant New Zealand environmental and regulatory considerations. Technical content has been developed from a review of international and national experience.

Longer term, GHANZ may also look at adopting some form of quality assurance programme such as those developed in Canada and in other countries. Such systems offer endorsement for GHP systems installed by individuals and/or companies with the necessary qualifications and commitments to quality and professionalism.

4.2 Training

A number of New Zealand GHP designers and installers have undertaken accredited training overseas.

An experienced, professional installer has the expertise and knowledge to:

- Calculate the buildings heat loss characteristics and associated heat demand.
- Size the system correctly (i.e., the ground loop, heat pump and building distribution system).
- Advise on environmental considerations (e.g., ground conditions, take of groundwater, drilling).
- Advise on the best configuration of the ground loop suitable for the specific location.
- Advise on the best type of distribution system for the building.
- Install and commission the GHP complying with relevant regulations and standards.
- Advise on servicing requirements.
- Provide a service checklist and contacts in case of problems.
- Provide a warranty for the GHP installation.

Ultimately, the goal is to develop training opportunities specific to New Zealand that can be delivered through local training providers.

5. CONCLUSION

GHPs offer a mature, proven, energy efficient technology that can contribute to meeting some of New Zealand's expected growth in heating and cooling demand, using a renewable, nationally available resource.

The Geothermal Heat-pump Association of New Zealand (GHANZ) has been established to promote GHP technology, encourage quality and expand the New Zealand GHP market. Initiatives to date have included identifying barriers to uptake, encouraging quality, development of promotional material and improved collaboration and communication.

Join GHANZ and assist in making this technology a part of New Zealand's energy future!

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