GROUND SOURCE HEAT PUMPS

In summertime, your garden absorbs solar energy and stores it in the ground as heat. A Ground Source Heat Pump (GSHP) enables this heat to be captured in wintertime and transferred into your house to warm it. As an option, the heat can also be used to heat your hot water, either completely (60ºC) or partially (eg, 45ºC). As we saw last month, it is likely that the overall Coefficient of Performance (COP) of a GSHP system will be between 3 and 4, ie, the heat output will be 3 to 4 times greater than the electrical input.

In effect, a heat pump acts as a boiler – a very expensive boiler. But compared to a gas boiler, there are many benefits: lower running costs, lower carbon emissions, no maintenance, and an expectation of many years of trouble-free operation. Once installed, GSHP systems are fairly unobtrusive, both visually and acoustically. They have a long life expectancy: about 25 years for the pump, and about 50 years for the underground pipes. It's a case of fit and forget.

Ground temperatures

Many sellers of GSHP's include in their publicity something like this:

> "*The temperature of the ground one or two metres below the surface remains the same throughout the year, 8ºC – 12ºC.*" – Stroma LZC.

The statement is not strictly true, and even if it were true, it would be misleading. At a metre or two below the surface, the temperature of the ground varies. It is warmest near the end of summer (eg, 12ºC), and coldest near the end of winter (eg, 8ºC).

But the statement more seriously misleads by implying that the temperature of the ground remains the same even if a heat pump is installed. With a pump extracting heat from it, the ground gets colder, and if the ground collector is undersized, the ground around the pipes may even freeze. The colder the ground, the lower the COP of the pump.

Nonetheless, in wintertime the average ground temperature is substantially higher than the average air temperature. Over most of the heating season, a GSHP operates with a smaller temperature lift than an Air Source Heat Pump, and has a higher efficiency.

Collecting the heat

Heat from the ground is collected by circulating cold liquid through underground pipes.

Two methods are in use:

- *Indirect collection*
  This is the usual method – the ground collector is independent of the heat pump.
  The collector consists of one or more loops of plastic pipe, through which cold 'brine' is pumped to absorb heat from the ground. The heat collected by the brine is transferred to the refrigerant in the heat pump via coils around the evaporator.
  The pipe is usually polyethylene, 20 mm – 40 mm diameter. The so-called

brine consists of water with enough antifreeze (eg, propylene glycol) to prevent freezing down to –10ºC. (Though the temperature of the ground should remain above zero, the temperature inside the evaporator may be below zero.)

- *Direct collection, DX*
  The ground loop itself forms the evaporator of the heat pump. The refrigerant expands directly into it, giving rise to the terminology, ‘DX system’ (Direct eXpansion).
  The ground loop is usually made of 15 mm copper pipe. Heat from the ground is transferred directly into the refrigerant, which is forced around the collector by the heat pump’s compressor – no separate circulation pump is required.
  Since the loop contains refrigerant, installers need to be suitably F-gas certified.

F-gas certification and DX systems

Nowadays, most refrigerants are fluorinated gases with no ozone depletion potential. But if they escape into the atmosphere they do have a big global warming potential. Recently it has become necessary for installers using these refrigerants to be certified.

A DX system is said to be more efficient than one with indirect collection, perhaps by about 20%. Because of the extra efficiency, the ground loop(s) can be shorter – so trenches can be shorter, too.

A DX system is most viable for small heat pumps.

Subsurface collectors

No matter whether direct or indirect collection is being used, a large area of ground is required for a ‘horizontal’ collector, or, as I am calling it, a ‘subsurface’ collector. If space is restricted, a costlier alternative is a ‘vertical’ or ‘borehole’ collector.

Extensive trenches have to be dug, typically 1.2 metre wide, and one to two metres deep, preferably in unshaded ground. (In a selfbuild situation, the ground is likely to be a ‘building site’ rather than a ‘garden’, and so excavations are more acceptable.)

The pipe is either laid in straight lengths, with parallel pipes at the bottom of a trench separated by at least 30 cm, or in a multitude of continuous loops, called ‘slinkies’. The pipe is embedded in sand for better thermal contact with the ground and for protection from stones. Joints below ground are best avoided, but if this is not possible joints should be fusion welded.

Usually more than one ground loop is required, and the loops have their ends connected to a pair of manifolds to split/combine the flow of brine. (Each manifold has an extra outlet to allow the pipes to be filled with brine and then purged of air. The manifolds are often fixed to an outside wall of the house.)

One advantage of slinkies is that the trenches (1.2 m wide) are shorter. Another is that, in suitable ground, the slinkies can be installed vertically in narrow trenches, typically 30 cm wide and 2m deep – this results in less spoil. Their disadvantage is that the overall length of pipe is greater. So, unless the pipe diameter is increased, more energy is required for the circulation pump. (The use of slinkies is controversial. Shorter trenches imply that the collector has access to a smaller store of heat.)

Slinky coils laid horizontally in trench

The length of pipe required depends upon the rate at which the pipe can absorb heat from the ground, and this depends on the nature of the surrounding ground – its conductivity, etc. For example, wet ground has a higher conductivity than dry ground. (Another benefit of wet ground is that heavy rainfall can help to thermally recharge the ground around the pipes.)

You can get an idea of what the subsoil and its temperature might be like for your site by downloading a report from the British Geological Survey – see below. Or you can get an excavator to dig one or more trial pits. (Indeed, you might have had trial pits dug, anyway, in order to know what foundations would be required for your house.)

Heat can be collected with a straight pipe at a rate of about 15 – 20 watts per metre of pipe. From a trench containing a slinky and a straight return pipe, heat can be collected at a rate of about 85 watts per metre of trench.

Borehole collectors

On a cramped site, or where it is undesirable to uproot an existing garden, boreholes can be used rather than trenches. The boreholes are usually 10 cm – 15 cm diameter, and vary from 15m to 150m deep. They must be well separated, at least 6 metres apart. One, or possibly two, loops are placed in each borehole – a loop consisting of two vertical pipes connected by a U bend at the bottom. The borehole is then filled from the bottom upwards with a thermal grout. (The grout aids conductivity, and prevents disturbance of any groundwater.)

Ground temperature increases a little with depth, and at 100m the ground might be 2ºC warmer than the average at the surface. A 100m borehole can supply heat at the rate of 3 kW to 4 kW, approximately.

Costing and sizing a GSHP system

According to the Ground Source Heat Pump Association the installed cost is about £1,000 per kW.

A guide by the Energy Saving Trust (EST – see Further Info) gives more sophisticated costings:

	Cost (£/kW)		
	Ground coil	Heat pump	**Total system**
Horizontal collector	250 – 400	350 – 750	600 – 1150
Vertical collector	550 – 750	300 – 750	850 – 1500

Installed costs of GSHP systems

As mentioned previously, the use of slinkies or a DX system results in shorter trenches, with reduced excavation costs.

It is important to size the system correctly, both the ground collector and the heat pump. Often the collector is sized to meet peak demand, and then usually the collector can also meet the cumulative demand over the whole heating period. (The ground around the pipes can be looked upon as a battery storing heat. Can it supply enough power (kW) at any moment, and does it have sufficient capacity (kWh) to last the whole heating season?)

The thermal capacity of a cubic metre of soil is roughly about 0.5 kWh per ºC. This is small when considering the total heat required over a winter, and shows why long trenches are necessary.

If the pump and collector are oversized, the excess capital cost which is wasted is considerable. If undersized, lower COP's result, and supplementary heating will be required.

Estimating your space heating requirements can nowadays be done fairly accurately. To have gained building regulations approval for your selfbuild, a SAP worksheet would have had to be calculated. Amongst other figures, the worksheet gives the theoretical Heat Loss Coefficient for your house. If the lowest outside temperature is taken to be –3ºC, and the required temperature inside is 20ºC, then multiplying the Heat Loss Coefficient by 23 gives the peak demand for space heating. This figure forms a good basis for assessing the size of the heat pump to be fitted. But if the heat pump is also to heat Domestic Hot Water, the pump may have to be larger. A rule of thumb is to increase the pump size by 0.25 kW per occupant. The ground collector should be larger, too.

However, there is another school of thought, and that is that the system should be deliberately undersized, with reliance placed on supplementary heating in very cold weather. According to the EST guide, if the heat pump system is undersized by 40% (relative to the peak heat demand), then the heat pump will deliver about 90% of the required heat overall, leaving only 10% to be supplied by supplementary heating. Under-sizing by 40% obviously reduces the capital cost considerably. So even if the supplementary heating were to be direct electrical heating, this strategy could well make financial sense, especially if any supplementary electricity were off-peak.

The carbon analysis depends on the nature of the supplementary heating. Using direct electrical heating would appreciably increase carbon emissions. In contrast, a wood stove would appreciably decrease the emissions.

But be wary of under-sizing the ground collector. This can have two adverse effects:

- The brine is not warmed up sufficiently in its circuit round the collector, so the COP of the heat pump is reduced.

- Towards the end of the heating season, the ground around the pipes becomes excessively cold, even frozen, and again the COP is reduced.
  Freezing of the ground might have an unfortunate long term effect. After thawing, the soil might leave an air gap around the pipes. Heat transmission would be reduced, and the efficiency of the system could progressively worsen from year to year. Rectification is rarely possible.

Practicalities

The heat pump itself is usually placed in the utility room or garage. The compressor is acoustically insulated, but nonetheless there will be a little noise when the pump is working, comparable to that from a chest freezer. Heat pumps are heavy – approximately, 80 kg to 200 kg.

New builds will have a small heat requirement, well below the 15 kW limit at which a three-phase electricity supply becomes necessary.

GeoReports

One of the GeoReports that can be downloaded from the website of the British Geological Survey (BGS) is the '*Ground Source Heat Pump Report*' (£53). Mostly for the expert, the report has information about local geology, conductivity of the ground, and groundwater. It also has information about temperatures.

The BGS website gives a sample report for the site of their HQ, located outside Nottingham. The average air temperature varies from 1ºC in January to 18ºC in July, with the average over the year being 10ºC. (These averages include overnight temperatures, of course.)

The average soil temperature over a year is 11ºC, but at a depth of 2m it swings from 7ºC to 14ºC. At a depth of 100m, the temperature is estimated to be a steady 14ºC.

FURTHER INFO:

Domestic Ground Source Heat Pumps
– Design and installation of closed-loop systems.
Published by Energy Saving Trust. Free download from:
www.energysavingtrust.org.uk.

Ground Source Heat Pump Association
www.gshp.org.uk.

British Geological Survey
www.bgs.ac.uk.

Kensa Engineering
UK manufacturer. Free downloads of lots of useful info:
www.kensaengineering.com.

Danfoss
www.ecoheatpumps.co.uk.

Nibe Energy Systems
Leading Swedish manufacturer. New GSHP's: F1145 and F1245.
www.nibe.co.uk.

Ochsner
Austrian manufacturer. Includes DX models.
www.ochsner.co.uk.

Dimplex
German-made heat pumps.
www.dimplex.co.uk.

Ice Energy
'The technical bit' on their website has a moving diagram of a heat pump.
www.iceenergy.co.uk.

Nu-Heat Underfloor & Renewables
Specialist design and supply company – UFH, heat pumps and solar.
www.nu-heat.co.uk.

Magpie Drilling
Borehole drillers.
www.magpiedrilling.co.uk.

Lankelma
'Push-in' vertical ground loops without drilling.
www.lankelma.com.

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