EMBRACING GROUND SOURCE HEAT PUMP TECHNOLOGIES FOR RURAL MĀORI COMMUNITIES

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ABSTRACT

Iwi/Māori have a long association with New Zealand's natural environment. This association is based on knowledge that has built up over time through centuries of interaction with the natural world. This includes the use of low temperature geothermal resources within many iwi/Māori communities.

The Low Enthalpy Geothermal Programme currently underway at GNS Science seeks to explore the low temperature energy potential of geothermal resources in New Zealand. The first part of the work program included exploring Mātauranga Māori, the knowledge that existed within Māori communities pertaining to traditional uses, and also to explore what technical capability and capacity these communities have or require to generate energy from this resource (Bradshaw & Faulkner 2009).

Ground source heat pumps (GSHPs) are an established technology, capable of delivering high energy efficient heating and cooling utilising the immense renewable energy stored in the ground, ground water or surface water. They are being recognised as an alternative to fossil fuel systems and can offer significant reductions in the overall CO_2 emissions.

Cultural factors can influence the acceptance and use of low temperature geothermal resources in New Zealand. Engaging with, and gaining an understanding of the public and stakeholders' knowledge and perceptions, can increase the opportunities for more predictable, profitable and successfully implementation of these technologies.

With an approach founded on traditional concepts of Māori knowledge, this paper discusses GSHP technology configurations, barriers for uptake and provides information from overseas experiences that offer valuable insights into how to support future cultural, social and economic initiatives to achieve a sustainable growth of GSHP.

1. INTRODUCTION

Until recently, geothermal energy has only been considered in areas where high temperature geothermal water or steam has been found. The use of ground source heat pumps (GSHPs) also known as geothermal heat pumps has changed the norms. In this case, the earth is the heat source for the heating and/or the heat sink for cooling, depending on the season. This has made it possible for people in all locations to use the earth's heat for heating and/or cooling.

In New Zealand ground source heat pump technology is immature and other nation's experiences might usefully assist in determining how this technology might best fit into our energy scene and how the technology might be promoted to increase uptake.

Using the energy from the ground as a heat source/sink, through GSHPs is an alternative to standard heating systems. It is an energy efficient, environmentally friendly and cost effective space condition, and hot water heating system. GSHPs have been gaining popularity and have experienced an annual increase of 10% in about 30 countries in the last 10 years. It is estimated that the present number of installed units totals some 2,940,000 in 43 countries (Lund et al. 2010).

As part of these activities GNS Science Māori Strategy seeks to identify the opportunities of GSHP technologies as a consideration for housing or marae development.

2. MĀORI TRADITIONAL CONCEPTS

GNS Science Māori Strategy explored Mātauranga Māori, the knowledge that existed within Māori communities pertaining to traditional low temperature geothermal energy uses. Furthermore they explored what technical capability and capacity these communities have or require to generate energy from this resource.

Mātauranga Māori refers to a body and *tradition of knowledge,* encompassing traditional concepts of knowledge and knowing – and including concepts related to the creation of knowledge – that are in a period of rediscovery. Hence, Mātauranga Māori denotes a variety of approaches to knowledge present within Māori knowledge including revealed and experiential knowledge and scientific knowledge.

The word 'rural Māori communities' refers to those living in, having a cultural relationship with, or significant interest, in the identified rural Māori communities where heating a home may lie just beneath their feet. The concept of exploring the expressions of the earth arises from a recognition that many Māori communities are seeking to restore their traditional knowledge bases as a dimension of protection and enhancement.

This is particularly the case in relation to contemporary issues, such as those relating to the environment and future management of natural (e.g. geothermal) resources. Neilson et al. (2010) found that an approach founded on traditional concepts of Māori knowledge, new technology applications, environmental planning and monitoring where indigenous approaches and perspectives were fundamental.

Acceptance of decisions can be linked to Māori interests and values, their social group conceived by their historical roots and relationship to rural Māori communities' Mother earth. The human body and the physical landscape were metaphorically united. The root of the word Papatūānuku is papa, which means base and foundation of the earth, rocks and its soils.

The earliest Māori stories speak of a man named Ngātoro-i-rangi, a tohunga (high priest) who guided the Te Arawa canoe to this land from Hawaiki, Ngātoro-i-rangi eventually arrived at Taupō-nui-ā-Tia (Lake Taupō) and, looking southward, decided to climb the mountains he saw there. Tongariro (the name literally meaning 'looking south'), where upon the two were overcome by a blizzard carried by the cold south wind.

Near death, Ngātoro-i-rangi called back to his two sisters, Kuiwai and Haungaroa, who had also come from Hawaikī sending the geothermal fire in the form of two taniwha (powerful spirits) named Te Pupu and Te Hoata, by a subterranean passage to the top of Tongariro. The tracks of these two taniwha formed the line of geothermal fire which extends from the Pacific Ocean and beneath the Taupō Volcanic Zone, and is seen in the many volcanoes and hot-springs extending from Whakāri to Tokānu and up to the Tongariro massif. The fire arrived just in time to save Ngātoro-i-rangi from freezing to death, but Ngāuruhoe his companion was already dead by the time Ngātoro-i-rangi turned to give him the fire. On this account the hole through which the fire ascended, the active cone of Tongariro, is now called Ngāuruhoe. Ngātoro-i-rangi was saved and the chain of thermal activity has been of great value to the people of Aotearoa (New Zealand) ever since. Therefore harnessing energy from the earth is embraced by Māori developments in utilizing energy to benefit mankind.

GNS Science argues that natural resources have the potential to provide a range of commercial and non-commercial benefits, but this resource utilisation must be consistent with long-term Māori custodial responsibilities. Scientific investigation can therefore provide the starting point, but Māori entities need to develop realistic and sustainable development options that have community support (Ganesh et al. 2010).

3. GROUND SOURCE HEAT PUMPS (GSHP)

The basic principle of a GSHP is illustrated in Fig. 1. As it can be observed, a geothermal heating and cooling system consists of three main pieces of equipment: a heat exchanger, a heat pump unit and a heating/cooling system. The thermal energy from the ground is extracted by means of a secondary working fluid which circulates through the heat exchanger. The heat pump then increases the temperature of the extracted heat to a level where it can be used in the heating system. If the desired effect is cooling, GSHPs can also take the heat from the building and then inject it into the ground.

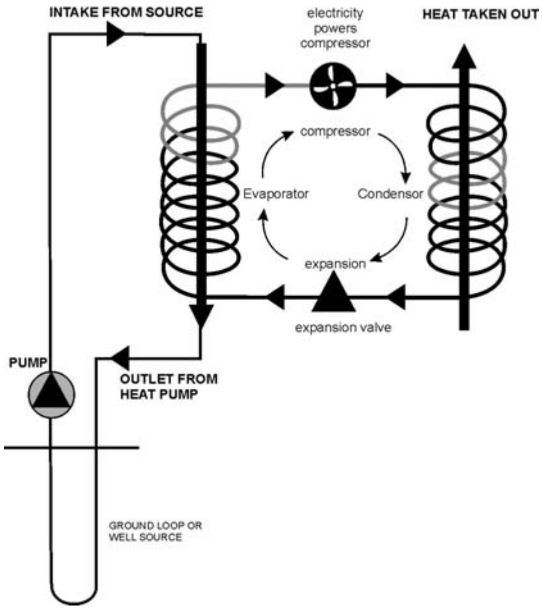

Figure 1: Schematic of a GSHP (Omer 2006).

3.1. Ground conditions

GSHPs take advantage of the fact that the ground below a few meters, and natural water sources, remain at a relatively constant temperature year round (Fig 2). Ground temperatures vary both with daily and seasonal cycles, the former dying out within a few tens of centimetres and the latter at some 15 m below ground surface (Ericsson 1985).

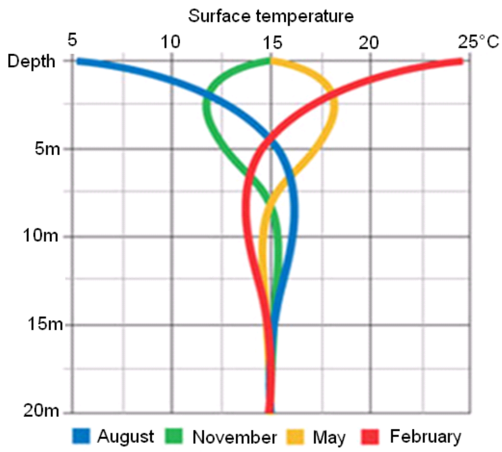

Figure 2: Schematic of the seasonal ground temperature.

Heat pumps can efficiently transfer heat from lower temperature energy sources (such as soils) to useful higher grade energy (and heat buildings), using a small amount of electrical energy.

In mid-winter, ground and water temperatures are warmer than air. Heat is extracted from the earth or water using a ground loop and delivered to the building. Heat is delivered through a ducted heating system, or by delivering warm water to radiator or an under floor heating loop system.

These systems can be reversed in summer to cool a building. Heat is removed from the building and delivered for storage into the earth or water source.

3.2. GSHP Technology configurations

GSHPs come in two basic configurations: closed loop and open loop systems, which are installed horizontally and vertically, or in wells and lakes. The type chosen depends upon the soil and rock type at the installation, the land available and/or if a water well can be drilled economically or is already on site. See Fig. 3 for diagrams of these systems (Lund et al. 2004).

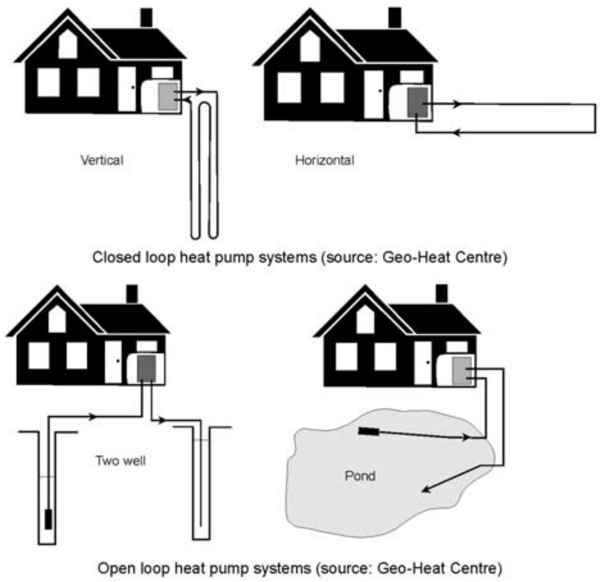

Figure 3: Closed and open lop heat pump systems (Lund et al. 2004).

In the closed loop system, a closed loop of pipe, placed either horizontally (1 to 2 m deep) or vertically (50 to 100 m deep), is placed in the ground and a water-antifreeze solution is circulated through the plastic pipes to either collect heat from the ground in the winter or reject heat to the ground in the summer (Rafferty 1997). The open loop system uses groundwater or lake water directly in the heat exchanger and then discharges it into another well, into a stream or lake, or on the ground (say for irrigation), depending upon local laws.

Open systems are mostly used for larger installations with suitable aquifers whereas closed loop systems are the most commonly used for domestic and commercial buildings (Granryd 2002), (Sanner 2001).

The efficiency of GSHP units is usually expressed by the Coefficient of Performance (COP) which is described as:

$$COP = \frac{\text{Useful heat output of heat pump (kW)}}{\text{Compressor power consumption (kW)}}$$

COP varies from 3 to 6 with present equipment (the higher the number the better the efficiency). Thus, a COP of 4 would indicate that the unit produced four units of heating energy for every unit of electrical energy input.

In Europe, this ratio is sometimes referred to as the “Seasonal Performance Factor” (“Jahresarbeitszahl” in German) and is the average COP over the heating and cooling season, respectively, and takes into account system properties.

3.3. Planning assessment

The installation and operation of GSHPs are regulated in New Zealand by the Resource Management Act 1991 and the Building Act 2004. Administration occurs at the national, regional, and local levels.

In most GSHP configurations, building consents are not required, whereas resource consents under the Resource Management Act are likely to be required (Bendall 2011).

There are a number of opportunities available to engage at the national, regional and local levels to improve the regulatory and planning framework that applies to these technologies. Recommendations that will assist in increasing the penetration of low enthalpy geothermal technologies in the New Zealand energy space include:

- Establish roles and responsibilities of interested agencies and groups to coordinate effort to support and promote LEG technologies
- Reduce regulatory controls, cost and timeframes through participating in regional and district plan review processes
- Seeking to establish a more uniform approach to ground source heat pump permitting

4. OVER SERAS EXPERIENCES

4.1 Barriers for uptake

Despite their high efficiency and low operating costs, the primary barrier to the market penetration of the use of ground source heat pumps is limited by the incremental cost of installing the ground loop.

The European Geothermal Energy Council (2007) promotes geothermal heating and cooling. In their action plan they highlight that new policy initiatives will need to address the barriers which currently hinder the rapid expansion of the market. The barriers include:

- Geothermal energy offers much lower operation costs, but investment costs are usually higher. In the short term, consistent and reliable support programmes, including those which promote innovative financing mechanisms, must help to overcome this barrier. In the mid- and long-term, economies of scale are expected to significantly decrease investment costs.
- In many countries and regions in Europe, information and awareness levels about the different Renewable Energy Sources (RES) heating technologies, and in particular about geothermal energy, are still quite low. Clear market signals, such as RES heating targets, as well as awareness campaigns proactively targeting suppliers (especially installers) can help to overcome this obstacle.

- Similar to energy efficiency, increased RES heating requires changed investment behaviour of millions of energy consumers. For a majority of them - be they homeowner or business or public bodies – RES heating is still exotic. Even if they are aware of the existence and know that many of them are mature technologies, mostly they are not considered when an investment decision, e.g. for a new heating system, is being taken.

- Insufficient data base: Presently, statistics on the heating sector and inventories of the geothermal resources in general are weak. A speedy establishment of robust market data and reliable statistics that allow the establishment of a baseline.

Other important factors related to the further development of GSHPs reported by Breembroek (1998), is the process of electricity deregulation. The deregulation process may affect the heat pump market in two ways: 1) heat pump economy might be influenced by changes in the energy price structure, and 2) the heat pump market might be stimulated or hindered, depending on changing utility market strategies.

Moreover, in the regulated market, some utilities have clearly supported heat pumps, in line with governmental energy-efficiency programs (e.g., by offering grants or special electricity tariffs). However, in a deregulated energy market, the market strategies of utilities will change. Only when the market matures and energy prices drop to a stable level will utilities offer incentives such as products/bonuses or energy efficiency services. Nevertheless, the ecological incentives like avoiding greenhouse gas emissions will further support GSHP development. The CO_2 tax in sight is a further (financial) incentive. Of course, there will be considerable differences in this respect from country to country.

The Navigant Consulting, Inc. (2009) investigated the status of GSHPs technology, market penetration and estimated the energy saving potential of GSHPs in the U.S. As part of the investigation they identified four market entry key barriers including:

- Increased first costs, poor performance, or poor reliability specifically associated with: Low manufacturing volumes; Immature product designs; Inexperienced/poorly trained installers and service technicians

- Lack of awareness

- Lack of familiarity, leading to perceived risks that can, in turn, inflate costs or discourage potential end users

- Lack of supporting sales, installation, and service infrastructure.

They also list technological, market, institutional, regulatory and other barriers to widespread adoption of GSHPs.

4.2 Initiatives to promote increased uptake of GSHPs

The European Geothermal Energy Council (2007) document aims at providing stakeholders and policy makers with detailed information and clear guidelines based on the existing experience with policies to promote geothermal energy.

The main instruments to achieve a sustainable growth of geothermal heating are:

- Financial incentives
- Regulations
- Standards
- Awareness Raising
- Training
- R&D and Demonstration projects

Soundarya (2010) describes how the initial cost issues could be offset by substantial subsidies from the federal and state governments. Utility companies offer special rates for customers who install GSHP systems that help to balance the supply of electricity, often overloaded during summers and left idle during winter months. The American Reinvestment and Recovery Act (ARRA) invest $350 million in geothermal technology, prioritising major areas such as geothermal demonstration projects, R&D, innovative exploration techniques, and geothermal resource assessment and classification systems. The Department of Energy (DOE) has announced the establishment of a national certification and accreditation program for the GSHP industry to help increase consumer confidence in the technology and reduce the potential for improper installation, as well as an assurance of system quality, performance, and reliability.

Lund (1989) gives an example of how incentives for geothermal heat pump installations, mainly to overcome the initial capital investment, the Public Service Company of Indiana (PSI) will pay residential developers the added cost of a geothermal heat pump over air-source heat pumps (the horizontal or vertical piping loop cost). To reduce the initial cost, PSI "mass produces" the installation of the geothermal heat pump by installing the system when the subdivision is under construction. This cuts the increment cost by about 50%. PSI considers this a good investment as it reduces the peak load, improves the load curve by adding winter demand, and reduces the need for costly new power plants.

4.3 Sweden a mature market

The Swedish experience with GSHP systems shows a significant growth trend since the development of heat pumps at the end of the 1970s, principally as a response to the 1979 international oil crisis. The key elements which have contributed to the success are government support, research and development of heat pump systems, an independent heat pump association, certified installers, quality standards, environmental benefits, a high level of awareness among the general public and decision makers in government and municipalities, and existing heating system predominately being based on central heating with circulated water.

From a technical standpoint the heat pump technology is well developed, with today's units being the product of thirty years research and development. If designed and operated correctly a ground source heat pump offers reduced running costs and reduced CO_2 emissions compared to other fossil fuel systems.

The level of maturity is now so high that GSHP systems have infiltrated the retrofit heating market and no longer require government grants as an incentive to GSHP installation. It is expected that the market will further expand (Lind 2010).

5. GSHP IN NZ

There is potential for ground source heat pumps to play a larger part in the New Zealand energy market. At present the percentage of heating requirements met by ground source heat pumps is insignificant.

A review of the literature reveals few studies reporting data on the use of heat pumps in NZ. The majority of the heat pump installations are in new build rather than existing housing retrofitting. A few installations have been the subject of monitoring to establish their effectiveness and running costs.

With regards to new technologies, confidence building, information sharing and awareness rising are vital.

Leading the market to a point where a significant number of systems will be installed will likely require an increase in support from government and using strategic guidance learning from success in GSHP market stimulation from overseas. This should be matched by development effort from those involved in the industry, establishing installer training schemes, quality labels and gaining the interest of utility companies. It is important that good quality systems are installed from the outset to avoid issues that have beset the GSHP industry in other countries from sub-standard early installed systems.

The GSHP market needs to be more firmly established in New Zealand. Until the market has reached a point where installation costs are competitive with other heating systems it is unlikely the general public will be sufficiently convinced to install units in significant numbers.

The barriers preventing this potential from being realized include lower heat demand in the residential sector, high capital cost of GSHP systems, lack of existing central heating systems, lack of installation experience; absence of quality standards and, low level of awareness among the general public and decision makers in government.

CONCLUSION

A ground-source heat pump (GSHP) system utilises the ground, ground water, or surface water as a heat source/sink for providing heating and cooling. The GSHP is generally recognised to be one of the most outstanding technologies of heating and cooling in both residential and commercial buildings, because it provides high coefficient of performance (COP), up to 3–6. The main benefit of using GSHPs over air source heat pumps is that the temperature of the subsurface is not subject to large variations experienced by air.

With increasing worldwide awareness of the serious environmental problems due to fossil fuel consumption, efforts are being made to develop energy-efficient and environmentally friendly systems by utilisation of non-polluting renewable energy sources, such as geothermal resources.

The main tools to achieve a sustainable growth of GSHPs are:

- Raising awareness
- Demonstration projects
- Harmonisation of regulations
- Development of installation guidelines
- Training

Social expectation and communication will have as much to contribute to increased uptake of low enthalpy geothermal energy utilisation as will appropriate economic technologies.

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