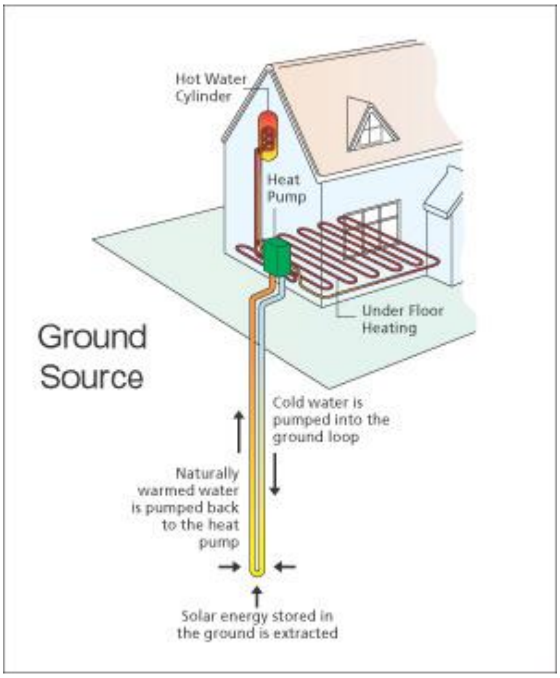
Ground Source Heat Pumps Explained

Heat pumps in general and ground source heat pumps (GSHP) are effectively reverse air conditioning systems. They use low temperature heat and convert if into a much higher and hence more useful temperature that can be used for water heating and general domestic heating. Using initial heat from the ground, together with the high efficiency of the heat pump will save a large amount of carbon dioxide emissions that would other wise be expelled into the atmosphere under traditional heating systems.

Ground source heat pumps are getting increasingly popular world wide with extra focus in the American and European markets. According to estimates, there are approximately 550,000 units installed world wide (of which 80% are domestic), and there are about 66,000 annual installations on going.

Although the technology is well used around the world, the UK market is lagging behind, with low level of awareness. This is likely to change, as a quality system offers excellent performance and significantly reduce carbon dioxide emissions and provide space heating.

Heat Pumps - Types of Systems



A typical ground source heat pump system has a ground heat exchanged, a water-to-water or water-to-air heat pump, and a heat distribution system, see chart below for a typical system's layout.

Previously systems used an open-loop application, where ground water was used. Where there is a suitable source of groundwater this type of system can be very cost effective, because the water is easy to move into the pump and back, while using relatively inexpensive wells that require limited land space. However, there are also common disadvantages to these systems, as water is not always easily available, corrosion can become a problem (subject to the quality of the water) and strict regulation on environment is limiting the use of ground water.

Because of the limitations of open-loop systems, the latest models are based on closed-loop (or ground coupled) systems, where the heat exchanger in the ground is made of a sealed loop of pipe that is buried horizontally of vertically underground. Most systems are indirect, where the antifreeze liquid solution circulates in the ground loop and the energy is transferred to the heat pump refrigerant through a heat exchanger.

Typical Applications

Ground source heat pumps are used for space and domestic water heating, as well as for cooling of buildings of various types and sizes. It is important to note that using ground source heat pumps for cooling will result in increased energy consumption.

Ground source heat pumps are especially suitable for new buildings, as the low temperature provision is perfectly suited to the demand of under-floor heating systems. They are also appropriate for installation in existing homes, especially when reducing heat demand. They can be financially attractive in areas where there is no coverage the mains gas grid or for developments that are planned to simplify the infrastructure.

Advantages

It important to get as high a temperature as possible from the ground, as well as keep the output heating temperature low to maximise the efficiency of the ground source heat pump system. Ground source heat pumps have typically higher efficiency than air source heat pumps, as the ground temperature is warmer than air temperature in the winter and cooler in the summer. A relatively stable ground temperature allows the heap pump to operate close to it s optimal design point, while changing air temperatures are much more volatile, both daily and on a seasonal level.

A ground source heat pump which supplies low temperature heating system (e.g. under-floor heating), will have seasonal efficiency of 300%-400% for indirect system and even higher (350%-500%) for direct systems. As reference, the seasonal efficiency of an air source heat pump is about 250%. Seasonal efficiency is the ratio of energy delivered from the heat pump to the energy supplied to it, averaged over a year (this includes energy required for circulation of the liquid inside the ground loops).

The high efficiency of the ground source heat pumps is minimising the electricity demand, and the respective CO_2 emissions that goes with it. The next example demonstrates the low carbon emission and high efficiency of the ground source heat pumps.

With an average CO_2 emissions factor for electricity of o.414 Kg/kWh, a ground source heat pump with a seasonal efficiency of 350% would yield emissions of 0.12Kg of CO_2 for every kWh of useful heat delivered. A high efficiency condensing boiler, with efficiency rating of 85% and CO_2 emissions factor of 0.194 for gas, would result in 0.23Kg of CO_2 for every kWh of useful heat delivered. This shows that the CO_2 emissions from a high efficiency boiler is almost double that of a ground source heat pump for the same unit of heat delivered. However, it is fair to note that during peak demand, some electricity provided to the heat pump may come from less efficient power stations with a CO_2 factor that is as high as 0.8Kg CO_2/kwH.

Ground source heat pumps have other advantages:

- High level of reliability – due to few moving parts and no exposure to weather
- High level of security – there are no visible external parts that can be damaged or vandalised
- Long life expectancy – normally life span of 20-25 years; the ground loop has life span of up to 50 years
- Low noise levels
- Low maintenance costs – no requirement for regular service
- No need for boiler or fuel tank
- No combustion or explosive gases within the building
- No flue or ventilation requirements
- No local pollution

Design Considerations

When considering ground source heat pumps, it is essential to get a very clear analysis of the building's heat loss, related energy consumption and the requirement for domestic hot water. A detailed calculation of these parameters will help determine an accurate size for the heat pump system, which is more crucial than traditional heating systems (such as condensing boiler), because the initial capital costs of a ground source heat pump system is much higher.

The design should avoid over sizing the system, as it will increase the initial costs, as well as make the system operate under part load, thus making it less efficient and more expensive. Equally, under sizing should also be avoided, as the system will not be able to cope with the heating demand, requiring top up heating with will reduce overall efficiency of the system.

A ground source heat pump can be designed to deliver all heating requirement. However, it might be more economic to design a dual system, where the heat pump covers the base heating load with an additional system to cover the peak periods.

Reducing the output temperature from the heat pump will increase its performance. Heat pumps normally provide output temperature limited to 50-55c for most application. This temperature is not high enough for heating systems with radiators heat distribution set up.

The depth of the ground loop is an important factor, especially when taking into account issues of the type of soil, rock and ground temperature. The temperature difference between the ground and the antifreeze fluid inside the loop is what is driving the heat transfer. The ground will show seasonal temperature swings at depths of up to 2m. If the depth is increased, the seasonal variations diminish and begin to lag the temperature on the surface. At a depth of about 1.5m the time lag is around one month. Below 10m the ground temperature remains virtually constant at 10-14c (depending on local geology and soil conditions).

The Environment Agency will not normally withhold permission/authorisation for closed loop ground source heat pumps. The agency, nevertheless, may provide comment on proposed systems where there is a risk of pollution to groundwater. Where these is a realistic risk of pollution to groundwater the Environment Agency may serve statutory notices to protect the groundwater.

The Heat Pump

Ground source heat pumps operate through a wide range of incoming water temperatures. Typically, water coming in at a temperature within a range of -50c to +120c with the heat pump delivering output temperature of 50c – 55c.
The efficiency of the pump will improve with the increase of the temperature of the inbound water and the decrease in required temperature of the outbound water delivered to the heating system.

Noise is normally kept to a minimum through an effective design of the heat pump. This is achieved normally through application of anti vibration mounting for the compressor and lining of the heat pump casing with acoustic insulation. Flexible connections can be used for hydraulic connection from the heat pump. Under normal circumstances, the heat pump should not be positioned close to areas such as the bedroom.

The pump is powered by an electric motor, which can cause disturbance to the electricity network, due to high starting currents. This becomes more obvious where there is only a single phase electric system and cal lead to flickering lights, voltage surges (which might affect electronic appliances) and premature fuse failure. This problem is normally dealt with through:

- Soft start controls to limit starting currents
- Compressors that are build specifically to utilise low starting torque
- Using a direct action electrical flow boiler to help the heat pump at peak heating demand
- Using several pumps (e.g. one pump per floor)
- Installing 3 phase electricity supply to support a 3 phase motor in the compressor

Heat Distribution System

The lower the required output temperature from the heat pump the more efficient it gets. Alternatively this can be compensated by higher input temperature (e.g. warmer ground), which would also improve the efficiency of the pump and the subsequent economic benefit. If, for example, the required temperature from the pump is reduced from 600c to 400c, the coefficient of performance can increase by more than 40%.

Table showing supply temperature requirement for several heating systems:

System	Delivery Temperature (0c)
Under floor heating	30-45
Air	30-50
Low temperature radiators	45-55
Conventional radiators	60-90

As the above table shows, ground source heat pumps are not appropriate as direct replacement for traditional boiler based central heating systems, due to the high temperature requirement. As the conventional radiators operate at temperatures of 60-90c, it would require a massive drop in temperature to allow the heat pump to power them. A temperature drop of 20c would require an increase of heating surface by 30-40% to retain the same heating output.

However, for new developments, where the wall and general insulation levels are good, it is possible to rely on low heating demand with low temperature water based system or under floor heating.

Under floor heating is undoubtedly the most effective space heating system to work in conjunction with ground source heat pumps. The ideal design should allow for floor surface temperature of 26c in order to utilise the heat pumps in the most cost effective way.

Water heating requires constant load year round. Normally the required temperature of the hot water tap is 35-45c in domestic systems. Because the heat pump is unable to raise the temperature of mains incoming water to this range of temperature in an instantaneous way, there is a need for hot water storage facility to store the hot water, in a similar way to conventional system where a condensing boiler stores the hot water in the cylinder (normally in the airing cupboard).

Since most heat pumps can only raise the water temperature to 55c, this means that the water inside the hot water storage tank would be around 50c. In such case a back up heating unit is required, such as an immersion heater to provide the additional heating required to store the water at 60c which is the requirement in order to reduce the risk of the development o Legionella. As explained above, since the efficiency of the heat pump is significantly reduced if required to heat water to high temperatures, it would be more cost effective to use the immersion heater to heat up the water from around 45c, rather that force the heat pump to push the temperature to 55c.