

Industry Briefing Note



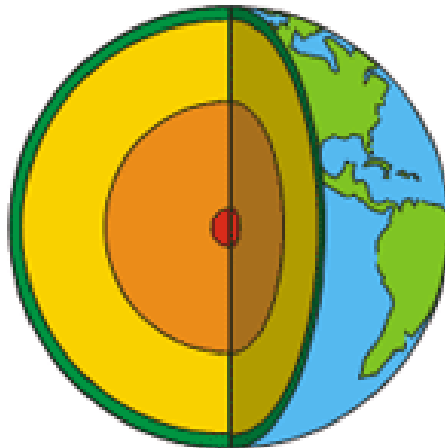
Ground-Source Heating & Cooling

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basic principles

Ground source heating and cooling (GSHC) involves the recovery of low grade heat from the ground or the disposal of heat from a building into the ground, usually utilising a heat pump. (What is a heat pump? See later). In the UK the temperature of the soil and upper few 10s of metres of rock are at a remarkably constant temperature, equal to the average air temperature at that latitude. The majority of this heat energy is provided by the sun with only a very small amount coming from the Earth's interior.



GSHC systems can be designed to provide a few kilowatts (kW) of energy for a home, with up to several mega-watts (MW) of energy for commercial and industrial schemes.

The fundamental science behind ground-source design and heat transport in the ground, is directly analogous to groundwater flow. In fact commonly used groundwater analysis is based on heat flow theory. The assessment of risks associated with GSHC is therefore an extension of hydrogeology. This extension is often referred to as "Thermogeology".

system types ...

There are two basic GSHC systems:

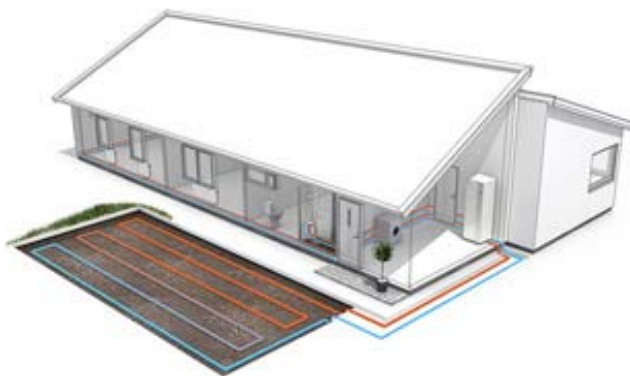
⇒ Open loop; Water is pumped from a borehole to a heat pump or heat exchanger. In

heating mode thermal energy is extracted from the water within the heat pump cycle. The cooled water is then re-injected to the aquifer or disposed-of to the environment.

⇒ Closed loop. Heat and/or cool is exchanged with the ground via plastic pipes filled with a carrier fluid. The pipes can be installed horizontally in trenches, in boreholes or in a lake. The length of pipe required to provide sufficient 'ground-source' depends on the building's seasonal heating/cooling characteristics and the properties of the rock.

open loop systems ...

In an open loop system groundwater is abstracted and circulated directly through the heat pump or indirectly through a heat exchanger. Due to the conductive nature and the specific heat capacity of the groundwater, an open loop system can deliver a large amount of energy from a single well (or borehole).



Water is abstracted from a borehole and passed through a heat exchanger/heat pump system. A Heat pump

can be rated to provide a few tens of kW up to many hundreds of kW. In heating mode a heat pump will reduce the temperature of the groundwater by (typically) 5° - 7°C and subsequently be used as part of a grey water supply system or discharged.

The discharge could be to the surface water system or back to groundwater. If discharge to groundwater is considered, a second borehole may be required. Both abstraction and discharge require consents and licences from the appropriate regulators.

vertical closed loop systems ...

A borehole or an array of boreholes are drilled and installed with a U loop of plastic pipe that circulates an antifreeze solution. The solution extracts heat from the borehole and delivers heat to the heat pump.

The heat is subsequently extracted from the solution before returning down the borehole. It is called a closed loop system because there is no direct interaction between the solution and the groundwater and/or rock mass.

This system has the advantages that it does not require the presence of an aquifer, there is very little risk of contaminating the ground and is not subject to Environment Agency licensing formalities.

Many rules of thumb abound but the heat energy that can be derived from a single borehole depends on seasonal heating and cooling load characteristics and rock thermal conductivity.

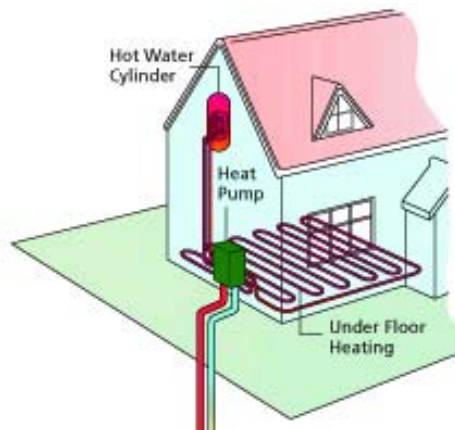
However, in the UK, a 'typical' 100m borehole can

provide approximately 4 - 6kW of energy.

horizontal closed loop systems ...

A horizontal closed loop system works on the same principal as the vertical closed loop system.

A pipe is coiled and placed in a 1 to 2m deep trench. This system will typically supply 1kW of power for every 10 to 12m of trench. The coiled pipes are often referred to as "slinkies" and the trenches should be spaced about 5m apart.



Pipes can also be installed without coiling and so require greater length of trench although the trench spacing can be less. Both have the advantage that they are easy to install although they both require a large installation area.

Pipes or heat exchange panels can also be installed in a lake provided there is sufficient depth and surface area.

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risks ...

The use of the ground as a source of heating or cooling has inherent risks. With closed loop systems, the largest risk is excessive heating or cooling of the ground around the boreholes or trenches. This can be due to insufficient length of ground-source, boreholes or trenches being too close together or too much thermal stress being put on the system.

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borehole yield; recharge; thermal breakthrough and thermal plume migration. These risks can be mitigated by appropriate design of the scheme and the building and ideally achieving an annual energy balance.

In order to assess, quantify and minimise risk, a GSHC system should be designed into the building from inception and requires liaison between building and systems designers and hydrogeologists and thermo-geologists. For all open loop schemes and closed loop schemes in excess of ~30kW, specialist advice should always be sought.

the pumps ...

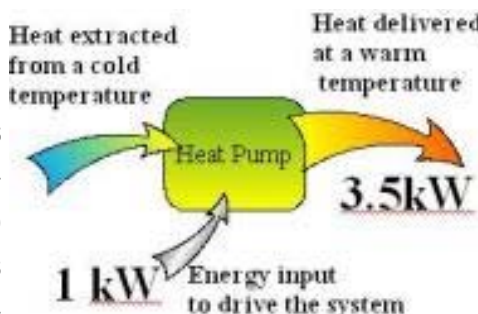
Ground source heat pumps make use of renewable energy stored in the ground, providing one of the most energy-efficient ways of heating and or cooling buildings.

They can be installed almost anywhere in the UK, using a borehole/s, shallow trenches or by extracting heat from a pond or lake. In a closed loop system, the collecting pipes contain an antifreeze mixture that extracts this stored energy, which can then be used to provide space heating and domestic hot water. In some applications, the heat pump can be reversed in summer to provide an element of cooling.

The only energy used by Ground Source Heat Pump systems is electricity to power the heat pump and circulation pumps. The efficiency of a

ground source heat pump system is measured by the coefficient of performance (CoP). This is the ratio of units of heat output for each unit of electricity used to drive the compressor and pump for the ground loop.

Average CoP over the year, known as seasonal efficiency, is around 3 - 4 although some systems may produce a greater rate of efficiency, depending on the type of heat pump and application. This means that for every unit of electricity used to pump the heat, 3 - 4 units of heat are produced, making it an efficient way of heating a building.



Ground Source Heat Pump systems have been widely used in other parts of the world, including North America and Europe, for many years. Ground Source Heat Pumps work best with heating systems that are optimized to run at a lower water temperature (35 - 55°C) than is commonly used in UK boiler and radiator systems. As such, they make an ideal partner for underfloor heating systems.



... and how they work

Anyone who has a refrigerator or an air conditioner has witnessed the operation of a heat pump. All of these machines, rather than making heat, take existing heat and move it from a lower temperature location to a higher temperature location. Refrigerators and air conditioners are heat pumps which remove heat from colder interior spaces to warmer exterior spaces for cooling pur-

poses. Space-heating heat pumps merely move heat from a low-temperature external source to a high-temperature interior space (your house).

An air-source heat pump, for example, extracts heat from outdoor air and pumps it indoors. A ground-source heat pump works the same way, except that its heat source is the warmth stored in the ground.

The process of elevating low-temperature heat to 35°C or more and transferring it indoors involves a cycle of evaporation, compression, condensation and expansion. A refrigerant is used as the heat-transfer medium which circulates within the heat pump as follows:

- ⇒ The cycle starts as the cold, liquid refrigerant passes through a heat exchanger (evaporator) and absorbs heat from the low-temperature source (liquid from the ground loop). The refrigerant evaporates into a gas as heat is absorbed.
- ⇒ The gaseous refrigerant then passes through a compressor where the refrigerant is pressurised, raising its temperature
- ⇒ The hot gas then circulates through a second refrigerant-to-water heat exchanger where heat is removed and pumped into the building at up to 60°C, although 35 - 40°C is sufficient for underfloor heating applications.
- ⇒ When it loses the heat, the refrigerant changes back to a liquid. The liquid is cooled as it passes through an expansion valve and begins the process again.

To become an air conditioner, the flow is reversed.

heat distribution ...

This typically consists of underfloor heating or high surface-area, low temperature radiators for space heating and in some cases water storage for hot water supply. Alternatively, warm air circulation from the heat pump can prove an efficient delivery mechanism.

costs & savings ...

A typical 8 - 12kW system costs £6,000 - £12,000 (not including the price of distribution system). This can vary with property, system size and location.

Vertical ground loop systems are significantly more expensive to install than horizontal ground loops, due to the higher cost of drilling a borehole. When installed in an electrically heated home a ground source heat pump could save as much as £1000 a year on heating bills and almost

Fuel Displaced	£ Savings per year	CO ₂ Savings per year
Gas	410	1.2 tonnes
Electricity	1000	7 tonnes
Oil	750	1.8 tonnes
Solid	350	6.5 tonnes

7 tonnes of carbon dioxide a year.

Savings will vary depending on what fuel is being replaced, but are illustrated in the table below.

Savings above assume ground source heat pump installed in a detached property and provides up to 50% of domestic hot water as well as 100% of space heating.