Analysis of the use of ground source heat pumps for Brazilian climate and soil conditions

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The use of ground source heat pumps (GHSP) has increased in several regions of the world in the last 10 years as a response to reducing carbon emissions, but in Brazil, there are significant markets to be explored. There are some challenges that must be addressed, such as drill costs and unbalanced loads. This paper analyses these aspects and provides some directions to overcome those challenges.

The use of GHSP has been a technological alternative to produce higher efficiency for air conditioning for cooling/heating buildings coupled with the reduction of the carbon emissions from building operations. In Brazil, this sort of technology started to drive attention and become an alternative for reducing carbon emissions and was included as one of the strategies in the Brazilian Energy Plan for 2050.

Ground Source Heat Pumps (GHSP)

Ground source heat pumps can be divided into ones that transfer heat to or from the soil or aquifer. Also, if the heat transfer is done to or from the soil, they can be sub-divided into a vertical bore, horizontal bore, trenched or slick loops (Figure 1).

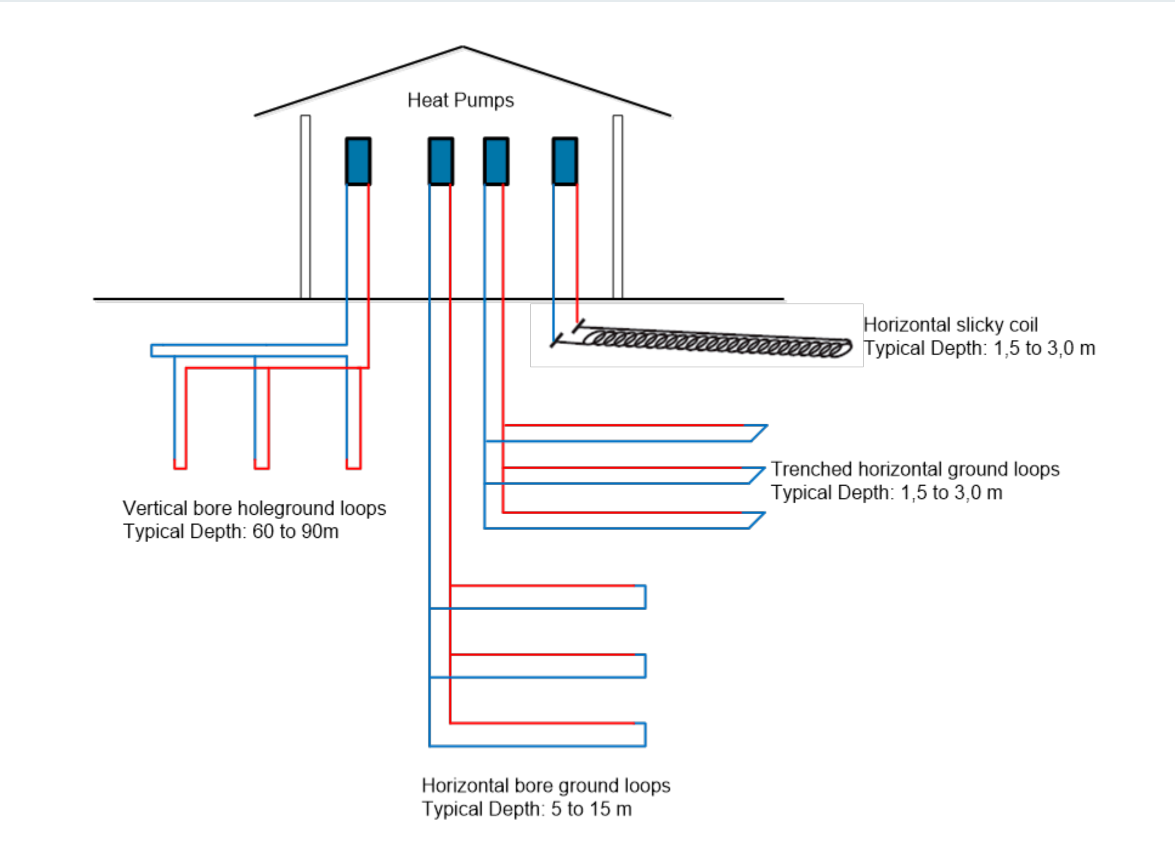


Figure 1. GHSP system with heat transfer to or from the soil.

When it comes to GHSP, which transfers heat to or from an aquifer, there are two wells that can be used: one to get low-temperature water, and the other to reject hot water (see Figure 2) or other water source (Figure 3).

Brazilian soil temperature and characteristics

The annual average ground temperatures are usually equivalent to the annual average air temperatures [1]. The ground temperature along the depth can be divided into two regions, a zone in the shallow ground, where the ground temperature varies with the seasonal change and a zone in the deeper ground (a depth of more than ~10 m below the surface) where the ground temperature remains relatively constant [2,3].

Considering that the Brazilian climate is diverse, a ground temperature variation from south to north is expected. For this reason, the feasibility of GHSP may

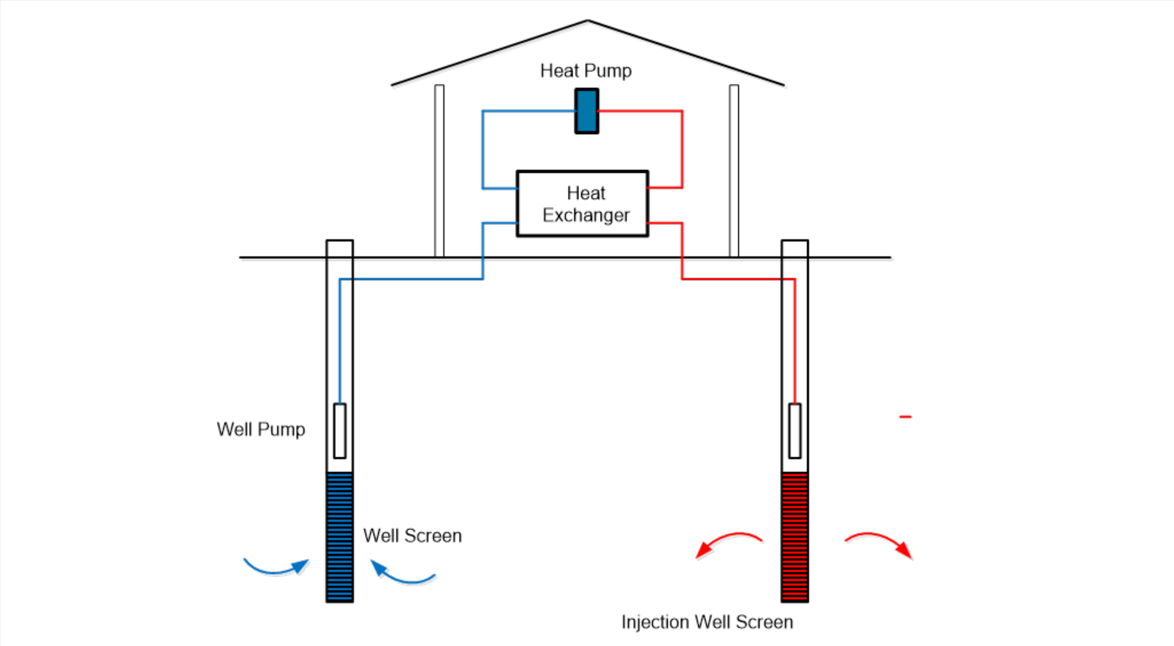


Figure 2. GHSP loops the system with wells.

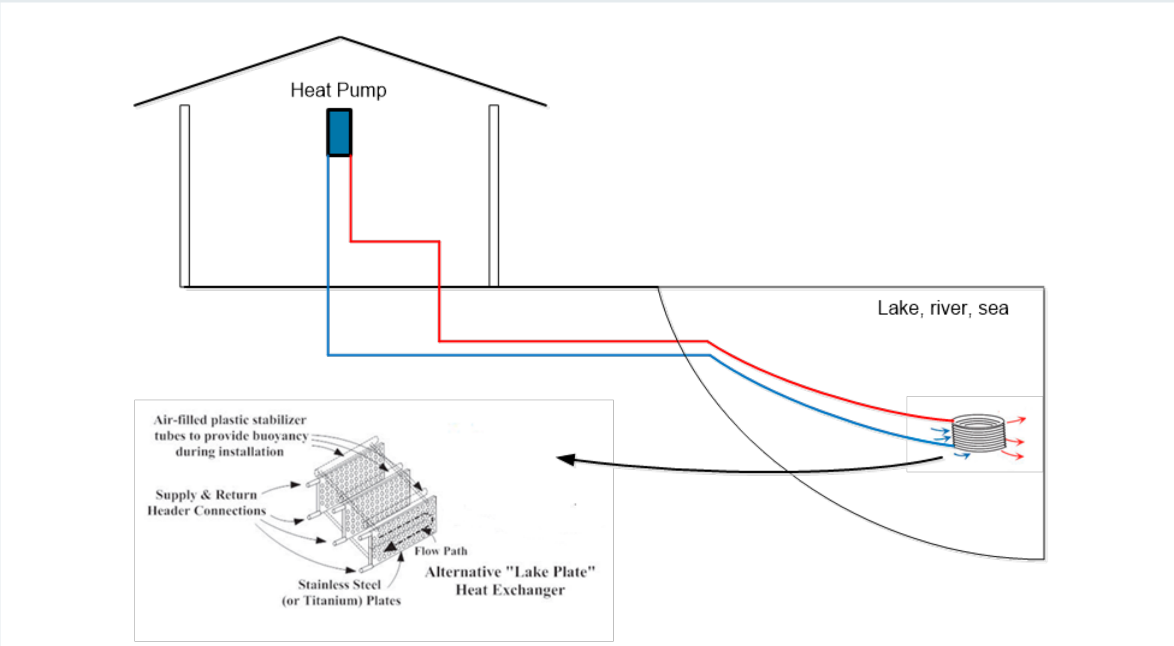


Figure 3. GHSP loops system in aquifers (lakes, rivers, or seas).

also be variable in this country. However, as commented in [3], in the tropics, the constant ground temperature in the deeper ground zone varies between 20ºC and 25ºC (locally even 28ºC), which still permits the cooling of buildings.

Another important local soil factor that influences the performance of the GHSP system is that unsaturated soils cover a large part of the Brazilian territory, and in these areas, due to the alternation of dry and rainy periods, the water content of the soils varies seasonally. As a consequence, the soil thermal conductivity, which is the most important thermal soil parameter [3], also varies seasonally, as observed experimentally in Morais et al. [4]. These authors found that the soil thermal conductivity is higher during the rainy seasons and decreases in dry seasons and recommend that this seasonal variation should be considered in the design of GHSP systems.

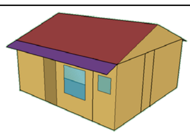
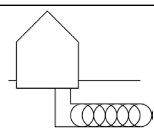
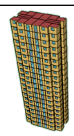
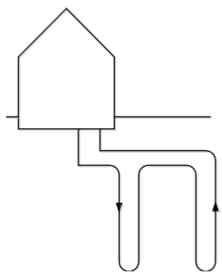
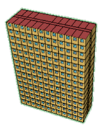
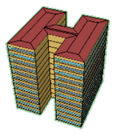
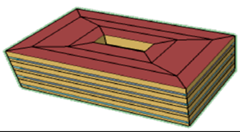
Research and applications of GHSP in Brazil
The applications of GHSP in Brazil are limited to, so far, two projects in a residence, in a research center building (Centre of Innovation in Sustainable Construction) and in a soft drink plant, and there are two other projects that will be built in the next two years for two hotels in the southeast region of Brazil.

Regarding research and technical studies, there have been over 10 research projects mainly focused on technical feasibility studies of the implementation of GHSP in different regions and building typologies.

One of these research is done by Santos [5], where the author analyses the soil temperature distribution in the state of Paraná (south of Brazil) to evaluate the feasibility of implementation of GHSP in that region. The study provides the measurement of soil temperature distribution in specific sites in Paraná that ranges from 16°C to 23°C. Based on those measurements, an evaluation of the increase of the COP for air conditioning is performed based on the refrigeration cycle providing an average gain in the COP of 59%.

Another study was done by ICare [6], where a feasibility analysis of the implementation of GHSP was done for the South and Southeast region of Brazil, which concentrates the largest portion of the Brazilian population (56,5%) and gross national product (69,1%). This study evaluates the energy and water consumption for GHSP for 6 building typologies in the 7 state capitals of South/Southeast regions. The evaluations were done using the simulation tool Energy Plus [7], where a comparison was done with the conventional air conditioning system for each typology, as shown in Table 1.

Table 1. Building typology and air conditioning systems.

<table>
<tr><th>Building typology</th><th>Building model</th><th>Conventional air conditioning</th><th>GHSP</th></tr>
<tr><td>House</td><td></td><td>Unitary split system</td><td>Slinky </td></tr>
<tr><td>Residential building</td><td></td><td rowspan="5">
Water chilled system</td><td rowspan="5">
Vertical closed loop</td></tr>
<tr><td>Office</td><td></td></tr>
<tr><td>Hotel</td><td></td></tr>
<tr><td>Hospital</td><td></td></tr>
<tr><td>Shopping mall</td><td></td></tr>
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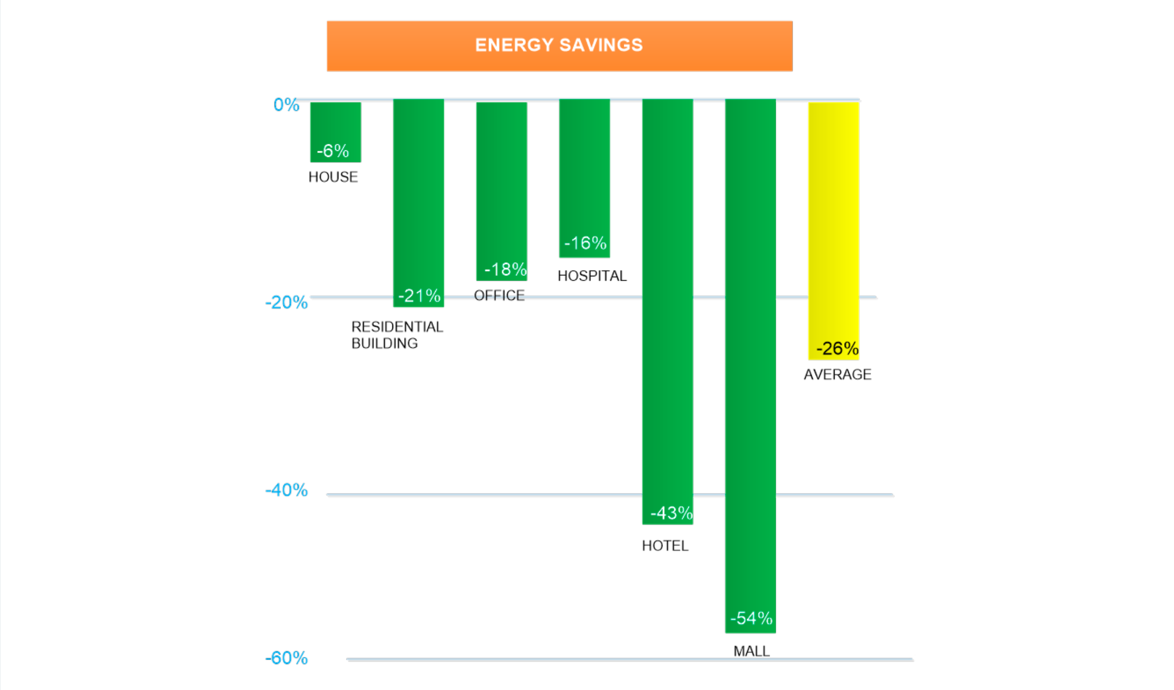

Figure 4. Energy savings of GHSP compared to conventional air conditioning systems for different typologies.

This study shows that energy consumption has a significant reduction, as shown in Figure 4, where the typologies that provide the highest savings are hotels (43%) and shopping malls (54%). For the typologies using water-chilled systems, there is also a considerable reduction in water consumption (from 40% to 60%) due to the elimination of the cooling towers from the system.

Despite the significant amount of energy and water savings, the cost to implement the GHSP is quite high, especially for the vertical loops, due to the cost of borehole drilling. Therefore, the payback time for the analysed typologies ranges from 10 to 15 years. Also, due to the Brazilian climate conditions, the need for cooling the building is much higher than heating. This imposes an unbalanced load on the soil, resulting in an increase in soil temperature close to the bore loops, reducing the efficiency of the GHSP system as well as its lifespan.

Studies are under development to deal with the high drill cost by analyzing the feasibility of using building piles to reject the heat to the soil. Regarding the unbalanced load, a feasibility study is under development to analyze the use of GHSP for cooling the building and producing heated water for showers, sinks or any process that requires hot water (product sterilization).

Finally, regarding increasing the accuracy of the simulation and the selection of GHSP and, therefore, a better design of GHSP systems, there is a lack of information related to the curves of the Coefficient of the Performance (COP) in partial loads and seasonal cooling/heating capacity of the GHSPs. This requires a joint effort of the research groups and GHSP manufacturers to run standardized tests to evaluate such curves.

Conclusions

Studies show great potential for the applications of GHSP systems in Brazil, especially for the South and Southeast regions, with significant reductions of water and energy consumption in residential and commercial buildings.

There is a need for further analysis to reduce the high borehole drilling cost by using thermo-active ground structures (piles and retaining walls), which are already incorporated into the building construction. Also, there is a huge challenge due to the unbalanced loads that occur in Brazil due to its climate conditions (higher demand for cooling) that can be addressed by using different GHSP configurations and a combination of energy supplies (heating and cooling).

Another important issue to be addressed is the lack of information on seasonal and partial load performance parameters of the GHSP, which requires a joint effort between research groups and the industry.

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