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Investigation of Using the Earth Air Heat Exchanger Systems in Greenhouse Heating

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Abstract: Greenhouse is an application where required climatic conditions to grow plants are controlled. These places have an important share in agricultural work. These applications allow the products to be grown year-round, not just in a short period of the year. One of the most important parameters in terms of cost is greenhouse heating. Especially in low temperatures, the heating system used to ensure that products in the greenhouse are not damaged has a great importance. However these systems also cause a great financial problem in the greenhouses. Earth-Air Heat Exchanger (EAHX) are low cost systems which have heating and ventilation potentials in the greenhouses. These systems which are based on the use of energy that the soil has, can be used in greenhouses and similar agricultural applications in terms of easy installation, practical structure that does not require any maintenance and very low energy consumption. EAHX consist of pipe systems in which air passes and a fan for air flow. In this study, using the Earth Air Heat Exchanger Systems in Greenhouse heating is investigated. The theoretical analysis of a greenhouse heating with the EAHX system is carried out for Şanlıurfa climatic conditions. EAHX system are made of galvanized pipes with 13 cm diameter and 16 m length at 2 m depth. The heat losses of greenhouse are calculated according to different methods. The heat supplied to greenhouse were determined experimentally. As results of this study, the required pipe lengths in meters per kW of heating were obtained. It is seen that the EAHX systems can be used for greenhouse heating. The results also show that EAHX systems is really an important alternative for renewable and sustainable energy saving strategies for greenhouse systems.

Keywords: Greenhouse, Heating, EAHX, Renewable energy, soil energy

1.INTRODUCTION

Greenhouses; is an agricultural structure in which the conditions suitable for the growth of plants are provided during periods when climatic conditions are not suitable and the factors such as heat, light, humidity and air movements can be controlled and artificial growth environments are provided for plants. Purpose in greenhouse management; the optimum environment conditions and the growing environment which are necessary for the periods in which the external conditions do not allow the plant growth, is to obtain the products with the highest economic value throughout the year. The provision of suitable conditions to the subordinate is closely related to the climate characteristics of the region where the greenhouse will be built. Heating in the greenhouses is required especially in cold periods in order to provide the heat demands required by the plants. However, many greenhouse in our country are produced without using the heating system. This leads to yields and declines in quality during the colder months, resulting in massive losses of producers. Keeping your heating needs to a minimum, getting the highest possible quantity and quality is the main goal of the greenhouse companies. Achieving this goal is made possible by efficient use of the energy consumed for heating and energy saving measures. Greenery can also become one of the most important agricultural activities in our region due to the regular use of labor force during the year. Especially in greenhouses, this heating process can be further accelerated by lowering heating costs by using natural resources (solar energy, geothermal etc.) (Çaylı,2014; Demiray, 2015 and Kaptaner, 2016).

Greenhouse has started in Turkey in the Mediterranean region for the first time in 1940 and then spread to the Aegean and Marmara regions. Today, undergrowth farming is most concentrated in the Mediterranean region. (TUİK, 2015). Table 1 shows the distribution of greenhouse areas by cities.

Table 1. Distribution of Greenhouse Areas by Cities (TUİK,2014)

Cities	Greenhouse Areas (dekar)	Percentage
Antalya	248.253	%38,2
Mersin	158.845	%24,5
Adana	94.478	%14,6
Muğla	42.650	%6,6
Samsun	21.511	%3,3
İzmir	14.993	%2,3
Aydın	13.579	%2,1
Hatay	10.487	%1,6
Diğer	44.309	%6,8

When examining greenhouse practices in the world, it is possible to classify them considering different latitudes and different greenhouse technologies in the following way:

Cool Climate Countries: The main countries in the cool climate zone with annual average (at sea level) below 10 ° C are Netherlands, England, Denmark, Germany, Romania, Bulgaria and Russia. With 10,000 hectares of glass greenhouses and production technology, the Netherlands is the first country in these countries. Greenhouse building elements are pipe, profile, steel rod and aluminum, cover materials are glass. A high investment is needed to establish greenhouse construction and heating systems.

Temperate Climate Countries: The main countries in the temperate climate range with annual average (at sea level) between 10 ° C and 20 ° C are Spain, France, Japan, Turkey, Italy, Greece, Israel. Favorable environmental conditions allow greenhouses to be profitable. Greenhouses are rapidly increasing in these countries due to average temperatures are high, especially in winter, as they reduce heating costs which is the largest input to the greenhouse. The covering material used for the greenhouses is usually plastic.

Countries with Two Climate Regions: Main countries in the two climate zones annual average (at sea level) between 0 ° C and 20 ° C are Spain, Netherlands, Italy, Belgium, Egypt, Morocco and China. The common feature in these countries is the glass and plastic greenhouses are together (TUİK, 2015).

Greenhouse heating applications have a huge impact on product quality and growing time as well as crop yields. Especially in recent years, using solar energy from renewable energy sources instead of fossil fuels as greenhouse heating has become increasingly prevalent. Traditional energy production methods are one of the major causes of environmental pollution today and the issue of reducing the consumption of fossil fuels used in these methods by the reasons of international commitments on the environment is on the agenda. Also, the fact that fossil fuels will be end up after a while is also known. While heating the greenhouses may result with high quality yields, also it will reduce the cost of chemicals. This situation is very important in the environment conscious communities and has a great importance for human health and the environment. (Tokgöz, 2006; Baytorun et al., 2013))
The most important parameter in terms of cost is the heating process. For heating greenhouses;

- Heating with stoves,
- Central heating
- Heating with hot air,
- Heating with electrical energy,
- Heating by utilizing waste energy,
- Heating by utilizing renewable energy (solar, geothermal etc.) methods are being used.

Different renewable energy sources are utilized in greenhouse heating processes. These sources are mainly solar energy, geothermal energy and biomass energy. It is mandatory to give importance to using renewable energy sources in the greenhouses to reduce greenhouse heating costs and to minimize the use of fossil energy resources that are harmful to the environment. It can be contributed to energy security and socio-economic development by the using of renewable energy resources, which have a great potential in agricultural applications, especially in greenhouses (Kendirli and Çakmak, 2010; Taşkın and Vardar, 2016). Esen and Yüksel (2013); did an experimental study by using different renewable energy sources in the heating of a greenhouse at 6 m * 4 m * 2.10 m dimensions. According to this study, as the result of working in Elazığ climatic conditions, it has been reached to 23 ºC temperature which is required for growing many plants. Therefore, it has been stated that different energy sources can be used for greenhouse heating.

Earth-Air Heat Exchangers are systems that benefit from a certain depth of soil temperature. It consists of a fan that provides air movement and a pipe system located under the ground. A certain depth of soil temperature is higher than outside temperature in winter while lower in summer.(Fig 1) For this reason, the EAHX system can be used for heating in winter and for cooling purpose in summer. There are open circuit and closed circuit systems.

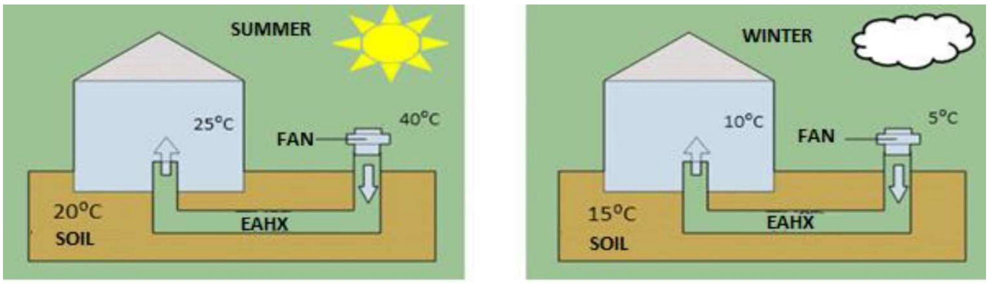

Figure 1. Schematic view of EAHX systems

2.MATERIALS AND METHODS

EAHX Usage in Greenhouse Heating

In this study, heating of greenhouses with EAHX from renewable energy systems was investigated. Figure 2 shows the heating of a greenhouse with EAHX schematically.

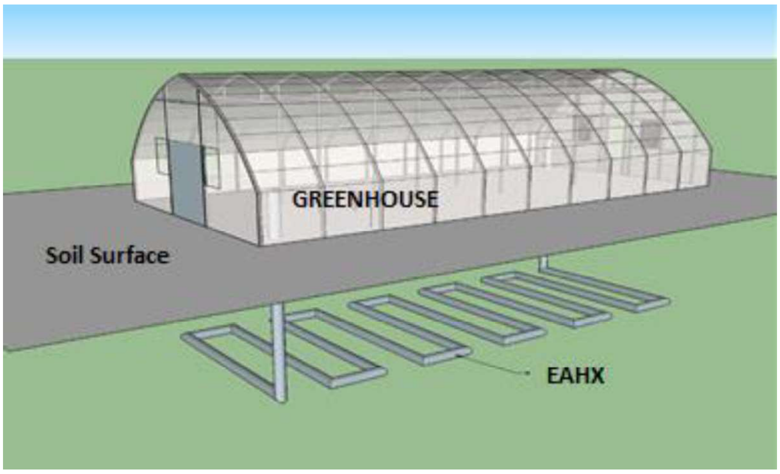

Figure 2. Heating of greenhouse by EAHX

There are many studies on the using of EAHX systems in greenhouse heating. In the greenhouse heating application where the closed circuit EAHX is used; exergy modeling and performance analysis of the used system has been done. In the study where energy and exergy efficiency of the system has been investigated, the use of EAHX in the greenhouse was examined in terms of sustainability index. (Hepbaşlı, 2013)

In another study which the optimal design for EAHX used in greenhouse heating with the help of exergoeconomic analysis is investigated, it was stated that the absence of exergy is arised from by the losses in the fan and heat exchanger. In order to analyze and improve the system performance, the efficiency of the exergy of both the COP and the general system has been investigated. The average COP and exergy efficiency has been determined as 10.51 and 89.25%, respectively. (Özgener and Özgener, 2011).

In a study investigating the use of PV / T and EAHX in the greenhouses in India with considering four weather conditions for five climatic regions (open, foggy, foggy-cloudy and completely cloudy), the system has been compared with various energy measurements such as energy payback time, electricity generation factor and life cycle conversion efficiency (Nayak and Tiwari, 2010).

In another study set up at the Ege University Solar Energy Institute, the performance characteristics of the U-type EAHX with 47 m horizontal and 56 cm nominal diameter for heating the greenhouse were investigated. As a result of the measurements, it was determined that the average heat taken from the soil is 3.77 kW. When the heat taken from the soil and the pipe length is taken into consideration, it is calculated that 80.21 W / m heat has been gained from EAHX. As a result of the calculated exergy analysis; the maximum daily heating coefficient (COP) value for the system was obtained as 6.18. The total average COP value in the experiment period was found as 4.74 (Özgener and Özgener, 2010).

In another study where a thermal model for greenhouse heating was developed, EAHX has been used with thermal curtain. The thermal performance of a greenhouse with thermal curtain and EAHX is compared to a greenhouse with thermal curtain and geothermal energy. According to the results obtained with dividing the greenhouse into three regions, it is stated that an earth-air heat exchanger may be an alternative source for heating the greenhouse if there is no geothermal energy. (Shukla et al. 2006).

It has been stated that the closed EAHX system is more efficient than the open system in another greenhouse application, which is placed in a 3.5 m deep soil and is heated by THID system using 42 m length PVC pipe with a diameter of 0.25 m. The thermal parameters such as the heating potential of the THID, COP and pipe yield, are not directly proportional to the performance of the EAHX used greenhouse (Deldan et al. 2017).

Calculation of Greenhouse Heat Requirement

Many different methods are being used to determine the required heat requirement for greenhouses. One of these methods is a calculation based on the minimum or maximum heating load. The maximum heating load is calculated as using the mean value of the month when the highest temperature detected over many years and the minimum heating load is calculated as using the long years average of the month when the lowest temperature detected over many years. The most important factor in the calculation of the heat requirement for greenhouses is the difference between the minimum ambient temperature determined according to the meteorological records at the place where the greenhouse is to be built and the desired temperature level in the greenhouse at that time (Yüksel, 1989; Arın and Akdemir, 2002).

The calculation according to the type of greenhouse and the used covering materials in addition to the external climatic conditions is shown in equation 1. The heat requirement coefficient used in the equation is given in Table 1.

$$Q = A_H * h * (T_i - T_d) \quad A_H = A_G * F \tag{1}$$

The total heat requirement coefficient used in Equation 1 varies depending on the type of greenhouse, the type of cover material used, the external climatic conditions, and the type of heating and irrigation system used in the greenhouse. Table 2 summarizes the total heat requirement coefficients for greenhouses covered with different cover materials and different precautions were taken for heat conservation at 4 m/s wind speeds (Akyüz et al. 2017)

In equation:

Q : Total heat power requirement [W]
A_H : Greenhouse exterior surface covering area [m^2]
A_G : Greenhouse floor area [m^2]
F : Cover surface factor
h : Total Heat Requirement Coefficient [W. m^{-2}. K^{-1}]
T_i : Desired internal temperature value at greenhouse [°C]
T_d : The lowest average outdoor temperature value of the where greenhouse is built [°C]

Table 2. u value according to cover materials

Covering material and material for heat protection	u' value (W.m^{-2}.K^{-1})
Single layer glass	6,0-8,8
Single layer PE plastic	6,0-8,0
Double layer glass	4,2-5,2
Double layer hard plastic PMMA 16 mm	4,2-5,0
Double-layer PE plastic	4,0-6,0
Single layer glass with heat curtain or plastic greenhouse	3,2-4,8

The heat energy requirement depending on the greenhouse features and equipment used in the greenhouse is calculated by Rath (1992) with the help of a 2-way equation developed based on DIN 4701 standards (Baytorun et al. 2013)

$$Q = \sum_{n=1}^{8760} \left(\left((t_{i_n} - t_{i,OH_n} - \Delta t_{s_{p_n}}) . u' . A_c . (1 - EE_{ES_n}) \right) . t_{si} \right) \tag{2}$$

Q : Annual heat energy requirement of the greenhouse [W$_h$]
ti,OH : The true indoor temperature value at unheated greenhouse[ºC]
ΔtSp : Temperature increasing due to solar energy at greenhouse [ºC]
AC : Greenhouse cover surface area [m^2]

$EEES$: Saving rate of energy conservation precaution used in greenhouse [-]
n : hours of the year [h]

In another study, taking into consideration the climate conditions in Ankara, the heating requirements of seven greenhouse with different types, sizes and materials were calculated according to the approaches of ten different researchers and the obtained results were evaluated. In the study, which results were close to each other, it was stated that the highest heating loads were obtained in PE covered greenhouses when greenhouse type and covering materials were taken into consideration. Since the heating cost is the most important factor in greenhouse cultivation production costs, accurate calculation of heat-demand capacities in the greenhouse is extremely important in reducing production costs. Therefore, a computer program has been developed that can accurately calculate the greenhouse indoor heat-demand capacities with considering the area where the greenhouse is located, grown product, the covering material used, the heating system and the greenhouse floor area criteria. The results belong to Şanlıurfa of the study for different cities and greenhouse characteristics are given in Table 3. (Kendirli 2015; Gürdil et al., 2009)

Table 3. The heating capacities required for 1 da tomato greenhouse according to different cover materials for Şanlıurfa, (kW)

City	Glass (3.8 mm)	PVC (1 mm)	Artificial glass (acrylglas) (2 mm)	Double glass (6 mm) space	Double glass (15 mm) space	Double glass (12 mm) space	Plastic double artificial plate (10 mm)	Plastic double artificial plate (5 mm)
Şanlıurfa	81.70	81.11	78.23	48.03	35.40	41.83	34.26	60.95

Calculation of heat loss in study has been calculated according to Equation 3 (9).

$$Q_s = \left[\frac{A_1}{R_1} + \frac{A_2}{R_2} + \cdots\right](T_i - T_o)(f_w)(f_c)(f_s)$$
(3)

Q_s : *Greenhouse heat loss, kW*
$A_{1,2}$: *Surface area of various components in greenhouse, m²*
$R_{1,2}$: *Thermal resistance of the components in the greenhouse* $\left(\frac{m^2}{W.^0C}\right)$
T_i : *Greenhouse interior design temperature,* ^0C
T_o : *Greenhouse exterior design temperature,* ^0C
f_c : *Greenhouse building type factor*
f_s : *system factor for greenhouse*
f_w : *Wind or front factor for greenhouse*

As a result of the calculations made for Şanlıurfa considering the average temperatures of December, January, February and March months; the greenhouse heat loss was found as 3,2844 2,8322, 3,8794 and 3,6176 kW respectively. The heat obtained from the EAHX system shown in Figure 3 is calculated by Equation 4. (Bulut at al., 2016)

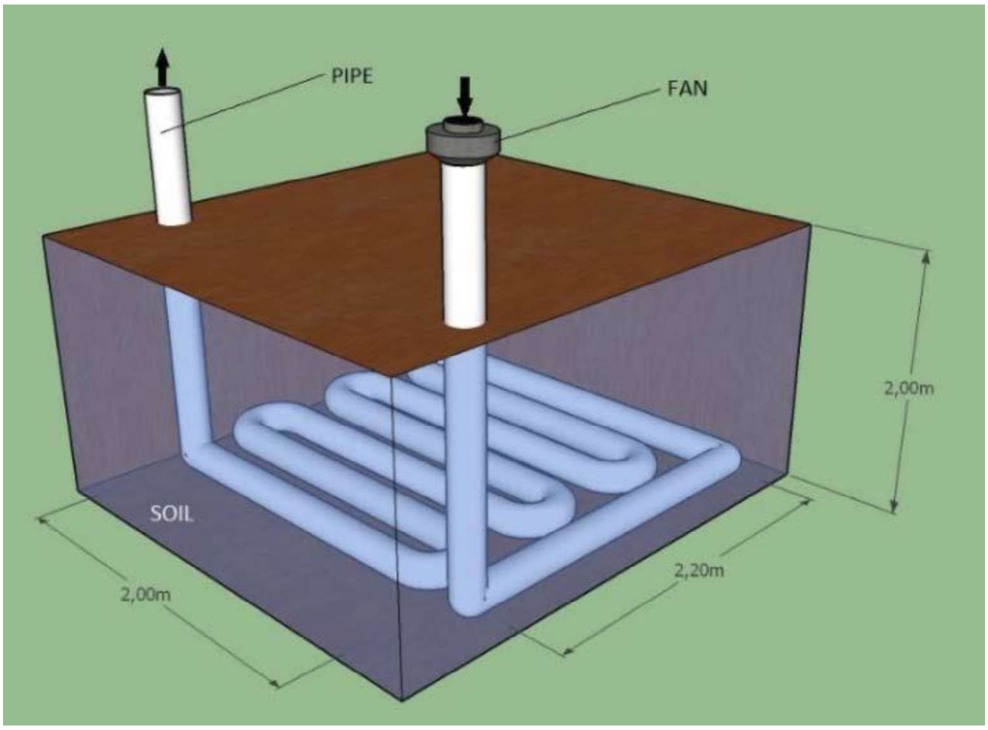

Figure 3. Schematic drawing and general properties of EAHX system

$Q_{Thıd} = m.C_{hava}\,|T_g - T_ç|$ (4)

$Q_{thıd}$: Amount of heat extracted from the soil
Tg (ºC) : air inlet temperature,
Tç (oC) : air outlet temperature
m : mass flow of the air (kg/s)
Chava : specific heat of the air (J/kg oC).

As a result of the calculations, the amount of heat extracted from the soil by EAHX was found as 703.674, 686.718, 898.668 and 813.888 W for December, January, February and March, respectively.

3.RESULTS AND DISCUSSION

In this study, greenhouse heating was investigated by using Earth Air Heat Exchanger. By investigating the studies done on this subject, it is investigated that the heat needed in winter of a greenhouse in Şanlıurfa climatic conditions can be met by EAHX. The results are expressed as follows.

a) As a result of calculations made for December, January, February and March, it is determined that the heat loss for these months was 3,2844 2,8322, 3,8794 and 3,6176 kW respectively.
b) For the same period, the heat taken from the soil by EAHX is calculated as 703.674, 686.718, 898.668 and 813.888 W.
c) The average of the heat taken from the soil for these four months was calculated as 775,737 W and the ratio to the length of horizontal pipe below the ground which is 16 m was obtained as 48,48 W / m.

As a result, it has been determined that by using EAHX, the amount of heat required for greenhouse can be compensated in a certain way, thus heating costs can be reduced. It has been observed that the use of EAHX as a closed system will increase efficiency.

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