# SOCIETIAL ACCEPTANCE OF GROUND-SOURCE HEAT INNOVATIONS FOR RURAL MĀORI COMMUNITIES WITH THE EXAMPLE OF NGATI RANGIWEWEHI

Gina Mohi[1], Paul White[2] and Diane Bradshaw[2]

[1]Te Maru o Ngāti Rangiwewehi, 12 Western Road, PO Box 131, Ngongotaha, Rotorua

[2] GNS Science, Private Bag 2000, Taupō, New Zealand

gina@rangiwewehi.com

**Keywords:** *Māori, rural Māori communities' source heat pump, geothermal heat pump, low temperature, low enthalpy.*

## ABSTRACT

Ground-source heat pumps (GSHPs) are an established technology, capable of delivering 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. GNS Science Māori Strategy seeks to identify the opportunities of GSHP technologies as a consideration for housing or marae development.

This technology has much to offer communities, particularly in rural areas because resource use is relatively benign. Also, this technology has much to offer Māori and the important rural marae that fulfil a crucial role in New Zealand communities.

In this paper, we describe a comprehensive framework for ground-source heat pump technologies in rural Māori communities aiming at societal acceptance of resource use and the technology associated with ground-source heat pumps. For these communities, resource utilisation must be consistent with long-term Māori custodial responsibilities. The framework is developed and tested with Ngāti Rangiwewehi and the Awahou Marae on the shores of Lake Rotorua.

## 1. INTRODUCTION

Iwi/Māori have a long association with New Zealand's natural environment that is based on knowledge that has built up over time through centuries of interaction with the natural world. This includes the use of natural resources within many iwi/Māori communities. Mātauranga Māori 'Mātauranga Māori' (Māori knowledge) also includes tradition but is a broader collection of Māori knowledge, or set of subjects relating to esoteric and spiritual knowledge based in the past but often used and evolving in the present, for the future (Bradshaw and Faulkner, 2009).

Rural Māori communities include those living in, or having a cultural relationship with or significant interest, in identified rural Māori communities. 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 usage of natural resources. Neilson et al. (2010) found that indigenous approaches and perspectives were fundamental to developments associated with Māori communities. A common understanding of all of these cultural aspects will be important in determining the key developmental options available for the community. Whilst resource utilisation must be consistent with long-term Māori custodial responsibility, (kaitiakitanga) it is essential scientific investigation provides the starting point to highlight what development options exist, what technologies need to be developed, what (financial, technical) support is required, and what hurdles need to be overcome to initiate the appropriate type and scale of resource utilisation.

Current understanding of social processes affecting the societal acceptance of innovative technologies is limited. The issue of societal acceptance needs to be addressed to support the knowledge among the community in the planning and implementation procedures to develop successful communication strategies.

This paper assesses the potential of the societal acceptance approach to design a case for adopting ground-source heat technology using the example of the Ngāti Rangiwewehi Tarimano Marae located on the shores of Lake Rotorua. This paper also summarises potential ground-source heat pumps sources (the ground, Awahou Stream and Lake Rotorua) and estimates the heating and cooling requirements of the marae. From this example, we draw conclusions on the development of future improvement strategies and describe a cultural methodological framework.

## 2. SOCIETAL ACCEPTANCE

Societal acceptance of development generally includes three key dimensions: (1) socio-acceptance; (2) community acceptance; and (3) cultural acceptance. The socio-acceptance of GSHPs in New Zealand is in its infancy and further research could enhance the economic understanding of these within the New Zealand environment. Despite the high efficiency and low operating costs of GSHPs, the primary barrier to the market penetration is the incremental cost of installing the ground loop. The Swedish experience with GSHP systems shows significant acceptance by society with growth in use 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 systems predominately based on central heating with circulated water (Lind, 2011).

Māori entities need to develop realistic and sustainable development options that have community support (Ganesh et al., 2010). 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, water, rocks and its soils. (Bradshaw and Faulkner, 2009). As there are many barriers to technology uptake, it is recommended that guidance and resources be developed that can be used to assist Māori communities with how to manage new innovative technologies. This may include the creation of a 'roadmap' to assist Māori with the development process; education and development of resources; the building of networks and partnerships between agencies involved with facilitating iwi/hapū/Trust groups to meet and share knowledge and ideas. Māori-centred research requires a high degree of involvement of Māori at all levels. This should be factored in when undertaking research.

Research assists with understanding the importance and aspirations of the iwi/hapū/trust communities. Such an understanding will be key to developing partnerships and pursuing opportunities for the future. Research should also be undertaken to define how best traditional knowledge can be incorporated into planning and policy related to ground-source heating. There is potential to investigate other international experiences of utilising natural resources (e.g. for housing, health, commercial development). Future research could investigate the nature and extent that government agencies engage in trialing new technologies in communities, and how they do this, with a view to defining best practice. Areas requiring further research with respect to Māori perspectives include: traditional and historic uses, environment (including climate, geology, hydrogeology, surface hydrology and chemistry and geophysics), GSHP options and cost-benefit analysis.

## 2. NGATI RANGIWEWEHI

Ngāti Rangiwewehi is an iwi as derived from the confederated tribes of Te Arawa, Ngā Pūmanawa e Waru o Te Arawa, (the eight beating hearts of Rangitihi). Ngāti Rangiwewehi have lived and co-habituated within the Mangorewa Kaharoa area since the time of Whakaue-kaipapa, a seventh-generation descendent of Tamatekapua, the captain of the Te Arawa canoe. Tarimano Marae, Te Awahou is the home of Ngāti Rangiwewehi.

The tribal rohe (boundaries) of Ngāti Rangiwewehi includes the area north and west of Lake Rotorua (Figure 1). The area begins at the centre of Mokoia Island (Te-Motu Tapu-a-Tinirau), and fans out toward the shores of Lake Rotorua. Bordered to the south by the Waimihia Stream which feeds into Te Rotorua-nui-a-Kahu, Ngāti Rangiwewehi lands take in Te Awahou travelling east toward Puaraurewa, forming the north eastern boundary of the Te Waerenga Block with Ngāti Parua to the east.

Ngāti Rangiwewehi is the kaitiaki over the traditional ancestral lands and associated waters and therefore maintains the kaitiaki status over its natural and physical resources within the core and ancestral areas identified by Ngāti Rangiwewehi.

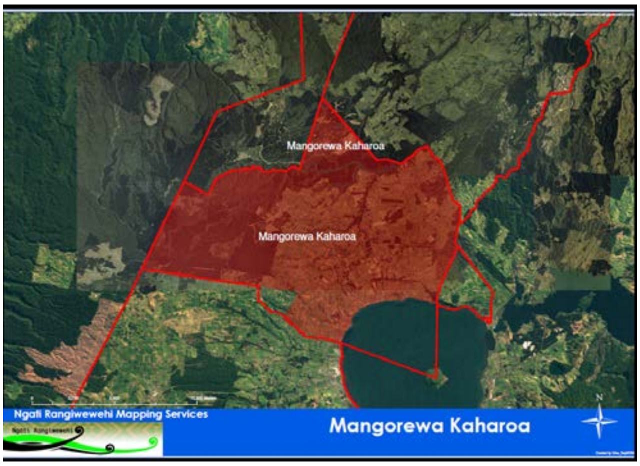



Figure 1. The tribal rohe of Ngāti Rangiwewehi.

### 2.1 Importance of the Tarimano Marae

Tarimano Marae is located on the north western shores of Lake Rotorua, and next to the Awahou Stream (Te Wai Mimi o Pekehaua) which flows into Lake Rotorua. Te Awahou Village is an iwi-based rural community with a marae-centric focus. As a rurally-based Maori community with an iwi/marae-centric focus, the sustainable use and development of its natural and physical resources use is a pre-requisite component in the socio-economic development of the members of Ngāti Rangiwewehi. As such, Te Awahou Village, in particular Tarimano Marae is the foremost priority for any iwi development enterprise undertaken by Ngāti Rangiwewehi.

## 3. DEVELOPMENT OPPORTUNITIES FOR GSHP AT TARIMANO MARAE

A preliminary assessment of the storm water and drainage systems servicing the Tarimano Marae complex (Te Tari Taiao, 2009) led to further technical analysis being commissioned as part of a larger marae-based project looking at the impacts of climate change on the Awahou community, in particular around Tarimano Marae, incorporating a feasibility investigation into the re-development of the whare-kai and ablutions complexes.

The aim of this project was to prepare a sustainable marae management plan to help guide social, cultural and economic development for Ngāti Rangiwewehi, having regard to the known, and foreseeable, physical and environmental constraints including the predicted impacts of climate change. Ngāti Rangiwewehi has been utilising an in-house Geographical Information System (GIS) to support a number of its strategic goals and objectives including Waitangi Tribunal claims, local government engagement processes and the management and protection of its natural and physical resources.

It is considered appropriate and prudent to therefore engage the appropriate technology to assist in the development of a sustainable marae management plan. The development of specialist reports produced to support this investigation included a geotechnical and structural integrity assessment; an energy audit of the current energy status of Tarimano Marae and analysis of "off-grid' energy systems; including a full series of complimentary maps analysing climatic, geological and ecological factors (Te Tari Taiao, 2012).

The development of a sustainable management plan for Tarimano Marae has initiated the desire to further investigate the feasibility of utilising ground–source heat pumps to heat and cool communal buildings including the meeting house and wharekai (communal dining room**)** as an energy-efficient, environmentally clean, and cost-effective space conditioning systems option being considered for Tarimano Marae. Additional benefits are that heat pumps offer significant emission reductions potential, particularly where they are used for both heating and cooling, particularly where the electricity is produced from renewable resources. Within this case study, the ability to service the GSHP system using solar and micro-hydro power energy generation systems will be critical to the successful installation at Tarimano Marae.

## 4. GSHP DEVELOPMENT OPTIONS FOR TARIMANO MARAE

Local air temperature is one control on the use and energy requirements for GSHP. Therefore monthly average temperatures measured at Rotorua are reviewed to assess the potential use of GSHP for heating and cooling. Potential sources for GSHP include the ground, Awahou Stream (located adjacent to at Tarimano Marae) and Lake Rotorua, Figure 2. Power requirements, and annual energy demand, are estimated for a GSHP system at Tarimano Marae.

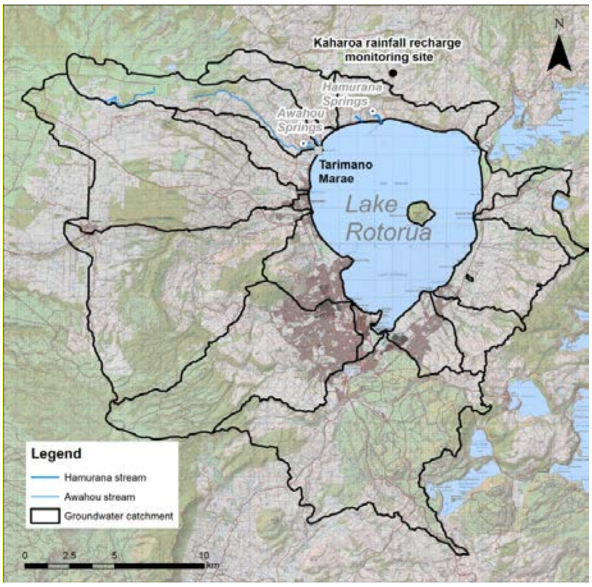



Figure 2. Location of Tarimano Marae and Awahou Stream.

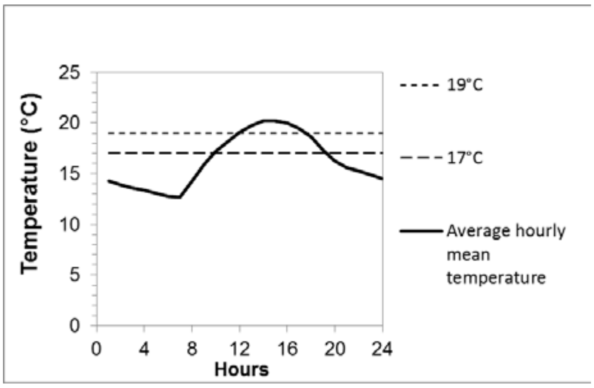
### 4.1 Annual requirement for GSHP

Annual average air temperatures in Rotorua is approximately 12.9 °C with lowest average temperatures in July (7.6 °C) and highest average temperatures in February (18.0 °C), Table 1.

Building heating and cooling is generally required when air temperature is outside the range approximately 17 °C to 19 °C (National Rural Electric Cooperative Association, 1988). The annual requirements for heating are greater than the requirements for cooling, as indicated by average monthly air temperatures in Rotorua (Table 1). Heating is potentially required in 12 months of the year including: heating over the full day in 6 months of year (May to October) when average high temperature at Rotorua is less than 17 °C; heating for parts of days in the other 6 months of the year when average low temperature at Rotorua is less than 17 °C. Cooling is potentially required for parts of days in 4 months of the year (November to March) when average high temperature at Rotorua is greater than 19 °C. Cooling is not potentially required over full days during the year as average low temperature at Rotorua is never greater than 19 °C. The potential demand for heating and cooling is also demonstrated by average hourly temperature in March 2011 (Figure 3). Potential heating demand in this month occurs on average between 19 hours and 9 hours, when average temperatures are below 17 °C, and cooling demand occurs between 9 hours and 19 hours, when average temperatures are above 19 °C. Actual heating and cooling demand will also depend on the occupancy pattern of communal buildings.

Table 1. Monthly and annual temperature statistics, Rotorua (http://www.rotorua.climatemps.com).

| Month | Average high (°C) | Average low (°C) | Monthly average (°C) |
|---|---|---|---|
| January | 23.0 | 12.7 | 17.9 |
| February | 23.0 | 12.9 | 18.0 |
| March | 21.1 | 11.6 | 16.4 |
| April | 18.3 | 8.8 | 13.6 |
| May | 15.1 | 5.9 | 10.5 |
| June | 12.6 | 4.2 | 8.4 |
| July | 12.1 | 3.1 | 7.6 |
| August | 13.0 | 4.4 | 8.7 |
| September | 14.7 | 6.0 | 10.4 |
| October | 16.7 | 7.9 | 12.3 |
| November | 19.0 | 9.6 | 14.3 |
| December | 20.9 | 11.3 | 16.1 |
| Annual average (°C) | 17.5 | 8.2 | 12.9 |






New Zealand Geothermal Workshop 2012 Proceedings
19 - 21 November 2012
Auckland, New Zealand

Figure 3. Average hourly temperature in March 2011 (National Institute of Water and Atmospheric Research, 2012) showing potential requirements for heating, when temperatures are below 17 °C, and for cooling, when temperatures are above 19 °C.

### 4.2 Potential sources for GSHP

Potential sources for GSHP include the ground and surface water (i.e. Awahou Stream or Lake Rotorua). Huka Falls Formation sediments occur at the ground surface at Awahou. These sediments are approximately 200 m thick at the lake's edge (White et al., 2007). These sediments are typically composed of unconsolidated pumice and sediments, that are partially water-bearing above lake level, to a depth of approximately 50 m. Typically, Huka Falls Formation sediments below 50 m depth are relatively impermeable lake deposits, including mudstones. Huka Falls Formation sits on Mamaku Plateau Ignimbrite (White et al., 2007).

A pump test in Huka Falls Formation measured a transmissivity of 200 $m^2$/day, storativity of 2 x $10^{-3}$ and a hydraulic conductivity of 4.5 m/day (White et al., 2007). Shallow ground temperatures in the Huka Falls Formation are not measured. However, ground temperatures at Tarimano Marae is probably equal to average annual air temperature at Rotorua (approximately 12.9 °C, Table 1) at about 10 m depth rising by approximately 3 °C per hundred metres of formation below this depth. Temperatures above 10 m depth are probably in the range approximately 8 °C to 18 °C, i.e. the approximate range in average monthly temperature (Table 1).

Monthly average temperatures in surface water bodies show less variability than air temperatures. Water temperatures in Lake Rotorua are typically 15 °C in winter and usually 19 – 20 °C, but as much as 23 °C, in summer. Temperature in Awahou Stream was an average of 12.8 °C in the period 2002 to 2003 (Centre for Biodiversity and Ecology Research, 2012). Temperature in Hamurana Spring (Figure 2) is relatively uniform over time (average 12.3 °C and standard deviation 0.5 °C in the period 1992 to 2003; Centre for Biodiversity and Ecology Research, 2012) and is approximately 13 °C in summer (Rowe et al., 2005).

### 4.3 Options and energy requirements for GSHP

A heat source (either a closed loop or an open loop) and a heat pump are the two major components of GSHP systems (National Rural Electric Cooperative Association, 1988). Water-air systems take heat from water to warm air and can be used for heating and cooling. Water-water systems can be used for heating only (e.g. under-floor heating). Water, or another fluid, is circulated through closed loop systems and a heat pump removes heat from the fluid. Open loop systems pump water from wells or surface water. Commonly, the efficiency of GSHP systems is compared with the air-air heat pumps that are prevalent in domestic residences.

Ground source options for Tarimano Marae include: 1) a ground source with horizontal or vertical closed loop configurations ; 2) an Awahou Stream source with a closed loop system; and 3) a lake source with a closed loop system.

A ground source with a horizontal closed loop could take heat from the shallow Huka Falls Formation through excavated trenches or pits. Average temperatures in the excavated areas would probably approximate annual average air temperature (12.9 °C, Table 1). Costs associated developing this GSHP source would include excavations and sufficient pipe work to provide for heating and cooling. A vertical closed loop could take heat from a well that penetrates deeper (i.e. warmer by an estimated 3°C per 100 m of well depth) Huka Falls Formation sediments. Costs associated with a vertical closed loop includes the costs of pipe work and drilling.

An Awahou Stream source would incur costs for trenching the approximately 40 m distance from Tarimano Marae to the stream and pipe work in the stream to provide for heating and cooling. The river bed of Awahou Stream at Tarimano Marae is approximately 2 m wide, which should be suitable to provide the space required for pipe work. Awahou Stream flow is approximately 1700 L/s (White et al., 2007) which should be suitable to provide heating and cooling requirements for the marae. An open loop system is not recommended due to likely biological fouling of the pipe work, as noted by National Rural Electric Cooperative Association (1988). Consent under the Resource Management Act may be required for implementation of an Awahou Stream source and consideration of the needs of stream users will be required in the design of any in-stream works.

Costs for a Lake Rotorua source would include trenching the approximate 400 m distance between Tarimano Marae and the lake and pipe work in the lake. Lake temperature is more variable over time than Awahou Stream. Therefore a GSHP using the lake will be less efficient than Awahou Stream for heating and cooling. Resource Management Act may be required for the use of this source and consideration of the use of the lake by boats and fishermen will be required in the design of any in-lake works.

Three 3 kW heat pump units are probably required for the communal buildings on the Tarimano Marae. The meeting house probably requires one unit with two units in the wharekai. These GSHPs have an estimated annual energy requirement for heating and cooling of 1833 kWh in a year, using the 'bin' method (National Rural Electric Cooperative Association, 1988) to approximate the occupancy pattern of communal buildings. Approximately 75% of the annual energy use is for heating with the balance for cooling. GSHP would use less energy than conventional air-to-air systems because the annual energy requirement of three 3 kW air-to-air systems is an estimated 2391 kWh.

## 5. CONCLUSIONS

Societal acceptance of development generally includes three key dimensions: (1) socio-acceptance; (2) community acceptance; and (3) cultural acceptance. Cultural acceptance is fundamental to developments associated with rural Māori communities and resource utilisation must be consistent with long-term Māori custodial responsibility (kaitiakitanga). Ngāti Rangiwewehi occupies the area north and west of Lake Rotorua. Tarimano Marae, located on the north western shores of Lake Rotorua, and adjacent to the Awahou Stream, is the focus for any development undertaken by the iwi. Ground–source heat pumps to heat and cool the wharekai and associated buildings are an option for the marae.

The potential annual requirements for heating and cooling were assessed using monthly air temperatures measured at Rotorua. Potential annual requirements for heating are greater than the requirements for cooling. This is because heating is potentially required in 12 months of the year including full days in the May to October period when average monthly high temperature at Rotorua is less than 17 °C. In contrast, cooling is potentially required for parts of days in 4 months of the year (November to March) when average monthly high temperature at Rotorua is greater than 19 °C.

Ground source options for Tarimano Marae include the ground, Awahou Stream and Lake Rotorua. A ground source with a horizontal closed loop could take heat from the shallow Huka Falls Formation through excavated trenches or pits. An Awahou Stream source would incur costs for trenching from Tarimano Marae of approximately 40 m and pipe work in the stream to provide for heating and cooling. Costs for a Lake Rotorua source would include trenching the approximate 400 m distance between Tarimano Marae and the lake and pipe work in the lake. The costs of GSHP are probably least for an Awahou Stream source. This is because ground works, including trenching and other excavations, are the least for this source.

Three 3 kW heat pump units are probably required for the communal buildings (meeting house and wharekai) on the Tarimano Marae. The meeting house probably requires one unit with two units in the wharekai. These GSHPs have an estimated annual energy requirement for heating and cooling of 1833 kWh in a year which is less than an estimated energy requirement of 2391 kWh for conventional air-to-air heat pump systems.

**ACKNOWLEDGEMENTS**

Our thanks to Magali Moreau-Fournier for drafting a figure in this paper.

**REFERENCES**

Bradshaw, D., Faulkner, R.: Low Enthalpy Geothermal Energy Resources for Rural Māori Communities –year one report. (2009).

Centre for Biodiversity and Ecology Research, 2012. Rotorua lakes database. http://cber.bio.waikato.ac.nz/ Lakes_web/cover.html.

Ganesh, N., Kamau, R., Stokes, F., Lynn, A., Molano, W.: Māori, Science and Innovation – Themes and Industry Issues to Inform Scenarios. Discussion Document for: Māori Economic Taskforce. November 2010. BERL ref #4902. (2010)

Lind, L.: Swedish Ground Source Heat Pump Case Study (2010 Revision), GNS Science Report 2010/54. (2011).

National Rural Electric Cooperative Association: Closed-loop/ground-source heat pump systems. Installation guide. NRECA Research Project 86-1. 236p. (1988).

National Institute of Water and Atmospheric Research. CliFlo database. http://cliflo.niwa.co.nz/. (2005).

Neilson, G., Bignall, G., Bradshaw, D.: Whakarewarewa a Living Thermal Village, Rotorua, New Zealand. Proceedings World Geothermal Congress 2010, Bali, Indonesia. (2010).

Rowe, D., Gibbs, M., Bowman, E., Lodge, S.: The Hamurana Stream in Lake Rotorua: some potential effects of its diversion on the trout fishery and on summer nutrient dynamics. National Institute of Water and Atmospheric Research Ltd client report HAM2005-025 for Bay of Plenty Regional Council. 40p. (2005).

Te Tari Taiao.: Tarimano Marae Complex and Activities Club Infrastructure Assessment. Preliminary report to Tarimano Marae Trustees, Te Maru o Ngāti Rangiwewehi Iwi Authority. (2009).

Te Tari Taiao.: Geographic Information System (GIS) Marae Modeling Project - Final Report to Te Puni Kōkiri, Te Maru o Ngāti Rangiwewehi Iwi Authority. (2012).

White, P.A, Zemansky, G., Hong, T., Kilgour, G., Wall, M.: Lake Rotorua groundwater and Lake Rotorua nutrients – phase 3 science programme technical report. GNS Client report 2007/220 to Environment Bay of Plenty. 402p. (2007).