HOME HEATING USING GEOTHERMAL ENERGY

An introduction to using ground sourced central heating in New Zealand

IGSHPA
Down to Earth Energy

Central Heating
NEW ZEALAND

Introduction

The purpose of this guide is to give the end user the basic information required to assess the viability of installing a GSHP system. It covers the different types of systems, the benefits, limitations, costs and suitability of the various technologies.

Please contact us for more detailed information.

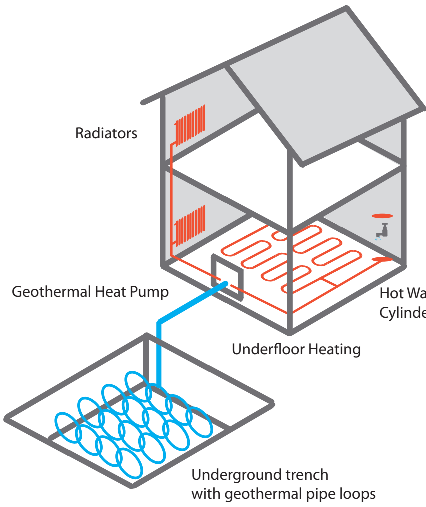
Contents

Introduction	2
What is meant by Geothermal Energy?	3
How do geothermal heat pumps work?	4
What type of systems are available?	5
Ground Loop Systems	6
Open Loop & Direct Water Systems	7
Geothermal Design Considerations	8
Benefits Of Using Geothermal Energy	11
How much does it cost to install and run a geothermal system?	13
Our Expertise	14
Geothermal FAQs	15

What is meant by Geothermal Energy?

The term geothermal means to heat from the earth. Geothermal, or Ground Source Heating as it is also known, is not necessarily referring to the natural hot springs that are found around New Zealand. In these areas, the hot spring water is piped directly into houses to heat them. The geothermal heating that we are referring to is the transfer of heat from earth that is not naturally hot.

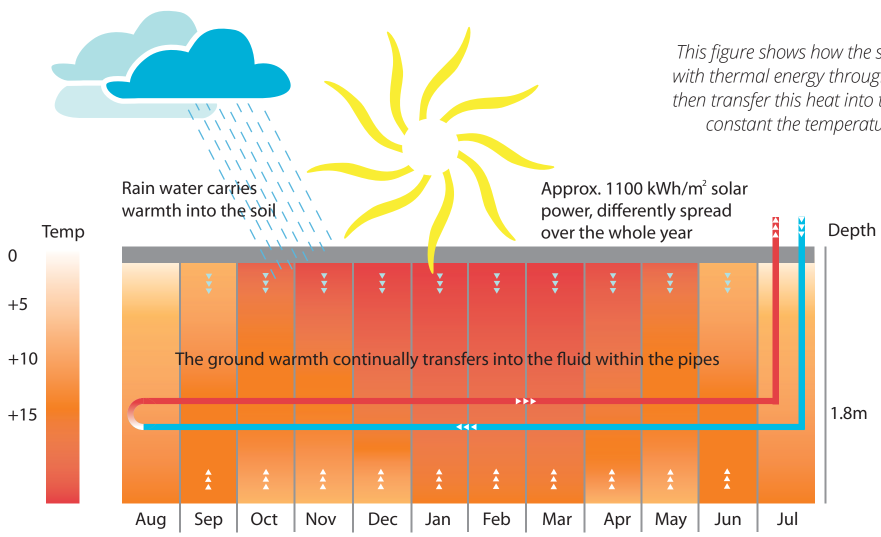
These systems draw heat from under the ground using pipes in a vertical borehole or a series of pipes laid horizontally a few metres below the surface, and fluid in the pipes to transfer the heat from the earth to an appliance that upgrades the heat to a temperature suitable for heating a home.



Layout of a typical geothermal heating system

Solar energy from the sun is absorbed by the ground during the year. Protected from extremes of heat or cold air temperatures, the ground here will remain at about 12°C all year round. The heat you get from the fluid in the pipes in the ground will not in itself be warm enough to heat the home. It must be 'boosted' to the level needed for heating a home using an electrical appliance known as a 'geothermal or ground source heat pump'. Put another way, the earth produces a huge amount of low temperature heat that the heat pump converts into a small amount of higher temperature heat suitable for heating the house.

The geothermal or ground source heat pump is an indoor electrical appliance that squeezes the most energy from a unit of electricity. In a well designed system, every unit of electrical energy put in will yield up to five units of heat energy even when the outside air temperature is below freezing. The energy from the ground is available in most locations, 24 hours of the day, 365 days of the year making it the greatest renewable energy of all.



This figure shows how the sun recharges the soil with thermal energy throughout the year. GSHP's then transfer this heat into the home. Notice how constant the temperature stays at 1.8m.

How do geothermal heat pumps work?

A few meters below the earth's surface the temperature of the ground remains relatively constant all year round, despite the outside air temperature. At this depth, the ground temperature is warmer than the air above it during the winter and cooler than the air in the summer.

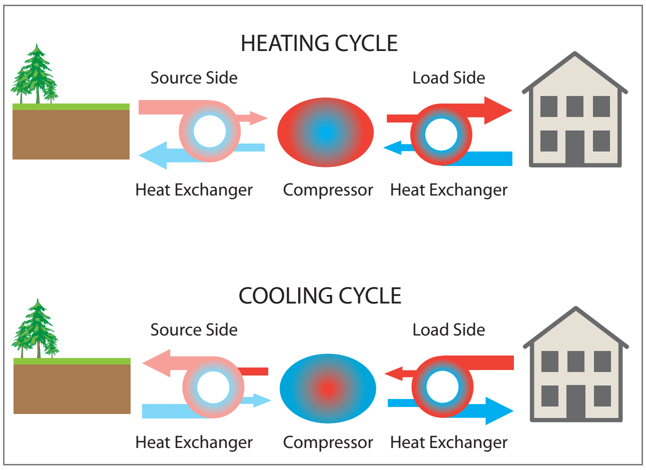
GSHPs harness this energy store by exchanging heat with the earth through a ground heat exchanger or geothermal loop field. Also called ground-source heat pumps, these systems move heat from the ground to a dwelling in winter, and pull heat from the dwelling and expel it into the ground during summer. Instead of creating heat by burning a fuel, GSHPs transfer heat from one place to another using refrigeration cycle technology. By compressing and expanding refrigerant, energy in the form of heat can be transferred from the heat exchanger in a heat pump to the house heating system. Electricity is used to drive the compressor as opposed to creating heat.

GSHP's can be used to provide home heating and domestic hot water heating. They can also provide cooling. GSHP's are particularly suitable for low temperature distribution systems such as warm water underfloor heating as the lower the temperature required by the distribution system in the house, the more efficient the system will be. This guide concentrates on the application of residential homes, but the benefits of the technology exponentially grow when applied in the commercial field.

Although GSHP's are increasing in their use all over the world, the technology is still relatively new in NZ but growing rapidly. The performance of these systems is such that they are now a very carbon efficient form of home heating and cooling.

A GSHP system consists of 3 elements:

- A ground heat exchanger which collects heat from the ground
- A water to water or water to air heat pump which raises the heat collected from the ground to a useful temperature for use with in the house heating system
- A heat distribution system within the house by which means the heat produced from the heat pump is emitted through the house



The three loops of the heating & cooling cycle

To visualize this, imagine 3 loops. The loops are all individually sealed but have contact with each other and pass heat one to another. Each loop has a pump that circulates the fluid in the loop.

The first is the ground loop that takes the heat from the ground. The ground loop circulate a very large volume of low temperature heat. This ground loop passes its energy to the second loop which is the refrigeration loop or heat pump. This is where the work is done to raise the temperature of the ground supplied heat.

The second loop then transfers its raised temperature heat to the third loop, which is the house heating system. These 3 loops circulate continuously to complete the heating system.

In other words the heat pump takes the large amount of low temperature heat and transfers this into a small amount of higher temperature heat suitable for heating a house.

What type of systems are available?

Three types of Geothermal Heat Pump systems are available:

Direct Expansion (DX) - Where refrigerant is circulated directly through the ground loop

Indirect - Where a brine (water and antifreeze) circulates through the ground loop and then to the heat pump

Open loop - Either using water from a bore hole or pond/lake and circulating this through the heat pump

The most common form in Europe, North America and NZ is the **indirect ground loop.** This is due to the long expected lifespan and trouble free operation. The majority of installed systems are indirect.

In an **Indirect circulation** system, the ground loop consists of a sealed loop of high density polyethylene pipes containing a fluid that is usually a mixture of water and antifreeze. This fluid is pumped around the loops, extracting the earth's warmth through the wall of the pipe into the fluid. This in turn is then transferred into the refrigerant of the GSHP via a heat exchanger within the heat pump.

In a Direct Expansion (also known as DX) the heat pump's refrigerant is circulated directly through a copper ground heat exchanger. DX systems can be more efficient than indirect systems as they remove one process of heat exchange from the system. This means that for a given output, DX requires a shorter ground coil compared to an indirect system, giving an installation cost saving.

However as most DX systems are situated in shallower soil (usually around 500mm) they are more exposed to frosting in areas of cold climates. This shallow depth also means that DX systems can be affected by tree and plant roots, driveways or any construction above the heat exchange area.

Another downside is that DX systems require large quantities of refrigerant in the ground and there is greater potential risk of contaminating the ground if the ground coil is ruptured. The ground coil itself is usually made from copper pipe that is coated in a protective plastic. The plastic coating is required as copper corrodes quickly when brought into contact with the ground. The copper is also soft and malleable so as to be able to uncoil it during installation (as opposed to heat treated 'hard' copper often used in plumbing systems) this also makes it vulnerable for kinks and damage during installation or indeed during compaction of back filling.

Conversely, Indirect systems buried at 1.8m do not suffer from being frost prone and are too deep to be affected by most tree and plant roots. This also means that the land above the pipe field can be more easily used by the household. For example, Central Heating New Zealand recently installed a geothermal loop which then had a tennis court installed above it.

The International Ground Source Heat Pump Association of Oklahoma USA does not indorse the DX geothermal system and nearly all heat pump manufacturers world wide concentrate on the indirect method for geothermal design and development due to questions over long life, reliability and the potential negative effect on the environment.

Ground Loop Systems

The pipes that make up the geothermal ground loop are buried in the ground either in a horizontal trench at a depth of typically 1.8m or vertically in a bore hole. The choice of these two types depends on the land area available, local ground conditions and excavation or drilling costs. As excavation or drilling costs are generally higher than the price of the pipe, it is important to maximize the heat extraction per unit length of trench or borehole.

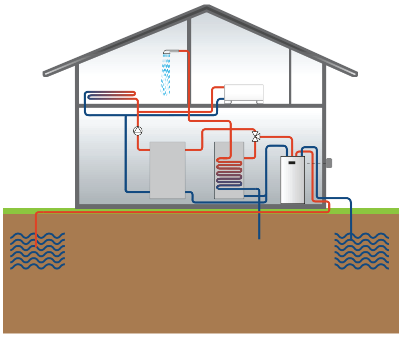
Horizontal trenches require relatively large areas free from hard rock or large boulders and a minimum soil depth of 1.5m. They are particularly suitable in rural areas where properties are larger. It is possible however to install a horizontal loop field in a typical suburban property by increasing the width of the trenches and the multiples of pipe in the trenches. The amount of trench required can also be reduced if the pipe is laid in a series of overlapping coils referred to as a Slinky. These can be placed vertically in a narrow trench or horizontally in the bottom of a wider trench. The trench lengths are likely to be 20-30 percent of the length of a single pipe configuration, but the pipe length may double for the same thermal performance.

Vertical ground loops are used where land area is limited and usually for larger installations. A U tube is where 2 pipes run parallel to each other and have a u bend at the bottom. This u tube is inserted in a vertical bore hole and then the bore hole is backfilled to create the contact with the surrounding earth. Vertical ground loops are more expensive than horizontal because of the associated drilling machine costs. They do however have good thermal efficiency to the length of pipe required. Multiple boreholes may be needed for larger residential applications.

The ground loop can also be laid under water, for instance in a pond or lake. Seasonal variations in the water are likely to be greater than the ground, but the heat transfer is higher so overall efficiencies are higher than ground loops in the earth.

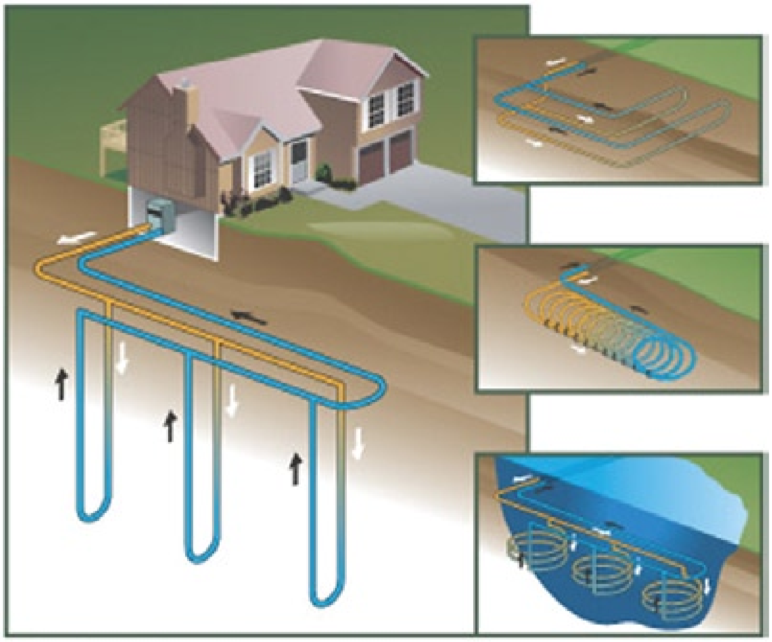
Open Loop & Direct Water Systems

Another method to exchange heat with the ground is by using water from an aquifer. In this method a vertical bore is drilled into the aquifer for water extraction. Water is pumped up from the aquifer and through the heat pump and then back down a second bore which is the rejection well. No water is actually consumed, just several degrees of temperature is exchanged into the heat pump.



The extraction and rejection wells need to be far enough apart so that the temperature of the water entering the heat pump is not compromised by the rejection water. These systems are very efficient and work well in areas that have good volumes of aquifer water that is not too difficult to access.

When installing open loop and direct water systems it is always recommended that local council regulations be investigated to ascertain what consents, if any, are required.



types of geothermal loops (clockwise from left)
Vertical Loops, Horizontal loops, slinky loops and open loops.

Geothermal Design Considerations

Ground Characteristics

The key to any of the systems previously described, is the knowledge of the soil characteristics that the ground loop will be buried in. The reason is that different soil types give up heat to the ground loop at different rates. This is known as conductivity. When the conductivity is known, an accurate ground loop design can proceed. Typically conductivity can be estimated by experienced geothermal ground loop designers by analyzing the soil to get approximate value.

Soil conductivity testing

For more sizeable installations where the requirement is large, such as a commercial project, a conductivity test should be performed. This is done using a specialist machine that data logs the flow and return temperatures in one bore hole and from the data collected the exact conductivity can then be calculated in Watts per meter for the particular pipe size used.

The temperature of the ground also has a bearing on the design of the ground loop. Temperatures should be taken during the period that load will be required from the loop, ie winter time for a heating dominant load. The reason for this is that the sun gives the earth a lot of energy but the earth is a huge storage mass. The actual earth temperature, at approximately 1.8m deep, lags the season by 6 months; ie the earth is warmest at the end of the summer due to the accumulation of heat and will be at its coldest at the end of winter. However in general despite these seasonal fluctuations the ground remains around approximately 12°C at 1.8m deep.

Loop Field size, spacing & layout

Sizing of the geothermal loop field depends upon the building heating load, soil conditions, ground loop configuration, moisture levels, local climate and landscaping. Sizing of the ground loop is critical. The more pipe used in the ground loop, the more heat can be extracted. However care needs to be taken that the pipes are spread over a large amount of ground otherwise localised freezing of the earth could take place. To put it another way; if the extraction rate is higher than what the ground can give up, the fluid in the pipes will not be sufficiently recharged by the earth.

As the ground loop can be up to 50% of the total cost of the heating installation, it is uneconomic to over size so the accuracy is critical for minimizing capital expenditure. Undersizing the ground loop leads to the ground loop running colder than design temperature. This results in less than optimum efficiency from the heat pump and at worst the heat pump may fail to function.

Ground loop sizing is complex and is usually performed with specialist software programs that model the resulting thermal extraction from the ground. A reputable geothermal company should be able to provide a design stating Watts per m^2 extraction and other associated information.

The deeper the ground loop the more stable the ground temperature and the higher the collection efficiency. Horizontal loops are typically installed at 1.8 meters deep. To reduce thermal interference multiple pipes should be laid no closer than 300mm apart. To avoid interference between adjacent trenches, minimum distance between the trench centres should be 2-3 meters. Vertical bore holes should be 5 meters apart.

Pipe layout also should consider the dynamic hydraulic pressure drop in the ground loop and keep this to a minimum so that the pumping power required is not excessive and that the flow rate of the fluid in the pipes is turbulent to maximize heat transfer.

Piping Material

The piping material affects the service life, maintenance costs, pumping energy capital cost and heat pump performance. It is important to use high quality materials for buried ground loop pipes. In indirect ground loops High density polyethylene (HDPE) is commonly used but PEX pipe is also available.

A high ratio of wall thickness to pipe diameter is required so that the pipe can withstand the pressure of compaction under the ground without distortion. The pipes are joined to manifolds or headers under the ground by heat fusion. This is proven to be the most reliable method long term. Any other type of mechanical joint is not recommended.

Manufacturing a 'slinky' ground loop pipe

Geothermal Design Considerations

Circulating fluid

The circulating fluid is what transfers the heat energy of the ground to the heat pump. The fluid is usually water with an antifreeze additive. The antifreeze is needed as the average operating temperature of the ground loop fluid can be around 0°C.

Care needs to be taken with the antifreeze as this changes the pumping characteristic of the fluid and usually increases its viscosity and lowers the pumping speed which is adverse on heat transfer.

The circulating pump must be suitable for chilled water pumping and have low electrical load requirement to ensure overall efficiency of the system.

Recharge from the Sun

A common myth is that the geothermal loop can be recharged from a sunny or wet day in the winter. This is a claim made by companies burying ground loops at less than a metre deep. This is a fallacy as the soil depth at 500mm is generally colder than 5˚C all winter and one or two sunny days will not be sufficient to increase temperature at this depth. Soil temperatures are given daily in local newspapers where this can be verified.

Installation

The installation of horizontal ground loops is relatively straight forward, but vertical ground loops require highly specialist knowledge, not just by the drilling contractor, but also regarding pipe specification, joints and grouting procedures.

Pressure testing before back filling so all joints can be checked and thorough flushing prior to the connection of the heat pump is paramount for good performance.

Preferably the ground loop should be installed by professionals who have undergone the International Ground Source Heat Pump Association Accredited training course.

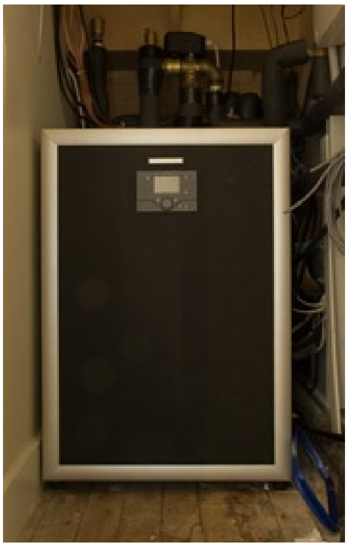
Benefits Of Using Geothermal Energy

Efficiency

To maximize the efficiency of a heat pump when providing heating, it is important not only to have a low temperature distribution system in the house, but also to have the highest source temperature possible.

Overall efficiencies for GSHP's are inherently higher than for air source heat pumps, because ground temperatures are higher than the mean air temperature in winter and lower in summer. The ground temperature also remains relatively stable allowing the heat pump to operate constantly close to its optimal design point.

Air temperatures however, vary both throughout the day and seasonally and are lowest at times of peak heating demand. Air also has a lower specific heat capacity than water, so to supply the same energy, more air must be supplied to the heat pump, which in turn requires more energy. For heat pumps using ambient air as the source, the evaporator coil will require regular defrosting at low temperatures.



Typical understair cupboard installation of a ground sourced heat pump

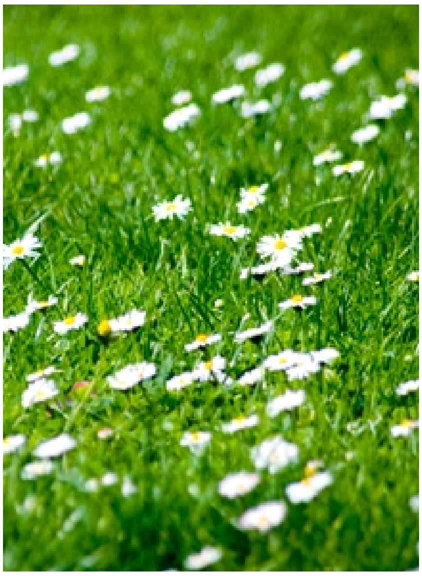
For well designed GSHP systems used to supply low temp water based heating systems, seasonal efficiencies of between 300 and 400 percent are common and can be higher (350-550%) for direct expansion, open loop water systems and oversized indirect closed loop systems.

By comparison the seasonal efficiency of an air source heat pump system is about 250% although this depends on the regional climate in the heat pump location. The seasonal efficiency is the ratio of the energy delivered from the heat pump to the total energy supplied to it, measured over a year or heating season (including energy demands for circulation. Eg: to circulate fluid around the ground heat exchanger).

GSHP's are an ideal alternative solution in areas where cold climates can affect the winter performance of air-sourced heat pumps

Benefits Of Using Geothermal Energy

Environmental & operational



As well as reducing purchased energy consumption and CO2 emission, GSHP's have a number of other environmental and operational advantages.

- As the ground is heated by solar energy, and the heat pumps have a high COP, the running costs and resultant CO2 emissions are very low.
- Since the heat source for the heat pump is either pipes or well water hidden underground, there is no need for any external equipment such as fan units or fuel tanks. This means it is very quiet in operation and visually unobtrusive.
- Because the ground coil is buried to a depth of 1.8m it is possible to plant trees and use the land above the coil.
- High security (no visible external components to be damaged or vandalized)
- Long life expectancy (over 50 years for an indirect closed loop geothermal field) with low maintenance. No regular servicing requirements
- **No combustion gases**
- **No flue or ventilation requirements**
- **No local pollution**

How much does it cost to install and run a geothermal system?

The installation costs for a GSHP system vary depending on the size of the house. A new 200 sq m house may cost $35000+GST to have a system installed, but other factors, including those mentioned above in this booklet, may also have a bearing on the final amount rather than just the area a house covers.

Installation cost is only one part of the equation though. GSHP systems are incredibly efficient with the ability to run at up to 400% efficiency. Whilst installation costs may be high compared to that of other central heating systems, their greater efficiency means that Geothermal Heat Pumps are one of the most economical heating units to run. Current energy prices mean that the cost of delivered heat can be up to half of that of alternative gas, diesel and wood pellet boilers.

GSHP systems have been successfully installed in existing houses as well as new-builds throughout New Zealand. The GSHP system is well suited to the low temperature delivery of hydronic or warm water in-slab heating. However a popular option is also for a water radiator system due to the flexibility of their operation.

Central Heating New Zealand Ltd have designed and installed over 35 GSHP systems in New Zealand. They are the only company in New Zealand to have undertaken thermal conductivity testing to establish heat extraction ability in ground formations. Our engineers are International Ground Source Heat Pump Association (IGSHPA) certified designers and installers.

The above home in Christchurch was retrofitted with a GSHP when the owners renovated. Running radiators throughout the house has slashed their heating costs and now see's the heat pump working at efficiencies of greater than 300%

When choosing Central Heating New Zealand to specify your ground-sourced geothermal heating system you can have confidence in the performance of your system and a guaranteed long-life, low-maintenance heating solution that will last for many years to come.

Our Expertise

Central Heating New Zealand are the experts in heating New Zealand homes and can offer you professional heating advice in order to get the most efficient and effective heating for your home. We have the skills, products and people to help you. Get expert technical advice and customer support and be assured that we distribute only the highest quality European products. Our team works harder to create the right heating system for your home, budget and lifestyle.

Your home and your comfort is essential for your health and well being. To transform your lifestyle contact the experts in absolute warmth and comfort, Central Heating New Zealand, so you can live like it's summer all year round.

Below are just a few reasons to consider CHNZ as your GSHP Installer/Designer:

- **An established warm water central heating company with 10 years of experience**
- **In-house HVAC engineers**
- **Certified International Ground Source Heat Pump Association (IGSHPA) Designers and installers**
- **Proven track record in installing GSHP systems in New Zealand**
- **Supplier of top-quality DeLonghi/Climaveneta Heat pumps**
- **50 Year Ground Loop pipe guarantee**

Find out more about IGSHPA at
http://www.igshpa.okstate.edu/

Ph 0800 357 1233
52 Pilkington Way, Wigram, Christchurch
Email: enquiries@centralheating.co.nz
www.centralheating.co.nz

Geothermal FAQs

To install ground source heating do I need to be living in an area with some geothermal activity?
No, anywhere in New Zealand is suitable for a ground sourced heat pump as the system extracts the latent heat energy from 1.8m below the surface.

Are GSHPs only suitable for new buildings or can they be installed in existing homes too?
Ground sourced heat pump systems are suitable for both new and existing homes but factors such as heat demand and the method of heat distribution (eg radiators or underfloor) need to be taken into account when designing the system.

Can radiators or a combination of radiators and underfloor be used with a geothermal heat pump?
Yes, but systems including radiators require greater demand and high temperature heat pumps.

How much can I expect to pay for a geothermal system?
All systems are individually designed for the specific requirements of each home, but expect to pay a minimum of $30,000 for an underfloor system in a 150 sq m home.

Do I need a big section to install a geothermal system?
Not necessarily. Ground loop sizing is dependent on the kW demand of the home, so a smaller house will need a smaller ground area. Bores (with vertical piping) can be used but this can be cost restrictive due to high drilling costs.

Can I use a geothermal heat pump to heat a swimming pool in addition to my home?
Yes but such systems requires careful planning a pool heating demands need to be calculated into the system design from the very start.

Does a geothermal system require 3 phase power?
Some systems may require 3-phase power depending on the heat demand of the home. Those systems that require high kW output, eg high temperature systems using radiators. The general rule is houses up to 200 sq m should be suitable for single-phase power.

Can I change my existing radiator central heating system to Geothermal?
It is possible, however high temperature geothermal systems heat water to a lower temperature than boiler-based systems. This means that radiators and pipework may have to be resized or amended to achieve the same levels of comfort if a geothermal system is retrofitted to an existing high temperature distribution network.

Can I change my existing underfloor central heating system to Geothermal?
Yes. Underfloor systems have lower temperature heat demands so your heat source can usually be switched from either boilers or air to water heat pumps to a ground sourced heat pump

How can I reduce the cost of installing a geothermal system in a new build property?
Higher thermal efficiency through higher R values in wall, ceiling and subfloor insulation is the best way to reduce costs. Thermally broken double glazing will all add to lower heat demand which can significantly reduce the size of heat pump and ground loop required. Also keeping a system as standard as possible with minimal design complexity will help to keep costs to a minimum.

Central Heating
NEW ZEALAND

CENTRAL HEATING NEW ZEALAND
Ph +64 3 357 1233 Fax +64 3 343 1236
PO Box 31-274 Sockburn, Christchurch 8444, New Zealand
Email info@centralheating.co.nz

www.centralheating.co.nz