J. Appl. Environ. Biol. Sci., 4(3)300-314, 2014

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Technical Feasibility Study of Geothermal Energy Use of Meshkinshahr Site for Greenhouse Heating

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Received: November 4 2013
Accepted: February 28 2014

ABSTRACT

Among the most important factors for social, industrial and prosperity development is energy, and in particular, inexpensive energy. Therefore, applying energy management and surveying is considered as a part of requirements and needs for increased productivity of production factors. Greenhouse heating can be provided using different systems and various methods. This research was done on geothermal site of Meshkinshahr for greenhouse heating in 2014. The required heat load was calculated that was designed considering the influence and transfer of the heat through greenhouse cover (load loss). Typical thermal systems, including space heating systems and floor and platform heating systems were considered. The geothermal site of Meshkinshar has the heating capacity of at least 123 greenhouse units in the conditions of glass cover at interior temperature of 22 degrees Celsius and the peak load of 100%, which indicates the high potential of this region to provide heating needs of greenhouse products and reducing energy costs. In general, in this site, in terms of technical parameters of greenhouse number, floor and platform heating systems, the most suitable cover material was obtained as the double-layer polyethylene with internal temperature of 12 degrees Celsius with a peak load of 60%. Also, regarding the annual heat load factor, this coating material gained an acceptable ranking for the geothermal site of Meshkinshahr.

KEYWORDS: Geothermal site of Meshkinshar, Technical factors, Number of greenhouses, Greenhouse heat load factor, Number of pipes in the heating floor and platform

INTRODUCTION

Energy, and in particular inexpensive energy, is one of the most important factors for social, industrial and prosperity development. Therefore, applying energy management and surveying is a part of requirements and needs to enhance the productivity of production factors. We are faced with the problem of decision-making when at least there are two solutions to reach the target. Thus, decision-making includes the selection of the optimum project among the alternative projects based on standards, and the criteria that are used for determining priorities and preferences (Haj Saghti et al., 1998). Limited resources make us to use the existing resources optimally and apply the funds in the most appropriate way. Improper use of funds, not only may lead to lost opportunities for the investor, but also would cause irreparable losses. In order to avoid such losses and efficient use of capital, each investment plan needs to be evaluated before implementation with the help of reasonable regulations and criteria. Meanwhile, the feasibility studies should define the required technology for a particular project and evaluate the technological alternatives to select the most appropriate technology in terms of most favorable combination of the plan components. Hence, the necessities of selecting appropriate technology and the use of technology to provide the interests of society and production include its correct assessment. In such an investigation, the plan cost and profitability is mostly considered. It should be noted that the process of technology assessment requires the consideration of many factors that only two types of technical and economic assessments are reviewed here (Majidian, 1997).

Introducing the potential for geothermal energy in Iran and Meshkinshahr

Extensive studies were began since 1976 in Iran to identify potential sources of geothermal energy by Ministry of Energy in cooperation with the ENEL Italian consulting engineers in northern and north west areas of Iran in an area of 260000 square kilometers. The research results revealed that areas of Sabalan, Damavand, Khoy, Maku and Sahand with an area over 31000 square kilometers are appropriate for performing further studies and exploiting geothermal energy. In this context, the exploration program including geological, geophysical and geochemical studies was planned. Current Mountain Sabalan has caused by Pliocene time

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activity that has continued after the ice age (Darvish Zadeh, 1991). Sabalan Mountain located in the city of Meshkinshahr, Ardabil province is composed of a volcanic great mass of mixed type of Andesite rock in the form of Caldera that has placed a geothermal field within itself. Examining the chemical characteristics of the region volcanic rocks suggests that the igneous rocks of the region have been created as a result of thickening of the Earth's crust in this area due to pushing of Iran's plane beneath the Caspian plane. By chemical analysis of volcanic rocks and determining their age through determining the isotopic age (K - Ar), the possibility of a relatively shallow magma reservoir under Sabalan Mountains appears (Tables 1 and 2). Deformation of sedimentary rocks under pressure of volcanic mass has caused massive disruption and drift of the volcanic pile in the north east direction And opening up the Moeil Valley. In continual of the drift, a small volcanic dome of Trachyte and Dacite material has created near the Moeil village, which is likely related to an Apophyse of a Magma reservoir beneath Sabalan Mount that serves as the heat source of Meshkinshahr geothermal system. Chemical studies on hot springs show that the groundwater contains neutral and condensate magmatic gases, which indicates the possible presence of a relatively shallow magma reservoir confirmed by the geological surveys (Yousefi et al., 2002; Parsavnd et al., 2008).

Table 1 - Analysis of Average core elements (ppm) in samples from geothermal fluid (writer, 1392)

elements	**CO_2**	**WH_2S**	**$C0_3$**	**Li**	**Ca**	**K**	**Na**	**Sio2**	**So4**	**F**	**CL**	**B**	**HCO3**	**TH**	**PH**
values	72.85	10.8	4	10.9	8.1	341.4	1762	559.7	108.7	6.18	290	24	100.5	35	8.4

Table 2 - Analysis of the main physical parameters of the geothermal fluid samples (writer, 1392)

Parameters	**Temperature (C°)**	**Density (kg/m3)**	**Enthalpy (kJ/kg)**	**flow rate (kg/s)**	**Critical pressure (bar)**	**Pressure in the discharge (bar)**
values	90.63	965.30	4.223	16.42	1.15	12.6

Based on the information obtained, Meshkinshahr area is more suitable for drilling deep geothermal exploration wells to produce electricity and direct use due to following reasons:

A. The reservoir temperature with geometric estimates of 240 ° C
B. Presence of numerous hot springs, such as Qinerjeh at 16 km form the south of Meshkinshahr with temperature of 85 ° C
C. Using the gravity results, it was found that Meshkinshahr area has a broad spectrum of low-density sediments with high porosity and permeability
D. Sabalan area is extremely favorable hydrogeologically for geothermal reservoirs water supply, and most precipitation penetrate deep underground reservoirs through fractures, faults and cracks.

Babi et al. (2007) designed and studied on-soil warm pipe heating system in geothermal greenhouses in Algeria. The researchers, based on the principle and equation of thermal equilibrium, simulated the thermal and moisture behavior of this type of heating system throughout the 24 hours a day to examine the possibility of using and producing in the recession season of orchard and vegetable productions in the area. Based on the results, they predicted that in the near future in the southern part of Algeria, the demand for using geothermal hot fluid system becomes much more than solar energy applications in greenhouses in the working recession season. Yousefi and Nurollahi (2006), unlike other researchers, used the GIS model for the exploration of geothermal resources and determined 18 regions with potential of geothermal energy in Iran. Ghorbani (2007), given the location of Iran in the Cenozoic volcanic belt, considers it having active areas of geothermal energy and states that unfortunately except for health and treatment uses of numerous springs of hot water in the area, none of them has been exploited so far. The researcher has measured the temperature intensity of geothermal resources of regions with domains belonging to the Neogene – Quaternary period associated with volcanic activity, such as Damavand, around Sahand , Sabalan and, in general, large parts of Azerbaijan with anomalous heat from the geothermal view and has proven the thermal anomalies in all mentioned areas. Ghorbani believes that there are four dividable areas suitable for geothermal energy has that include in terms of priority as: Sabalan, Mako - Khoy, Damavand and Sahand. Eghtedari (2010) believes that dramatic development of greenhouses in the country has occurred while due to the lack of available technologies, energy consumption for producing each unit of product in them is several times higher than the global average. In this case, the rise in energy prices appears as a challenge for producers of greenhouse crops, leading to encourage them to use new technologies in order to reduce the energy consumption. He considers using techniques to reduce energy consumption, including reducing the heat loss from the greenhouse, improved production efficiency, improved efficiency of heating, cooling and irrigation systems, reduced electrical energy consumption and improved greenhouse management as effective factors on reducing energy consumption for production per each unit of product. The researcher in comparing different methods of greenhouses heating concluded that the radiation treatment has the highest performance, while central method (warm water and hot steam) has an optimal performance. Finally, the hot air method has the lowest performance. However, the radiation method can only be used in certain circumstances and in small plants. According to conducted studies, the researcher considers the hot water technique as the best and most common method of greenhouses heating. However, this is only true when the conventional heating method in the country would be hot weather; thus, due to the low efficiency of converting fuel to heat in the boiler system, the use of this system is not recommended. Recently, water heating systems with efficiency greater than 95 % have presented to the market. The researcher suggests that using the proper fuel is one strategy to improve the efficiency of the heating system in the hot water system.

According to Momeni and Saeed (2010), more than 90 wells with depths of 400 to 2800 meters for heating the greenhouses were drilled in Tunisia. In Tunisia, to use the geothermal energy, the hot water with a temperature of 40-80 degrees Celsius is mined from the depths of the earth and transferred into the greenhouse by polypropylene tubes to heat up their surroundings. Then, with a temperature of 30 to 250 degrees Celsius is removed from the greenhouses and entered into the pond to be used for watering gardens. According to research done in Tunisia, the amount of flow required to heat the greenhouse is about 6 lit/s per hectare on average in the coldest night, while the average amount of crop water requirement per acre is about 0.6 lit/s during the period of plant growth. Thus, the total volume of water requirements for greenhouse heating in one season will be about 60500 m3/ha. Studied and examined the simulation and prediction the behavior of greenhouse environment, or in other words, the ability to control the thermal behavior of greenhouse based on linear and nonlinear regression model and the feasibility for programmable controllers in modern greenhouses based on accurate predictions of physical quantities within the greenhouses. For plan success, the researchers continually simulated the climate inside the greenhouses to make applying proper control possible. According to researchers, a condition to create a suitable environment for greenhouse plants is to provide and maintaining the warmth or heat factor, even with solar source or other additional panels systems.

Study purpose

Developing the use of renewable - geothermal energies in Iran, especially in Meshkinshahr region, Ardebil province

General objectives of the research

1. Proving heating energy for greenhouses by using geothermal energy
2. Choosing the best heating system in geothermal greenhouses based on technical criteria

The specific and applied objectives of this research can be mentioned as follows:

- Review and determine the amount of required heating load in the internal temperature and different structure of the greenhouse based on the static model
- Estimation the number of applicable greenhouses with different peak loads and internal temperatures and different structural conditions of the greenhouse with selected thermal technology
- Estimating the size and amount of pipes required for floor heating and warming platform systems of the greenhouse in different structural conditions in different internal temperature and varied peak times in the greenhouse
- Study and calculating the annual heat load factor to describe the efficiency of greenhouse projects with geothermal system based on different peak load conditions and different internal temperature conditions in varied greenhouse structures

MATERIALS AND METHODS

Evaluation of technical factors

Determining the climate conditions of the study area

The geothermal site is located in northeastern Sabalan and at 20 km from south of Meshkinshahr with relatively cold winters. Therefore, to determine changes in external temperature in greenhouse design, the data from synoptic weather stations of city of Meshkinshahr within the years of 2007 and 2011 were used (Meshkinshahr synoptic weather report s, 2013). It should be noted that the meteorological data in the synoptic stations had been developed by month and year, among which the data related to daily temperature and wind speed were selected and evaluated as its relevance to the topic research. The average daily temperatures during the months of the year in the statistical periods of 2007 to 2011 showed that the coldest and the warmest months are January and July, respectively. The coldest average daily temperature during a five-year period was related the thirteenth day of January with -6.9 ° C that this temperature was considered as the basis of the coldest greenhouse outside temperature in the calculations of technical factors (Gilani and Mohammadkari, 2011). In review of the monthly average heating load for Ardabil region during a year, the maximum power requirement in January was stated, which is a part of the heating period. Therefore, the observations of these researchers are consistent with maximum load obtained in load peak tables required for greenhouse heating with different covers and temperature levels inside the greenhouse in January. According to Table 3, it can be concluded that during the period of 2007-2011, the maximum monthly wind speed in March was equal to 9.97 m/s and lowest monthly wind speed was in October as 5.05 m/s.

Table 3. Average maximum wind speed in each month for Meshkinshahr in the period of 2007-2011

Month	January	February	March	April	May	June	July	August	September	October	November	December
Mean of maximum wind (M/S) speed	7.19	7.52	9.97	8.54	7.51	6.76	6.14	5.60	5.56	5.50	6.41	**6.84**

Calculating the required load heat

To approach an optimal design, we need to estimate energy consumption. The optimal plan is a plan capable of minimizing the structure costs over its economic life. The priority for designer of the heating and cooling systems includes maximum loads or peak load, based on which, the size of heating and cooling devices is determined that the determination of these loads is called "Plan Conditions". To ease the selection of plan criteria, statistical information of meteorological stations in the region must be used (Kreider et al., 2009). The regional climate reaches to its minimum temperature in intervals during the year so that the energy received from the sun becomes so close to zero. Hence, the received solar heat should not be considered in calculation of peak heat load, unless the system structure has the capability of long term storage of this type of energy. If the temperature of Ti inside is assumed to be constant, analysis by static technique would be sufficient (Kreider et al., 2009). Structural loads calculation is divided into two parts, including load calculation in the floor structure and the calculation of loads in the ceiling and the walls. Heat transfer from the floor structure is usually negligible and relatively constant throughout the year, since the soil temperature varies only slightly throughout the year. For computing the walls and windows as well as the doors, with determining maximum and minimum temperatures of each month as well as the location longitude and direction, the effect of different building walls on the temperature or thermal loads of building is examined. Analysis and estimation method in most energy simulation programs includes performing the calculations (heat loss or diffusion) at a specified time and subsequent thermal equilibrium establishment between interior space and the environment (outside). Computer programs and applications provided to simulate energy (calculating the heat load) are generally of two types (Ebrahimpoor et al., 2004). In calculation of static method, the heat load of greenhouses can be simply calculated by considering the heat transmission losses and losses due to heat penetration into the greenhouse. To determine these losses, the dimensions of the greenhouse, including the surface cover and the size of the greenhouse need to be specified. The surface of coating material and the size of the greenhouse specify the type and form of the greenhouse (Soltandoost, 2010).

Dimensional specifications of Quonset greenhouse structure based on FAO standards

The greenhouses dimensions (size) depend on the size of the earth. In a design introduced by FAO for greenhouse constructs, all the greenhouse structure was prefabricated and without any welding and fully from galvanized iron that is assembled by bolts and clamps.

Regarding engineering, the structures should be necessarily resistant against wind with the speed of 120 kilometers per hour and the weight of snow up to a height of 80 cm (in case of turned on heating system). In this construct, to provide proper ventilation, side windows with the height of 1.5 meter on each side, pad and fan systems at the beginning and end of the greenhouse and all-around skylight exactly at the bow top are imbedded (Dehnavi, 2012). The greenhouse structure must be designed according to optimal conditions of plant growth to obtain the maximum available benefit.

Selecting the range of internal temperatures of the greenhouse

One of the other important factors in designing a greenhouse is the temperature inside the greenhouse, which depends on the type of plants grown in it. Each crop needs an optimum growth temperature range to achieve the maximum performance (Elsner, 2000). Thus, it will need specific temperature conditions and limits for optimal growth that three points are important in this regard:

1. Each plant has an optimum temperature that may change in different stages of its growth
2. For many plants, the optimal growing conditions may occur in night and day different temperatures
3. The minimum and maximum temperatures are important for most plants (Omid & Shafaei, 2004).

Figure 2 and Table 4 show the optimum temperature for some greenhouse crops. In general, we can say in design a greenhouse, its indoor temperature should be selected in accordance with the heating requirement of the grown plants. Such a temperature for growth is between 17 °C and 22 °C in most plants that with addition the solar energy influence on different climate conditions, the plant growth temperature range would be between 12 °C and 22 °C. Thus, in the designs, the temperatures lower than 12 °C require heating system, while temperatures higher than 22 °C require cooling system. In providing heating from the greenhouse floor, the design temperature is selected as 15°C (Elsner, 2000; Salokheh and Sharma, 2011).

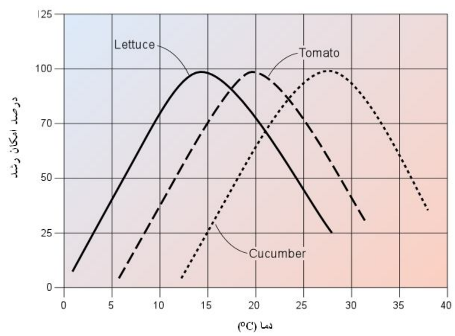

Figure 2. Growth curves of some greenhouse plants (Kaya, 2005)

Table 4. Temperature requirements of some greenhouse plants (Serpen, 2008)

Greenhouse products	Tomato	Eggplant	Red pepper	Cucumber	Greenhouse cereals
Necessary temperature at day (°C)	24-19	30-25	27-21	24-22	21-15
Necessary temperature at night (°C)	14-18	18-19	15-19	16-18	-

Calculation of heat transfer coefficient, "u" (w/m^2°C) for different coating materials based on regional wind speed

Heat transfer coefficient or overall heat use coefficient is energy requirements for maintenance of 1 degree Kelvin temperature difference between inside and outside per one square meter of the ceiling area (Zabeltitz, 2009). The value of heat transfer coefficient for different greenhouse coatings varies depending on wind speed. Table 5 shows the relationship between heat transfer coefficient and wind speed for different coating materials.

Table 5. The value of heat transfer coefficient based on wind speed (W/M^2°C) for common greenhouse coatings (Serpen, 2008)

Type of coating materials	(m/s) Speed of wind					
	0.00	2.25	4.47	8.98	11.18	13.41
Glass	4.34	5.40	5.91	6.47	6.59	6.7
Fiberglass	3.95	4.91	5.39	5.87	6.01	6.12
Monolayer polyethylene	4.60	5.68	6.19	6.76	6.87	6.98
Double-layer polyethylene	3.04	3.58	3.83	4.07	4.13	4.18

According to the table value of heat transfer coefficient and wind status and speed in Meshkinshahr region, their curve and regression equation were estimated through SPSS software to determine the heat transfer coefficient of different coating materials for Meshkinshahr region. In order to determine the value of heat transfer coefficient of the coating material to estimate the total heat loss, the resulted regression equation shown in Figures 3 and 4 was used.

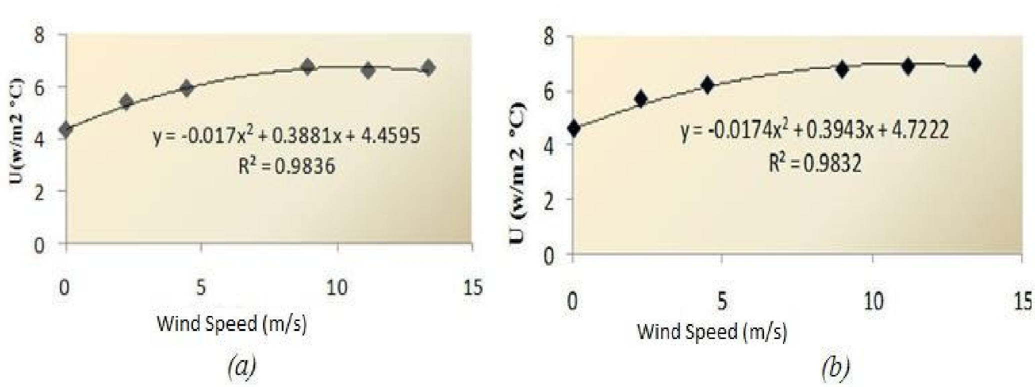

Figure 3. Heat transfer coefficient for glass coating (a) and fiberglass (b) based on wind speed

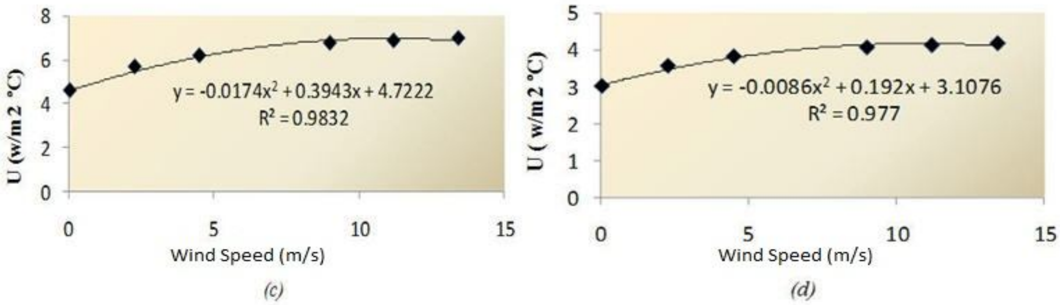

Figure 4. Heat transfer coefficient for single-layer PE coating (c) and two-layer polyethylene (d) based on wind speed

The estimation results of the regression equations between the two variables of wind speed and the heat transfer coefficient showed that due to positive ß in all equations, the relationship between quantitative variables of X and Y is positive. In other words, the heat transfer coefficient increases with wind speed increase (ß values for different coating materials as+0.3881, + 0.3495, +0.3943, +0.192). The results showed that more than 98% of variations in heat transfer coefficient is controlled by wind speed variable (R2 values of explaining coefficient for all equations is equal to 0.98 and just for two-layer PE is equal to 0.97) (Rezaei, 1995).

How to calculate monthly transfer heat loss from the walls and roof in internal temperatures of the greenhouse design for a variety of materials and coatings of the greenhouse (w)

One of the most important factors in thermal equilibrium of a structure is the heat flow through its coating materials. When the temperature range is small enough, the heat flow can be assumed linear based on temperature difference. This approximation for the heat flow through the coating material of the structures is usually appropriate. Therefore, the heat flow in each part of the structure coating can be calculated by multiplying the area of that part (A) by thermal conductivity of that part (U) by the temperature difference between inside and outside (Ti-To) (Karidar et al., 2010, 410). In assessing heat loss through the transition, the calculation of greenhouse roofing material area in terms of square meters is the first phase of the heat loss estimation (Serpen, 2008; Kasapolu, 2005; Porges, 2008; Stoker and Jones 2001; KiaKameli, 2003).

$$Q_t = UA(T_i - T_0)$$

Qt = Conductive heat loss from the walls and ceiling (w)
U = Heat transfer coefficient (w/m^2°C)
A = Area of the greenhouse covering materials (m^2)
Ti = Temperature inside the greenhouse design (C °)
T0 = Temperature outside the greenhouse design (C °)

How to calculate the heat loss through the influence in the internal temperatures of the greenhouse design and for all types of greenhouse covering materials (W)

The rate of changes or movement of the air is a function of wind speed, type of roofing material of the greenhouse and the temperature inside and outside of the greenhouse that the values for different types of greenhouse covering materials are shown in Table 8. After selecting the value of ACH based on the type of roofing material of the greenhouse, the next step is to calculate would be the size or volume of the selected greenhouse. The values of 12, 17 and 22 degrees Celsius for internal temperature of the greenhouse were considered to comply with the planted crops requirements, and the outside temperature was determined in accordance with the tables of average daily temperature for the twelve months of the year. Also, the value of 1006 (j/kg°C) for the quantity of heat capacity (Cρ) was extracted from the table of monthly average physical parameters of production test of the geothermal wells in Meshkinshahr site to be used in equation Qi. It should be considered that in estimating the heat loss through infiltration, if the heat capacity is considered, then multiplying the value of this capacity by the specific gravity of air would not be necessary. However, if the specific heat capacity is required in dissipation equations, then, the obtained heat capacity should be multiplied by the air specific mass (Silovinski, 2009). The specific gravity of air in the above calculations was considered as 1.29 (kg/m^3) (Zupunski, 2013).

Calculating Loss of Heat through Penetration at Internal Temperature for Greenhouse Design and For All Kinds of Greenhouse Coating (W)

Climate change is subject to wind speed, type of greenhouse coating and internal and external temperatures of greenhouse and its values were calculated for different types of greenhouse coatings and values of 12, 17 and 22 °C were considered for internal temperature of greenhouse according to need of the cultivated products and external temperature was also considered based on tables of mean daily temperature for 12 months. Value of 1006 j/kg°C was obtained for quantity of the heat capacity (Cρ) using table of monthly mean of physical parameters of production test in wells of Meshkin Shahr geothermal site in Equation Qi. It should be noted that if heat capacity is considered for estimation of loss of heat through permeation, multiplication of this capacity by air specific mass will not be necessary but if specific heat capacity is required in loss equations , heat capacity value should be multiplied by air specific mass(Slowinski, 2009). Air specific mass has been considered 1.29(kg/m3) in the above calculations (Zupunski, 2013). At the end, losses of heat were estimated through permeation under different load and structural conditions using the available data (Serpen, 2008) and (Kasapolu, 2005) and (Porges, 2008) and (Stoker and Jones 2001). According to the following Equation, loss of heat will have direct relationship with volume of greenhouse, air convection, specific heat capacity, and internal and external temperatures of the greenhouse.

$$Q_i = V \times ACH \times C_\rho \times \rho \times (T_i - T_\circ) / 6300$$

Qi=loss of heat through permeation (W) , V= volume of greenhouse (m^3), ACH=air change per hour , Cρ= air specific heat capacity in fixed pressure (j/kg °C) ،ρ=air specific mass or density in air volume (kg/m3), Ti=internal temperature of the greenhouse design ()°C), T°= external temperature (°C)

Calculating total heat loss or heat load of different coating materials and different temperatures (W)

Total heat losses include sum of transferred heat loss and heat transfer through permeation which are estimated with Qtotal. By determining maximum heat load, optimal heating system can be selected for space of greenhouses and considering nature of greenhouse products, heating system in greenhouses is divided into three sections: space of greenhouse, subbed and sub platform . To complete design of heating system, heat load will be required for two subbed and sub platform systems which are calculated in the next Sections (Kasapolu, 2003).

$$Q_{total} = Q_t + Q_i$$

Designing Technical Specifications of the Required Heat Exchanger

To design heat exchanger and considering chemical and physical specifications of the geothermal fluid, type and dimensions and other technical and economic specifications of the exchanger were determined based on physical and chemical specifications of the geothermal site of Meshkin Shahr by GEA PHE Systems and GEA PHE Systems (A.A.K, 2013).

Calculating Number of Greenhouse

To estimate the number of greenhouse, the heat energy available in the studied geothermal site should be calculated and thermal power of the geothermal site should be determined. Available thermal energy was estimated by multiplying heat capacity of fluid by water specific mass and its total value was regarded equivalent to specific heat capacity of the fluid. Specific mass of the fluid was estimated 9650.30 kg/m3 using PF-Soft 1 software.

$$H_{available} = m \times C_p \times \Delta T \times \rho$$

$$H_{potential} \text{ or } Q = m^\circ \times C_p \times \Delta T$$

Havailable = available heat energy of the geothermal fluid (W), Hpotential = available heat value obtained from geothermal fluid (MJ), m, m°=mass flow rate of geothermal fluid (Kg/s)، Cp= specific heat capacity of geothermal fluid (Kj/Kg), ΔT=temperature drop along heat exchange cycle or heating cycle ( ) , ρ=water specific mass or density in m^3(Kg/m3)

(Mega joule –year) 31.104 = (Mega joule –hour) 0.0036 ×(hour - month) 720=conversion of watt hour of fluid heat energy into annual megajoul

Calculating the Number of Greenhouse for Different Coatings and Different Internal Temperatures

The number of greenhouse based on available heat energy is calculated from geothermal fluid and monthly base load for the coldest month (January) for different coatings through NG.

$$NG = H_{availabil} / H_{base}$$

NG= the number of executed greenhouse considering available heat energy of geothermal fluid, Havailable=available heat energy of geothermal fluid (W), Hbase=base heat in which greenhouse will be designed (W).

Calculating Annual Heat Load Factor (AHLF)

To mention efficiency of the geothermal greenhouse project, it is necessary to calculate Annual Heat Load Factor (AHLF).

1 Calculation of the density of water using the IAPWS-95 formula

$$AHLF = E_{Anuual} / E_{available}$$

AHLF= annual heat load factor, Eavailable= available heat energy of the geothermal fluid (MJ), Eavailable=annual heat energy of the greenhouse heating system (MJ)

$$E_{Annual} = Q_{Total} \times NG$$

EAnnual= annual heat requirement of greenhouse heating system (MJ), QTotal= annual heart requirement for different coatings and with different internal temperatures (MJ), NG=the number of executed greenhouse considering available heat energy from geothermal fluid

Calculating length of heating pipes

Calculating losses in Subbed System or Heating System of Soil

In subbed heating system, uniform and desirable distribution of temperature is more important in floor of the greenhouse. Steps of designing heating floor system (Kasapolu, 2005 and Kasapolu, 2003) include: A-determination of heat load for greenhouse (QTotal), B-calculation of floor temperature required for greenhouse considering the available load (TP), C- calculation of length and number of required pipe (Lpip), depth of the required piping or distance of pipes from floor area of the greenhouse (H). Heat load peak of the greenhouse which had been calculated before is also applied in design of the subbed heating system. Therefore, the next step is to determine floor temperature of the greenhouse (TP). Its value is subject to floor temperature of the greenhouse, temperature of greenhouse space and mean temperature of coating material of the greenhouse which emits through radiation and convection. To calculate floor temperature of the greenhouse, Mathematica7 software was used due to long calculation and probability of error in calculations (Gray, 2008). After determining floor temperature of the greenhouse, greenhouse mean temperature difference logarithm was estimated according to Equation 4 based on temperatures inside the greenhouse and then mentioned based on load peaks. In the third step, Equations 6 and 7 were used for determination of length, number, depth, and distance between the required pipes. Internal surface temperature for different coatings at different temperatures (IST) can be calculated for Equation 5 through Equation 1 and also mean temperature is calculated through Equation 2 for non- thermal surfaces in walls and ceiling of greenhouse (AUST) which is the necessary parameter of Equation 5 (Kasapolu 2005 and Kasapolu, 2003).

$$IST = IDT - (0.0291 \times 3.6 \times U \times DT) \tag{1}$$

IST= internal surface temperature in the coldest month (°C), IDT=internal design temperature ((°C), U=monthly heat transfer coefficient for different coatings in the coldest month (w/m2°C), DT= internal and external temperature difference (°C)

$$AUST = \frac{A_1 \times IST_1 + A_2 \times IST_2 + \cdots + A_n \times IST_n}{A_1 + A_2 + \cdots + A_n} \tag{2}$$

AUST = mean temperature for non-thermal surfaces in walls and ceiling of the greenhouse (°C),
A = surface area of the coating (m^2), IST=internal surface temperature of greenhouse (°C)

$$\frac{q}{A} = 0.472\left[\left(\frac{1.8T_p+492}{100}\right)^4 - \left(\frac{1.8AUST+492}{100}\right)^4\right] + 2.186\left(T_p - T_a\right)^{1.32} \tag{3}$$

$\frac{q}{A}$ = ratio of heat to area (w/m^2), Tp= greenhouse floor surface temperature (°C), Ta= greenhouse internal air temperature (°C), AUST mean temperature for non-thermal surface in walls and ceilings of greenhouse (°C)

To design subbed heating system , inlet and outlet water temperature of the system , diameter of the pipe , length of the pipe , distance of two pipes and pipes burial depth (distance between pipe and floor of greenhouse) are of the key factors affecting uniform distribution of heat and efficiency of subbed system. In most designs, burial depth of the pipes is considered between 10 and 30 cm (averagely 15cm) and minimum diameter of the pipes is also considered 20 mm in calculations (Fenglan 2008). The following Table shows necessary parameters for Equation tm and L for the heating floor system.

Equations 4 shows calculation of greenhouse surface mean temperature logarithm(tm)in which one of the necessary variables for the Equation is estimation of the required pipes (L) for heating floor system .

(4)

$$t_m = \frac{(T_{wi} - T_{w\circ})}{Ln(\frac{T_{wi} - T_p}{T_{w\circ} - T_p})}$$

Tm= greenhouse surface mean temperature logarithm (°C), Twi=inlet water temperature ()°C), Two: outlet water temperature ()°C) , Tp: greenhouse surface temperature (°C)
Equation 21-3 shows calculation of length of the required pipes (L) for heating floor system in meter.

(7)

$$L = \frac{Q \times Ln\left[\left(8\left(\frac{H}{d}\right)^2 - 1\right) + 4\left(\frac{H}{d}\right) \times \sqrt{4 \times \left(\frac{H}{d}\right)^2 - 1}\right]}{4 \times \pi \times \lambda_j \times t_m}$$

L= length of the required pipe in heating floor system (m), Q=required heat load (W), H=burial depth of pipe (distance between soil surface and pipe) (M), d= external diameter of the pipe (mm), ، λj= geothermal conductivity (w/m°C), tm= greenhouse surface mean temperature logarithm (°C),
Relation 8 shows calculation of the number of required pipes for subbed heating which is obtained from division of the length obtained from Equation 7 and length of the selective greenhouse (FAO standard) (Kasapolu 2005)(Kasapolu 2003).

(8)

$$n = \frac{L_{pipe}}{L_{greenhouse}}$$

N=number of pipes, Lpipe= length of pipe (m), Lgreenhouse= length of greenhouse (m)

Heating platform system

In this heating system, polyethylene pipes or the similar materials placed below platforms or on the floor of greenhouse (below vases) are used for heating. Like steps of designing subbed heating system, the first step is also determination of total heat load of the greenhouse. Therefore, the next step is determination of temperature drop based on inlet-outlet temperature of fluid into the greenhouse heating system. Equation 9 shows calculation of the length of pipe for heating platform system. In this regard, diameter of the pipe and its layout are two important factors affecting control of temperature drop dependent on skill of designer and its execution. To calculate the required length in heating platform system, Mathematica7 software was used due to length of calculation in classic method. Equations 9 to 16 show calculation of length of the required pipes (L) for heating in the heating platform system (Kasapolu, 2005 and Kasapolu, 2003).

(9)

$$L = \frac{3.6Q}{\left[4.422 \times \left(\frac{1}{D}\right)^{0.2} \times \left(\frac{1}{1.8T_{ave} + 32}\right)^{0.181} \times (\Delta T)^{1.266} + 15.7 \times 10^{-10}\left[(1.8T_1 + 32)^4 - (1.8T_2 + 32)^4\right]\right] 11.345A}$$

L=length of pipe in heating platform system (m), Q=required heat load, D=external diameter of pipe (mm), Tave : average temperature ()°C)

(10)

$$T_{ave} = 255.6 + (AWT + T_{air})/2 \quad [°C]$$

(11)

$$AWT = T_{wi} - DT/2 \quad [°C]$$

AWT= average water temperature in greenhouse heating system ()°C), Ti=inlet water temperature (°C), Tair=internal temperature of greenhouse (°C)
(12)

$$DT = (3 + T_{ar}) - AWT$$

DT= change of greenhouse temperature
Therefore, considering two Relations (9) and (10), we will have:

$$AWT = T_i - \frac{AWT - T_{air} - 3}{2}$$
$$2AWT = 2T_i - AWT - T_{air} + 3$$
$$AWT = \frac{2T_i - T_{air} + 3}{3}$$

(13)

$$(°c)T_1 = 255.6 + AWT$$

(14)

$$T_3 = \frac{(AUST + T_{air})}{2}$$

(15)

$$(°c)T_2 = 255.6 + T_3$$

(16)

$$A = \frac{D \times \pi \times L}{W}$$

A =external surface of the pipe in length unit (m^2/m), L= length of greenhouse (m), W= width of greenhouse (m), D= external diameter of the pipe (m)

Equation 17 shows calculation of the number of pipe for heating platform system (Kasapolu, 2005 and Kasapolu, 2003).

(17)

$$n = \frac{L_{pipe}}{L_{greenhouse}}$$

N=number of pipes, Lpipe=length of pipe (m), Lgreenhouse: length of greenhouse (m)

Selecting percent of base load in design of greenhouse heating systems

In a successful and sustainable design, technical, economic, environmental and consumable dimensions of heating system should be considered (Polatidis and Harambopolus, 2006). Base load for geothermal energy has been selected in five ranges of 100%, 90%, 80%, 70% and 60% and the available overload is provided by common and renewable energies of the region like solar energy etc. therefore, capacity of thermal facilities can be obtained from difference between load peak and base peak considering base load and provision of overload with other thermal sources (Kasapolu, 2003, Emeish, 1999).

(18)

Heating equipment capacity (w) = Peak load (w) - Base load (w)

RESULTS AND DISCUSSION

The climate of the studied area

According to the images of wind roses (Figure 5) and the frequency figure of wind speed, the prevailing wind is from the southwest region, and the average speed of the wind in the station is 2.26 meters per second; also, more than half of the hours recorded in the region are without wind.

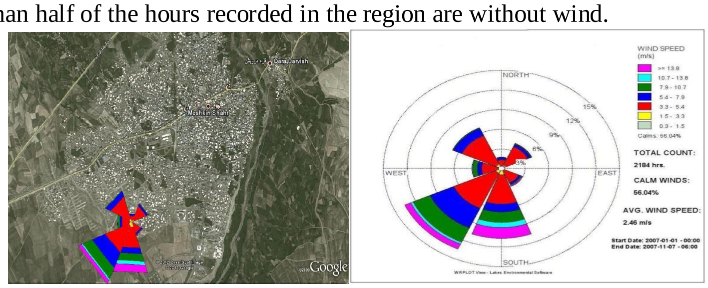

Figure 5. Wind rose of Meshkinshahr station during the statistical period of 2007 - 2011

According to the above diagrams and figures, we can conclude that the direction of the maximum wind and the prevailing wind is from the southeast side, which would be very important to determine the direction of building greenhouses; since the directions of the prevailing wind and the maximum wind in the region are the same. Also, regarding the wind speed range, the region is classified in the of gentle breeze range according to Bofort standard (Azari, 2008; Mohseni, 2010).

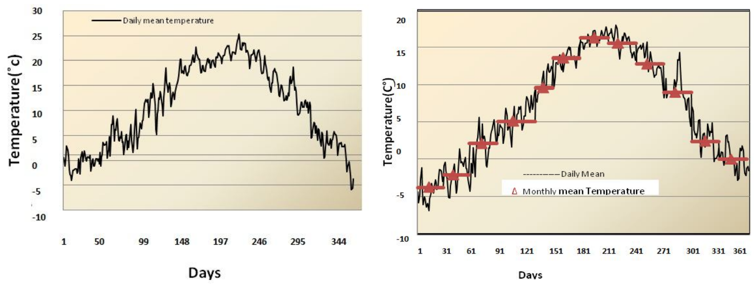

Figure 6. Changes in annual, monthly and daily mean minimum temperature in a five-year statistical period of 2007 - 2011

Therefore, in this respect, the construction of thermal plant of greenhouses will have technical and economic potential and primary justifiability. However, the maximum wind occurred in the statistical 5-year period should not be neglected; since the possibility of having negative effects on greenhouse structures in one day is not unexpected. Therefore, it is recommended to consider the regional maximum wind in designing the structures robustness.

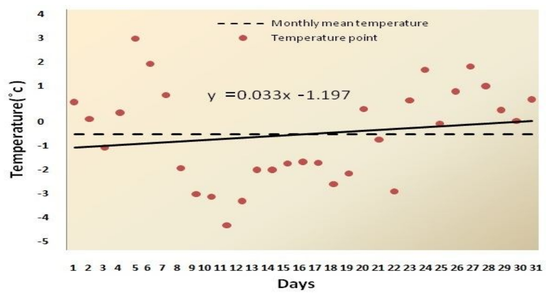

Figure 7. Changes in average minimum daily temperature in January in the period of 2007 - 2011

The required thermal load

According to the results of Table 7 for Meshkinshahr geothermal site, the monthly maximum heat transfer coefficient is related to March for single-layer PE coating material, while the minimum value is related to the months of September and October for bi-layer polyethylene coating materials. Also, among the four existing coating materials, the highest heat transfer coefficient was obtained in the single-layer polyethylene and the lowest in the two- layer polyethylene. In other words, the minimum heat transfer coefficient was seen in two-layer polyethylene, fiberglass, glass and the monolayer polyethylene, respectively.

Table 7. Monthly heat transfer coefficient (w/m2°c), U, for current greenhouse covers

Months of year	Glass	Fiberglass	Monolayer polyethylene	Double-layer polyethylene
January	6.37	5.80	6.67	4.04
February	6.42	5.84	6.70	4.06
March	6.64	6.05	6.92	4.17
April	6.53	5.95	6.82	4.12
May	6.41	5.83	6.70	4.06
June	6.31	5.74	6.60	4.01
July	6.20	5.64	6.49	3.96
August	6.10	5.55	6.38	4.13
September	6.52	5.54	6.38	3.90
October	6.08	5.53	6.36	3.90
November	6.25	5.68	6.53	3.98
December	6.32	5.77	6.60	4.02

According to the results of Figure 8 in Meshkinshahr region, the glass greenhouses with the internal temperature of 12 degrees Celsius had the highest and lowest transfer rate in March and October, respectively. However, the highest peak load requirements were estimated in January due to high total heat losses, and in contrast, the lowest peak load was related to the months of June, July, August and September.

Also, the maximum peak load requirements for greenhouse heating with glass cover were observed at internal temperature of 17 degrees Celsius for Meshkinshahr region in January, which are similar to the results of internal temperature of 12 degrees Celsius. Also, the maximum and minimum heat transfer coefficients for internal temperature of 17 degrees Celsius were respectively obtained in March and October. Comparing the estimated peak load requirements in three temperature levels suggests that the maximum peak load required for glass greenhouses would be in January and the minimum in July. Estimating the peak load for heating the greenhouses coated with fiberglass at internal temperature of 12 ° Celsius and its comparison with the table of glass coating materials at the same internal temperature, we can see that the highest and lowest peak load requirements and the heat transfer coefficient for both coating materials are similar in Meshkinshahr region. In other words, in Meshkinshahr area, the greenhouses with glass and fiberglass coating materials at internal temperature of 12 degrees Celsius are the same regarding the minimum and maximum peak load and heat transfer coefficient. Regarding the amount, about 10.5% of peak load less will be required in fiberglass with 12 degrees Celsius. Also, for heating the greenhouse with fiberglass cover at interior temperature of 17 degrees Celsius, the highest required peak load was obtained in January and the lowest in July. Comparing the tables of peak load for greenhouses with glass coating materials in the same temperature showed similarity, while regarding the mount, needs a peal load less as 10.5% compared to the glass. According to the results obtained for three internal temperature levels of 12, 17 and 22 degrees Celsius in fiberglass greenhouses, the maximum and minimum thermal loads were observed in January and July, respectively. The two- layer polyethylene coating materials are a standard cover for commercial greenhouses in cold climates like Idaho. The two- layer polyethylene needs less heating that the one-layer polyethylene; thus, a smaller fan and thus less electrical energy would be needed to conserve heating in the greenhouses space. Also, the heat transfer coefficient (U) in the double-layer polyethylene is less than the one-layer PE. Generally, the need to peak load reduces as approximately 34 % in bi- layer polyethylene compared to single-layer polyethylene (Rafferty, 2004). According to the results obtained in the study area, the total heat requirements in two- layer polyethylene at three temperature levels shows about 38% reduction compared to one-layer polyethylene that the percentage is consistent with Raferti's results.

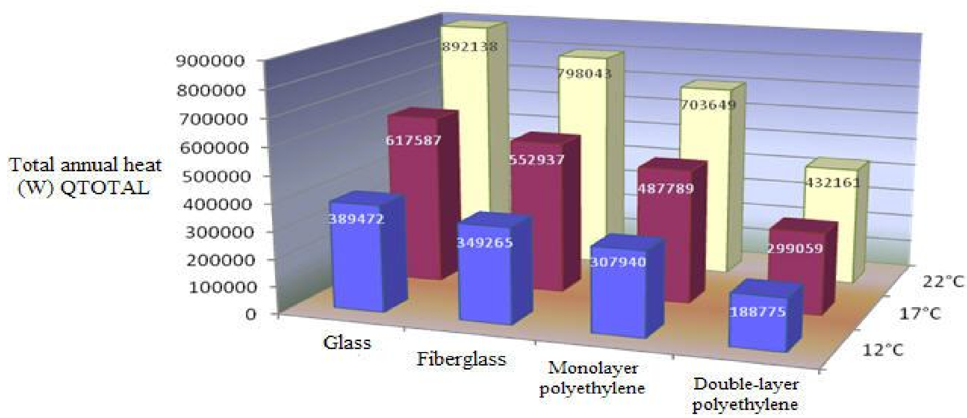

Figure 8. Total annual heat requirement (W), Q_{TOTAL}, for different coating materials at internal temperature of greenhouse design

Number of greenhouses

The highest number of greenhouses was related to the greenhouses with two-layer polyethylene coating with internal temperature of 12 degrees Celsius and peak load of 60%. In contrast, the lowest number was estimated for greenhouses with covering materials of glass and internal temperature of 22 degrees Celsius and 100 % of peak load. In other words, the number of possible greenhouses was respectively related to the two-layer polyethylene, single-layer polyethylene, fiberglass and finally the glass ones. The results obtained are consistent with the results of Kasapolu (2003), Kasapolu (2005) and Serpen (2008) in terms of the changes in greenhouse numbers.

Table A. Number of calculational greenhouses in different base loads for different coating materials with different internal temperatures

Load%	Glass			Fiberglass			Monolayer polyethylene			Double-layer polyethylene		
	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C
100	180	139	123	201	155	126	229	176	143	372	287	234
90	200	154	137	223	173	141	254	195	159	413	319	260
80	225	174	176	251	194	158	286	220	179	465	359	293
70	257	199	176	287	222	181	327	251	205	531	410	334
60	300	232	206	335	259	211	381	293	239	620	479	390

Annual heat load factor

The annual heat load factor is one of the most important indicators in determining the efficiency of estimated number of greenhouses. According to Table A, the maximum efficiency factor was related to glass greenhouses at internal temperature of 22 °C with a peak load of 60%; the others at the same temperature and peak load were respectively as fiberglass, single-layer polyethylene and double-layer polyethylene. Also, in the four coating materials, the least efficiency was obtained at internal temperature of 12 degrees and the peak load of 100 %. The results observed in the annual heat load factor are consistent with the results of Kasapolu (2005).

Table B. Annual heat load factor of the greenhouse (AHLF) considering the calculated number of greenhouses (NG)

Load%	Glass			Fiberglass			Monolayer polyethylene			Double-layer polyethylene		
	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C
100	42%	51%	60%	42%	51%	60%	42%	51%	60%	43%	51%	55%
90	46%	56%	72%	46%	57%	67%	46%	56%	66%	46%	57%	61%
80	52%	64%	93%	52%	64%	75%	53%	64%	75%	53%	64%	69%
70	59%	73%	93%	86%	73%	59%	60%	73%	86%	59%	73%	79%
60	69%	85%	100%	99%	85%	69%	70%	85%	99%	69%	85%	93%

The length of heating pipes

Soil heating system

According to the results of tables A and B, the maximum length and the highest number of tubes were related to the coating material of glass with an internal temperature of 22 degrees and a peak load of 100%. Also, the shortest length and the minimum number of tubes were seen in two-layer polyethylene greenhouses with internal temperature of 12 degrees and the peak load of 60%. The obtained results are consistent with the results of Kasapolu (2003), Kasapolu (2005) and Serpen (2008) in terms of the changes in the length and number of tubes.

Table C. The length of tubes required (L) for heating in floor heating system

Load%	Glass			Fiberglass			Monolayer polyethylene			Double-layer polyethylene		
	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C
100	821.41	685.56	841.37	954.56	614.62	754.31	1058.19	543.10	666.55	842.87	440.14	1493.05
90	739.37	617	757.23	859.10	553.15	678.88	952.37	488.79	599.89	758.58	396.13	1343.74
80	657.13	548.44	673.09	763.65	491.69	603.44	846.55	434.48	533.24	674.29	352.11	1194.44
70	574.98	479.89	588.95	668.19	430.23	521.01	740.73	380.17	466.58	590	308.09	1045.13
60	495.85	411.33	504.82	572.74	368.77	452.58	634.91	325.86	399.93	505.72	264.08	895.83

Table D. The number of tubes required (N) for heating in floor heating system based on the greenhouse floor length

Load%	Glass			Fiberglass			Monolayer polyethylene			Double-layer polyethylene		
	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C
100	23	19	23	27	17	21	29	15	19	23	12	41
90	21	17	21	24	15	19	26	14	17	21	11	37
80	18	15	19	21	14	17	24	12	15	19	10	33
70	16	13	16	19	12	15	21	11	13	16	9	29
60	14	11	14	16	10	13	18	9	11	14	7	25

B. Platform heating system

The results in tables C and D indicate that the maximum length and number of tables were related to the coating material of glass with an internal temperature of 22 degrees and a peak load of 100%. Also, the minimum length and number were seen in two-layer polyethylene greenhouse with an internal temperature of 12 degrees and peak load of 60%. The obtained results are consistent with the results of Kasapolu (2003), Kasapolu (2005) and Serpen (2008) in terms of the changes in the length and number of tubes.

Table E. The length of tubes required (L) for heating in platform geothermal heating system

Load%	Glass			Fiberglass			Monolayer polyethylene			Double-layer polyethylene		
	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C
100	1689.89	2181.67	3224.51	1551.03	2135.21	2889.95	1230.8	1886.77	2553.72	819.11	1154.41	1562.48
90	1520.90	2143.50	2901.16	1363.53	1921.69	2600.95	1107.72	1698.09	2298.35	737.19	1038.97	1406.23
80	1351.91	1905.34	2578.81	1212.02	1708.17	2311.96	984.64	1509.42	2042.98	655.28	923.53	1249.98
70	1182.92	1667.17	2256.46	1060.52	1494.65	2022.96	861.96	1320.74	1787.60	573.38	808.09	1093.74
60	1013.93	1429	1934.11	909.02	1281.13	1732.97	738.48	1132.06	1532.23	491.47	692.65	937.49

Table F. The number of tubes required (N) for heating in platform geothermal heating system

Load%	Glass			Fiberglass			Monolayer polyethylene			Double-layer polyethylene		
	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C	12°C	17°C	22°C
100	46	66	90	42	59	80	37	52	71	23	32	43
90	41	60	81	38	53	72	33	47	64	21	29	39
80	37	53	72	34	47	64	30	42	57	18	26	34
70	32	46	63	30	41	56	26	36	50	16	22	30
60	28	40	54	25	35	48	22	31	43	14	19	26

In general, it can be concluded that

Meshkinshar geothermal site has a heating capacity of at least 123 units greenhouse in terms of glass cover at internal temperature of 22 degrees Celsius and 100% of peak load, which indicates the high potential of this region in providing greenhouse products heating needs and reducing the energy costs. In overall, regarding technical parameters of the number of greenhouses, floor and platform heating systems, the most suitable coating material for this site was the two-layer polyethylene with internal temperature of 12 degrees Celsius and a peak load of 60 %. Also, regarding the annual heat load factor, the mentioned coating material gained an acceptable rating for Meshkinshahr geothermal site.

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