Ground-source heat pumps—more than hot air?

Chris Begert looks at an old technology with a potentially big future in heating and cooling buildings in Australia

With the world heating up, the demand for energy efficient air-conditioning systems continues to climb. Relatively unknown in Australia, ground-source heat pumps are one way to reduce the amount of energy used in cooling and heating while still maintaining a comfortable home. US president George Bush uses such a system to cool down his ranch during the hot and dry days in the desert, while making it warm and cosy when the sun goes down. So, what are heat pumps and are they any good?

Heat pumps are not a new technology and most households already have one—the fridge. The pipes at the back are hot compared to the inside of the fridge, as these pipes emit heat removed from inside. Usually heat moves from the hotter area to the cooler area but a heat pump reverses this direction. This feature is also used in refrigerative air-conditioners.

Photo: GeoConnections

The new East Melbourne library uses a ground-source heat pump.

How they work?

Refrigerative air-conditioners are so-called 'air-to-air' heat pumps. In summer they move heat from the air inside the building to the outside (or vice versa in winter). From an environmental perspective they perform reasonably in particular conditions. The heat pump's effectiveness is dependent on a number of factors including the insulation of the building, the zoning of the interior and the building's location.

To understand how a heat pump works it is important to keep in mind that heat and temperature are related but not the same. The same amount of heat can lead to different temperatures depending on how 'densely' the heat units are packed. The higher the density of heat units, the higher the temperature will be. So even when it is freezing in winter the air still contains heat.

An electrically driven heat pump consists of a fluid which is pumped around in pipes, (the cold ones are called the evaporator, the hot ones the condenser) as well as a compressor and an expansion valve. When the fluid is within the evaporator it is colder than its surroundings and collects heat. The following example should help to understand what a heat pump is doing.

Imagine there are 50 heat units to be moved from one area to another and there is a soccer ball storing 100 heat units. When the size of the ball is decreased to the size of a marble (by applying pressure) the temperature inside the ball will increase since the same amount of heat units have to share a much smaller space. If the ball is then placed into an area colder than the ball, it will adjust its temperature to the ambient temperature by releasing some of the heat units. This heats up the surroundings and cools down the ball. Once half of the units have escaped the ball, its size is increased again and the temperature of the ball will drop because only 50 heat units now share the original volume.

If the ball is then placed back into a hotter area, the ball's temperature adjusts to the ambient temperature by collecting heat units. The surroundings are thus cooled by the ball while the ball is heated. When it is back to storing 100 heat units, the process starts again.

So much for the theory, but how can

this be used? Easily! The cold pipes are used for cooling while the hot pipes can be used for heating. This is how a heat pump can do both heating and cooling.

Conventional air-conditioners exchange heat between the outside air and the building. However, the outside temperature varies significantly over each day and over the year, which leads to reduced efficiency.

However, ground-source heat pumps transfer heat between the house and the ground. They make use of the fact that the temperature some metres below the surface is fairly constant over the whole year, varying between 10°C and 15°C. On a very hot day when the outside temperature is 40°C and the desired room temperature is 22°C, the reverse-cycle air-conditioner needs to provide at least an 18°C temperature difference between the condenser and the evaporator, while the ground-source heat pump only needs to provide a temperature difference of 7°C. This is easier to achieve and less energy is required.

Setting up a system

Setting up a ground-source heat pump takes a bit of work because pipes have to be buried underground. When choosing horizontal systems, the pipes are laid up to 1.8 metres deep and a large area of ground is required. The other option is to drill several holes straight down to a depth of at least 80 metres. This is the most expensive method but uses only a comparatively small area. If there is some sort of water body available, such as a dam, pond, river or the ocean, this can also be used, but the pipes have to be covered by at least three metres of water.

The performance of heat pumps (both air-conditioners and ground-source heat pumps) is measured by the coefficient of performance (COP). This is the ratio of the energy of the heat being moved to the electricity consumed. A modern reverse-cycle air-conditioner has a COP of three or so (which means that 1kWh of electricity moves 3kWh of heat) while ground-source heat pumps can achieve COPs of more than six. Well, this sounds all very tempting, so let's go and get one!

A good idea, but there are some problems. First of all there are not too many distributors of ground-source heat pumps in Australia. Unlike in other countries, especially Sweden, the ground-source heat pump is underdeveloped here. Not only are there a lack of government policies and subsidies to promote their development, but not many people have heard about the technology, therefore the demand for ground-source heat pumps is low.

Also, most systems that are currently available are too big for houses in built-up areas, especially when the residents have already tried their best to reduce their air-conditioning requirements by using exterior blinds, cross ventilation and other energy-efficiency measures.

However, the currently available ground-source heat pumps would suit an apartment complex, the shared use of more than one house, or could be applied in a commercial or industrial environment quite well.

The most critical point at the moment is the price to set them up. They are expensive and can be considered to be the Porsche of the air-conditioner world. Good technology has its price—they cost about four times what a conventional system would cost.

There are currently some excellent ground-source heat pump options available, but when used for small-scale applications such as pool heating, air-conditioning for single households and hot water services, they are not really price competitive compared to conventional systems or solar water heaters at the moment. But let's see what the future brings.

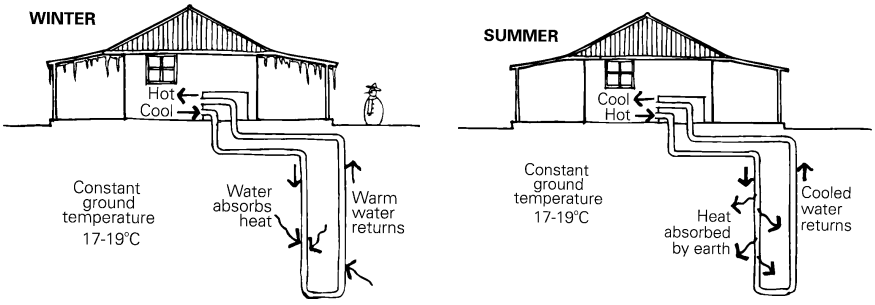

Image: Your Home Technical Manual

Ground-source heat pump quick facts

- They can deliver hot water and provide comfortable temperatures at home during the whole year by exchanging heat between the building and the ground
- They use about half the electricity of conventional air-conditioners, which also means half the greenhouse gas emissions
- They can be more expensive to set up but save money over their lifetime because of lower energy use
- The systems currently available are best suited for district heating and cooling, apartment blocks and commercial and industrial applications.

For more information

Geoexchange
www.geoexchange.com.au

GeoConnections
www.geoconnections.com.au

FHP Manufacturing
www.fhp-mfg.com

IEA Heat Pump Centre
www.heatpumpcentre.org

RETscreen
www.retscreen.net

For more information on ground-source heat pumps, see the extended article on the ATA website at www.ata.org.au