# *The Orangehouse Renewables Information Series:*
# GROUND SOURCE HEAT PUMPS


AN EXAMPLE PLANT ROOM

## An introduction

Having been widely used in Europe and North America for many years ground source heat pumps (GSHP) are becoming far more common in the UK. A well designed and installed system will provide super-efficient heating and hot water for decades. GSHPs are getting quieter, more efficient and even more environmentally friendly. A GSHP works by collecting solar energy from the ground and concentrates it into usable heat. Generally in the UK even if you drill a vertical borehole 150 metres deep the vast majority of the heat collected is solar energy rather than geothermal. The heat pump uses the same technology as a fridge or freezer - heat energy from the ground boils a refrigerant gas (in the same way that water in a kettle becomes steam) which can then be compressed or concentrated by the compressor to give us usable heat. The harder we squeeze the hotter it gets! This is where the electricity is consumed to power the system. For every unit of electricity consumed we expect to produce up to 5 units of heat – making a heat pump 500% efficient. As a comparison, gas or oil boilers are around 90% efficient.

GSHPs historically have had fixed speed compressors but are now increasingly inverter driven. This means the compressor speed can vary leading to several benefits:

- As heat demand increases, the compressor runs faster and in warmer weather can run slower and more efficiently - reducing running costs
- The compressor starts slowly and then ramps up gradually, so there is less of a demand spike on the electricity grid allowing for a smaller fuse rating and lower power supply requirements
- Flow temperature and system output can be closely adjusted to follow outdoor temperatures – this is known as 'weather compensation'

## Suitability

GSHPs are ideal for both new and existing properties. They are more discreet than air source systems as the heat collector is buried out of sight and there is no outdoor unit. On larger projects where several air source heat pumps need to be used it can be a more cost effective and elegant solution to use ground source. On both new and existing properties, the key consideration is getting the efficiently generated heat into the building via correctly sized radiators, underfloor heating or fan coil units.

## Sizing, design and ground collectors

A GSHP system is sized in the same way as a gas or oil boiler. At Orangehouse Renewables we produce detailed room by room heat loss calculations to ensure that the heat pump will supply all of your space heating and hot water.

The ground heat collector is designed to act as a rechargeable battery – heat is extracted in the winter and replenished by the sun and rain during warmer weather. This ensures that the ground works efficiently for a long time. An undersized heat collector extracts too much heat leading to ground cooling - over a period of years this can lead to the ground freezing and system failure. A correctly designed ground collector has a design life of 50 years but should last one hundred years.

Generally, the ground temperature is around 12°C when the heat pump is switched on in the autumn. Due to heat extraction over the winter the ground temperature may have lowered to around zero by the spring. Solar heating over the summer returns the ground to around 12°C ready for the following winter.

Different types of ground have different thermal properties. For example, for ground source it is a case of "the wetter the better" as water provides better connectivity from the ground to the pipe and water movement through the ground replenishes the extracted heat. Wetter ground is thermally far more productive than dry ground, so dry ground needs a larger ground collector i.e. more pipe needs to be installed (buried).

Horizontal pipes are buried around one metre deep as this is deep enough to avoid cold winter weather and ensure that the collected heat energy isn't lost during transfer to the heat pump. Due to the disturbance installing these pipes the ground may take up to a year or even longer to settle and may not be exactly the same as prior to the installation. The land above these pipes can be used for grazing animals, growing plants, permeable driveways and even building upon, as long as care is taken not to damage the pipework. Rainwater helps recharge the ground so permeable surfaces are best. If the ground loops are damaged (such as by a digger or fence post), they can be repaired. Although if the collector is under a building and fails there are very limited options. Fields and paddocks are ideal for installing horizontal collectors. Landscaped gardens can have more issues with tree roots, drains and services.

LAYING PIPE IN TRENCHES

## Horizontal ground collectors

Ground temperatures vary across the country and as you would expect they are higher in the south and warmer near the coasts. Birmingham is the coldest place in the country being the furthest from the sea. Horizontal heat collectors are installed in one-metre-deep trenches as at this depth there is a consistent temperature of about 12°C all year round. Mains water pipes are installed at this depth as there is no risk of them freezing during cold weather.

*'SLINKY' HORIZONTAL GROUND COLLECTORS*

There are two ways of arranging the collector pipes in the ground. Horizontal pipes can be laid in long straight runs in narrow trenches or arranged as a flat coiled pipe in wider trenches called slinkies.

To maintain the rechargeable ground heat 'battery' these trenches have minimal spacing requirements. Straight pipes are usually a minimum 1 metre apart. As slinkies have more pipe in an area of ground they extract heat quicker and so need to be at least 3 metres apart.

## Boreholes

Where space is limited or system capacity requires it, the ground heat collector can be installed vertically instead of horizontally. Boreholes are typically drilled from around 80 to 150 metres deep. Installing a vertical borehole collector costs more due to the specialist drilling process required. It is hydraulically more efficient to drill two shallow boreholes rather than one deep one as the pressure drop is lower so less pumping energy is needed to circulate the heat transfer fluid.

A ground source drilling rig is considerably smaller than the piling rigs commonly seen on the side of motorways or building sites. Obviously rigs do vary in size, but generally if a large van can access an area so can a drill rig. Drilling requires a considerable quantity of ancillary kit such as casing to keep the boreholes open, a grout machine for sealing them, drill rods for the actual drilling and skips to control the spoil.

There are two methods of drilling boreholes – air or water flushing. At the bottom of the column of drill rods is a drill bit that grinds out the rock. To remove the drilling debris either air or water can be circulated down the centre of the drill rods so that the drilling arisings can rise up through the drilled hole. These arisings are collected and managed at the surface to ensure a relatively clean and tidy site. There is always a certain amount of mess as a drill rig is essentially a machine for making mud!

*A DRILL RIG AT WORK*

## Manifold

The ground heat collector pipes, whether installed vertically or horizontally, are individual loops that need collecting up. This is achieved with a manifold which essentially acts as a junction box where the individual loops are connected to a pair of header pipes that run to the heat pump. This manifold can be mounted on a wall but is more commonly a chamber buried in the ground. All that will be visible from above the surface is the lid – which looks like a manhole cover.

*A MANIFOLD CHAMBER*

## Joining Pipes

As considerable time and money has been invested in installing the ground heat collector we need to ensure that there are no leaks. This is done using the same technologies as gas and water mains by either electrofusion or butt welding the pipes together. The installed pipework is filled with water and pressure tested to ensure sound joints before the trenches are back filled.

## Heat collection

To collect heat from the ground heat transfer fluid is circulated from the heat pump, round the ground loop and back again. This fluid is similar to antifreeze - even if the ground temperature falls below zero the heat pump does not become iced up and crack. This transfer fluid is generally mono-ethylene or propylene (food grade) glycol, although other types are available for more sensitive sites.

To ensure efficient heat collection we need balanced flow across the ground heat collector; not some loops providing the heat and hence getting cold while others are under-utilised. We design for the heat transfer fluid to be "spinning" as it travels down the collector pipes to optimise heat collection. To minimise the electrical energy needed to power the circulation pump, we aim for laminar (straight flow) in the header pipes.

## Cooling

A heat pump is a very honest machine that pumps heat - as one side gets hotter the other gets cooler. GSHPs can provide cooling in two ways - active or passive. Passive cooling is where a small pump circulates the approximately 12°C heat transfer fluid from the ground, through the building and back into the ground to dump the heat. Active cooling involves running the compressor to generate chilled water that is used to cool the building. The collected heat is stored as warm water or dumped into the ground. As the compressor consumes electricity active cooling is less energy efficient than passive. Ground source cooling is more efficient than conventional air conditioning as heat is being dumped into the approximately 12°C ground rather than 25°C or 30°C summer air.

## Flow temperatures

Conventional gas and oil boilers historically have worked at high flow temperatures (around 70°C - 80°C) which are blended down with cooler water to achieve lower underfloor heating temperatures which is very inefficient. A heat pump is more efficient as it increases the circulating fluid to the required target temperature and no hotter, rather than blending it down.

Heat Pump flow temperatures are between 35°C - 55 °C which works particularly well to:

- Allow the heat pump to run efficiently with minimal running costs
- Deliver gentle background heating throughout the day rather than short bursts of heat morning and evening with a cool spell in the middle - especially helpful for homes or buildings occupied all day
- Deliver heating water at the required outdoor temperature or by working harder (compressor squeezes the gas more) to deliver 55°C for hot water for showering/washing up – too hot to put your finger in! A legionella cycle is programmed to run to prevent bacterial contamination.

## Radiators/underfloor heating

Appropriately sized radiators are required as heat pump systems operate most efficiently at lower flow temperatures. To emit an equivalent amount of heat into a room at these lower flow temperatures, a larger surface area of radiator is required. Generally extra panels or fan assisted radiators can be specified.

Underfloor heating systems are increasingly a standard feature and complement heat pumps for the following reasons:

- With underfloor heating the large floor surface area acts as the radiator (rather than a smaller metal panel on the wall) delivering effective room heating at efficient lower flow temperatures
- The lack of radiators allow for far more flexibility in room layout
- The floor can be heated up with low-cost electricity. This then acts as a thermal store, gently radiating heat during periods of higher cost electricity

*EXAMPLE OF 'SNAIL SHELL' UNDERFLOOR HEATING*

## Hot water cylinders

High flow temperature gas and oil systems generally have a hot water cylinder with a 1m$^2$ heating coil. As the heat pump works at lower flow temperatures to effectively heat water and deliver a quick reheat time, we need a coil with at least 3m$^2$ surface area. The legionella pasteurisation cycle uses an electric immersion to achieve a higher temperature.

## Buffer tanks and Pipework

We generally install a buffer tank with our systems and although this costs more, we believe the efficiency, lifetime and performance benefits are worth the investment. This is because a buffer tank:

- Ensures there is sufficient volume of water available to allow the heat pump to run efficiently
- Provides a supply of heat to the heating system while the heat pump is recharging the hot water cylinder
- Reduces the number and frequency of compressor starts which prolongs compressor and ultimately heat pump lifetime
- Provides hydraulic separation between the heat pump and heating circuits

Historically it was cheaper and easier to install small bore central heating pipes. Many homes have 8mm or 10mm pipes rather than standard 15mm for radiators. Heat pumps need a good flow of water to work efficiently and radiators need a good flow to provide effective heating at heat pump flow temperatures. By installing a buffer tank we can effectively heat properties without having to replace all the pipework.

## Water pressure

Many older properties have two tanks in the loft. One is the cold-water header tank which relies on gravity using the height difference between the tank and tap to generate the pressure. The other is the feed and expansion tank for the heating system. This arrangement is not ideal. Generally, a shower pump is required to generate decent flow and pressure for a satisfactory shower and historically these have been noisy and unreliable. The heating system header tank can introduce air into the system leading to radiator sludge and a loss of performance. Normally when we install a heat pump system, we disconnect these tanks and switch to a sealed pressurised heating system with an unvented hot water cylinder. This higher-pressure mains water coming into the tank pushes the hot water out of the tap or shower for a more powerful and enjoyable showering experience.

## Controller

The system controller is generally placed somewhere visible or is part of the heat pump. The controller manages the heat pump, switches it between heating and hot water production, monitors system temperatures and pressures, records performance data as well as many other functions. Individual rooms or zones (e.g. ground floor and first floor) are generally controlled by thermostats, programmers and radiator valves - exactly the same as a conventional system.

*A NIBE CONTROLLER*

## Indoor plant

The indoor space required for the GSHP system is usually more than a conventional boiler system. As well as the floor standing heat pump there will be a hot water cylinder (usually 600mm in diameter), a buffer tank, a couple of expansion vessels, circulating pumps, valves and pipework. Orangehouse Renewables use acoustically insulated fittings to dampen any vibration noise. The plant can be installed into a utility room, garage or generous storage cupboard. The average footprint for this equipment is around 3m x 1m. The hot water cylinder can also be located away from the rest of the system such as inside an airing cupboard or in a loft.

## Planning and Permissions

As the ground heat collector is buried and the heat pump and cylinders are installed indoors nothing is visible outside. This generally means that GSHPs qualify for Permitted Development rights.

As heat pumps are electrically powered adequate electricity is crucial. Usually before a heat pump can be connected to the electricity grid permission has to be obtained from the owner of the power lines - such as Western Power. The other factor to consider is the draw of the heat pump which needs to be compared to the electrical supply to your property and other demands such as induction cookers or electric vehicle chargers. The heat pump itself generally needs a 32-amp fuse and a single or three phase electricity supply. Larger capacity systems will need a three-phase supply.

## Smart Grid

As the country switches to wind and solar electricity generation the price of electricity and the way we manage it is changing. The introduction of smart meters is developing the old Economy 7 model of different costs or tariffs at different times of the day. During the night electricity is cheaper and at peak times, such as between 4pm to 7pm, it will be much more expensive. Newer heat pump controllers have the capacity to connect to the new Smart Grid to receive start and stop signals in line with electricity pricing. In the meantime, we can set schedules to utilise lower cost electricity and store it as heat in the buffer or hot water tank to bridge more expensive periods. Scheduling or cleverer controls also allow optimising of any on-site electricity generation from solar PV or similar systems.

## Environmental impact

The refrigerant gases inside heat pumps are changing to provide better outputs, increasing efficiencies and environmental benefits due to their lower global warming potential.

If you run your heat pump on zero carbon or renewable electricity there are no carbon emissions. Burning fossil fuels produces carbon.


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## Running costs

As heat pumps use 1 unit of electricity to generate approximately 4 units of heat, they are the most efficient way to heat a building. Electricity at 14 pence per kilowatt hour equals 3.5 pence per kWh or unit of heat. Mains gas is typically around 4 pence, oil 5 pence and LPG slightly more expensive.

## Power supply

As heat pumps are electrically driven having your own solar PV or micro wind turbine installation will further reduce your running costs. Cleverer heat pumps can recognise or receive a signal when excess electricity is being produced and use the inverter to run the compressor slowly, converting this electricity into approximately 4 units of heat.

## Lifetime

We only install good quality GSHPs which should have a lifetime of around 20 to 25 years if regularly serviced and properly maintained. The expected lifetime of the ground collectors is at least 50 years.

## The Boiler Upgrade Scheme

The Boiler Upgrade Scheme (BUS) was launched on 1st April 2022 to replace the RHI grant scheme. It is designed to encourage the installation of heat pumps instead of gas or oil boilers. The BUS will pay £5,000 towards the cost of an air source heat pump and £6,000 towards the cost of a ground or water source heat pump.

## Servicing and maintenance

Like all machines with moving parts heat pumps need servicing to maintain optimal performance and operation. It is a condition of both the RHI grant scheme and manufacturer warranties that they are serviced annually – this will obviously extend the lifetime of the machine.

*EXAMPLE OF A BLOCKED FILTER – THIS CAN BE AVOIDED BY REGULAR SERVICING OF YOUR HEAT PUMP*

*AERIAL VIEW OF HORIZONTAL GROUND LOOPS*