



Geothermal Heat Pumps in New Zealand Introductory Technical Guide



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Contents

	SUMMARY	5
PART 1:	INTRODUCTION TO GEOTHERMAL HEAT PUMPS	7
	1. Geothermal energy overview	8
	2. Geothermal heat pump technology	10
	3. Geothermal heat pumps in New Zealand	12
	3.1. New Zealand applications	12
	3.2. Benefits	13
	3.3. Capital costs	13
	3.4. Choosing an installer	14
PART 2:	TECHNICAL INFORMATION	15
	4. Geothermal heat pump configurations	16
	5. Closed loop systems	17
	5.1. General technical information	17
	5.2. Horizontal loop systems	23
	5.3. Vertical loop systems	26
	5.4. Submerged loop systems	28
	6. Open loop systems	30
	6.1. General technical information	30
	6.2. Groundwater systems	32
	6.3. Surface water systems	36
	7. Geothermal energy storage	38
	7.1. Aquifer thermal energy storage	38
	7.2. Borehole thermal energy storage	39
	8. Regulatory considerations	40
	8.1. Regulatory requirements	40
	8.2. Environmental considerations	41
	REFERENCES	43
	FURTHER READING	44
	CASE STUDIES	45

Index of Figures and Tables

Figure 1	Sources of geothermal energy	8
Figure 2	Typical ground surface temperature profile with depth	9
Figure 3	Soil temperature variation from average annual temperature 2010	9
Figure 4	Schematic of a GHP system	10
Figure 5	Schematic showing how a GHP operates	11
Figure 6	Comparison of GHP configurations	16
Figure 7	Examples of thermal conductivity	18
Figure 8	Characteristics of common antifreeze solutions	19
Figure 9	Ground loop arrangements	20
Figure 10	Comparison of parallel and series installations for ground loops	21
Figure 11	Backfill material characteristics	21
Figure 12	Straight horizontal closed loop installation	23
Figure 13	Pipe arrangements in horizontal ground loops	24
Figure 14	Horizontal slinky installation	24
Figure 15	Pipe arrangement in a slinky ground loop	24
Figure 16	Vertical closed loop installation (multiple bore arrangement)	26
Figure 17	Single U-pipe and coaxial borehole heat exchangers	27
Figure 18	Cross sections of different types of borehole heat exchangers	27
Figure 19	Submerged closed loop installation	29
Figure 20	Submerged loop ready for sinking and anchoring	29
Figure 21	Single well, open loop, groundwater system	32
Figure 22	Double well, open loop, groundwater system	33
Figure 23	Standing column well, open loop, groundwater system	33
Figure 24	Secondary heat transfer fluid loop	34
Figure 25	Surface water heat pump system	36
Figure 26	Schematic of an aquifer thermal energy storage system	38
Figure 27	Borehole thermal energy storage	39
Figure 28	Potential resource consent requirements	40
Figure 29	Summary of environmental considerations	42

This guide was jointly developed by GNS Science Limited, the Energy Efficiency and Conservation Authority (EECA) and Environmental Management Services Limited (EMS). The technical content has been developed from a review of international and national experience.

The information presented is general guidance only and is not a substitute for professional advice. It is not intended to be used for making decisions or taking actions, nor is it intended to address the situation or objectives of any particular person or organisation. In particular, this guide should not be relied on for establishing compliance with the New Zealand Building Code or the Resource Management Act 1991.

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This document may be updated from time to time. The latest version is available from the EECA website (www.eeca.govt.nz).

Glossary of units

Unit (symbols)	Unit	A measure of:
$kWh/(m \cdot yr)$	kilowatt hour per metre and year	annual heat extraction
m^2	square metres	area
ppm	parts per million	concentration
PJ/yr	petajoule per year	energy
W/m	watt per metre	heat extraction rate
W/m^2	watt per square metre	heat extraction rate
m^3/h	cubic metres per hour	flow rate
mm	millimetre	length
m	metre	length
$^{\circ}C$	degrees Celsius	temperature
$W/(m \cdot K)$	watt per metre and Kelvin	thermal conductivity
kW	kilowatt	power

Summary

Purpose of the guide

This introductory guide details the installation and operation of geothermal heat pumps (GHPs), also called ground source heat pumps or geo-exchange systems, in New Zealand. It is intended to assist a range of stakeholders by providing an overview of geothermal energy, general technical information on the operation and installation of GHPs and relevant New Zealand environmental and regulatory considerations.

Structure of the guide

This guide is structured in two parts:

Part 1: Introduction to geothermal heat pumps

- Overview of geothermal energy
- Potential GHP applications in New Zealand
- GHP technology
- Benefits of GHPs, capital costs of installation and considerations for selecting an installer.

Part 2: Technical information

- General technical information on closed loop GHP systems
- General technical information on open loop GHP systems
- Geothermal energy storage and its role
- Key regulatory considerations.

An overview of GHPs

GHPs harness the low temperature geothermal energy stored in soil, rock, surface water or groundwater and make this energy available for heating and cooling.

Geothermal energy is any energy stored in or derived from the Earth; it is not limited to places with 'hot ground' like Rotorua or Taupō and is available nationwide. It is derived from three major sources: volcanic systems; stored energy from the sun; and energy radiated from the Earth's core. Stored energy from the sun and energy radiated from the Earth's core generate lower temperature geothermal energy that can be utilised by GHPs.

As this lower temperature geothermal resource is available from practically any building site in the country, GHPs have significant potential in New Zealand. They can be used for space heating and cooling in buildings, heating swimming pools, providing domestic hot water and supporting industrial heat use. GHPs are suitable from small applications (e.g. residential buildings requiring 5kW to 30kW systems) to large applications (e.g. large buildings and district heating schemes of 100kW to 1000kW or more).

GHPs utilise a naturally replenished, renewable energy source that is available all year round; they are efficient, low maintenance, durable, quiet and reliable.

GHPs work by collecting geothermal energy through a ground loop and then transferring this heat energy to an end use such as heating a building. They can also work in reverse to provide cooling by collecting heat energy from inside a building and disposing of it via the ground loop. Depending on the location and characteristics of the site, the ground loop can be installed vertically or horizontally, using straight pipe or in a series of coils, and as an open (extracting/disposing of fluid and heat) or closed (extracting/disposing of heat only) system.

Part 1: Introduction to geothermal heat pumps

This section provides an overview of geothermal energy resources in New Zealand along with a summary of potential GHP applications across residential, commercial and industrial sectors. It includes a brief overview of GHP technology, identifies key benefits, provides information on capital installation costs and guidance for selecting an installer.

GHPs harness the lower temperature geothermal energy stored in soil, rock, surface water or groundwater and make this energy available for heating and cooling. Applications include space heating and cooling in buildings, heating swimming pools, providing domestic hot water and supporting some industrial heat use. This energy source is naturally replenished, available all year round and accessible from almost any building site in New Zealand.

1. Geothermal energy overview

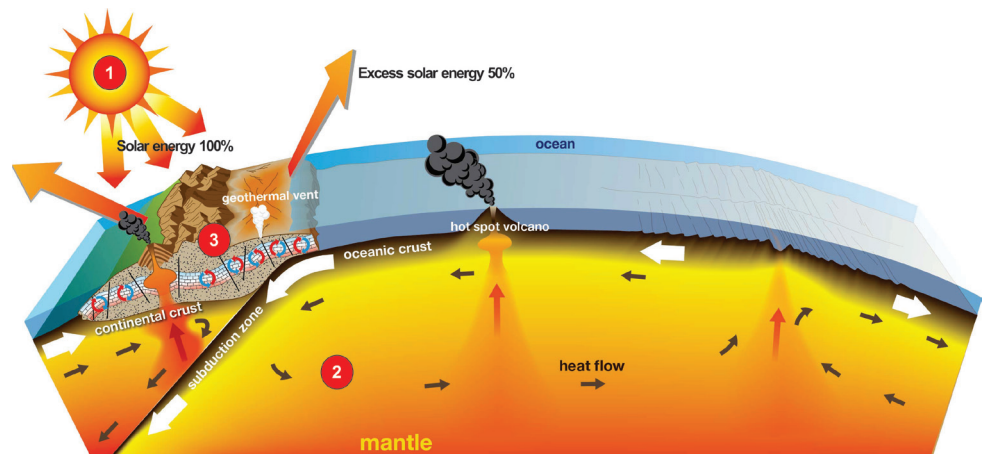
In meeting New Zealand's long-term energy demand we must find ways to respond to the challenges of climate change while delivering renewable¹, secure, affordable and environmentally responsible energy solutions. Geothermal energy could make an important contribution towards meeting these challenges.

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

Geothermal energy (Figure 1) is heat from three sources:

1. Volcanic systems: Localised areas of higher heat flow occur with volcanic and geothermal activity, where tectonic plates move apart or collide, or in hot spots under mid-ocean volcanic islands. Faults, fractures and permeable formations act as channels for heat to flow to the surface.
2. The sun: About half of the solar energy that reaches the Earth's surface is absorbed and stored by the land and the oceans.
3. The Earth's core: Heat is generated deep within the Earth. Away from areas of volcanic or geothermal activity, this heat moves slowly and continually to the surface. In New Zealand, ground temperature increases by about 30°C for every 1,000m of depth.

Figure 1. Sources of geothermal energy (1. Volcanic systems; 2. Solar energy; 3. The Earth's core)



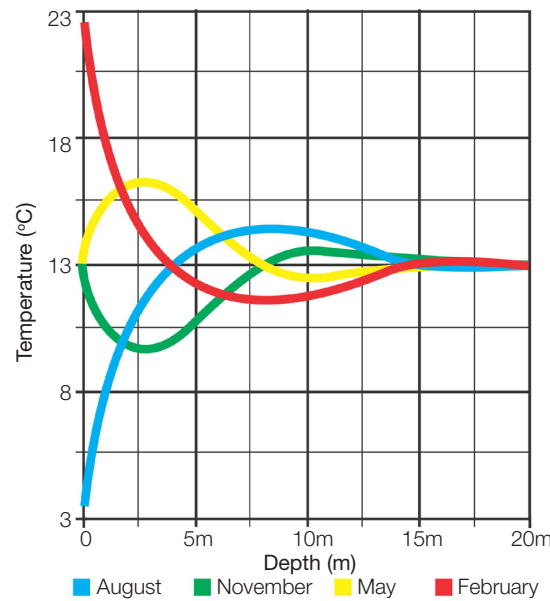
(Source: GNS Science)

New Zealand has a long history of developing high temperature geothermal resources associated with volcanic systems. Electricity has been generated from high temperature resources in the Taupō volcanic region since the late 1950s.

However, lower temperature geothermal resources in New Zealand are currently under-utilised. These lower temperature resources provide relatively constant ground temperatures throughout the year and GHPs can harness this energy. Figure 2 plots seasonal ground surface temperature variations that show increasingly constant temperature conditions with increasing depth.

¹ The Resource Management Act 1991 defines renewable energy as energy produced from solar, wind, hydro, geothermal, biomass, tidal, wave, and ocean current sources (s.2).

Figure 2. Typical ground surface temperature profile with depth (Plotted for four months of the year)



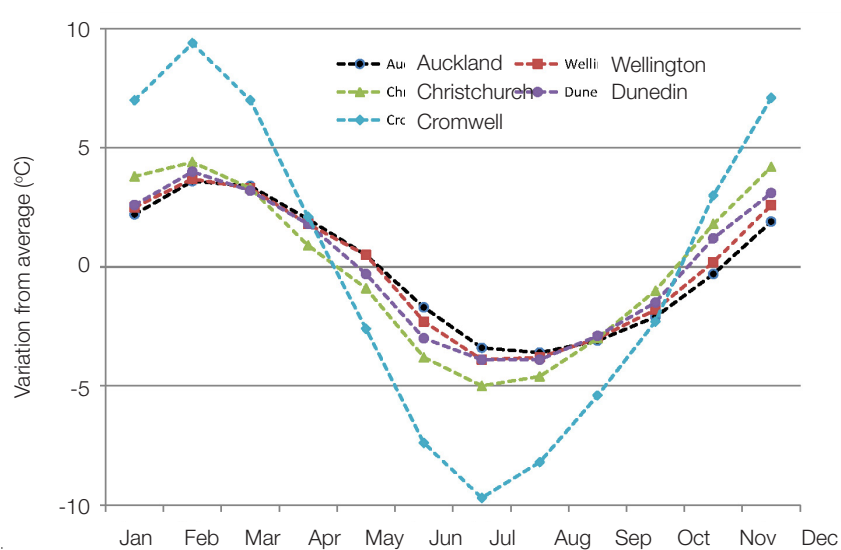
(Source: revised from www.dimplex.co.uk)

Ground surface temperatures in New Zealand typically average between 12°C and 15°C, and can swing by as much as 10°C from summer to winter. These variations are significantly less than the equivalent changes in ambient air temperature.

Ground surface temperature is site specific and depends on altitude and latitude. Actual ground surface temperature is best obtained from local water well logs or ground surface temperature surveys, however in New Zealand it typically varies between 13°C and 16°C.

The average ground surface temperatures recorded at various locations in New Zealand are: Auckland 16.1°C; Wellington 14.3°C; Christchurch 13.2°C; Dunedin 12.2°C; and Cromwell 13.4°C. Figure 3 shows seasonal variation from the average soil temperature at 1m depth for these locations, as measured by the National Institute of Water and Atmospheric Research (NIWA) in 2010.

Figure 3. Soil temperature variation from average annual temperature 2010

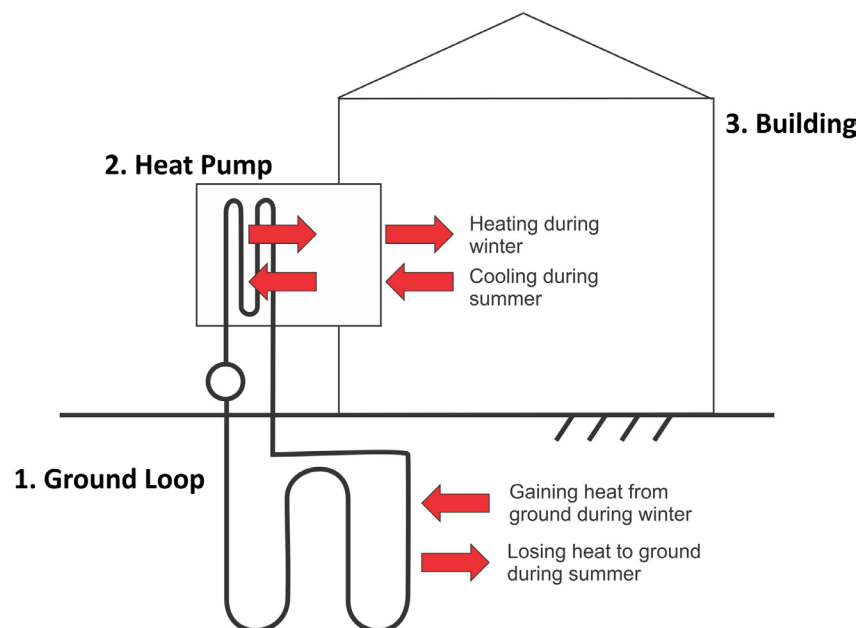


2. Geothermal heat pump technology

GHPs consist of three components described below and shown in Figure 4:

1. **Ground loop** – formed by a network of pipes (closed loop) or an intake and outlet structure (open loop) located underground or underwater, which is generally located outside of the building footprint. Its primary function is to collect heat from, or dispose heat to, the ground, groundwater or surface water. This is achieved by circulating a working fluid through buried or submerged pipes (closed loop systems) or taking groundwater or surface water directly (open loop systems). Section 4 provides a comparison of loop configurations.²
1. **Heat pump** – moves heat from a lower temperature fluid and releases it at a higher temperature to another fluid. In heating mode, the heat pump transfers heat collected in the ground loop to the application (e.g. space heating in a building or heating a swimming pool). In cooling mode, the process is reversed and heat is removed and transferred to the ground loop for disposal. See Figure 5.
1. **Distribution system** – the distribution system delivers heat to or removes heat from the application (e.g. space heating in a building or heating a swimming pool). For example, in a building one of the most efficient methods for space heating is to lay pipes in a building's concrete floor through which warmed water from the heat pump is circulated.

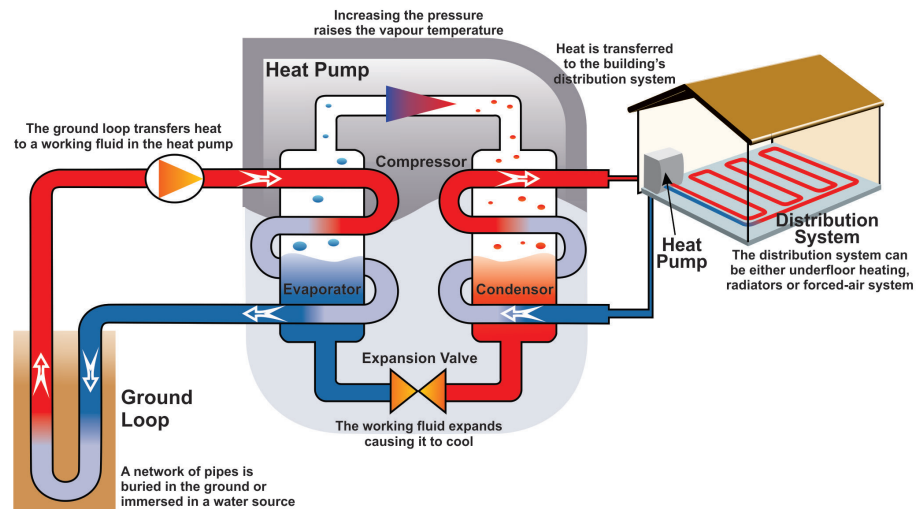
Figure 4. Schematic of a GHP system



(Source: revised from www.newenergydirection.com)

³ GHP configurations 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. Where there is sufficient land area, a horizontal system may be more economic.

Figure 5. Schematic showing how a GHP operates



(Source: revised from www.earthenergy.co.uk/technology)

Air source heat pumps have been a popular heating and cooling solution in many New Zealand homes and businesses in recent years. At their core, they have the same heat pump componentry as GHPs, but rather than exchanging heat energy with the ground, groundwater or surface water, air source heat pumps exchange heat energy with the air.

GHPs achieve an efficiency advantage over air source heat pumps because they utilise geothermal energy that provides a reasonably constant temperature in the ground, groundwater and surface water. These environments are generally cooler than the air temperature in summer and warmer than the air temperature in winter, supporting more efficient summer cooling and winter heating respectively.

Heat pump technology

The heat pump component of a GHP functions in the same way as a household fridge. The following basic principles are used:

- A liquid absorbs heat as it vaporises (e.g. boiling water turning into steam).
- Compressing a gas increases its temperature.
- Expanding a gas reduces its temperature.
- As a gas loses heat, it will turn back into a liquid (e.g. steam condensing back to liquid water).

A heat pump uses these principles by circulating a refrigerant through a loop with two heat exchangers – one exchanger to gain heat, one to lose it.

A refrigerant is a liquid with a very low boiling point, meaning that it can evaporate into a gas and condense back into a liquid at lower temperatures.

When circulated in a loop between two heat exchangers, the refrigerant gains heat from one exchanger so that it turns into a gas, the gas is compressed (increasing in temperature) 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 ground 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 respectively.

3. Geothermal heat pumps in New Zealand

3.1. New Zealand applications

The geothermal energy accessed by GHPs can be utilised in New Zealand for:

- space heating and cooling at a small scale (e.g. residential buildings)
- space heating and cooling at a larger scale (e.g. commercial buildings, multi-storey office buildings, airport terminals, schools, shopping centres, sports facilities)
- district energy (heating and cooling) schemes
- water heating at various scales (e.g. for domestic use, swimming pools, greenhouses, aquaculture and industrial processes).³

The number of GHP installations in New Zealand is growing, although growth is slow compared with many countries. For example, in Europe, North America, China and Korea the adoption of GHPs is particularly high.

There is potential for greater use of GHPs in New Zealand. It is likely that GHP technology will be most attractive to larger energy users in the commercial and industrial sectors, where installation costs will be more quickly offset by reduced operating costs.

Similarly, GHPs are an option for whole-home central heating/cooling solutions in the residential market and/or where climatic conditions are more extreme and energy consumption for heating and cooling is higher.

Energy demand in New Zealand is projected to increase over time, and there is potential for GHPs to help meet this demand as an efficient, reliable and renewable energy solution. For example:

- In the residential sector, New Zealand has a history of single room heating, minimal investment in home heating technologies, energy efficient design and construction techniques; and generally lower expectations of levels of indoor comfort in winter compared with many other countries. In many countries with similar climates, central heating/air conditioning and high standards of insulation are considered basic necessities and this attitude is growing in New Zealand. Adequate home heating during winter is increasingly being seen as important for improved health. As New Zealand's population grows and attitudes change, energy demand for space heating and cooling in the residential sector is likely to increase.
- In the commercial sector (i.e. non-residential buildings such as schools, hospitals, office buildings, airports, factories and warehouses), energy consumption for heating and cooling is typically high, and even small improvements in energy efficiency can achieve significant cost savings. This is becoming an increasingly important focus for many businesses.

4 GNS Science has prepared a number of case studies on New Zealand GHP installations. Case studies are available from the GNS Science website and are attached to this guide.

3.2. Benefits

Accessing geothermal energy provides a range of benefits from increased energy efficiency and reduced costs for individual consumers, through to macro benefits for the energy market.

Geothermal energy is:

- accessible throughout New Zealand
- always available, regardless of climatic conditions or seasonal changes
- a renewable and reliable resource.

The main benefits of using GHP technology for residential and commercial heating and cooling are that GHPs:

- are an energy efficient form of heating and cooling, supporting healthier homes and buildings
- utilise a renewable resource
- are low maintenance, durable and highly reliable – for example, HDPE ground loops have a life expectancy in excess of 50 years
- are quiet and can be installed with no external unit, allowing improved integration with architectural considerations
- can be utilised in a range of applications and energy loads; current technology allows practical implementation from small applications (e.g. residential buildings requiring 5kW to 30kW) to large applications (e.g. large buildings and district heating schemes of 100kW to 1000kW or more)
- align with the Government's target for the increased use of geothermal energy resources.⁴

3.3. Capital costs

While GHPs offer significant benefits, they can be more expensive to install than other heating and cooling methods. This can result in longer pay-back periods, particularly for lower level energy users. It should be noted that, given the long life expectancy (approximately 50 years or more for some systems), once paid back, GHPs can offer many years of savings in energy costs.

Currently in Australia, where market conditions for GHPs are similar to New Zealand, pay-back periods of around six to seven years are possible.⁵ The pay-back period for many commercial and industrial buildings in Europe has been shown to be even shorter, mainly because GHPs are often installed in new buildings during construction by incorporating ground loops in foundation elements at no extra cost for drilling.

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
- the tendency to overdesign systems based on European or North American design standards.

These factors will be able to be mitigated as the market matures, which should result in lower costs for consumers.

⁴ The New Zealand Energy Strategy target is that by 2025 we will utilise up to 9.5 PJ/yr of energy from woody biomass or direct use geothermal additional to that used in 2005.

⁵ As indicated through work by the University of Melbourne.

One method to reduce capital costs in the short term is to design a GHP system to deliver base-load heating and cooling only, supported by conventional systems that meet peak-load energy demand. Peak-load energy demand is the maximum energy required to heat or cool a building to a desirable temperature during a maximum or minimum outdoor temperature event. For example, a building's heating system may be required to maintain 20°C inside the building throughout the year. In any given year, the outdoor temperature may vary between 30°C in summer and -5°C in the middle of winter. However, outdoor temperatures may only reach their maximum or minimum on a few days per year; for the majority of the year, outdoor temperatures will remain in a more moderate range. A GHP system can be designed to provide enough energy to meet heating and cooling demand for most of the year (base-load energy), rather than peak-load energy.

The benefit of this approach is that base-load energy could be provided by a ground loop that is approximately 60% of the size of a ground loop required for full peak-load,⁶ while still meeting almost 97% of the year's heating demand.

For those times of the year where base-load is insufficient, the ground loop would only partly heat or partly cool the building. There are several possible strategies for responding to this and one option is to incorporate a conventional auxiliary system (such as electric heating or solid fuel burner) to meet the heating or cooling shortfall.

While there is a range of possible variations within this strategy, at its core it offers a reduction in the ground loop size while maintaining almost all of the energy savings offered by GHPs. As the ground loop component represents a significant proportion of overall installation costs, this strategy can reduce pay-back time.

3.4. Choosing an installer

Good design and installation practices are fundamental to the efficient and effective performance of a GHP system. Inadequacies in the site assessment, poor material selection or system design (including the building heat distribution system) will result in poor system performance.

Key considerations related to the installation of a GHP are to ensure that:

- a robust calculation of the building's heat loss characteristics and associated heating and cooling demand is carried out
- an appropriate system size is specified (ground loop, heat pump and building distribution system)
- system design achieves long-term thermal sustainability
- environmental considerations are addressed (e.g. ground conditions, take of groundwater, drilling)
- the ground loop configuration is suitable for the specific location
- the distribution system is suitable and effective
- installation of the system complies with relevant regulations and standards
- there is a warranty for the heat pump and its installation.

These considerations involve specialised knowledge and experience, and it is recommended that GHP systems are designed and installed by experienced technical personnel. The installer should advise the owner of any service requirements and provide contact names and numbers in the event of problems.

Installers should hold the appropriate licence to carry out the required work (e.g. electricity, plumbing, refrigerant handling, drilling) and issue an electrical Certificate of Compliance if required. Where relevant, installers should hold a 'no loss certification' for the handling of refrigerants.

⁶ As indicated through work by the University of Melbourne.

Part 2: Technical information

This section presents technical information on GHP technologies. The technical content has been developed from a review of international and national experience. It provides guidance on the specific requirements of both closed and open loop systems and explains the role of geothermal energy storage. However, it is not intended as an installation guide or specification. This section also presents a summary of key regulatory considerations relevant to the installation of GHPs in New Zealand.

4. Geothermal heat pump configurations

GHP installations can function as open loop systems or closed loop systems as detailed in Figure 6. In summary:

- **Closed loop systems** operate by circulating a fluid through a sealed pipe network. This fluid is usually water or a water/antifreeze solution. The exception is a direct exchange (DX) system, which circulates a refrigerant through the ground loop pipe network. The circulating fluid flows in a continuous loop, collecting or discharging heat as it circulates. The only interaction with the environment is the transfer of heat through the pipe walls.
- **Open loop systems** operate by extracting fluid directly from the environment, either as surface water or groundwater. The water is passed through a heat pump unit (usually via a heat exchanger) before being discharged. The water is not consumed, contaminated or modified in any way, except for a slight change in temperature.

Figure 6. Comparison of GHP configurations

Type	Configuration	Description	Site requirements	Benefits	Disadvantages
Closed loop	Horizontal (straight or 'slinky' pipe)	Network of pipes laid in ground, at about 0.4 - 1.5m depth below the frost line depending on local conditions. Working fluid may be water-based or refrigerant (DX). NB: DX systems are installed above the water table.	Large area of open ground, preferably unshaded	Simple installation, lower cost	Large open area required for installation
Closed loop	Vertical	Straight pipes inserted in bore holes, generally less than 100m deep	Suits most sites	Able to be installed in a small area	Higher cost (drilling); likely requires resource consent
Closed loop	Submerged	Coil of pipe or flat plate heat exchanger placed into a water body such as a river or lake	Proximity to surface water body of sufficient size to support system	Limited land area required; lowest cost of all closed loop systems	Likely requires resource consent for works on the bed of river/lake
Open loop	Groundwater – single well and drainage field	Well drilled to access groundwater directly, discharged at surface	Access to suitable aquifer and land suitable to receive discharge water	Thermally efficient, limited land area required	High cost (drilling); consumptive groundwater take and discharge; likely requires resource consent
Open loop	Groundwater – double well	First well drilled to access groundwater, second drilled to discharge groundwater back to the same or other aquifer	Access to an aquifer	Thermally efficient, limited land area required, non-consumptive water take	High cost (drilling); likely requires resource consent.
Open loop	Surface water	Direct take of surface water from stream/river /lake. Discharge water returned to source	Proximity to surface water body of sufficient size to support system	Thermally efficient, limited land area required, non-consumptive water take	Likely requires resource consent for water take and discharge and for works on the bed of river/lake

5. Closed loop systems

5.1. General technical information

Closed loop systems operate by circulating a working fluid through a network of pipes. The only interaction with the environment from closed loop systems is the exchange of heat between the surrounding ground or water and the working fluid. There is a variety of configurations, including water/antifreeze based horizontal, vertical, submerged systems and the refrigerant filled DX systems.

Site requirements

A closed loop GHP may be installed on almost any site in New Zealand. The size and configuration of available land, existing landscaping and the location of underground utilities or sprinkler systems all influence GHP system design.

Horizontal ground loops (generally the most economical in New Zealand) are typically used for newly constructed buildings that have a large associated open space area, such as in a rural or rural-residential setting.

Vertical installations are often used for existing buildings because they do not need a large land area for installation and minimise ground disturbance. They may also be suitable for sites with smaller land available area or where the energy load requirement is high.

The depth of soil cover also contributes to system design. In areas with extensive hard rock or with soil that is too shallow to trench, vertical ground loops may be installed instead of horizontal loops.

If a pond, lake or river is available on site or in close vicinity, a submerged coil system or an open loop system (see Section 6) may be an option.

Ground loop sizing

Sizing of the ground loop is important and is dependent on the site, surface and subsurface characteristics and energy demand. If sized correctly, the system will meet the required heating and cooling demand, appropriately balancing efficient operation and installation costs. A ground loop that is too big for the energy demand required will heat/cool effectively but will be more expensive and require more pumping energy. The ground loop installation accounts for 30% to 50% of the total system cost.

A ground loop that is too small for the energy demand can 'stress' the energy resource, by trying to extract too much energy from too small an area, thereby reducing efficiency. In extreme situations, the heat extraction rate can be higher than the natural rate of renewal, resulting in a gradual decline over time in the amount of energy available for extraction, and in time, system failure.

If a system can be designed to provide 'balanced loads', significant efficiency advantages can be gained and ground loops can be much smaller than in unbalanced systems. A system is balanced if it takes roughly the same amount of heat out of the ground in winter for heating as it puts back in the ground during summer for cooling. In this case, the system is effectively 'banking' heat energy during summer, and withdrawing it in winter.

To determine the required ground loop size, an analysis of local geological conditions is required. For example, different soil types have different heat transfer rates; heat transfer capability tends to increase as soil texture becomes increasingly fine. Soil thermal properties are strongly influenced by water content. In general, an increase in the water content of soil results in higher thermal conductivity. These considerations will determine the amount of piping required to meet the heating/cooling load. Figure 7 shows generic thermal conductivity for various soil and rock types.

Figure 7. Examples of thermal conductivity

Medium	Indicative thermal conductivity (W/(m*K))
Water	
Fresh water	0.58
Soil	
Sand, dry	0.15–0.25
Sand, moist	0.25–2
Sand, saturated	2–4
Loam	0.25–2
Clay, dry to moist	0.15–1.8
Clay, saturated	0.6–2.5
Igneous rocks	
Granite	1.9–5.2
Andesite	1.9–4.7
Basalt	1.4–4.8
Gabbro	1.6–3.6
Pumice	0.6–0.9
Rhyolite	1.3–1.7
Sedimentary rocks	
Mud stone	1.9–2.9
Limestone	1.4–6.2
Sandstone	2.1–3.5
Greywacke	2.8–4.8
Metamorphic rocks	
Gneiss	1.7–5.7
Marble	2.1–5.5
Quartzite	5.2–6.9
Schist	2.1–4.5
Slate	1.6–2.6

(Source: GNS Science)

A robust understanding of the ground conditions (i.e. soils, geology, thermogeology and hydrogeology) will account for these factors and assist with accurate system design. A qualified and experienced GHP designer will be able to access and interpret this information as part of the design process, using analytical software. For larger installations, engineers, geologists and/or other technical professionals are also required to ensure robust, optimised design.

For larger projects, a thermal conductivity test is normally undertaken. This test involves the use of specialised equipment to accurately determine the conductivity and emissivity of the ground at a particular site. While these tests can be expensive, they ensure accurate system design and provide clarity on how much energy can be sustainably extracted from the ground.

Piping materials

The piping material used affects service life, maintenance costs, pumping energy, capital cost and heat pump performance. High quality materials are required for buried ground loops and high or medium density polyethylene is commonly used. It is preferable for the ground loop to be made from a continuous length of pipe. Any subsurface connections in high density polyethylene pipe should be made using fusion techniques to the manufacturer's specifications.

For DX systems, copper pipes are used. These pipes must consist of refrigeration quality copper with a seamless coat of polyethylene or polypropylene with 1mm wall thickness to provide corrosion protection.

Where it enters the building, external pipework should be insulated and sleeved. When the GHP is delivering heat, the ground loop circuit will normally be operating below the building interior's dew point temperature. Good quality insulation and vapour sealing of internal pipework and fittings in this circuit is therefore essential to minimise condensation risks. The pipework should be configured to avoid damage if any condensation does occur.

The pipe diameter should be large enough to keep the pumping power requirement small, yet small enough to cause turbulent flow to ensure good heat transfer. Pipe diameters between 20mm and 40mm are usual for closed loop systems. DX systems typically use smaller diameter pipes of 8mm, 12mm or 15mm.

Working fluid

In heating mode, the working fluid inside a ground loop collects heat from the surrounding ground or water. Even though ground surface temperatures might be as high as 15°C, much of this heat is extracted by the heat pump unit; most ground loops are designed with a return temperature of around 0°C. For this reason, with water-based systems it is usual to add antifreeze to the solution to prevent freezing.

In areas of New Zealand with milder climates, it is possible to design a ground loop to provide warmer return temperatures, such that antifreeze solution is not required.

If used, the type of antifreeze protection will depend on the design of the ground loop and it is important to comply with the manufacturer's specific recommendations for antifreeze concentration. Antifreeze can be harmful if not handled correctly. Figure 8 compares environmental characteristics and considerations for common antifreeze solutions used in New Zealand.

Figure 8. Characteristics of common antifreeze solutions

Fluid	Corrosion risk	Health risk	Fire risk	Environmental risk
Methanol	2	3	3*	2
Ethanol	2	2	3*	2
Propylene glycol	1	1	1	1
Potassium acetate	2	1	1	2
CMA (calcium magnesium acetate)	2	1	1	2
Urea	3	1	1	1

(Ratings: 1 = little or no potential problems; 2 = minor potential for problems; 3 = potential problems, caution required;

*Pure fluid only. Diluted antifreeze (25% solution) is rated 1)

Refrigerants

A refrigerant is a substance with a low boiling point temperature that goes through a reversible phase transition from a liquid state to a gas state as part of the process.

Refrigerants are present within the heat pump unit of all GHP systems (Figure 5) and are also used directly in the ground loop in DX systems (see Section 5.2).

Compliance with the Australia and New Zealand Refrigerant Handling Code of Practice 2007 is mandatory⁷ for the handling of fluorocarbon refrigerants by refrigerant handling licence holders or refrigerant trading authorisation. Essential requirements of the code are that:

- heat pump systems must be able to be installed, operated, serviced and decommissioned without loss of refrigerant
- heat pump systems must be installed by an appropriately qualified person with a no-loss refrigerant handling certification
- refrigerant must not be intentionally released into the atmosphere.

A number of different refrigerants have been used in the past and all have some degree of impact on the environment. It is important to minimise the possibility of refrigerant leaks because they can damage the ozone layer and increase greenhouse gases. Early refrigerants, chlorofluorocarbons (CFCs), have been replaced with hydrochlorofluorocarbon (HCFC) compounds, such as R-22, which are now being replaced with blended hydrofluorocarbon (HFC) compounds. Research into more environmentally benign alternatives is ongoing.

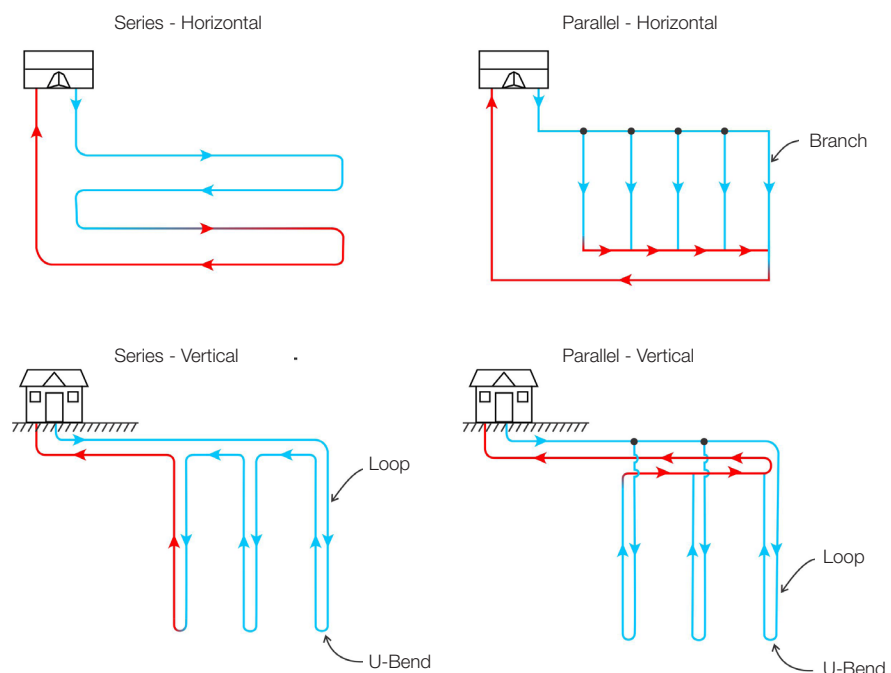
DX systems (see Section 5.2) have approximately 10 times more refrigerant than an equivalent water-based ground loop system.

Ground loop arrangements (series or parallel)

Multiple closed ground loops (vertical or horizontal) can be arranged in series, in parallel or a combination of both. Parallel loops are most common with series loops typically only being suitable for small applications.

Figure 9 shows both series and parallel installations. In series systems, the working fluid can take only one path through the ground loop circuit. In parallel systems, the fluid can take two or more paths through the circuit. Parallel arrangements use a reverse return rather than direct return to the building so that all parallel flow paths are of equal length, helping to ensure a balanced flow distribution.

Figure 9. Ground loop arrangements



(Source: revised from www.geo4va.vt.edu/A2/A2.htm)

⁷ Since 1 January 2008.

The type of arrangement will influence the pipe diameter, pump power requirements and installation cost. Advantages and disadvantages of series and parallel arrangements are summarised in Figure 10.

Figure 10. Comparison of parallel and series installations for ground loops

System configuration	Advantages	Disadvantages
Parallel installations	Reduced pressure drop along shorter flow paths results in smaller pump power requirements.	Header lines must be larger diameter than individual loops and so require more complex pipe joining operations. Special care needed to ensure complete air removal from all flow paths when purging system at start up.
Series installations	Single pipe diameter entails simpler pipe fusion joints, enabling quicker installation. Single flow path enables easier purging to remove air from the loop when filling with water or antifreeze solution.	Longer flow path requires larger diameter pipe to minimise pressure drop and maintain pump power at reasonable levels. Requires a larger pump, increasing overall energy use. Requires greater antifreeze volumes. System capacity limited by total pressure drop from end to end, so not suitable for large building applications.

Backfilling and grouting

When installing the ground loop, it is important to ensure good long-term thermal contact with the ground. To do this, horizontal loops are usually laid on a bed of sand and then covered with a layer of sand for protection. Care must be taken to avoid damage when backfilling and the backfill material should be screened for hard material (i.e. rocks, stones etc.).

For vertical loops, grout is used to backfill the drill holes following the pipe installation. Low hydraulic permeability, high thermal conductivity grout (e.g. 'high solids' bentonite) or a thermally enhanced, low permeability grout is used (Figure 11). Drill holes should be sealed in accordance with best practice to prevent groundwater contamination (see Section 8).

Figure 11. Backfill material characteristics

Backfilling material	Thermal conductivity (W/(m*K))
Bentonite	0.8–1
Thermally enhanced grouts with quartz	1–1.5
Water saturated sand	1.5–2
Bentonite with graphite	3

(Data source: http://talon.stockton.edu/eyos/energy_studies/content/docs/proceedings/HELLS.PDF)

The ground loop should be pressure tested prior to the backfilling or installation in a borehole. It should also be flushed and purged of air before being charged with the working fluid.

Commissioning

In the commissioning process, the function of all components should be checked and confirmed as fully operational. The ground loop, if correctly designed and constructed, will not require flow balancing. The fitting of balancing valves and other similar devices should only be installed where they are necessary because of the type of system being installed, as dictated by site and installed equipment characteristics or constraints.

The system owner should be instructed in the use and maintenance of the system and who to contact for post-installation support and advice.

The location of all buried pipes should be recorded and mapped in order to prevent future works disrupting or damaging the ground loop.

Decommissioning

A standard ground loop installation is expected to have an operational life of over 50 years and potentially more than 100 years. In the event that a particular system is being retired from active use, it is important that the system is appropriately decommissioned.

An unused and undrained ground loop will eventually deteriorate and could leak antifreeze, or in the case of a DX system, refrigerant. There is also potential for future construction works to rupture an inactive loop if records of the location of the loops are not available. Leakage poses a potential threat to the environment, especially to groundwater resources.

All fluid in the ground loop should be displaced, removed and appropriately disposed of at the end of active service.

For vertical loops, following removal of the working fluid a hole should be excavated at least 1.5m below the ground surface around the pipe, and this section of pipe removed. The remaining pipe should be completely filled with high solids bentonite slurry. The slurry should be allowed to spill into the excavation to provide a cap at least 0.3m thick above the pipe. The remainder of the excavation should be filled with compacted earth or pavement.

The Environmental Standard for Drilling of Soil and Rock (NZS 4411: 2001) includes guidance for the decommissioning of drilled holes. Regional councils will also have specific requirements to ensure the protection of groundwater (see Section 8).

5.2. Horizontal loop systems

CLOSED LOOP: HORIZONTAL LOOP

Typical uses: Residential with larger lot sizes/access to land

Configurations: Straight, multiple or slinky

Pipe depth: 0.4m–1.5m

Loop spacing: 1–3m (spacing between trenches)

Pipe spacing: $\geq 0.3\text{m}$ (multiple pipes within trench)

Pipe material: High density polyethylene

Pipe diameter: 20–40mm

The horizontal closed loop is the most common type of ground loop for GHPs in residential applications in New Zealand. Installation is generally simpler and less expensive than other configurations, particularly if undertaken during earthworks for the construction of a new house or building where earthmoving equipment is already on site.

There is a wide variety of configurations available. Typical horizontal loops consist of a single, straight pipe arranged in a grid pattern and buried on average between 0.4–1.5m deep (Figure 12). A working fluid is circulated through the network of pipes and provides the medium for heat transfer from the ground.

Heating mode shown.
Can be operated in reverse to provide cooling.

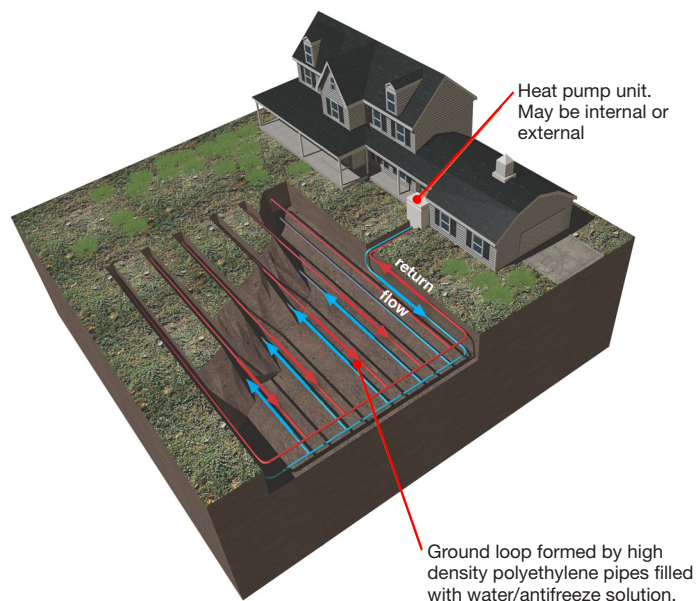
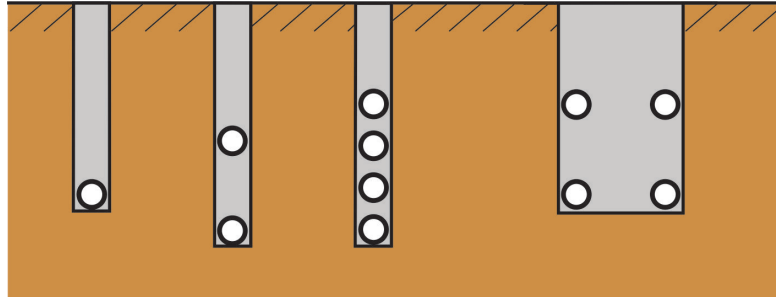


Figure 12. Straight horizontal closed loop installation

Horizontal single pipe ground loops are installed over relatively large open areas, free from hard rock or large boulders with sufficient soil depth. Heat extraction rates are influenced by soil properties and other factors and are typically 20W/m^2 to 30W/m^2 of ground. For a fairly standard residential property requiring 10kW of heat from the ground, the ground loop will need to be installed over approximately 200m^2 to 300m^2 of open ground.

In alternative ground loop configurations, the single pipe can be doubled or quadrupled (Figure 13) or the pipe can be coiled before it is laid which is generally called a 'slinky' or 'SVEC' collector (Figures 14 and 15). These arrangements increase the surface area of pipes within each trench, thereby reducing the total excavation area required to install the ground loop.

Figure 13. Pipe arrangements in horizontal ground loops



(From left to right: single, doubled and quadrupled pipes per trench) (Source: revised from Bose, 1988)

Figure 14. Horizontal slinky installation

Heating mode shown.
Can be operated in reverse to provide cooling.

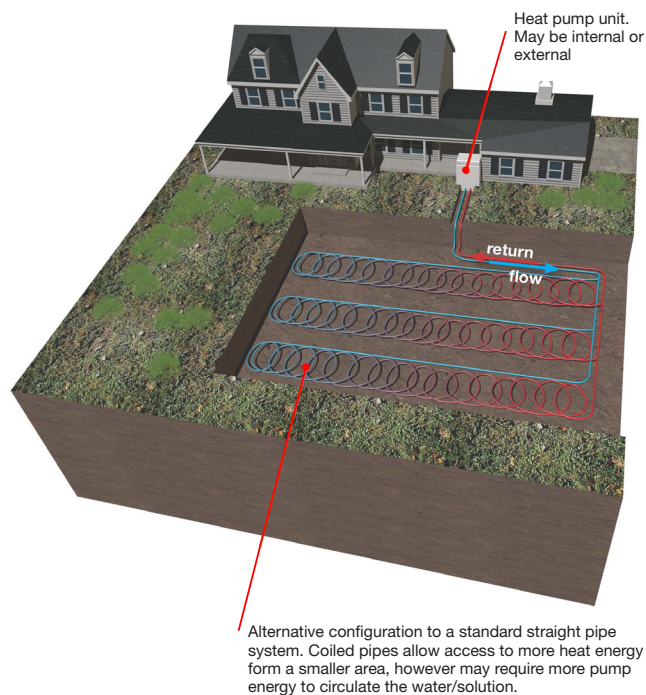
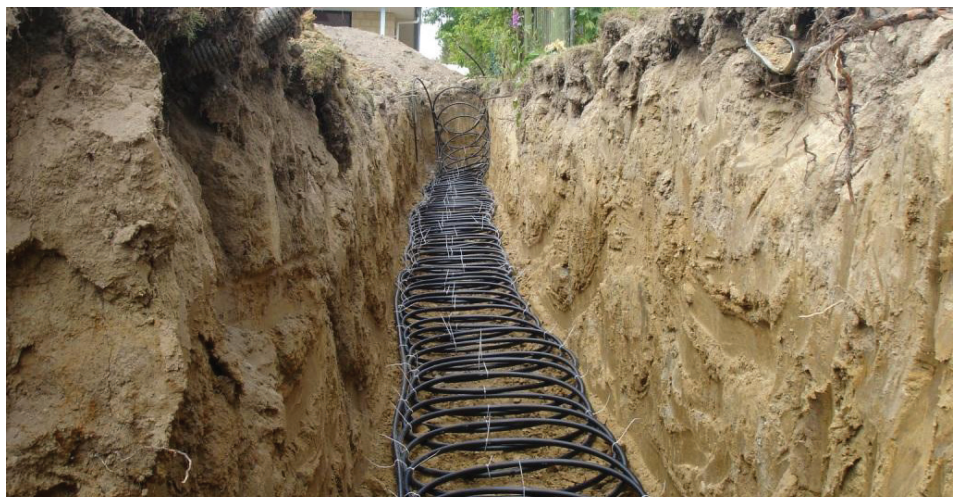


Figure 15. Pipe arrangement in a slinky ground loop



(Source: Central Heating New Zealand)

Design considerations

Horizontal ground loops primarily access stored heat from solar radiation reaching the Earth's surface. During summer months when solar radiation is highest, the ground is 'recharged', replacing heat removed by the ground loop during winter. Rainfall and groundwater levels can assist to disperse and transport this heat, increasing the ability of the ground to recharge. The ground loop should therefore be buried to a depth that can take maximum advantage of this heat source whilst avoiding future landscaping or vegetation issues. In New Zealand, this is likely to be about 0.4m to 1.5m, depending on local conditions.

The length of each 'branch' of the ground loop should be considered to reduce pressure drop across the ground loop as much as possible. Pressure drop and purge calculations should be completed by an experienced GHP designer to minimise the required pumping power. For example, the maximum branch length for a single slinky loop is usually 50m. Any longer than this will mean the pumping energy required counters the efficiency advantage of a GHP.

To reduce thermal interference between pipes where multiple pipes are laid in a single trench, pipes should be at least 0.3m apart. To avoid thermal interference between pipes in adjacent trenches, each trench in single pipe installations should be 1m or more apart and multiple or slinky pipe trenches should be 3m or more apart.

Installation

There is a variety of installation methods possible, including:

- stripping (i.e. laying pipes and backfilling)
- trenching (i.e. laying pipes and backfilling)
- direct placing of pipes with ploughs.

The method chosen will depend on site characteristics, budget and local regulatory requirements. Different methods will generate different site effects and may trigger resource consent requirements (see Section 8).

Direct exchange systems

The key point of difference with a DX system is that it does not use water or antifreeze as the working fluid. Instead, DX systems circulate refrigerant directly through plastic coated copper tubing.

DX systems are generally more suitable for smaller installations; however, multiple distributed compressor units (tandem system) can allow DX systems to serve large buildings. DX systems can be installed in a horizontal trenched configuration at least 0.5m below the frost line or a shallow vertical (or diagonally installed) U-tube configuration, to a maximum depth of 30m. However, DX systems should be installed above the water table to prevent interaction with ground water.

Plastic coated copper pipe is used to carry the refrigerant, with pipe diameter generally between 8mm and 15mm. Particular attention must be paid to pipe spacing to avoid the formation of a continuous ice layer in winter. Correct pipe spacing is determined by heat extraction ratio per metre.

As a refrigerant is being used, trained and certified refrigeration contractors must be used for the installation (see Section 5.1). The GHP manufacturer's procedures must be followed. DX systems require specialist knowledge and should be installed by appropriately trained and experienced technical personnel.

New Zealand consumers and installers should be aware that DX systems are restricted in some European countries and in others there are specific guidelines that require only shallow installations above the water table to prevent interaction with groundwater. Even though refrigerants have low solubility in water and new refrigerant types have lower environmental risks, any leak in a DX system risks the introduction of refrigerant mixed with compressor lubricants into groundwater with the potential associated implications for water quality.

5.3. Vertical loop systems

CLOSED LOOP: VERTICAL LOOP

Typical uses: Commercial or high energy demand applications

Configurations: U-pipe or coaxial; parallel or series

Pipe depth: 15–120m

Bore spacing: 10m

Pipe material: High density polyethylene or cross-linked polyethylene

Pipe Diameter: 20 – 40mm

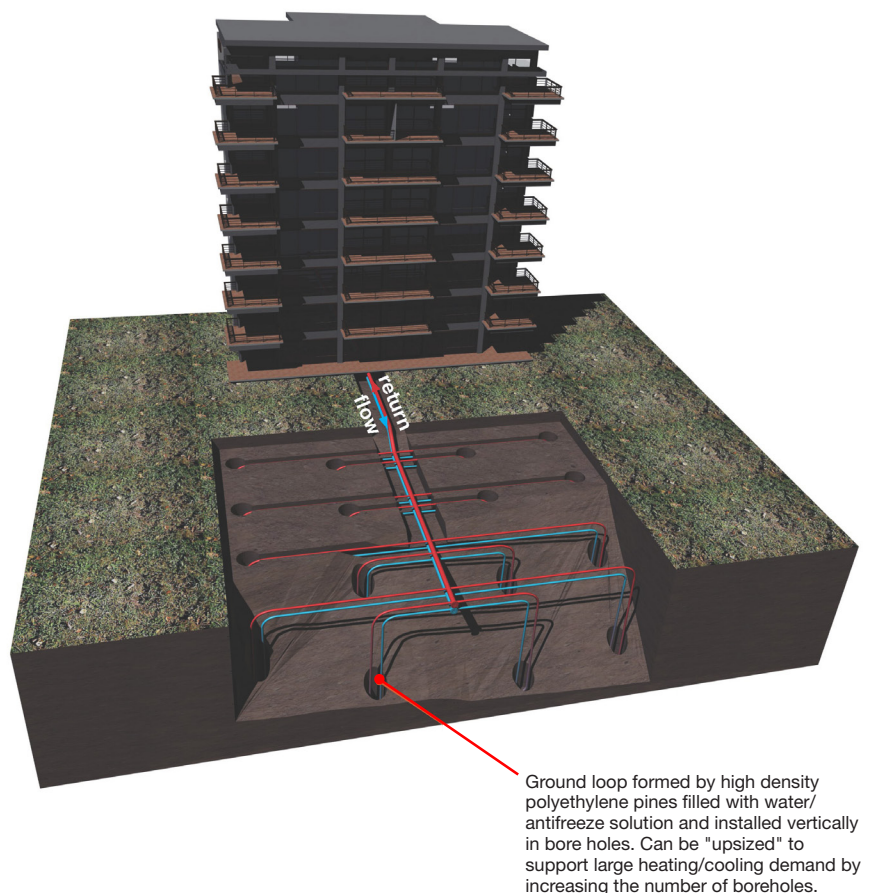
Vertical ground loops are used where the land area is more limited or where there is a high heat load for larger buildings. Vertical loops can also be used where the soil is too shallow for trenching or for existing buildings as they minimise disturbance to landscaping.

Vertical ground loops consist of pipes installed into drilled boreholes generally 100mm to 150mm in diameter and between 15m and 120m deep (Figure 16).

Maximum energy extraction rates depend on the geothermal heat flow and are typically 50W/m to 80W/m of bore hole. For example, 50 bores drilled to approximately 120m could provide 500kW of heat to supply a large commercial building.

Figure 16. Vertical closed loop installation (multiple bore arrangement)

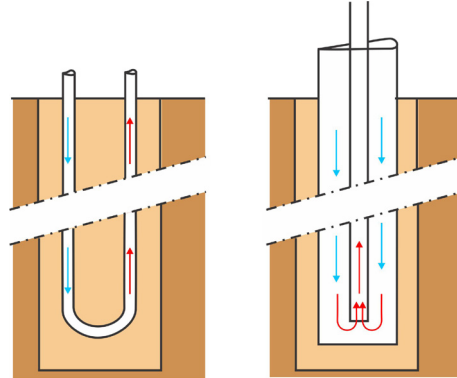
Heating mode shown.
Can be operated in reverse to provide cooling.



There is a variety of borehole heat exchangers in use. The two most common designs are U-pipes and coaxial (concentric) pipes (Figures 17 and 18).

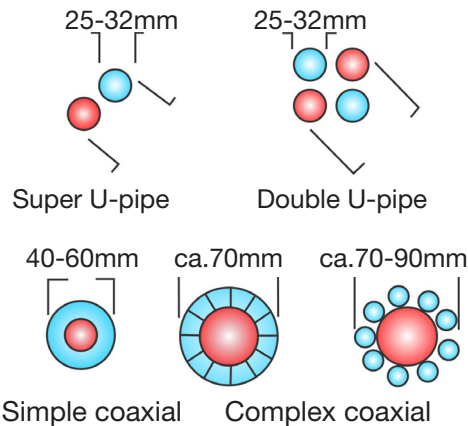
Where a vertical ground loop is installed across two or more bores, it can be arranged in a parallel or series system (see Section 5.1). Modern installations are typically installed in parallel because the total liquid flow allows for a smaller pipe diameter, reducing the overall system installation cost.

Figure 17. Single U-pipe and coaxial borehole heat exchangers



(Source: revised from Nordell, 2008)

Figure 18. Cross sections of different types of borehole heat exchangers



(Source: revised from Sanner, 2001)

Design considerations

Similar to horizontal systems, vertical systems recover heat from stored solar energy at shallower depths but they can also make use of the geothermal heat flux at depth. Flowing groundwater or percolating water will also influence the rate of heat recharge.

Where the ground loop extends below a water table with significant groundwater flow, heat dispersion will result. This can be helpful for single borehole cooling or heating systems; however, where several boreholes are drilled for a larger system or separate schemes are located in close proximity, thermal interference might need to be considered. To address this, boreholes should be at least 10m apart. The minimum distance to the building should be 2m and the minimum distance to water supply and waste pipes should be 1.5m. Multiple boreholes should be connected to a manifold with individual isolating valves for each loop. This will allow individual loops to be isolated when filling the ground collector, or if a leak occurs.

Thermal conductivity testing is usefully carried out via test bores to ensure accurate loop design for larger systems.

Installation

Installation methods for vertical installations include:

- hammer drilling
- rotary drilling
- down-hole motor drilling.

The method chosen will depend on site characteristics, available drilling rig and budget.

Vertical installations are likely to require resource consent from the regional council for drilling activities (see Section 8).

Energy piles

During the construction of new commercial buildings, vertical ground loop systems can be readily incorporated into foundation elements. There is a wide variety of methods to achieve this; however, in its simplest form in larger buildings, this involves incorporating a ground loop with the buildings foundation piles as they are installed to create an 'energy pile'.

Even if a GHP is not proposed initially for the site, 'future proofing' the building by incorporating high density polyethylene pipes into the foundation can make good sense – it should not add significant cost or complexity to the process as piles are being installed as part of the building's foundations anyway. The ground loop can then be connected up to a GHP system at any stage, providing an efficient heating and cooling option.

5.4. Submerged loop systems

CLOSED LOOP: SUBMERGED LOOP

Typical uses: Any site must have access to pond, lake or river

Minimum installation depth: 2m

Pipe spacing: Various

Pipe material: High density polyethylene. Other options include plate heat exchanger or mat systems

Pipe diameter: 20–40mm

The presence of a pond, lake or river within or near the site of a GHP installation may allow the use of a submerged, closed loop installation. In this case, a working fluid is circulated through a loop submerged in the water body. Heat energy is exchanged with the water body through the fluid circulating in the loop.

Submerged loops can be formed by coiled polyethylene pipe, mats or plate heat exchangers. Submerged loop pipe systems typically require about 30 linear metres of piping per system kW demand. The water surface area requirements (i.e. the size of the water body) will vary depending on the water depth and the degree of water column stratification.

Some commercial, industrial or institutional buildings and some recreational facilities have artificial ponds for aesthetic or functional reasons and these may have adequate surface area and depth to support a submerged loop system.

Seasonal variations in the water temperature are likely to be greater than variations in ground temperatures but this is balanced by the improved heat transfer rate of water. Submerged closed loop systems can achieve higher efficiencies than closed loops buried in the ground, allowing for shorter overall pipe lengths.

Design considerations

It is recommended that the coils be submerged at least 2m below the water surface in order to maintain adequate thermal mass at times of low water conditions. This would also minimise the chance of damage by people using the body of water for recreational activities (if applicable).

Lakes and ponds are generally preferred over river installations which may be subject to moving boulders or debris that can damage the submerged coils. Pipes must also be anchored to resist the flow of water.

Installation

Most installations will require that some portion of the loop is laid in the ground from the building to the water source. The guidelines for a horizontal ground loop installation for this portion of the loop should be followed (see Section 5.2).

Generally, the simplest method of installation is to fully construct the coils on land prior to submerging. The constructed pipe network can then be floated out onto the body of water until it is in position and suitably arranged ahead of sinking and anchoring in place (Figures 19 and 20). Concrete anchors can be used to secure the loop, preventing movement and maintaining pipe spacing.

When choosing a location for the installation, the installer should be mindful of other users of the water body and any situation that may create a conflict between other users of the lake and the pipes should be avoided.

Figure 19. Submerged closed loop installation

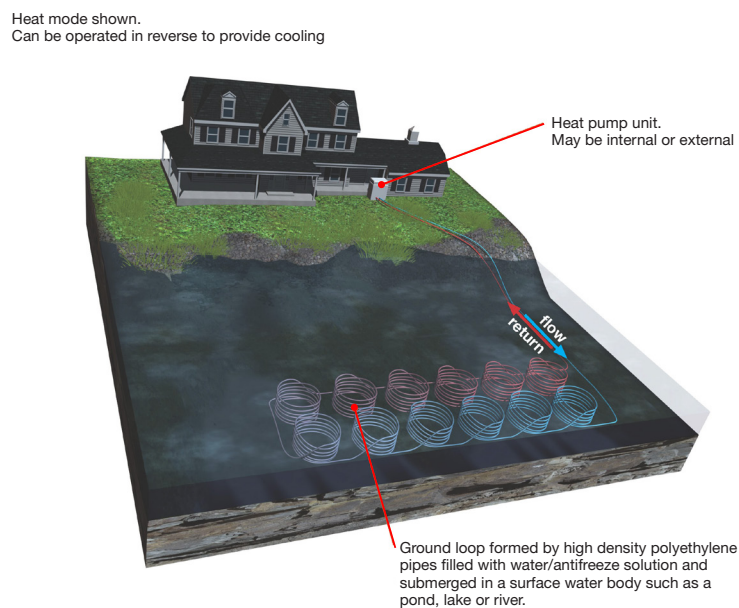


Figure 20. Submerged loop ready for sinking and anchoring



(Source: <http://media.treehugger.com/assets/images/2011/10/Conventional20Lake20Loop.jpg>)

6. Open loop systems

6.1. General technical information

Open loop systems operate by the direct take of groundwater or surface water. Water is taken from an aquifer (groundwater), lake, stream, river or ocean (surface water) and pumped to a heat pump before being discharged. This water flow is used to transfer heat in the same way that working fluid is used to exchange heat in a closed loop system.

There is a variety of configurations for open loop systems, including:

- single well and drainage field
- double well
- standing column well
- surface water systems.

Site requirements

Water in sufficient quantity and quality must be readily available to support the installation of an open loop system. A hydrogeological analysis of the site and chemical analysis of the water will provide an indication of the suitability of the proposed water source for use as a heat source and sink.

As the water take is generally non-consumptive (i.e. will not result in any reduction in water volume at the source), the water body does not need to be large; however, it does need to be able to sustain minor temperature variations and provide enough heat energy to support heat pump function.

The location of the water (i.e. distance from the heat pump) and the quality of the water will influence GHP system design. For example, a deep aquifer or surface water body located a long way from the heat pump unit will require greater pipe length and larger pumps to overcome the greater resistance. Efficiency losses caused by larger pump requirements should be considered.

Water loop sizing

The correct sizing of an open loop system is critical. For every installation it is important to accurately calculate the necessary water take and discharge to generate the heating/cooling load required. As with closed loop systems, sizing should be performed by experienced technical personnel (see Section 3.4).

Piping materials

All piping should be suitable for use in groundwater (i.e. non-toxic), corrosion proof and meet the same requirements as for public or private water supply wells. When installed in surface water, pipeline material should also be able to withstand bed erosion and flood events.

The chemical composition of the water must be taken into account when choosing pipe material. The pH, chloride ion and free oxygen levels are important. Regular cleaning to remove mineral deposits that build up on the inside of the pipes might be required. Filtration equipment or secondary heat exchangers should be used with surface water to deal with potential contaminants (e.g. sediment, detritus).

Commissioning

In the commissioning process, the function of all components should be checked and confirmed as fully operational.

The system owner should be instructed in using and maintaining the system and who to contact for post-installation support and advice.

A location map of all buried pipes and water intakes and outlets should be made and retained in order to prevent future works or activities disrupting or damaging the GHP components.

Decommissioning

Any groundwater bore should be decommissioned in accordance with regional council requirements at the end of service life. This will include backfilling/grouting requirements and may also require that specific information about the decommissioned bore be recorded and provided to the council.

For surface water systems, all components in or on the bed of any water body should be removed.

6.2. Groundwater systems

OPEN LOOP: GROUNDWATER SYSTEMS

Typical uses: May support smaller applications; however, due to drilling costs, often used for commercial or high energy demand applications

Configurations: Single well, double well, standing column well

Well spacing: 60–180m

Pipe material: Steel, high density polyethylene

If access to groundwater from the site is feasible it can be used as the heat source/sink for a GHP installation.

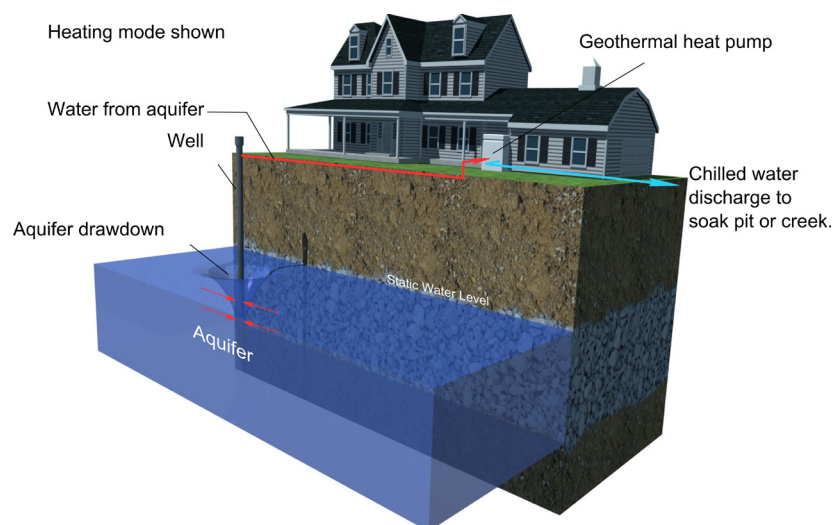
In groundwater systems, water is drawn from an aquifer, supplied to a heat pump and then either discharged to the same well, another separate discharge well or to a surface drainage field (subject to local regulatory requirements). The aquifer must be suitable for use and should have sufficient flow and permeability.

The take and use of groundwater is managed under the Resource Management Act 1991 and the relevant regional council should be consulted to check resource consent requirements (see Section 8).

Energy extraction rates are influenced by aquifer properties including flow rates and permeability and are typically around 0.25m³/h for each kW required.

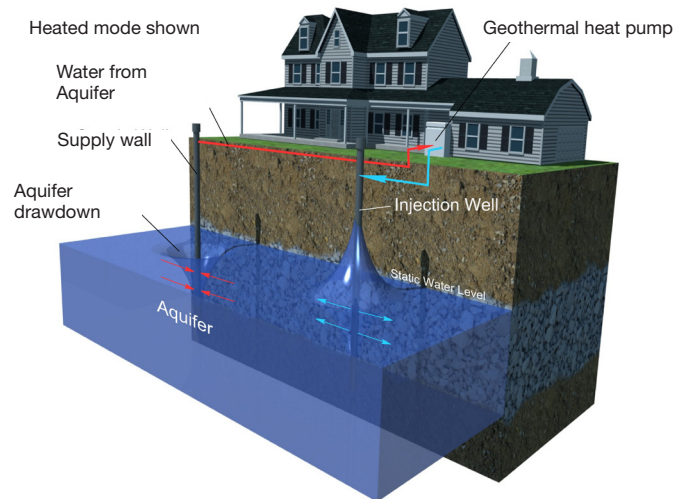
Single well systems (Figure 21) consist of a single well drilled to access groundwater, with the water discharged at the surface (e.g. to a nearby creek, lake or drainage field). This can be an economical solution if a well already exists on the site, such as an irrigation or drinking water well; however, flow rates will need to be large enough to meet the needs of a heat pump.

Figure 21. Single well, open loop, groundwater system



Double well systems (Figure 22), with separate supply and discharge wells, are the most common form of groundwater-sourced GHP. The benefit of this type of system is that the aquifer is not depleted by taking water. A double well system may be the only option where environmental regulations limit or prohibit discharge to surface water bodies or drainage fields.

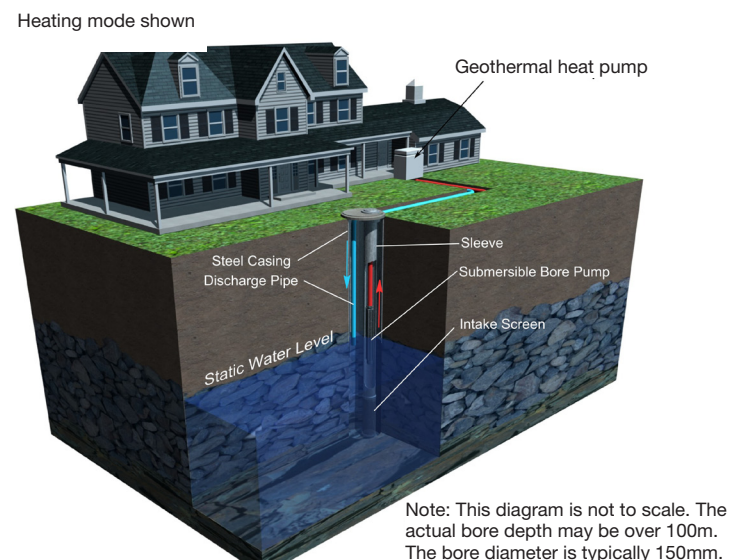
Figure 22. Double well, open loop, groundwater system



A variation of the single well is the standing column well (Figure 23) where heat is extracted out of bedrock, and groundwater is used as the transfer medium. In this configuration, all or most of the discharge water is injected back into the source well. This minimises the amount of surface discharge. This configuration is generally only feasible in areas with fractured bedrock.

During periods of peak heating and cooling demand, the system can be designed to 'bleed' a portion of the return water to cause net groundwater inflow to the column from the surrounding rock formation. This may be required if there is a risk of the water temperature in the standing column well dropping below 8°C (while being used for heating) which can cause damage to the evaporator. Bleeding the well can also allow for greater energy to be taken from/discharged to the well by drawing new water into the standing column recharging/ dispersing heat.

Figure 23. Standing column well, open loop, groundwater system



Design considerations

Any other users of the aquifer will need to be identified and their proximity to the proposed GHP installation determined.

The presence of other groundwater-sourced GHPs and other groundwater users will limit the location of new wells so as not to interfere with their operation and not to thermally overload the aquifer. A factor in determining the safe separation of systems is the flow rate of the water through the aquifer and the ability for the surrounding geology to absorb or provide heat.

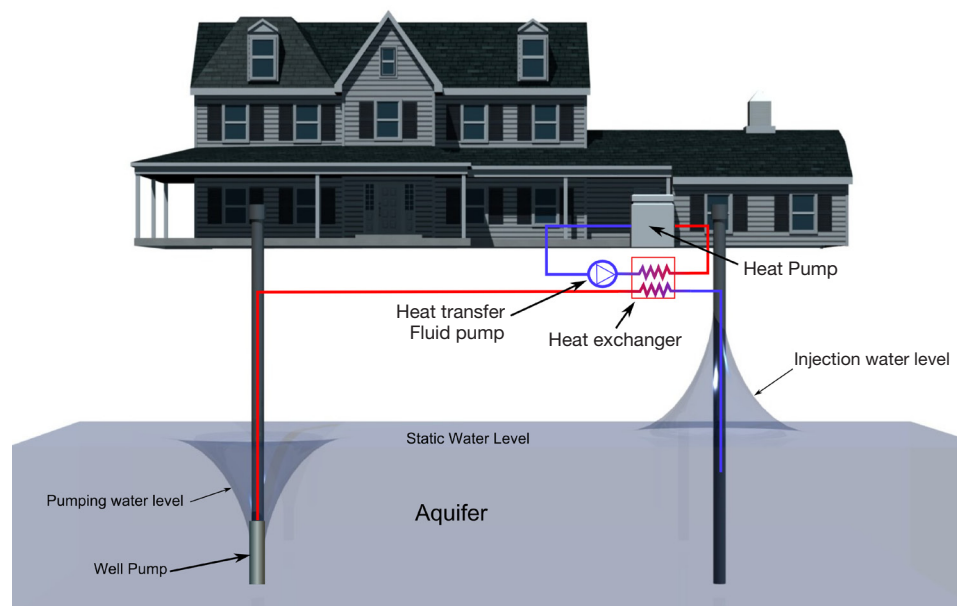
In double well systems, the distance between the production and injection wells is an important design consideration to address factors such as flow losses and thermal interference. Well spacing is typically in the range of 60m to 180m, depending on system cooling or heating load, the typical duration of the maximum load and the aquifer characteristics. If a particular aquifer has high volume or flow, well spacing can be reduced. For example, in some cases it can be effective to place wells as close as 10m apart. Reinjection wells should always be located downstream from production wells to prevent thermal interference.

Balancing heating and cooling loads is important when designing the discharge well for double well or standing column systems. A greater time operating in one mode or the other can cause adverse effects on the local chemistry/microbiology which may reduce the longevity of the injection well. This may require additional effort to maintain the system's performance and reduce the effects that might cause loss of permeability of the injection well.

Aeration and pressure changes in the water can also lead to enhanced microbial and bacterial growth in the injection well. This in turn can lead to precipitation of iron compounds that plug the injection well and reduce its permeability. The aquifer quality can be protected from any chemical discharges from the heat pump systems through the use of a heat exchanger and secondary heat transfer loop (Figure 24). This configuration can also be used to protect the heat pump unit in situations where the water source is of poor quality or corrosive, such as where sea water is used. Typically, the secondary heat transfer fluid is a solution of water and antifreeze (see Section 5.1) to prevent freezing.

The use of a heat exchanger and secondary heat transfer fluid keeps the groundwater out of the heat pump system, allowing for easier cleaning and maintenance.

Figure 24. Secondary heat transfer fluid loop



Groundwater systems tend to require more maintenance than other systems. Allowance needs to be made for accessing the wells for clearing, cleaning and testing.

Wells can be of the order of 80m deep depending on the depth to the aquifer(s). The system pump needs to be selected to handle this head and the electricity consumption required to lift the water needs to be taken into account when considering the overall efficiency of the system and how it compares to alternative heating and cooling technologies. For deeper bores, the pump size is only required to lift the water. Once primed, the syphon effect greatly reduces the pumping load by drawing the water down the reinjection bore with its own weight. This process should be factored into the design to ensure maximum efficiency.

A water chemistry analysis will be able to indicate potential problems with corrosion, clogging of the well and scale. The material of the heat exchanger will need to be selected to be compatible with the expected chemicals in the water and the secondary heat transfer fluid. If the hardness is greater than 100ppm then this may indicate that a closed loop system is more suitable for the site.

If reinjecting groundwater, it should be returned to the same source aquifer and should not be exposed to the open environment or any contaminant.

If discharging water to surface disposal, consideration will need to be given to the effects on the receiving environment. This might include erosion, microbial growth and effects on the soil chemistry. The disposal basin must be sufficiently large and have its bottom filled with highly permeable sands and gravels to allow for infiltration. The basin can lose permeability over time due to silting, microbial and bacterial plugging. Drainage basins may need to be cleaned periodically.

Surface disposal is not advisable where aquifer depletion is a potential risk.

When designing the intake and injection well, the expected particle size should be determined and an appropriate screen selected.

Installation

It is important for the protection of groundwater quality that bore construction complies with the Environmental Standard for Drilling of Soil and Rock (NZS 4411: 2001).

All wells should have the same grouting and casing requirements as for a public or private water supply wells. All activities around the storage and installation of grouting and backfilling should seek to ensure that no chemical and microbial contamination is introduced into the well.

If clay or hardpan is encountered above a water-bearing formation, the permanent casing and grout should extend through the clay and/or hardpan.

6.3. Surface water systems

OPEN LOOP: SURFACE SYSTEMS

Typical uses: Commercial or high energy demand applications – often used for cooling. Requires access to large volume of water

Configurations: Seawater or freshwater

Surface water systems (Figure 25) can be a cost-effective option for those sites with access to a nearby body of water of sufficient volume to support heat pump function.

Suitable bodies of water can include lakes, large ponds, rivers and the ocean.

Surface water systems work by drawing water from the source to a heat pump and then returning it to the original source in such a way that the discharged water does not return to the intake.

Cooling mode shown

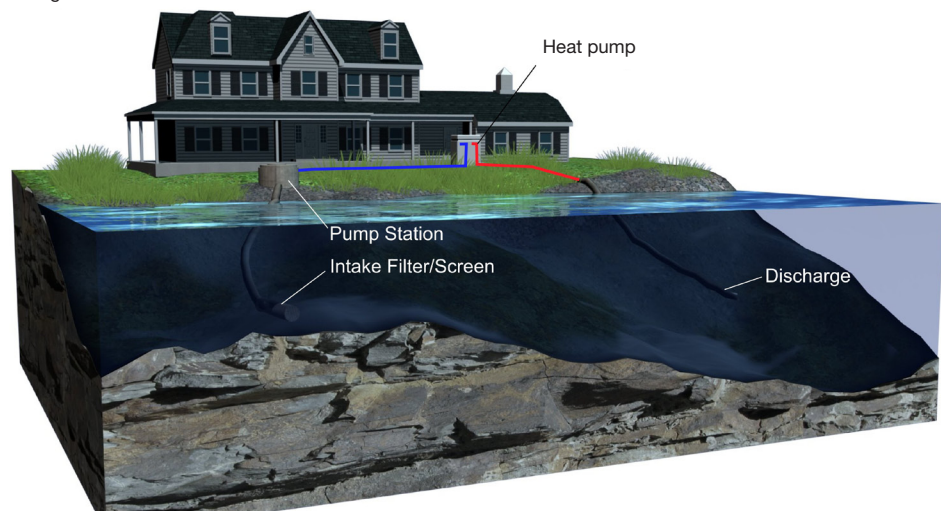


Figure 25. Surface water heat pump system

Open loop surface water systems are especially suitable for providing cooling, and can sometimes be used for direct cooling. Thermal stratification in the ocean or deep lakes results in cold water below the thermocline remaining undisturbed throughout the year. In some cases this water is cold enough to provide direct space cooling simply by being circulated directly through water/air heat exchangers in the building, which eliminates the need for a heat pump. In such cases, however, building loop water temperatures must be

kept below 12°C to dehumidify the air effectively.

Design considerations

Surface water temperatures will fluctuate more with seasonal changes than ground temperatures. If the system is intended to be used for heating, an assessment of annual temperature fluctuations in the water source being considered is particularly important. If temperatures in the intake water are at risk of dropping below 8°C there is a risk of freezing.

The body of water being used will commonly be a natural feature with associated ecological properties. Consideration must be given to any adverse effects of the construction and operation of a heat pump on the natural health of the ecosystem. The presence of effects from other GHP systems operating on the same body of water must also be considered.

The system must have a screen or filter on the intake to exclude entry of silt, debris and fauna. If used in a river the intake will also need to be designed to withstand the effects of erosion, deposition and flood events.

The intake and discharge should be accessible for periodic inspection and maintenance.

An onshore pump station will be required. This will need to be designed with maintenance in mind, including provisions for pump flushing and easy access for maintenance. Open loop systems should be flushed out periodically to remove any mineral build up in the heat exchangers.

Installation

When considering installation, resource consent requirements need to be assessed. Surface water systems generally require resource consents associated with the take and use of surface water, works on the shoreline, works on the bed of a river or lake and for discharging thermally altered water (see Section 8).

Anchor blocks should be installed on the intake and discharge pipeline to ensure they remain in position despite changes in river flows or lake levels. Depending on the length of the pipe, several anchor blocks may be required to 'pin' the pipeline to the river or lake bed.

The shoreline components should be located where flood events will not damage them, and where they will not interfere with normal shoreline use. The effects of erosion caused by changes in water flow patterns around shoreline components should also be considered.

7. Geothermal energy storage

While natural processes generate the geothermal energy accessible by GHP systems, ground temperatures can also be changed artificially to benefit the functioning of a GHP system and increase overall system efficiency.

This can be undertaken through geothermal energy storage (GES). An example of GES is where heat energy is discharged to the ground in summer in such a way that it can be accessed during winter for heating.

Seasonal storage of heat should be considered by larger scale energy users, such as hospitals, office buildings and shopping centres. While system design and operation can be more complex, energy savings can be substantial.

In addition, compared with GHP systems that are used for heating only, a GES scheme can cover the same energy requirements with fewer energy wells, at a closer spacing, thereby reducing investment costs.

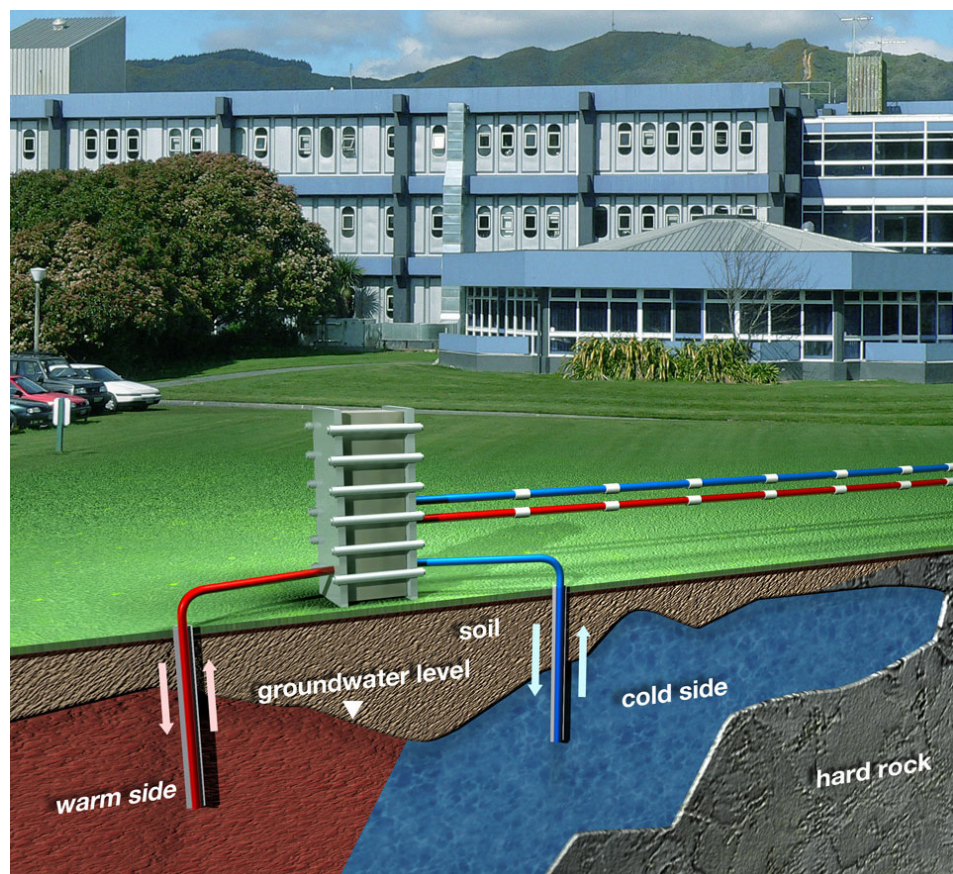
The design of GES systems ultimately reflects the conditions available at the project site. The feasibility of a GES system needs to be determined by suitably qualified technical personnel.

Two types of GES systems are discussed below: aquifer energy storage and borehole thermal energy storage.

7.1. Aquifer thermal energy storage

Aquifer thermal energy storage (ATES) systems use groundwater directly as a heat storage medium (Figure 26).

Figure 26. Schematic of an aquifer thermal energy storage system



(Source: GNS Science)

High permeability groundwater systems with little or no fluid movement are the preferred conditions as the stored energy is less likely to dissipate.

In order to implement storage concepts, the aquifer should be tapped by boreholes serving as extraction or injection wells. In summer, the system operates in cooling mode, extracting heat from the application (e.g. from inside a building) and discharging this heat energy into the aquifer through the injection wells. This heat is then extracted back from the aquifer in winter to provide heating. All groundwater is returned to the aquifer from which it was taken. The wells or group of wells should be arranged in such a manner that any mutual thermal or hydraulic influence between the warm and cold sides of the system does not affect the storage process to any great degree.

Design is complex and the system must be carefully balanced to ensure that the energy extraction/injection rates can be supported long term.

7.2. Borehole thermal energy storage

Borehole thermal energy storage (BTES) systems use borehole heat exchangers to store heat and/or cold in solid rock or soil and in the groundwater that might be found therein.

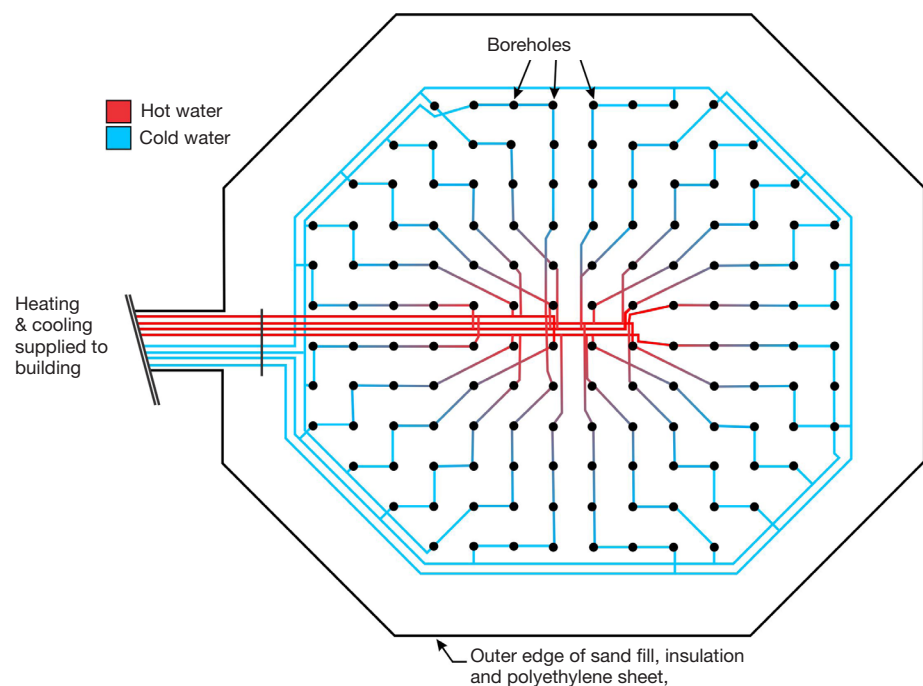
Unlike ATES systems, BTES systems do not need a flow of groundwater to and from the system.

BTES systems are best suited to rock and soil with medium thermal conductivity and high specific heat capacity. For effective storage, relatively large BHE fields are required.

The BHE system consists of a number of boreholes arranged in a compact geometrical pattern. The system should have a favourable ratio of volume to surface area (large volume and small surface area) since a large proportion of the thermal losses occurs through the overlying surface. The arrangement of the boreholes should be as uniform as possible. One favourable pattern is a hexagonal configuration (Figure 27) because all the pipes are arranged at equal distances. To provide good thermal contact with the surrounding soil, the borehole is filled with a high thermal conductivity grouting material.

It is necessary to verify whether the rate of groundwater flow at the site will result in high thermal losses as such locations will not support this type of system.

Figure 27. Borehole thermal energy storage



(Source: revised from www.dlsc.ca/borehole.htm)

8. Regulatory considerations

8.1. Regulatory requirements

In New Zealand, the installation and operation of GHPs is primarily regulated under the Resource Management Act 1991 (RMA) and the Building Act 2004.

The RMA is administered by regional and district / city councils that may issue resource consents in order to manage the environmental effects of certain activities.

Regional councils manage the effects of activities on water, coast, air, soil and geothermal systems from activities such as earthworks, well drilling, work on the bed of a river or lake, and water and heat use and discharge. District and city councils manage the effects of activities on land through compliance with district plan performance standards.

Regional plans and district plans specify when a resource consent is required for a particular activity or effect and the level of scrutiny that will apply. Each plan has different planning objectives, policies and rules in accordance with the particular local environment. The effect of this is that the consenting requirements for GHPs will vary in different parts of New Zealand.

Depending on the type of installation and the relevant district plan and regional plan, some GHP installations may require resource consent. Some of the activities associated with GHP installation that could trigger the requirement for resource consent are identified in Figure 28. Note that this figure is provided as a guide only and is not exhaustive.

Figure 28. Potential resource consent requirements

Activity	GHP system	Resource consent may be required for	Consent may be required from
Drilling	Vertical closed loop systems Groundwater systems	Drilling into or over an aquifer/groundwater	Regional council
Earthworks	Any system, particularly horizontal closed loop systems where large volumes of soil may need to be moved	Moving more than the permitted volume of earth	District or city council
Installing pipes in a surface water body	Submerged coil systems Surface water systems	Installing a structure in, on or over the bed of a lake or river	Regional council
Water take	All open loop systems	Take of water	Regional council
Water discharge	All open loop systems	Discharge of water	Regional council

A further consideration is the Building Act 2004 which sets a number of performance standards that buildings must comply with through the New Zealand Building Code. Compliance is determined by building inspectors within local councils. Generally, the focus of these performance standards is to ensure that new buildings are safe, healthy and well constructed. In most configurations, building permits are not required for GHPs, providing there is no interference with building foundations.

As GHPs can vary significantly in terms of configuration, design and location, GHP owners/ installers should check with the relevant council to identify resource consent or building permit requirements. Council staff will be able to provide advice.

8.2. Environmental considerations

If you are required to seek a resource consent for a particular GHP system, you will be required to show how any adverse environmental effects will be avoided, remedied or mitigated.

In general terms, adverse effects from GHP systems can be avoided through correct design and installation techniques. Improper well-drilling practices, leakage of antifreeze solutions, leakage of refrigerant and loss of pipe integrity represent the greatest potential for environmental impacts. Positive effects include contributing to reduced energy use and providing a renewable heating and cooling solution.

Figure 29 summarises environmental considerations associated with GHPs.

Figure 29. Summary of environmental considerations

Potential environmental effect	GHP system	Management techniques
Sediment run off	All systems during installation, particularly horizontal systems	Follow best practice guidelines for sediment control measures (e.g. limit the amount of time disturbed earth is exposed by re-seeding or landscaping as soon as possible, consider overland flow paths and install silt fences to protect waterways and neighbouring properties). ⁹
Antifreeze leakage	All closed loop systems except DX	Choose antifreeze with low toxicity. Follow pipe manufacturer's installation and testing procedures. In particular, limit the number of subsurface joints, ensure any subsurface joints are constructed using appropriate techniques (e.g. fusion welding), complete pressure test before back filling ground loop and ensure that appropriate measures are in place to prevent spillage during filling. Protect pipes during backfilling by screening material for sharp rocks/debris. Monitor pipe pressure during operation.
Refrigerant and/or lubricant leakage	All systems, particularly DX	Compliance with the Australia and New Zealand Refrigerant Handling Code of Practice 2007. Compliance with AS/NZS 1677.2: 1998. Protection of DX ground loop by sheathing of copper pipes, appropriate location away from areas of possible future soil disturbance, appropriate backfilling techniques and mapping of pipe locations.
Pathway for groundwater contamination through borehole	Vertical closed loop systems Open loop groundwater systems	Consider surface conditions (e.g. presence of contaminants). Position well head away from low-lying areas where surface water may flow or ponding may occur. Ensure proper sealing/grouting of borehole. Comply with the Environmental Standard for Drilling of Soil and Rock (NZS 4411: 2001).
Rate/amount of water take	All open loop systems	Discuss requirements with relevant regional council to confirm water take restrictions. Calculate required flow rates and conduct an assessment of effects on the water sources. Consider the use of 'non-consumptive' techniques such as standing column well or double well systems or other methods of returning water taken to its source.
Rate/amount of water discharge	Open loop groundwater systems Some surface water systems	Discuss requirements with relevant regional council. Ensure discharge will not cause erosion and consider the effects of severe weather (e.g. freezing or flooding) conditions. For subsurface discharges (e.g. standing column well or double well) ensure well is designed to avoid any risk of overflowing.
Works on the bed of a lake/river	Closed loop, submerged coil Open loop, surface water	Discuss requirements with relevant regional council. Consider the effects of severe weather (e.g. flooding) conditions. Consider possible habit disturbance or destruction of aquatic plants and animals. Ensure any materials installed are environmentally benign (e.g. avoid the use of timber treated with toxic preservatives).
Thermally altered ground	All closed loop systems, particularly DX	Ensure that the heat energy taken from/disposed to the ground is balanced to avoid excessive ground cooling or heating. This can be undertaken by designing the ground loop to suit soil type and location with particular regard given to pipe spacing.
Thermally altered water	All open loop systems Submerged coil systems	Ensure that any temperature change of source water after reasonable mixing is not excessive and does not generate negative environmental effects Consider flow rates/volumes of water source and the ability to absorb thermally altered water.

⁹ While designed for Auckland soils and climate, TP90 prepared by the former Auckland Regional Council (now Auckland Council) is used in many parts of the country to guide sediment control practices. Technical Publication Number 90: Erosion and Sediment Control Guidelines for Land Disturbing Activities in the Auckland Region.

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Further reading

Resource	Description	Internet link
GNS Science: Earth Energy Website	GNS Science, Te Pū Ao, is New Zealand's leading provider of Earth, geoscience and isotope research and consultancy services.	www.gns.cri.nz/earthenergy
EECA	The Energy Efficiency and Conservation Authority (EECA) encourages, supports and promotes energy efficiency, energy conservation and the use of renewable sources of energy in New Zealand.	www.eeca.govt.nz
GHANZ	Geothermal Heat-pump Association of New Zealand.	www.ghanz.org.nz
edDGE	A pilot demonstration project for direct geothermal energy technology, funded by the Victorian Government, Australia.	eddge.com.au
Canadian Geo-exchange Coalition	Canadian geothermal heat pump industry association.	www.geo-exchange.ca/en
International Ground Source Heat Pump Association	Non-profit, member-driven organisation established in 1987 to advance ground source heat pumps. Based in the United States.	www.igshpa.okstate.edu
UK Environment Agency	Environmental good practice guide for ground source heating and cooling	publications.environment-agency.gov.uk/PDF/GEHO0311BTPA-E-E.pdf
Energy Efficiency Best Practice in Housing	Domestic ground source heat pump guide to design and installation of closed loop systems.	www.gshp.org.uk/documents/CE82-DomesticGroundSourceHeatPumps.pdf



Case studies

The following case studies have been prepared by GNS Science to showcase the successful application of GHP technologies in New Zealand. These case studies and more information on the use of geothermal energy can be accessed from GNS Science's "Earth Energy" webpages: www.gns.cri.nz/earthenergy.

Ground Source Heating for a Wanaka family home

By Lisa Lind (GNS Science), Simon Bendall and Jo Bell



Rafe Maclean's newly built Wanaka home utilises a ground source heat pump for its heating and hot water requirements.

Architect and home owner Rafe Maclean designed his 222 square metre home in Wanaka to be warm, dry and energy efficient.

"With a young family, we wanted a home where every room could be kept warm and comfortable right through winter."

Winter temperatures in Wanaka regularly drop below zero, so this can be an expensive and challenging enterprise.

Rafe, who often provides heating advice to his residential and commercial clients, chose to install two separate ground source heat pump systems in his own home. A 15 kW system that supplies heat to the underfloor heating system, heating the entire house, and a domestic hot water unit designed to provide hot water year round.

The two separate systems operate by circulating a carrier fluid through pipes buried in the ground (captor areas). As the fluid circulates underground it absorbs heat which is transferred to the buildings heating system by the heat pump unit.

The heat energy originates from deep within the earth and from solar energy absorbed at the surface and is available year-round. The captor area for the underfloor heating unit covers approximately 300 m², while the domestic hot water captor field is 35 m². Rafe's property is well suited to this type of installation as the captor field receives all day sun, allowing for a fairly shallow installation (approximately 600 mm). This provides additional heat gains from the sun's energy.

Key Benefits:

- Maintains high heating efficiency even when air temperatures are low
- All rooms in the home are heated evenly
- Low running costs, noise and visual impact

Key Features:

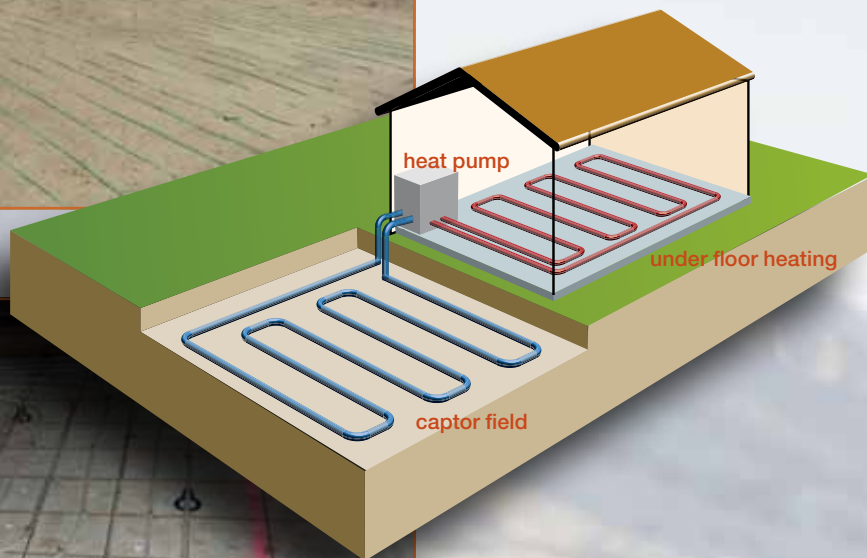
- Geopack 15 (15 kW) system providing heat to underfloor heating system
- DHW60 (Domestic Hot Water Unit) system providing hot water year round
- Heated area: 177 m²
- Horizontal Captor Area: 335 m² & 35 m²



The "captor field" being installed.



The under floor heating system. Heat generated by the captor field is used to heat water that is circulated through these pipes, installed in the concrete slab foundation.



"THE REAL BENEFIT OF GROUND SOURCE HEAT PUMPS IS THAT THEY MAINTAIN HIGH ENERGY EFFICIENCY THROUGHOUT THE YEAR."

"The real benefit of ground source heat pumps is that they maintain high energy efficiency throughout the year, where air source heat pumps can suffer efficiency losses at low air temperatures."

The system was installed by Next Energy Ltd, a Christchurch based company specialising in geothermal heating.

"A big plus for us was the installer we worked with. They have a strong reputation and we found them to be trustworthy and responsive to our needs. They have been very good at checking in on us to ensure that everything is working as it should", says Rafe.

As an architect, Rafe is also keenly aware of the design benefits of such a system.

"From a design point of view, it can be challenging trying to appropriately site the large and sometimes noisy outdoor units that come with air source heat pumps. Our ground source heat pump presents no such problems – it is small, unobtrusive and about as noisy as a household fridge"

Rafe and his family are currently enjoying their second winter in their new home in Wanaka.

"Now, no matter where you go in the house, it's comfortable and warm" says Rafe.

Rafe Maclean

Home owner and architect

Rafe Maclean Architects

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New Zealand requires reliable, renewable energy sources into the future. The Government is supporting GNS Science in fostering increased use of renewable resources. By 2025, the Government's Energy Strategy aims for direct use of geothermal energy to account for more than 12 PJ/year.

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Queenstown Family Home Heated From 120 m Underground

By Lisa Lind (GNS Science), Simon Bendall and Jo Bell



This architecturally designed home is heated with a vertical ground source heat pump.

Ground source heating was a natural choice as a heating solution when Ian Adamson designed his family's energy efficient home in Queenstown.

Ian Adamson is the Principal and Executive Director of the Queenstown office of Warren and Mahoney Architects and has just spent his first winter in his new family home near Dalefield.

As an architect, Ian has a unique insight into the construction industry, and knew what he wanted to achieve when building his own home.

He says it was vital to ensure that his family were warm and comfortable all year round, but sustainability and environmental considerations were equally as important.

The home has been designed to be as energy efficient as possible. High levels of insulation are a feature of the home, well beyond minimum specifications set in the building code.

It has also been designed to take advantage of a sheltered northerly aspect, with concrete slabs acting as thermal mass areas by gaining and storing the sun's energy.

Given the focus on energy efficiency during the design phase, when it came to a heating solution, ground source heating was a natural choice.

"The extremes of our climate here in Queenstown and a belief in sustainability have strongly influenced our decision to run with ground source heating," Ian says.

"We wanted a highly efficient heating solution with low operating cost and without the hassle of chopping wood or ordering diesel or wood pellets. Ground source heating was a good fit. We also like that we are using a fully renewable resource by accessing latent energy from the ground."

While the site was large enough to install a horizontal captor field, Ian opted for a vertically installed, closed loop system.

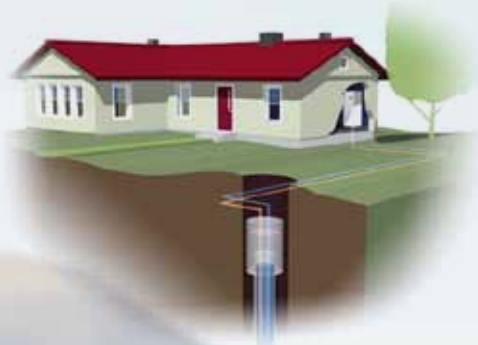
"The benefit of a vertical system is

Key Benefits:

- Vertical system requires very small installation area
- Maintains high heating efficiency even when air temperatures are low
- All rooms in the home are heated evenly
- Low running costs, noise and visual impact

Key Features:

- 2 x 120 m deep bore holes, closed loop system
- 11 kW system providing hot water to underfloor heating pipes and hot water for domestic use
- Heated area: 280 m²



“WE LIKE THAT WE ARE USING A FULLY RENEWABLE RESOURCE BY ACCESSING LATENT ENERGY FROM THE GROUND.”



Ground source heating remains highly efficient, even when outside air temperatures plummet.



Vertical systems are generally quick and tidy to install, and don't take up much space.

that we were able to install without any major disruption to existing landscaping, it didn't affect our construction schedule and hasn't tied up a large area of land.

“I was initially concerned about the drilling process and resulting mess, however it was the complete opposite with the rig in and out in six days, complete with holes grouted. All slurry was collected and removed from site.”

The system consists of two bores, 12 metres apart, drilled to a depth of approximately 120 metres.

A 'U' shaped pipe was installed in each bore before they were sealed and capped.

A water/glycol solution is circulated through these pipes to gain heat from the earth. As the site is not over an aquifer and there is no risk of groundwater contamination, resource consents from the local council were not required for this project.

Having been through their first winter, Ian and his family are impressed with their heating system.

“We have moved from a smaller house where you tend to heat spaces you are occupying, to now running the entire house at 20°C, with bedrooms around 18°C. The system is completely self regulating and hassle free.”

Ian says choosing an installer was an important decision in the process. He engaged Flushed Plumbing to install an 11 kw Bosch system.

“It is a big investment, so we wanted it done right. We liked that our installer has a direct association with the manufacturer of the heat pump unit. We had the confidence that it would be installed right the first time.

“At the end of the day, we have a lovely, new, warm home and we really like that we are using a fully renewable resource by accessing latent energy from the ground.”



A drilling rig is needed on site to install a vertical ground source system.

Ian Adamson

Home owner and Architect

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Heated pool, warm home – thanks to ground source heating

By Lisa Lind (GNS Science), Simon Bendall and Jo Bell



This architecturally designed home is heated with a vertical ground source heat pump.

Richard Markham-Barrett wanted to economically heat his new Kapiti Coast home and indoor swimming pool and ground source heating provided the perfect solution.

The new home is on an elevated rural property overlooking the Kapiti Coast and Kapiti Island.

“We have magnificent views from here and we built the house with this in mind,” says Richard.

“Another important feature for our new home was to include a heated indoor swimming pool.”

To make the most of the views, large areas of glass were installed without blinds or curtains. Even though the home has high levels of insulation throughout and the glass is double glazed, Richard admits that the large areas of glass make the home more difficult to heat

Add in a heated swimming pool, and Richard was facing the prospect of costly energy bills.

“We are rural, so there is no gas line to our house. Our options for heating were limited to bottled gas, diesel or electricity.

“Using conventional heating solutions, all of these options would have been extremely expensive for us. We decided that a heat pump was the only way we could economically generate the heating energy we need.”

“We chose a ground source heat pump, because of the efficiency advantage they have over air source heat pumps. A ground source heat pump remains efficient no matter what the outside air temperature is, and with our heating needs, this means a real cost saving for us.”

Richard worked with Central Heating New Zealand to design and install the system which is a horizontal ‘slinky’ coil ground source heat pump. It consists of seven trenches, each 25 meters long, 1 metre wide and 2 metres deep.

Key Benefits:

- Slinky coils require less space than straight pipe installations
- Economical way to heat swimming pool and home
- Maintains high heating efficiency year round

Key Features:

- Horizontal ‘slinky’ pipe close loop system
- 16 kW 3 phase system providing hot water to underfloor heating and indoor swimming pool
- Heated area: 400 m² + pool



The slinky coils are installed in a network of trenches.



The 'slinky' pipes laid in the trench.



The indoor pool, heated with energy from the earth.

The trenches are joined at one end by a header trench. A network of coiled slinky pipes is laid in the trenches and connected with a heat pump unit mounted on an external wall of the house.

The slinky pipe installation allows for a lot of pipe to be installed in a small area. The same system installed with straight pipes would need longer trenches to gain the same heat energy from the ground.

"With the slinky coils, you can have shorter trenches. I decided that I could save money on digger time with this installation method. I built and laid the slinky pipes myself using designs and advice from Central Heating New Zealand, who then completed the installation and commissioned the system."

The system provides hot water for underfloor heating and keeps the indoor pool heated to 32°C all year round.

The house is large, with approximately 400 m² of heated area. Only the garage isn't heated. One third of the floor area is tiled, which means the warmth of the underfloor

heating can be felt directly.

The bedrooms are carpeted, and Richard says: "While you don't get quite the same 'warm feet' feeling as with the tiles, the bedrooms are still very comfortable and warm."

The system is also capable of running in reverse, cooling the floor in the summer.

"To be honest though, we have never used it in cooling mode. The house has been designed so you can open it right up for good air flow. On a hot day we open it up and it cools down quickly."

Richard has spent a lot of time fine tuning his system for maximum efficiency.

"One thing I would definitely recommend is a triple feed meter. This allows you to take advantage of cheaper electricity rates at off-peak times."

"I have my system set to only come on during off-peak times which is late at night, when electricity is roughly half the cost of peak time. The pool and concrete pad don't lose much heat during the day, and are just topped up at night at

the cheaper rate."

At the time of installation, this was still a new technology in New Zealand, and Richard was "pushing the envelope of the knowledge and skill base available". This meant that he had to be flexible, as did the installer, but Richard is happy with the process.

"We are very happy with the final result. Central Heating New Zealand were great to work with, and made sure that everything was done correctly and to internationally recognised standards. Our house is warm and comfortable in winter, we have a heated indoor pool, and we pay less for our electricity bill than a friend of ours with less space to heat and no pool."

Richard Markham-Barrett
Home owner

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Well water heats renovated Christchurch home

By Lisa Lind (GNS Science), Simon Bendall and Jo Bell



This renovated Christchurch home uses groundwater for heating.

Well water and ground source heat pump technology provided the heating and domestic hot water solution for Colin Megaw's renovated Christchurch home.

Colin undertook extensive renovations on his 50-year-old family home three years ago.

The renovations extended the home to almost double its original size, added underfloor, wall and ceiling insulation, as well as double glazing to second story windows.

However, as an older home it was still not as efficient at retaining heat as a new build. The original heating system was diesel-powered, hot-air central heating, which proved costly to run.

"With the old diesel system, we only heated a couple of rooms in the house, it was just too expensive otherwise. Our renovations improved the levels of insulation, but also made the house much bigger so we needed a better way to heat that space.

"Burning diesel is also not the most environmentally friendly way to heat your home, and we wanted to do something about that too," says Colin.

Key Benefits:

- Heat gained from well water already supplied to the home
- No visual or audible impact
- Maintains high heating efficiency year round

Key Features:

- Open loop single well heat pump and soak pit
- 24 kW system providing hot water to 15 radiators for domestic use
- Heated area: 300 m² (approximately)



Warm water generated by the heat pump is circulated through radiators.



Quiet and unobtrusive, the heat pump unit is stored underneath the stairs.

Central Heating New Zealand came up with a solution to use well water to heat the home using ground source heat pump technology. This is a system they have used elsewhere on lifestyle blocks where a well is needed for potable water supply.

"I had heard about ground source heat pumps, but there weren't many around in New Zealand at that time.

"From a friend in the UK I knew that they were economical and had a low environmental impact."

Water supplied by the well is used in two ways; to fill a tank with cold potable water for general household use, and to supply a ground source heat pump unit, located in a cupboard under the stairs, with heat energy.

The heat pump is able to access low levels of heat energy held within the well water.

As the well water passes through the heat pump, heat energy is extracted, concentrated, and used to supply hot water for domestic use and home heating.

The cooled well water exiting the heat pump is discharged into a soak pit, where it ultimately returns to its source.

Generally, the most efficient method of using a heat pump is to combine it with under-floor heating, where warm water supplied by the heat pump is circulated through pipes installed within a concrete pad foundation.

As this heat pump was installed as part of a renovation of an older home, water-filled radiators were a more practical choice.

The home has 15 radiators located throughout. These are supplied with water heated to 60°C and are controlled automatically by indoor and outdoor temperature monitoring.

"With this system we are able to heat the entire home for about the same energy cost as heating two rooms with the old system," says Colin.

"WITH THIS SYSTEM WE ARE ABLE TO HEAT THE ENTIRE HOME FOR ABOUT THE SAME ENERGY COST AS HEATING TWO ROOMS WITH THE OLD SYSTEM."

Colin Megaw

Home owner

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New Zealand requires reliable, renewable energy sources into the future. The Government is supporting GNS Science in fostering increased use of renewable resources. By 2025, the Government's Energy Strategy aims for direct use of geothermal energy to account for more than 12 PJ/year.

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Ground water for airport cooling and heating

By Lisa Lind (GNS Science), Stefan Mroczek (GNS Science) and Jo Bell.



Aerial view of Christchurch Airport.

New additions to Christchurch International Airport see a modern heating and cooling system utilising low temperature geothermal energy.

Located twelve kilometres from Christchurch city centre, Christchurch Airport services almost six million passengers a year with an increase of 1.5 million forecasted by 2020.

To accommodate all these passengers, replacement of the 50 year old domestic terminal and upgrades to the existing international terminal have been undertaken. Part of the upgrade is a state of the art heating and cooling system designed by Beca, an engineering consultancy.

“How we operate the system is pretty clever and the scale on which we are using ground water at the heart of the energy efficiencies is new for New Zealand, if not further afield. The system is based on 3.6-megawatt water-cooled chillers and variable speed pumps that direct energy around the building. Ground water from the wells onsite is passed through heat exchangers and discharged back through the soak pit into the ground”, says Justin Hill, who led Beca’s mechanical services on the project.

The system’s clever design means that very little energy is wasted. When ambient temperature permits, water from the wells is used to cool the airport with no aid from chillers. The 12°C water is pumped from the aquifer via boreholes to heat exchangers. This cools the water in the loops which travel around the airport.

“To take advantage of the efficiencies of the ground water cooling, spaces that require year-round cooling have air-conditioning systems designed to operate solely on ground water.”

In addition, two chillers work in combination with the ground water. When direct cooling is not covering demand, the water can be further cooled by the chillers.

“Areas subject to seasonal changes are designed to utilise a combination of ground water and mechanical refrigeration cooling. When the temperature cannot be achieved using ground water alone, mechanical refrigeration is enabled in stages to match the demand from the building”.

Key Benefits:

- Minimises usage of electricity
- 12°C ground water provides free cooling most of the year
- Geothermal heat pumps cover most of the heating demand

Key Features:

- Provides heating and cooling to Christchurch International Airport
- Two 3.6 MW chillers
- Serves six million travellers annually



Chillers used to heat and cool the water for use throughout the airport.



The terminal building where the heating is utilised.

Most of the heating requirements at the airport are also fulfilled by the chillers. By acting in reverse (as geothermal heat pumps) the chillers remove heat energy from the ground water. This energy is used to heat the 40°C heating loop. The ground water is then returned to the aquifer several degrees colder. The Building Management System, a computerised central control system, determines which demand is greater and controls the chillers to either provide heating or cooling.

Mike Parker, Services Manager at the Christchurch Airport, believes that one of the major benefits the system imparts is how the dynamics of the building are catered for. "The different dynamics of the building are dealt with by one piece of plant. For example, the first floor food court is generally calling for cooling even on colder days whilst the check in hall at ground level is calling for heat."

Christchurch Airport is certified carbon zero. An important part of this is the cooling system, says Mike, "The fossil fuel [LPG and diesel boilers] that used to heat the domestic terminal has been replaced by electricity [for use in the chillers] and as we currently have a supply contract with Meridian, all electricity is generated from renewable resources."

In addition to this there will be maintenance benefits associated with there no longer being boilers or cooling towers.

A review carried out at the start of the project indicated that there would be a 20% decrease in the energy benchmark for the entire building.

With a design life time of about 50 years for the piping, and 20 plus years for other components, the heating and cooling system is set to serve Christchurch Airport well into the future.

"TO TAKE ADVANTAGE OF THE EFFICIENCIES OF THE GROUND WATER COOLING, SPACES THAT REQUIRE YEAR-ROUND COOLING HAVE AIR-CONDITIONING SYSTEMS DESIGNED TO OPERATE SOLELY ON GROUND WATER."

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Christchurch International | **airport** Limited

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Heating from a water hazard

By Lisa Lind (GNS Science), Simon Bendall and Jo Bell.



The Wairakei International Golf Course uses a geothermal heat pump to heat its building.

A golf course pond is usually only responsible for lost balls, but Taupō's Wairakei International Golf Course uses one of its water hazards for heating a new clubhouse.

Wairakei International Golf Course is recognised internationally for its distinctive blending of recreation with restoration and conservation.

The course is surrounded by a recently completed 2 m tall fence, five kilometres in length, specially designed to keep out predators like rates, mice, stoats, weasels, hedgehogs, feral cats and possums.

Plant and animal pest eradication programmes and the re-planting of around 25,000 native trees and five thousand exotics create an environment where native species are beginning flourish.

Nigel Lloyd, Wairakei International Golf Course Manager, says: "A long term goal has recently been realised with the release of two kiwi into the sanctuary, and the future looks bright for increasing populations of kiwi and other endangered species."

"When it was time to build a new clubhouse it was a natural extension to the conservation theme to find an energy efficient, environmentally friendly heating solution."

Nigel says that an existing man-made lake, built to provide a water hazard for the golf course, provided the solution.

The temperature of the water in the lake remains relatively constant year round and this low grade heat is collected by a geothermal heat pump in a closed loop, submerged coil configuration.

A pipe was laid in a trench leading from the clubhouse to the lake, approximately 200 metres away, where it is anchored to the bottom with weights and arranged in a circuit to access as much of the lake as possible.

Key Benefits:

- Heat gained from existing manmade lake on golf course
- No visual or audible impact
- Maintains high heating efficiency year round

Key Features:

- Closed loop, submerged coil, geothermal heat pump
- 20 kW system providing underfloor heating for golf clubhouse
- Heated area: 350 m² (approximately)



The heat pump unit is mounted discretely in an outdoor locker.



A hazard for golf balls, a haven for bird life, and a source of heat for the clubhouse.



The ground loop pipe where it enters the lake.

The circuit completes by the return pipe running in an adjacent trench back to the clubhouse.

“Generally the lake depth is between 1 and 2 metres and the pipes in the lake are black and difficult to see. Once the trench was backfilled and grassed over, the entire system is almost completely invisible.”

The heat pump unit is mounted in a locker on a clubhouse external wall and circulates a fluid through the pipe network. This fluid gains heat from the lake and takes it to the clubhouse where it supports a hydronic underfloor heating system within the clubhouse.

The clubhouse houses a shop, bar and café, and changing rooms and is used extensively by members and visitors.

Right House provided the system design and installation. The Wellington-based business works to make homes and buildings energy efficient and make responsible decisions with the earth's resources.

Nigel considers ground source heating a logical and practical choice for the golf course.

“The heating solution we ended up with makes use of what we already have on site. It's clean, quiet, and cost effective to run, and ties in well with our conservation ethic.”

“IT'S CLEAN, QUIET, AND COST EFFECTIVE TO RUN, AND TIES IN WELL WITH OUR CONSERVATION ETHIC.”

Nigel Lloyd

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golf+sanctuary



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