Proceedings World Geothermal Congress 2023
Beijing, China, April 17 – 21, 2023

Geothermal Earth-Air Heat Exchanger, a solution for reducing greenhouses energy consumption in Iran

Davar Ebrahimi[1], Javad Nouraliee[1]

1. Renewable Energy Research Department, Energy and Environment Research Center, Niroo Research Institute, Tehran, Iran
debrahimi@nri.ac.ir

Keywords: Earth to Air Heat exchanger, Greenhouses, Geothermal Energy

ABSTRACT

Using renewable energy for space heating and space cooling has been considered in many countries, but due to low energy prices in Iran, these kinds of energy resources are not very attractive to consumers. Increasing the area of greenhouses in Iran leads to an increasing amount of consumed energy. One of the low-cost methods that can reduce energy consumption in greenhouses is geothermal Earth-Air Heat Exchangers (EAHE), which save a substantial amount of energy in both heating and cooling modes. It is a renewable technique based on a geothermal source used for space heating and space cooling by exchanging heat with the ground. The working fluid is air and the ground works as a heat source due to its heat storage capacity. The annual temperature of the soil at a certain depth t is nearly constant. This constant temperature in the earth is cooler than the ambient air in the summer and warmer than the ambient air in the winter. It is essential to devise strategies for their development in Iran because the implementation of these systems does not require advanced technologies and it is possible to use them throughout the country. At the moment in 14 greenhouses of the country, with a total area of 12 hectares, EAHEs are being used. The area of the country's greenhouses is currently about 16,000 hectares, with annual electricity consumption of around 2,000Mw. Also, the amount of natural gas consumed by these greenhouses is more than 4 billion m^3 per year. The development plan for greenhouses for the next 10 years is about 34,000 hectares which required a huge amount of energy supply for them. This study examines energy consumption reduction in greenhouses by using EAHE.

1. INTRODUCTION

The increase in population and economic growth in the world has caused concern about the security of energy supply. The required energy can be produced from sustainable resources that have minimal environmental effects. Geothermal energy is one of the renewable energy resources that can provide the energy needed for different applications regardless of weather conditions and daily and seasonal weather changes. In a general classification, geothermal resources are classified into two categories, shallow resources and deep resources. Deep sources of geothermal energy require drilling, power plant construction and high initial investment cost, while shallow geothermal resources are very inexpensive and accessible anywhere on the planet. Shallow resources of geothermal energy are divided into two main categories: geothermal heat pumps and Earth to Air Heat Exchangers. These systems use ground temperature for pre-heating and pre-cooling.

Surface Temperature of the ground is similar to ambient temperature and changes by fluctuation of ambient temperature. These fluctuations decrease with increasing the depth and under the 5 m depth, ground temperature remains relatively constant, So Ground is a thermal sinks that can be used for cooling and heating of air or water [1].

Earth to Air Heat Exchanger (EAHE) is a promising technique than can be used to reduce the heating and cooling energy load and improvement of space thermal comfort conditions (Figure 1). Installation of these systems is proposed as a low-cost and applicable method in the short term, which saves the energy consumption of some units. In Iran, these systems are currently used in some greenhouses by the private sector. According to the studies, cooling and heating of greenhouses is one of the most expensive food supply activities. Greenhouses cooling and heating in some climates where the ambient temperature is much lower or much higher than the desired temperature, will be very expensive. Cooling and heating systems in some greenhouses where there is no concern about preserving water and energy resources, consist of: air conditioning systems, fans and pads, spray cooling, radiant heating, natural gas etc. All of them supply their energy from electricity or fossil fuels. The results obtained from the efficiency of EAHE systems in greenhouses indicate the importance of developing their installation in industrial spaces.

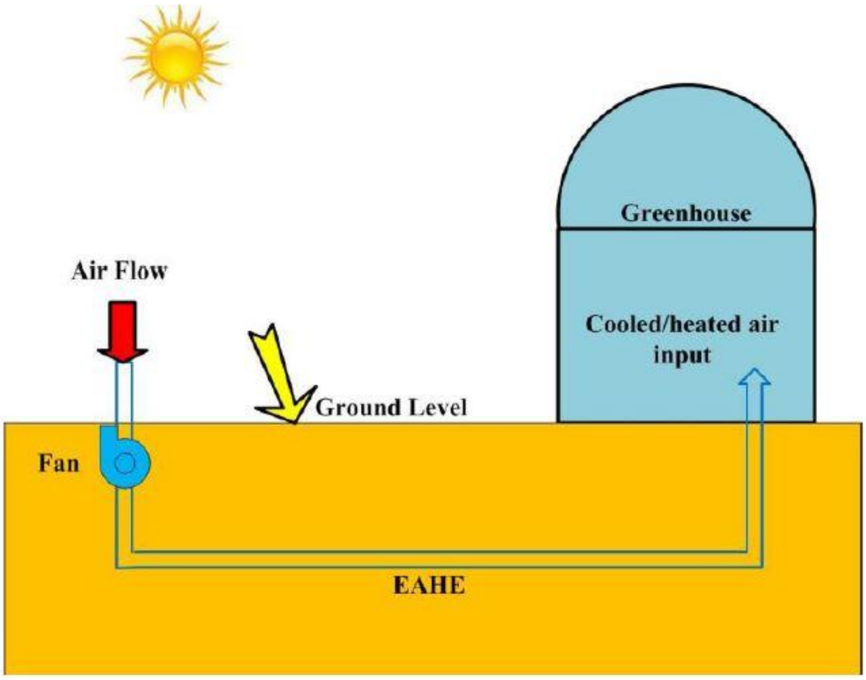

Figure1. Schematic image of an Earth to Air Heat Exchanger (Faridi et.al, 2021)

1. TECHNICAL SPECIFICATION OF EAHE

EAHE systems consists of some tubes lied under ground in order to pass the air. The performance of EAHE depends on parameters such as pipe materials, geometric dimensions (length and diameter of pipes), burial depth of the pipes, air velocity and soil or ground temperature. These parameters effect on the thermal efficiency and it is necessary to determine their effects in order to achieve thermal comfort.

1.1 Pip Materials

Pipe materials are mostly metal or plastic, which are buried a few meters deep. Pipes materials can affect the output temperature. Some materials that have high thermal conductivity also have a high heat transfer. The review of the implemented projects related to the EAHE in different parts of the world indicates that the type and materials of the pipes is based on their availability and cost. The output temperature of the pipes has not changed significantly by changing the materials of pipes. Although pipes with high thermal conductivity can increase the efficiency of EAHE systems, they may not be used due to the cost of them. For example, materials such as copper and steel are much more expensive and less accessible compared to PVC and polyethylene (Ghosal, and Tiwari, 2006).

1.2. Geometric dimension and design

The design of the EAHE system and the geometric dimension of the burial pipes play an important role in the efficiency of EAHE systems. Some parameters that should be considered for this purpose include the length of the pipes, burial depth, and diameter of the pipes. Usually, the length of buried pipes is considered to be between 20 and 60 meters and they are placed at a depth of 2 to 4 meters (Darius et.al, 2017). Many studies have been done regarding the geometrical dimensions of the EAHE pipes. Based on the results, increasing the length of the pipes increases the efficiency of the system, but this is usually effective up to 50 meters, beyond that, there is no noticeable change in the outlet temperature. The diameter and thickness of the pipes are also effective factors, so that the efficiency of the system decreases with the increase in diameter and thickness. Theoretically, the deeper the pipes are buried, the more it has a positive effect on the system performance, but since the changes are not very noticeable at depths more than 4 meters, there is no need to lay pipes at greater depths because it increases excavation cost. In the Figure 2, a picture of the land preparation for piping is shown.

1.3. Air flow

In these systems, inlet fans, outlet fans, or both are used to transfer the air, so air flow affects thermal performance of EAHE systems. It is found that the increase of air velocity in EAHE system leads to the decreasing thermal performance of the EAHE system. This is caused by the shortened time in contact between air and the ground, therefore the heat from the air has not enough time to achieve thermal equilibrium with the ground (Misra, et.al 2013).

Figure 3. Land preparation for piping an EAHE

1.4. Soil type

One of the parameters that affects the efficiency of EAHE systems is soil characteristics around the buried pipes. Thermal properties of soil depend on various factors such as soil type, saturation, gradation, porosity, etc. The best soil composition for the efficiency of these systems is sandy soil (Misra, et.al 2013). This soil has better heat transfer and cause better performance of EAHE. Soil thermal conductivity plays an essential role in heat transfer, which is dependent on soil moisture and density (Alia et. Al, 2014). The effect of soil type on the efficiency of the EAHE has not been well studied. Most of greenhouses are built in sedimentary alluvial soils, where have very diverse soil types. But it is possible to improve the efficiency of the system by transferring soils that have higher thermal conductivity to the pipe burial site. In many countries, the temperature changes versus depth has been calculated. For example, Figure 4 shows the temperature changes (at different depths) in the Las Vegas city, USA (Figure 4).

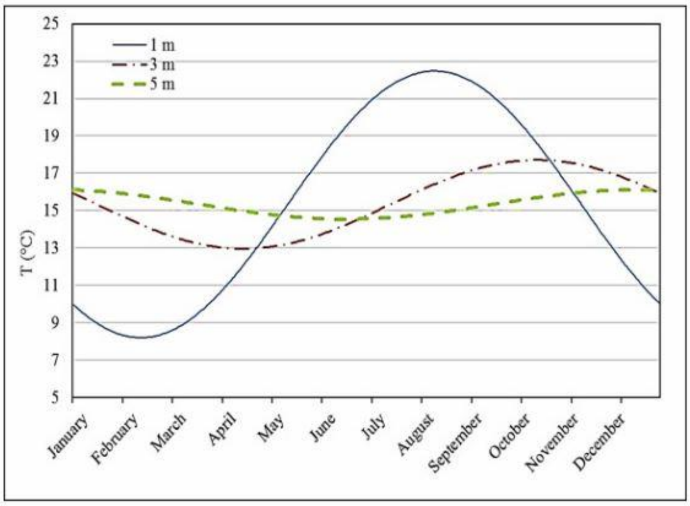

Figure 3. Monthly temperature changes in different depths, Las Vegas, USA (Vidhi, et. Al, 2018)

2. Feasibility study on applications of EAHE in Iran

Shortage of agricultural products in dry climates with low precipitation and the evaporation, such as Iran, lead to development of greenhouses in different regions of the country. Greenhouses area in Iran by 2030 will reach about 34,000 hectares. The energy required in greenhouses is much more than traditional methods of producing crops. This energy is used in two parts of the heating-cooling and ventilation system. Considering the increasing development of greenhouses in the country, their energy consumption will be one of the challenges in the field of energy that should be noticed. Meanwhile, there is a suitable method to reduce electricity and

fuel consumption during peak energy consumption, and that is the use of EAHE. Due to the sensitivity of greenhouse products to temperature changes, these systems can provide a desired temperature in greenhouses. EAHE has significant advantages over other energy supply systems in greenhouses included:
-Low construction cost: These systems consist of simple components and the equipment used in them is accessible.
-Low maintenance cost: Another advantage of using these systems is their low cost of maintenance, it has been mentioned as the most important advantage of these systems.
-No pollution and emission: Pollution in greenhouses is caused by the emission of CO_2 gas, which is caused by the use of fossil fuels. This issue is one of the main problems that greenhouse owners face during winter. The emission of CO_2 gas has a negative effect on products and sometimes leads to the loss of some more sensitive products. Using EAHE is one of the most effective ways to reduce emissions for greenhouse products and increase harvest.
-Can be used in different seasons of the year: As mentioned earlier, EAHE works based on the constant temperature of the earth, which does not change during different seasons. Therefore, these systems can be used during the hot and cold seasons of the year.
-Heat uniformity: using these systems can lead to heat uniformity throughout the greenhouse and the product will be the same in different parts of greenhouse.
Based on the data provided by the greenhouse affairs office in Iran, the current energy consumption in greenhouses and the demand of the amount of energy they will need until the end of the 10-year development plan are presented in Table 1.

Table 1: Energy consumption in the greenhouses in Iran and demand for the next 10 years

Energy Consumption	Gasoline (L)	Natural gas (m^3)	Electricity (Mw)
Per hectare	250000	300000	0.13
Total consumption	1200000000	3360000000	2100
Demand until 2032	2550000000	7140000000	8000

Based on the results obtained from EAHE projects in Iran, Using these systems have more than 30% of saving energy, so they can be a promising systems to reduce energy consumption in greenhouses.

6. CONCLUSION

Earth to air Heat Exchanger system is one of the low-cost renewable methods used for pre-heating and pre-cooling of industrials and residential buildings space heating. Various parameters have an effect on the efficiency of these systems, including: Pip Materials, Geometric dimension and design, Air flow and Soil type. It is beneficial to them as auxiliary cooling and heating systems and by installing these systems, a significant amount of energy savings can be achieved. Recently, these systems have been used in some greenhouses in Iran, which have good results. According to the development plan of greenhouses in Iran, by using geothermal Earth-Air Heat Exchangers can reduce energy consumption in greenhouses.

REFERENCES

-Alia, A., Mohameda, M., Aala, M.A., Schellartb, A., and Taitb, S. (2014), "Thermal and hydraulic properties of sandy soils during drying and wetting cyclesl," ASCE Journal of New Frontiers in Geotechnical Engineering, pp. 129-138.

-Darius, D., Misaran, M.S., Rahman, Md., Ismail, M.A., Amaludin, A. Working parameters affecting earth-air heat exchanger (EAHE) system performance for passive cooling: A review. International Conference on Materials Technology and Energy. IOP Conf. Series: Materials Science and Engineering 217 (2017) 012021 doi:10.1088/1757-899X/217/1/012021.

-Faridi, H., Arabhosseini, A., Zarei, Gh., Okos, M. Degree-Day Index for Estimating the Thermal Requirements of a Greenhouse Equipped with an Air-Earth Heat Exchanger System. Journal of Agricultural Machinery. Vol 11, No. 1, Spring-Summer 2021, p. 83-95.

-Ghosal, M., G. Tiwari, 2006. Modeling and parametric studies for thermal performance of an earth to air heat exchanger integrated with a greenhouse. Energy Conversion and Management, 47(13–14): 1779-1798.

-Misra R, Bansal V, Agrawal G D, Mathur J and Aseri T K, 2013 CFD analysis based parametric study of derating factor for Earth Air Tunnel Heat Exchanger. Applied Energy. pp 266-277.

- Pfafferott J, Walker-Hertkon S, Sanner B. Ground cooling: recent progress. In: Santamouris M, editor. Advances in passive cooling. London:Earthscan; 2007:190-227.

-Vidhi, R. Organic Fluids and Passive Cooling in a Supercritical Rankine Cycle for Power generation from Low Grade Heat Sources. Available online: https://scholarcommons.usf.edu/etd/5322 (accessed on 15August 2018).