GEOTHERMAL ENERGY USING GROUND SOURCE HEAT PUMPS

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ABSTRACT

Geothermal energy can mean many things to different people. A common view of this energy is that which is found in seismic regions where hot water and steam rise to the ground surface and can be harnessed for everyday use. Where this energy does not occur, boreholes can be extended downwards to obtain water at increased temperatures for use in a range of heating applications. If the conditions are appropriate, it is also possible to drill boreholes to several kilometres below the surface to extract water hot enough to produce electricity using turbines at the surface.

However, there is another form of geothermal energy which makes use of the ground at normal temperatures within a few tens of metres of the surface as a heat source and sink to heat and cool buildings. The key element of this technology is the ground source heat pump or GSHP. In winter, the GSHP extracts heat from water circulating in ground loops and delivers it to a building. In summer, the reverse happens with the GSHP extracting excess heat from the building and dumping it to the ground. While direct geothermal energy is extensively used in other countries, it is rarely encountered in Australia and New Zealand. It is highly likely, however, that for a range of reasons, this is going to change dramatically in the not too distant future.

This paper presents an overview of the principles of the technology and the various factors which influence the capital and operating costs of these systems. Consideration will be given to common design methods and why it is important that more research and development needs to be directed at the performance of ground loop systems, particularly for conditions encountered locally.

1. BASIC PRINCIPLES

Below a depth of around 5 to 8 metres below the surface, the ground displays a temperature which is a degree or two above the weighted mean annual air temperature at that particular location. In Melbourne, the ground temperature at this depth is around 18°C with temperatures at shallower depths varying according the season. Further north, these constant temperatures increase a little while for more southern latitudes, the temperatures are a few degrees cooler. Figure 1 shows these variations for a test site at the University of Melbourne.

Direct geothermal energy uses the ground and its temperatures to depths of a few tens of metres as a heat source in winter and a heat sink in summer for heating and cooling buildings. Fluid (usually water) is circulated through a ground heat exchanger (or GHE, which comprises pipes built into building foundations, or in specifically drilled boreholes or trenches), and back to the surface. In heating mode, heat contained in the circulating fluid is extracted by a ground source heat pump (GSHP) and used to heat the building. The cooled fluid is reinjected into the ground loops to heat up again to complete the cycle. In cooling mode, the system is reversed with heat taken out of the building transferred to the fluid which is injected underground to dump the extra heat to the ground. The cooled fluid then returns to the heat pump to receive more heat from the building. Figure 2 shows a schematic view of a reversible system in which the ground loops of the GHE are installed in a borehole and are connected to the structure's conventional heating and cooling distribution system via a GSHP. Note that these drawings are not to scale and the borehole would only be around 75 to 150mm in diameter.

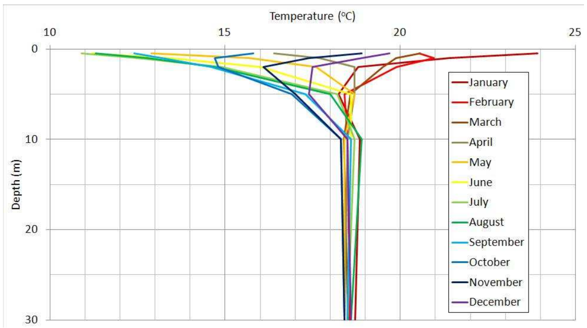

Figure 1: Variation of ground temperature with depth for University of Melbourne during 2011

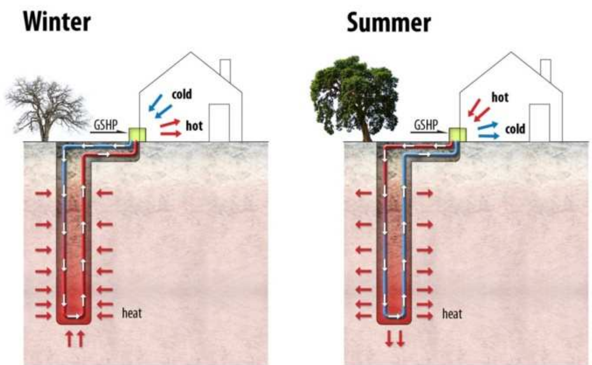

Figure 2: Schematic view of a direct heating and cooling system (borehole not to scale).

According to the CSIRO, energy use in buildings accounts for 26% of Australia's greenhouse gas emissions and heating and cooling accounts for over half of this. Introduction of direct geothermal heating and cooling to Australia and New Zealand on even a moderate scale would have a significant impact on power requirements with enormous economic and environmental benefits.

The key to this is that for each kilowatt of electrical energy put into a direct geothermal system, about 4 kilowatts of energy is developed for the purposes of heating and cooling. This means that outside the capital costs of the installation, 75% of the power is free. Furthermore, as much of the electrical power in Victoria is generated with brown coal, replacing 75% of the energy used with a clean renewable energy source, the greenhouse gas emissions are reduced to as little as about 25% of what occurs with current practice. Clearly, these are crude assessments of what is possible and other fuel sources must be taken into account. However, the figures do indicate some of the significant economic and environmental benefits that can be achieved.

While the capital costs of installation of a direct geothermal system are still a little high, with industry becoming better geared to needs, and with better systems of design and installation, costs should fall rapidly over the next few years. This, combined with the likely major increase in costs of conventionally derived energy, will mean that capital costs can be recovered in a few short years.

2. KEY ELEMENTS OF A DIRECT GEOTHERMAL SYSTEM

2.1 General

There are three main components of a direct geothermal system and each of these requires careful consideration when a system is being designed. These components are:

- the ground heat exchanger (GHE) system or the ground loops that are placed in the ground for the selected fluid to pass through to extract or dump heat,
- the ground source heat pump or pumps, and
- the building to be heated or cooled; its system of heating and cooling distribution as well as its heating and cooling demand.

2.1 Ground Heat Exchanger

There are two basic types of GHE; closed loops and open loops. A closed loop system comprises pipes placed in the ground through which a fluid passes and the heat exchange occurs by conduction through the walls of the pipes. Therefore, the fluid remains sealed in the pipes and does not come into contact with the ground. There are several advantages to this system. One of the main advantages is that there is no extraction of water from the ground and therefore no need to obtain extractive licensing. A second important advantage is that there is no problem of contamination either from the loop water entering the ground, or perhaps more critically, from the ground water contaminating the workings of the pumps.

An open loop system involves water being removed from the ground and returned after heat is extracted or added. Clearly, considerable care must be directed at the location of the return system so that the discharge water does not affect the intake temperatures. One of the major advantages of these systems is that relatively large volumes of water can be handled leading to large quantities of heat exchange. However, as suggested above, there can be significant environmental consequences with the temperature of the return water.

For closed loop systems, the GHE can be located horizontally or vertically (or indeed at any convenient angle in between). Vertical systems can be installed in purpose built boreholes as shown in Figure 3 or in elements of foundations as shown in Figures 4 and 5.

Figure 3: Double ground loops in a borehole with a grout pipe.

Figure 4: Ground loops in a reinforcing cage of a large diameter pile before installation (Enercret, Vienna).

Figure 5: Ground loops in the reinforcing cage of a diaphragm wall during installation.

Purpose drilled boreholes tend to be used with residential buildings whereas the inclusion of pipes in foundation elements tend to be the general approach with the larger commercial and industrial buildings.

Where there is adequate space under, in or around a building, horizontal loops can represent an economic alternative. Although these systems are not as efficient as vertical systems principally because they are closer to the surface and therefore located in the ground where temperatures are cooler in winter and warmer in summer (see Figure 1), shallow excavations tend to be cheaper and the cost of the extra piping is not normally excessive. Figure 6 shows a horizontal system recently installed for a large residential building on the Mornington Peninsula near Melbourne and Figure 7 shows a horizontal system to be placed in the platform of an underground railway station in Vienna.

Figure 6: Large horizontal "slinky" ground loop installation before backfilling

Figure 7: Horizontal ground loops in a mass concrete underground railway platform (Enercret, Vienna).

It would be reasonable to observe that wherever there is contact with the ground, in whatever form, it may be possible to make use of this contact to produce a system for heating and cooling buildings. So it is not only a case of making use of this contact in foundations, it could also involve tunnel linings, retaining walls, service trenches, road and other embankments and quarry backfills. Where there is an adequately sized body of water in the form of a dam, a lake or indeed a large water tank, loops installed in the water could provide a significant source or sink for heating and cooling.

Before leaving this general overview of GHEs, it may be worth considering the relative merits of the two main GHE systems that are encountered in Australia and New Zealand. One of these involves the use of HDPE pipes through which water is used and the other involves the use of copper pipes through which a refrigerant is used. It is tempting to believe that because copper is a very much better heat conductor than HDPE, the copper/refrigerant system must be better. However, it is the ground conductivity (which is not greatly different from the conductivity of HDPE) and its dominant mass surrounding the GHEs which control performance with the copper having almost no influence. This has been demonstrated experimentally (Colls) and numerically (Bidermaghz). Therefore, when considering the cost of the copper loops, the severe restrictions that must be placed on the length of the copper loops to ensure the refrigerant functions properly, the likelihood of corrosion of the copper, the risks of leakage of refrigerant, and the inability of these systems to act passively, this author is very much in favour of the HDPE/water systems. This seems to be the general case elsewhere in the world where HDPE/water systems are by a very long way the most preferred system.

2.2 Ground Source Heat Pumps

The technology associated with GSHPs is comparatively well advanced with a large number of sizes and types currently available, although regrettably, not manufactured locally.

The principle of a heat pump is illustrated in Figure 8. Water containing heat from the ground loops arrives at the first heat exchanger of the heat pump where it comes into indirect contact with a cooler liquid refrigerant. Heat passes from the hotter water to the cooler refrigerant causing the refrigerant to evaporate. The gaseous refrigerant then passes into a compressor where the gas is compressed to significantly increase not only its pressure but also its temperature. The hot gas then passes through the second heat exchanger where cooler water or air from the building comes into indirect contact with the refrigerant and heats up. As a result of the removal of heat from the refrigerant, it condenses back to a liquid at a relatively high temperature. When this liquid then passes through an expansion valve, the temperature drops considerably ready to accept more heat from the water arriving from the ground loops. In cooling mode, the heat pump simply operates in reverse with heat from the building being transferred to the water of the ground loops and then being dumped to the ground.

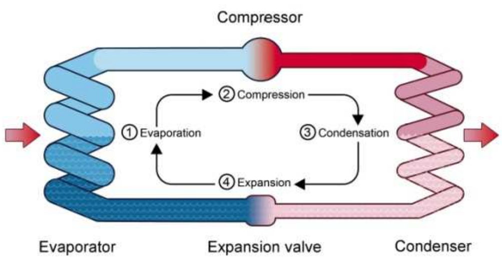

Figure 8: The operation of a heat pump.

The size of an individual heat pump will vary in size depending on capacity but typically for a residential application, a heat pump would be the size of a bar fridge.

2.3 The Building

Clearly, the building which is to be heated and cooled is a critical part of any direct geothermal system not only in terms of the distribution system selected for the building but also in terms of its heating and cooling demand. The distribution system used can take a number of forms but the most common make use of either water or air as the transfer medium. Water gives hydronic heating in the floor slab, through radiators or through fan coil units mounted at appropriate locations about the building and air is usually delivered through ducts located in the floor. These distribution systems are the same as conventional systems and details of these may be found in standard heating, ventilation and air-conditioning (HVAC) references.

The heating and cooling demand of a building can also be determined by well establish procedures found in the literature and this will be a function of many factors including the climate, construction forms and materials of the building itself, the effects of sun and shade, ventilation, lights and appliances, people present and their activity and building use and purpose.

3.0 METHODS OF DESIGN

3.1 Heating and cooling loads

The starting point of any design is determining the heating and cooling demand for the building. There are a number of methods by which this can be achieved ranging from rules of thumb, through simple manual methods to the more complex software packages that can be purchased from many sources. Rules of thumb are usually related to the local climatic conditions and often take the form of a number of watts per square metre of building floor area required for heating and cooling. For example, in Melbourne, typical rules of thumb for residential peak heating and cooling loads are 75 and 100 watts/m^2 respectively. This suggests that for a house of about 200m^2 floor area, the peak loads will be about 15 and 20kW respectively. As these numbers suggest, for Melbourne, the highest demand on HVAC systems is the cooling demand at the height of summer. For cooler climates, such as would be encountered in northern Europe and Canada, it is the heating demand which dominates.

For commercial and industrial buildings, rules of thumb become even less reliable than for residential buildings. This is because of the many diverse activities which may be taking place in such a building. It is not just the people present who have a big influence on the heat generated, the influence of the processes, the machinery, the lighting and the ventilation can be very large as well.

A more reliable approach to the determination of peak loads for any given building is through the various types of software that are currently available. These include programs such as HAP, DesignBuilder, TRNSYS and System Analyzer.

The above loads have been expressed in terms of the peak power required for the worst case of heating and/or cooling. For conventional systems, this is generally sufficient as this defines the capacity of the machinery required to satisfy the worst design heating and cooling demand. The energy (power x time), although very important with regard to the operatonal cost, has no real influence on the capital costs of a conventional system. For geothermal systems however, while power also has an important influence on the capital costs of installation, the energy used is important not only with regard to operatiopnal costs but can also significantly influence the capital costs of installation. This will be discussed in more detail later.

3.2 Heat pump selection

There are a number of factors which will influence the selection of a GSHP. The main factor is the capacity of the pump for the heating and cooling loads estimated for the building. Then there are a number of factors which have to be considered in order to obtain the system most suited for a given application. These may include:

- The entering water temperature to the GSHP which in turn controls the leaving temperature. This latter temperature is the lowest at design heating conditions and will determine if antifreeze is needed in the ground loops.
- The entering water temperature for a given GSHP will also control the power input required as well as the heating/cooling delivered and therefore determine the Coefficient of Performance (CoP) or efficiency of the GSHP.
- The flow rate of the water in the ground loops which will determine the pipe sizes to be used as well as making sure that the water flowing in the loops is in the turbulent regime.
- The airflow characteristics for a ducted air system or the water flow characteristics of a hydronic system.

There are many other factors which may need to be considered but their discussion is well beyond the scope of this paper. Reference is made to the ASHRAE Handbook for more details.

3.3 Design of GHEs

One of the first decisions that has to be made in any direct geothermal installation is what form of system will be used. If the building is a large commercial or industrial building with significant foundations including large diameter piles, then it is almost certain that these elements will provide the location for the ground loops. Where such a building is located on relatively good founding materials, then other forms of GHEs would have to be considered, and these may not be as economically viable as the former situation. Horizontal systems are rarely adequate for this form of building.

In the case of residential buildings, horizontal GHEs are often a cheaper alternative than vertical GHEs (CGC (a)). However, if there is inadequate space for a horizontal system, it may be necessary to consider a vertical system (although combinations are possible).

It then becomes necessary to decide on how long the total ground loop must be. Once this is determined, and having decided on the length of each borehole, the number of boreholes can be established.

There are a number of rules of thumb which can be used to give some assessment of the length of ground loops. One such rule is that for each metre of vertical borehole, it would be reasonable to expect a heating power contribution of about 60 watts with cooling a little less. This would mean that for a residential building demanding a peak heating load of about 15kW, approximately 250m of ground loop would be required. This could be accommodated with 5 x 50m boreholes with the boreholes spaced at a distance of at least 5m.

It must be emphasised, however, such a rule of thumb should only be used as a guide to ground loop length as there are a number of factors which could have a significantly influence but not be taken into account. These include the geology, soil/rock properties and their variation, location, elevation, orientation of loops, borehole/trench size, backfill/grout characteristics, pipe sizes and spacing and most importantly, the balance and relative magnitude between the heating energy and the cooling energy extracted from the ground loops. More sophisticated methods of loop design may be found in design manuals such as IGSHPA (a) and CGC (a). There is also a variety of software available for this purpose such as TRNSYS, EED and GLD.

While each of these design methods use a variety of approaches to design, the general principles can be demonstrated by considering the method used by IGSHPA (a). For a geothermal system in heating mode, and for a single loop in each borehole, the total required length of vertical boreholes (L) is given by

$$L = \frac{HC\left(\frac{CoP-1}{CoP}\right).(R_B + R_G.F_H)}{T - \left(\frac{EWT_{min} + LWT_{min}}{2}\right)} \qquad (1)$$

where HC is the capacity of the GSHP at design heating conditions, CoP is the coefficient of performance of the GSHP at design heating conditions, R_B is the thermal resistance of the borehole, R_G is the thermal resistance of the ground outside the borehole, F_H is the run fraction of the GSHP during the design heating month (i.e. the proportion of the time the pump has to run to provide the required heat), T is the steady state ground temperature at the borehole location, and EWT_{min} and LWT_{min} are the entering and leaving water temperatures respectively on the ground side of the GSHP. Note that LWT_{min} is the minimum temperature that will be experienced by the ground and it is important that this is adequately above 0°C otherwise antifreeze will be needed in the water of the ground loops.

The values of HC, CoP, EWT_{min} and LWT_{min} are determined with the selection of the GSHP and can be read off the performance data sheets provided by the manufacturer. F_H can be established from an analysis of the variations of demand for the design month. R_B is given by

$$R_B = \frac{1}{S_B.k_{grout}} + \frac{\ln\left(\frac{D_o}{D_i}\right)}{4\pi k_p} \qquad (2)$$

where D_o and D_i are the outside and inside diameters of the ground loop pipe, k_{grout} and k_p are the thermal conductivities of the grout and the ground loop pipe and S_B is a dimensionless shape factor which is a function of the location of the ground loop pipes in the borehole, the diameter of the borehole, D_B, and the outside diameter of the pipe, D_o. IGSHPA (b) considers 3 possible ground loop configurations as shown in Figure 9 and S_B is given as

$$S_B = \beta_0 \left(\frac{D_B}{D_o}\right)^{\beta_1} \qquad (3)$$

The coefficients β_0 and β_1 are as follows:

Configuration	β_0	β_1
A	20.10	-0.9447
B	17.44	-0.6052
C	21.91	-0.3796

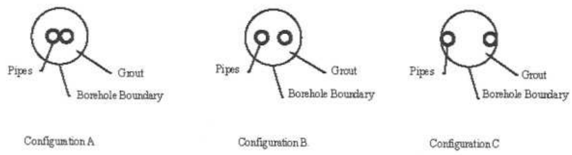

Figure 9: Configuration of a single ground loop in a borehole (IGSHPA (b)).

IGSHPA (b) indicates that a value for S_B which is an average between configurations B and C would be a reasonable assumption for most installations.

The thermal resistance of the ground outside the borehole, R_G, is given by

$$R_G = \frac{\ln\left(\frac{D_G}{D_B}\right)}{2\pi k_G} \qquad (4)$$

where D_G is the diameter of the ground around the borehole beyond which there is little change in temperature (usually taken as about 5m), and k_G is the thermal conductivity of the ground.

It may be instructive to estimate the total length of borehole required to heat a typical house in Melbourne where the peak heating demand is 15kW. If we assume a single loop is inserted in each borehole of 114.3mm diameter (4.5 inches) and the ground loop is to comprise HDPE piping of 25mm outside diameter with a wall thickness of 2.27mm. The thermal conductivities of the ground, the grout used and the HDPE are 2.2, 1.5 and 0.45 W/m°C respectively. For the 15kW GSHP chosen, the manufacturer's data sheets indicate that CoP= 4, EWT_{min}= 7°C and LWT_{min}= 4°C, and it has been established that the run fraction, F_H, of the pump will be 0.6. The steady state ground temperature in Melbourne is typically about 18°C.

Based on this data and using equations (1) to (4), the required total borehole length is about 310m which is a little more than was estimated using the rule of thumb discussed above. This could be provided with 6 boreholes to a little over 50m length. The boreholes would require a spacing of about 5m.

Now it is necessary to consider the influence of the relative amount of heating energy and cooling energy taken from the ground. Where the heat taken out in winter equals the heat rejected to the ground in summer, no correction is necessary. However, where the heat taken out exceeds the heat replaced in summer, there could be a progressive reduction in ground temperature to not only reduce system efficiency but also to cause potential ground freezing problems. Based on the above assessment for the house in

Melbourne, if the total heating energy taken from the ground per year were 20MWh and the total cooling energy 12 MWh, the IGSHPA design method suggests that the unbalanced ground load correction factor would be about 1.1 which would require the total borehole length to increase to about 342m. The greater the imbalance, the greater would be the increase in borehole length.

For a geothermal system in cooling mode, the processes followed to determine the total length of boreholes are similar to those outlined for heating.

It may be of interest to note that using the above data with the EED software, using 6 boreholes spaced at 5m in a 3 x2 grid pattern, 286m of borehole (or 6 boreholes to about 48m) was estimated as being adequate. If a double ground loop were to be used in each borehole, the total length of ground loops would be reduced to about 242m which suggests 5 boreholes to about 48m would be required.

4.0 METHODS OF INSTALLATION

With all the possible variations of geology, geometry, materials and equipment, there are many factors which must be considered when drilling boreholes and keeping them open, installing and connecting ground loops and header pipes and making sure they remain operational, do not leak or get blocked, grouting boreholes to optimise performance and connecting the GSHPs to ensure effective and continuous operation.

As an meaningful description of these methods is not possible in this paper, the reader is referred to IGSHPA (a) and CGC (a) for more information.

5.0 CAPITAL COSTS

As discussed above, because direct geothermal energy provides around 75% of the energy for heating and cooling at no cost, it is a technology which has major economic advantages over conventional fossil fuel technologies. However, while the general cost of furnaces, boilers, electrical heat exchangers and air source heat pumps used with conventional heating and cooling technologies are comparable to or a little cheaper than the GSHPs of geothermal systems, geothermal systems have a major extra capital cost. This is the cost of the GHEs, and these can be significant and generally need to be paid for up front. It follows that the cost effectiveness of any geothermal system involves minimising capital costs to allow fuel savings to provide as quick a pay-back period as possible.

The capital cost for a geothermal system in Australia and New Zealand is currently relatively high and, depending on a range of factors, could be as much as $25,000 to $30,000 (or more) for an average house with reasonably good thermal insulation. However, it should be emphasised that the industry in this part of the world is only just beginning and current high capital costs are due to the lack of experience, low volume of installations, unsophisticated drilling practices, poor availability of materials, the need to import GSHPs and the tendancy to significantly overdesign. The costs will certainly drop considerably once the market and the industry matures, just as has happened in other parts of the world. So what sort of cost is likely once this maturing has occured? Some guidance may be obtained from a comprehensive study undertaken by the Canadian GeoExchange Coalition (CGC (b)) in which it was shown that the average cost of a complete geothermal system in Canada was about $25,000. On the basis that Canada is generally about 2.5 times colder than, say, Melbourne, it would be reasonable to expect that a complete geothermal system could be installed in Melbourne for less than $15,000, perhaps even less. While other factors must be involved in this extrapolation, especially with respect to cooling loads, this order of cost does seem possible. When taking into account the costs of the conventional equipment replaced, it can be shown that pay-back periods of around 6 to 7 years are possible. This agrees reasonably with overseas experience for the residential installations. The pay-back period with many commercial and industrial buildings in Europe has been shown to be even shorter mainly because the GHEs are usually installed in deep foundations at no extra cost for drilling.

When the costs of conventional fuels increase (as they surely will), pay-back periods should become even more attractive.

6.0 STRATEGIES FOR LOWER CAPITAL COSTS

There are many possible strategies which can be adopted to allow for lower capital costs. One of the most important involves investigating the actual performance of GHEs and developing guidelines which will reduce the conservatism currently involved with the design of ground loops. This is particularly relevant to the conditions generally encountered in Australia and New Zealand. Other strategies include the use of hybrid systems in which other sources of energy are used in combination with geothermal. There are also major opportunities involving the reduction of peak loads demanded by a building through better design and insulation, the use of zoning techniques (where excess heat from one part of a building is used to heat another cooler part or where heating and cooling are not provided in areas not occupied), and the use of passive heating and cooling systems as well as night purging. The changing of tolerance, acceptance and/or expectancy levels for building temperatures could also make a considerable difference

Perhaps one of the most effective ways of reducing capital costs while maintaning significant reductions in operational costs is by using geothermal energy to provide base-load heating and cooling with conventional systems providing the peak-load energy. The logic behind this relates to the characteristics of the climate at any one location. For example, Figure 10 shows the temperature variations in a design year for Melbourne.

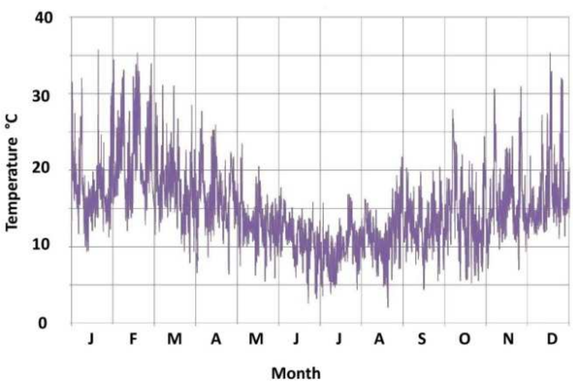

Figure 10: Annual design temperature variations for Melbourne.

The impotant thing to note with this figure is that while the temperatures are generally above the ideal building temperature of around 20˚C in summer (i.e. require cooling) and below 20˚C in winter, there is a great deal of temperature variations by the day and hour. A closer look at a detail in Figure 10 is shown in Figure 11 with the temperature variations for August.

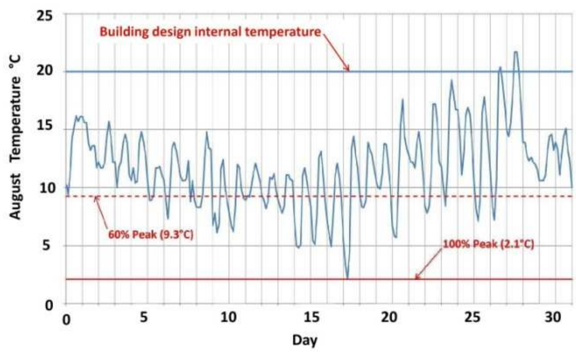

Figure 11: Design temperature variations for August for Melbourne.

For this particular month, had it been the design coldest month, the heating system could be designed for an external temperature of 2.1˚C and a building interior temperature of 20 ˚C. From our earlier example for a house, this might require 15kW to be provided by the geothermal system from 342m of boreholes containing ground loops. However, it can be seen from Figure 11 that this design temperature exists for only 1 hour. Indeed, as is also shown, there is only a small percentage of the hours in the month where the temperature is less than 9.3˚C which represents a temperature requiring only 60% of the peak load. While the capital cost of a geothermal system is approximately proportional to the difference between the building temperature and the peak design temperature (i.e. kW required), the cost of operating the system is approximately proportional to the area between the building temperature line and the temperature curve down to the design peak temperature (i.e. kW x time = kWh required).

As may be seen in Figure 11, for a peak design temperature 9.3˚C, the area between 20˚C and the temperature variation line for temperatures above 9.3 ˚C is about 95% of the total area between the 20˚C building temperature and the temperature variation line for August. This indicates that by providing only 60% of the ground loops, about 95% of the operating costs are covered. For the whole year, this 60% will provide almost 97% of the year's heating. Therefore, for this scenario, it would only be necessary to provide 9kW which could be provided by about 205m of boreholes. This suggests that the capital costs could be reduced while maintaining almost all of the the savings made on energy costs, thereby reducing pay-back time considerably. There are clearly a range of possible variations within this strategy.

But what would be the effect of catering for only 60% of the peak load? Basically, for those temperatures outside the 60% level, the equipment would only be capable of part heating or part cooling the building. There are several possible strategies for dealing with this but one of the most effective would be, as shown in Figure 12, to include an auxilliary system such as a conventional fuel furnace at a relatively moderate cost to provide the shortfall 5% of heating or cooling energy. In the case of residential buildings which have been retrofitted with a geothermal system, the auxilliary system could simply be the existing heating and cooling system which, while more expensive to run, would only be operating for a small proportion of the total time.

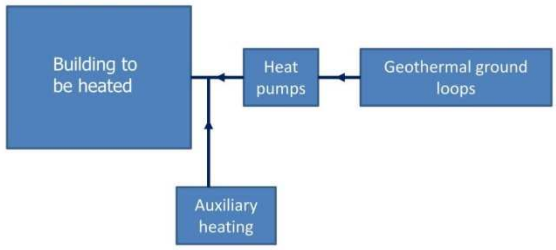

Figure 12: The use of an auxiliary system to reduce the capital costs of a geothermal system.

2. CONCLUDING COMMENTS

Based on the very rapid rise of direct geothermal energy systems for heating and cooling buildings in many other parts of the world, it is clear that it is a technology which will play an important part in our energy mix over the next few years as our reliance on fossil fuels is replaced. This is particularly true when considering the rapidly rising cost of these fuels as carbon taxes bite and as we all accept the need to reduce our production of carbon dioxide and other greenhouse gases.

Presently, in Australia and New Zealand, because the direct geothermal industry is in its infancy, the costs of installation are still unacceptable high. It follows that the sooner we can mobilise acceptance and demand, knowledge and expertise, training and accreditation, the sooner the trades, professions, developers, architects, regulators, politicians and the general public can have a mature direct geothermal industry providing clean, efficient and cost-effective heating and cooling for our buildings.

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