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# Ground coupled heat exchangers: A review and applications

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ABSTRACT

The use of ground coupled heat exchanger (GCHE) systems is increasing worldwide. They are mainly used for space conditioning, water heating, agricultural drying, bathing, swimming, etc. They reduce cooling load in summer and heating load in winter. GCHE systems make available excellent scope to conserve significant amount of primary energy and thus mitigating the impact on environment through emission reduction. This paper reviews the experimental and modeling studies carried out on GCHE systems. The reviewed literature focuses on performance of both types of GCHE systems viz. earth–air heat exchanger (EAHE) and ground source heat pump (GSHP) systems and brings out their merits and demerits.



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## 1. Introduction

The way towards energy and environment sustainability is the incremental adoption and promotion of renewable energy technologies, practices and policies [1]. Green building control strategies use various concepts of natural heating, ventilation and air-conditioning [2,3]. GCHE technique is one of them. It is an underground heat exchanger that can absorb from/release heat to the ground. The underground temperature remains relatively constant throughout the year or all year average of sol air temperature of its ground surface [4,5].

This constant temperature characteristic is due to high thermal inertia of the soil and as the depth increases, effect of temperature

*Abbreviations:* GCHE, ground coupled heat exchanger; EAHE, earth air heat exchanger; UAT, underground air tunnel; GSHP, ground source heat pump; DX-GCHP, direct expansion ground-coupled heat pump; $CO_2$-e, carbon dioxide-equivalent; CER, certified emission reduction; HVAC, heating ventilation and air conditioning; 1D, one dimensional; 2D, two dimensional; 3D, three dimensional; CFD, computational fluid dynamics; GHE, ground heat exchanger; PVC, polyvinyl chloride; PBP, payback period; ANN, artificial neural network; ID, internal diameter; COP, coefficient of performance; PCM, phase changing material; HETS, horizontal earth tube system; PV, photo voltaic; AC, air conditioner; EER, energy efficiency ratio; $T_{in}$, temperature at entry of pipe in °C; $T_{exit}$, temperature at exit of pipe in °C.

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fluctuations of the ground surface is reduced. Due to time lag between the temperature variations at the surface of the ground and below the ground, at a sufficient depth, temperature below the ground is always higher than that of the outside temperature of air in winter and is lower in summer. This temperature difference can be used for pre-heating in winter and pre-cooling in summer by installing appropriate GCHE system. Advantages of GCHE systems are high efficiency, stable capacity, good air quality, better thermal comfort, easy control, require simple equipments, low maintenance cost, environment friendly, long term cost effective, tax benefit, and noise free being the underground unit. Drawbacks are higher initial cost, limited availability of trained technicians and contractors. Performance of GCHE systems depends on air/liquid flow rate, depth and length of buried pipe/tube (sufficient for air/liquid to lose the heat to certain extent), material and diameter of pipe/tube, temperature difference between earth and ambient, initial soil temperature, rating of blower fan, and various combinations of pipes.

## 2. GCHE systems

GCHE systems have multiple primary objectives. These are to achieve the best operational efficiencies, the lowest possible operational cost and run environmentally safe, to have lowest possible initial cost and surface area, to increase interior comfort levels and long-term system durability, to make possible ease of service and maintenance and to earn revenue under certified emission reduction (CER). Sequestration of one ton of carbon dioxide-equivalent ($CO_2$-e) is represented by one CER unit. Developing country like India can earn additional revenue of $234 \times 10^7$ Euros under CER by using GCHE [6]. GCHE systems are preferred to those locations where fluctuation in ground surface temperature level is high and under the demands of reduction of $CO_2$ released into the atmosphere. According to connection and orientation, it can be classified as series and parallel, horizontal and vertical. According to flow substance, it can be classified as EAHE or underground air tunnel (UAT) and GSHP system. EAHE system concept is popularly used in colder countries for space cooling and heating, respectively in summer and winter, shown in Fig. 1 [7]. EAHE systems contain buried pipes in various combinations, in open loop as well as in closed loop. Air is blown through buried pipes using a properly sized blower fan installed at the entry or exit [8]. EAHE systems are cost effective and having long life but prone to air contamination from bacterial growth, corrosion due to moist/humid air and chemical reaction inside the tunnel may dither public acceptability in residential buildings which needs further investigations. Above drawbacks in adopting EAHE systems are overcome in GSHP systems which are suitable for space cooling/heating of residential buildings and small commercial offices.

GSHP systems are electrically powered, circulate a heat transfer fluid around a loop of buried pipe, use relatively constant temperature of the earth and transfer heat to or from earth. They can be classified as regular and direct exchange geothermal heating/cooling system or direct expansion ground-coupled heat pump (DX-GCHP).

In regular geothermal heating/cooling system, water or anti-freezing liquid or mixture of them flows through buried high density plastic tube as shown in Fig. 2. It is efficient technology but requires more space. Regular heating/cooling system can be further classified as horizontal and vertical. Vertical boreholes are more effective, efficient, need less piping area than horizontal loops but more expensive [9]. In vertical boreholes two-layer, two hole systems are more beneficial than one hole system [10].

In DX-GCHP system refrigerant flows through buried copper tube and exchanges heat directly with the soil as shown in Fig. 3.

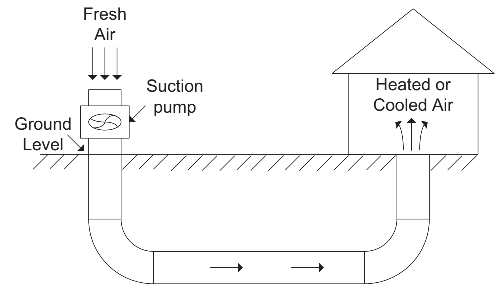


**Fig. 1.** Earth air heat exchanger system.

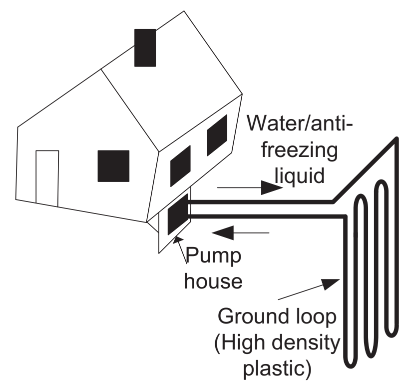


**Fig. 2.** Regular geothermal heating/cooling system.

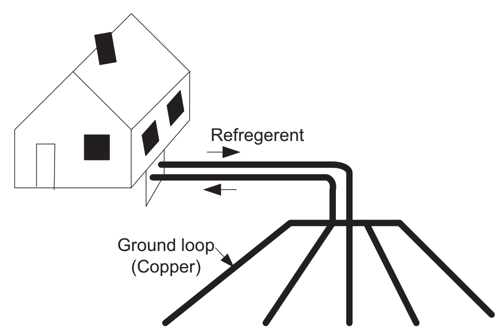


**Fig. 3.** DX-GCHP system.

Copper is a superior heat conductor in comparison to the most plastic materials. DX-GCHP systems are more appropriate for small space heating/cooling. It requires less excavation/drilling to install, more efficient because one step of heat exchange process is eliminated in comparison to other GSHP systems, no requirement of a circulation pump and increased thermal contact with ground that facilitate to overcome freezing problems associated with colder climates. Ground coils can be buried in different manners. Horizontal layout of coils avoids the difficulty of liquid refrigerant build-up, because there is no low point, but needs a huge size of ground. Vertical layout of coils is better than horizontal, but requires a condenser receiver and a metering system to overcome liquid refrigerant buildup within buried coils and get maximum efficiency by allowing relatively large quantity of refrigerant [11]. Common problems are overstressed particularly in cooling mode, suction line pressure drop and partially filled up with debris in vertical well that need design improvements [12]. Some other drawbacks reported are effect of corrosion on life of copper tube due to acidic property of soil, more quantity of refrigerant required due to leakage of refrigerant and adverse effect on soil [13,14]. Comparison between EAHE and GSHP systems is given in Table 1.

Though GSHP systems are costlier and have lesser life than EAHE systems, getting good response all over the world because