An idiot's guide to ground source heat pumps

Contributed by James

Ahh, warmth...we all want it. Here's a way of getting some.

Worldwide, more heating energy is produced this way than electricity is produced via solar photo-voltaic panels and wind power put together.

In Sweden, 90% of new homes are heated with ground source heating.

In 2002, approximately 41,000 heat pumps were installed across Europe, of which the UK installed 150. We're very slow at developing this technology. But things are changing fast.

What is it?

The simplest way of describing a heat pump is to use it's most common form: the fridge. A fridge takes heat from the air inside your fridge and discharges that heat out of the back. If you feel the grille at the back of the fridge you'll notice it's warm.

The process works because as a material is compressed, the amount of energy that it can hold is reduced, so energy is pushed out of the pressurised material. Imagine pumping up a bicycle tyre - you start with air at ambient temperature, and as you pump it into the tyre the valve gets really hot.

Likewise, if you let something depressurise, it cools down, like a camping gas cylinder when you take the burner off the top.

Inside your fridge, you have a big white plate. This is full of a volatile liquid at roughly normal (atmospheric) pressure. At the top of this plate is a copper tube which passes out of the top of the fridge, down the back, and into a big black cylinder at the base, this is the "heat pump". The pump compresses the liquid. As the liquid compresses, it can't hold as much energy, so it gives it off in the form of heat. The heat is dispersed via the large black grille at the back of the fridge (be careful when touching it, they’re really hot!!).

The newly compressed liquid is pushed back into the plate on the inside of your fridge via a very narrow pipe. When it exits this pipe, it expands. As it expands, it can absorb energy again, so it takes heat from the air inside the fridge and in so doing it cools the fridge down. The liquid returns to a normal pressure again, rises to the top of the plate and exits to be re-pressurised. And so it continues….

Fridges aren’t the most efficient things in your kitchen…in fact if you’ve got an old fridge like mine, its probably using more electricity than anything else in your entire house (apart from my old freezer sitting next to it!). But this inefficiency can be turned on its head if you utilise the heat, not the cold.

Now lets relate this to ground source heat. Instead of the air inside you fridge, you're taking energy from the ground, instead of the little compressor you’ve got a big compressor and instead of grilles at the back of the fridge you’ve got central heating. That’s it, really.

How much space do I need to get the energy I need?

From the above principles, many variants have evolved.

The two most common sources of energy for this technology are groundwater or rock. Across the UK, These vary in average temperature between 9- 11 centigrade, with an annual fluctuation at any location of only a degree or two. The smaller the fluctuation, the more you can fine-tune your system to a specific set of working parameters. To access groundwater or rock, you need at least one borehole

You can drill two boreholes and take water from one, pass it through you heat pump and re-inject to the other. This is called an OPEN LOOP system. The advantage with open loops is that the coolled water is put back into a different place from were the energy is taken out, so in theory, there’ll never be a ‘short circuit’ (see later)

Or you can drill just one borehole and put a heat exchanger down this single borehole. This is called a CLOSED LOOP system. Normally, the borehole is filled in with special material to encourage high thermal conductivity. The advantage of this system is that its cheaper, and even though its not as efficient when it comes to large buildings like hospitals, its great for small buildings like houses.

If boreholes are too expensive (they'll set you back at least a few thousand pounds each) and if you've got plenty of space (a paddock, for example) you could run an overlapping coil of PVC water pipe in rows approximately 1.5 –2 m below ground. At this depth, the annual fluctuation is minimal, so again the system can be optimised. This method is called a 'slinky' because it looks like a flattened spring. Water is passed through the pipes, effectively using the paddock as a massive solar collector, with the PVC pipes acting as a heat exchanger.

A slinky coil laid out close to surface

Other methods include dropping coils of PVC pipes into lakes (the Queen's favourite!) using atmospheric air (prone to variations in temperature), dropping slinkys vertically into deep trenches, using mine water discharges, building coils into pile foundations, or even linking the system to solar water heating panels. The list is almost endless. I'm going to concentrate on "traditional" ground source heating (GSH) for two reasons- I don't know much about the other types, and traditional GSH is now a tried and tested technology that can be trusted.

How much energy will I get and what are the costs?

Per metre of excavation, the energy you get from a borehole is very consistent and isnt dependant on rock type, water level or whether its closed or open loop. The energy you get is between 60 and 100 watts per drilled metre. The lower value will be for dry, loose rock and the higher value is for wet dense rock. Given that most domestic properties have a heating requirement of between 4.5-7 kilowatts, this equates to a borehole of between 50 and 100m, depending on conditions. If you choose to have an open loop (very unlikely for a small system), you would need two such boreholes.

Some indicative scheme costs:

House, Cornwall: Closed loop system, one borehole to 70m, 4kW output £5000

Bungalow, Nottinghamshire, closed loop system, one borehole to 68m, 6 kW output £6,000

Office block (location?), closed loop, 12 boreholes each to 48 metres, 60 kW output £38,000

Church, open loop, two boreholes unknown depth, 350 kW output, £140,000

For a small domestic system, a closed loop system can be installed for around £5-6000.

Is it environmentally beneficial?

Well, yes and no. You still need to put electricity into the system to get it to work. Normally, the amount of electricity you put in is a quarter of the energy you get out in terms of heat. This is called the coefficient of performance (COP), a heat pump often has a COP of 4. Under the former clear skies grant government grant scheme, heat pumps were required to have a COP of greater than 3.7 to be eligible for government grant.

In 2005, the Building Regulations published a standard assessment procedure for different forms of domestic central heating.
Please note that although recent, these figures pre-date the recent rapid increases in domestic oil and gas prices. Some figures:

Mains gas (in an modern efficient combi boiler) cost per kWh 1.63p, produces 0.194 kg CO2 per kWh

Bottled LPG cost per kWh 4.32, produces 0.234 kg CO2 per kWh

Heating oil cost per kWh 2.17p, produces 0.265 kg CO2 per kWh

Coal cost per kWh 1.91p, produces 0.291 kg CO2 per kWh

Electricity cost per kWh 7.12p, produces 0.422 kg CO2 per kWh

Ground source heat pumps cost per kWh 1.7p, produces 0.106 kg CO2 per kWh

So before the recent rapid increase in gas prices, GSH came in around the same price as gas per unit of heating, but much less carbon is used in producing that energy. Electricity is extremely costly and wasteful due to the loss of charge within the national grid, most electricity that's produced disappears before it ever gets close to your domestic system.

Often, people ask if a wind turbine could be used to provide the electricity. In theory, yes it could, but in reality, the start up power needed is a surge of around 4.5-6 kilowatts for a household unit. That's one heck of a large charge for a small domestic turbine, often rated at high hundreds or low thousands of watts. So you'd either need lots of batteries or still be attached to the mains. For this reason, connected wind turbines are the perfect compromise, because after initial power up of the heat pump, the energy requirement greatly reduces.

A domestic ground source heat pump installation-the stuff above ground looks very dull.

What are the problems and drawbacks?

The technology is best installed during construction. You can retro-fit to an existing building, but it's more expensive and your choices are limited.

This is primarily because of the level of heat this system can produce. Its not actually a very great increase in temperature. So whereas your existing radiators may run at 60 centigrade, this system will probably only run at 40 centigrade. This means you can't power your existing central heating radiators on it. GSH works well by warming a large area by a few degrees, unlike traditional radiators that warm a small area by many degrees. So the most efficient methods heating with GSH are under floor heating or large panel radiators, both of which are cheaper to install during construction.

In North America, they like having warm air central heating instead of radiators. I suppose it's so they can use the same system to pass cold air through during summer months. This system is easier to retro fit to an existing building, but it also runs slightly less efficiently.

A word of warning of the Coefficient of Performance (CoP) numbers- many companies are springing up at present and the market is increasing rapidly. The supplier who claims the highest CoP is more likely to make the sale. Some American companies are now advertising CoPs of around 6. However, it is very hard to corroborate CoP figures for GSH. Although the Clear Skies scheme required a CoP of 3.7, to the best of my knowledge the figures supplied by the manufacturers have never been checked or tested. Scandanavian companies have a long track record and are likely to have an accurate feel for the true CoP of their equipment. They are less likely to be interested in over-blowing their claims, because their markets are so large in their home countries.

The systems need to be designed well. At present, there are a number of companies who can do it well, but there are many new companies jumping on the band wagon. The consequences could be very expensive.

One such consequence is short circuiting of the system. This is were cold water being discharged back to the aquifer starts being taken up by the abstraction instead of ambient temperature water. The result is a reduction in efficiency, and a downward spiral in temperatures eventually resulting in freezing of the ground, and damage to your equipment. This is overcome in open loop systems by ensuring the discharge borehole is down gradient of the abstraction borehole. In closed loop systems, its overcome by ensuring that pumping is undertaken at low rates to allow cooling to disperse and the ground temperature to equilibriate (this is why closed loops are more suited to small heating schemes)

Although you will not need a water abstraction licence, you (or your designer/ agent) are strongly advised to contact the Environment Agency at an early point. You can use the general contact number from the Environment Agency’s web site, tell them which river catchment
you live in, and ask to speak to the groundwater officer for that area. They will be pleased to help, and are a good starting point for ground conditions. They are also likely to give you some recommendations regarding drilling a borehole, whether you're drilling into a major aquifer or a zone protected for a public water supply, for example. Remember, it's your taxes that pay for them so don’t be afraid to use them…Unfortunately, they can't recommend companies.

The Environment Agency are at present drawing up guidance regarding the implementation of ground source heat pump schemes. At the time of writing, (late summer 2006), there is no national policy on the management of these projects.

A last word, throughout this note, I’ve assumed that most people in the UK will be interested in this technology for heating. The same system can be also used for cooling but this is very, very much less efficient than heating.

The images in this article are from:

Running on Empty News Group

http://groups.yahoo.com/group/RunningOnEmpty2/

and Navitron

http://www.navitron.org.uk/heatpumps.htm

Link to Environment Agency home page :

http://www.environment-agency.gov.uk/

Association Of Environmentally Conscious Builders is a useful site:
http://www.aecb.net