Ground Source Heat Pumps | info 04

Introduction

The temperature below the surface of the earth is warmer than typical winter temperatures, yet cooler than summer temperatures above the ground. This even environment arises from the capture of solar energy during the summer, the huge thermal mass provided by the earth and because the top few metres of soil provide a layer of insulation to stop the ground losing heat during the winter.

A ground source heat pump (GSHP) can use and upgrade this stored energy to provide useful heat for a building - conversely the reduced temperature below ground in summer can cool a building using the same GSHP system. Ground-source heat pumps are one of the fastest growing applications of renewable energy in the world. The worldwide installed capacity is over 12 GWth with an annual energy use of over 20 TWh from around one million GSHP systems worldwide [Lund].

Figure 1 & 2
heat pump and the installation of the ground loop
All images supplied by National Energy Foundation

South West Resource

The South West is well suited for the increased deployment of heat pump systems. The natural resource available is good as the South West receives the greatest level of solar radiation in the UK. In addition, the rural nature of South West England means there are a high number of off-gas heat users reliant on oil, LPG and electricity. Heat pumps show a better financial case against these more expensive fossil fuels.

The South West also has strong expertise in delivering heat pump technologies with at least five specialised companies based in the region and over 2.5MWth of systems installed as of 2006.

Technology

A heat pump system collects heat from the ground and upgrades it before distributing it through a building via hot air ducts, low temperature radiators or under floor heating. The heat pump itself is electrically driven, and typically, each kilowatt (kW) of electricity used extracts more than 3 kW of renewable energy from the ground. The ratio of heat delivered to the building to the electricity used is the coefficient of performance (COP) and values of 3 to 4 are typical.

A ground-source heat pump system comprises three elements: a heat pump, a ground loop and an interior heating/cooling distribution system.

The Ground Loop
The ground loop consists of long lengths of pipe buried in either horizontal trenches or vertical boreholes. Water or an antifreeze/water mix circulates around the pipe-work and carries heat back to the heat pump in a "closed loop."

A horizontal collector system consists of a series of pipes laid out in trenches, usually one to two meters below the surface, which are backfilled. Afterwards, normal landscaping can be applied and the area used as parkland, gardens or car-parking. In cases where there is not enough space for a horizontal ground loop vertical boreholes can be used.

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The Heat pump

The heat pump is the central point within the whole system where heat transfers between the ground loop and heating/cooling system within the building.
The heat pump operates using the same cycle as a refrigerator. In heating mode, heat from the ground loop arrives at the heat exchanger (the evaporator). On the other side of this heat exchanger is cold refrigerant in a mostly liquid state and heat flows into the refrigerant. This heat causes the liquid refrigerant to evaporate, but raises its temperature little. This gaseous, low pressure and relatively low temperature refrigerant then passes into an electrically-driven compressor which raises the refrigerant's pressure and, as a consequence, its temperature. This now higher temperature, higher-pressure gas within the compressor, feeds into a second heat exchanger, called the condenser.

Air or water is pumped through this condenser and since the refrigerant is hotter than the air in the building or the water in the heating circuit, it transfers heat to it. As a result, the refrigerant's temperature drops slightly and it condenses back to a liquid. This still warm liquid refrigerant then passes through an expansion valve. The valve reduces the pressure of the refrigerant, thereby suppressing its temperature further. Finally, this low temperature liquid flows to the evaporator, and the cycle repeats.

In addition, a desuperheater can be used to provide domestic hot water from the circuit. The desuperheater is an auxiliary heat exchanger at the compressor outlet which transfers excess heat from the compressed gas to water that circulates through a hot water tank.

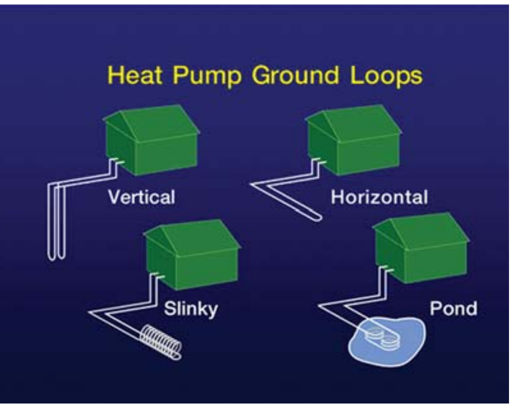

Figure 3
The variety of ground loops for heat pumps.

The Heating and Cooling distribution system

Under-floor heating is the ideal heat distribution system for a GSHP as it operates at a low temperature. Oversized radiator systems and air-duct distribution systems can also be used - traditional radiator systems with higher flow temperatures may result in lower efficiencies from the heat pump unit.

Figure 4
Example of a horizontal ground loop.

Site Suitability

The main decision on the chosen ground source option is whether there should be a horizontal or vertical ground loop. Horizontal systems can be particularly cost effective if excavating and trenching equipment are available during the early phase of a new build. Borehole systems, although more expensive, will be attractive on sites where space is at a premium.
When using a horizontal ground loop system, trenches really need to be at least two metres deep to harness a reasonably consistent year-round heat source. A typical domestic installation is 7-8 kilowatts (kW), and for trenches you'll need about 50 to 80 metres of pipe per kW, or 10 metres of 'slinky' (coiled pipe) per kW. The trenches could be straight or curved and laid in any direction to suit your site, providing they are always a minimum of five metres apart to avoid heat transfer between pipes.

For vertical ground loop systems, boreholes will need 20 to 50 metres of pipe per kW, and will usually be 100-150 metres deep - which means you may need two to four pipes per borehole, or possibly more than one borehole. Pipe diameter should be 20-40mm for best performance - large enough to reduce pumping power but small enough to increase flow velocities so causing turbulent flow (better heat transfer).

GSHPs use electricity to run. Unless this is coming from a renewable source, such as a wind turbine, or via a green tariff, this will result in emissions of carbon dioxide from the generation of the electricity.

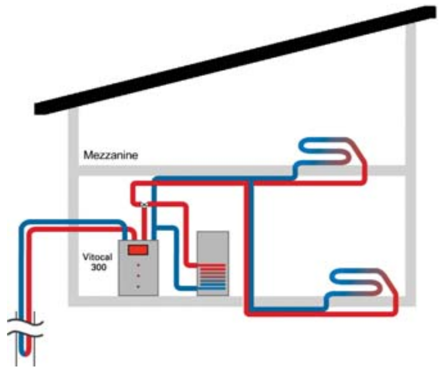

Figure 5
Schematic of a Ground Source Heat Pump system at The National Energy Foundation in Milton Keynes

Design

Sizing of the heat pump and the ground loops is essential for the correct operation of the system. If sized correctly a GSHP can meet 100% of space heating requirements. Please note that sizing is a job for specialists. GSHP systems are most effective when applied to properties with high energy efficiency standards, particularly new build. It is a good idea to explore ways of minimising space heating and hot water demand by incorporating energy efficiency measures.

Issues

- Noise levels will be similar to a refrigeration unit of a similar scale. The only real concerns centre on noise from the pumps and compressors - it is best to place the heat pump away from bedrooms and other noise sensitive locations.
- Heat pump systems have minimal visual impact as the ground collectors are buried and there is no requirement for a flue or any fuel storage and delivery.
- As there is no combustion there are no regular maintenance requirements for a ground source heat pump system.
- There are no planning issues for most systems. For borehole systems, the underlying geology will need to be carefully assessed.

Finance

The capital cost of the heat pump and the ground loop will be considerably more than a gas or oil boiler. The payback period will depend on whether the trenches were dug during the construction of the building and whether the original heating system is electric, gas or oil, and whether off-peak electricity can be used.

Sizing tools

A very simple but approximate sizing tool for schools is available for free download from The Centre for Energy and the Environment (www.ex.ac.uk/cee/re). For homes and other buildings, a more complicated but more accurate free sizing tool can be downloaded from RETSCREEN (http://www.retscreen.net/ang/t_software.php).

Costs and Grants

The cost of a professionally installed GSHP ranges from about £1,000 to £1,700 per kW of peak heat output. A rule of thumb is that the heat pump itself will be £400 to £600 per kW, with trenches £300 per kW or boreholes £500 per kW. Vertical borehole systems would be at the higher end of this scale, due to greater installation costs. Suppliers should be contacted for up to date costs.

Various grant schemes are available for home-owners, farmers and other businesses. The Low Carbon Buildings Programme (LCBP) from the DTI can offer a grant of £1,200 subject to an overall 30% limit of the installed cost (exclusive of VAT) for home owners. Public buildings and not for profit organisations are eligible for a 35% grant through Phase 2 of the LCBP program.

For more details see Grants fact sheet.

More Information

- Regen SW maintains a list of local installers on its website: www.regensw.co.uk/directory
- Various EST guides are available from the EST website (www.est.co.uk/myhome/publications/):
  - **Ground source heat pumps**
  - **Domestic Ground Source Heat Pumps**: **Design and installation of closed-loop systems** (**CE82 / GPG339**)
  - **Heat Pumps in the UK – a monitoring report** (**GIR72**)
- Heat Pump Association www.feta.co.uk
- International GSHP Association: www.igshpa.okstate.edu
- Geothermal Heat Pump Consortium www.geoexchange.org
- Canadian Earth Energy Association www.earthenergy.ca

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EarthEnergy, http://www.earthenergy.co.uk/pdf/FAQ.pdf

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