Evaluation of the environmental and social benefits of Geothermal Energy by studying the case of 5th high School in Municipality of Drama

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Abstract

Geothermal Energy seems to be the promising one for daily use in the future, since it is a low Carbone emission renewable source of sustainable energy without to be related with climate change. One kind of use of Geothermal Energy it is the application for heating or cooling of a building. In this case, the system uses electricity to get thermal energy between the building and the ground in order to a higher or lower temperature depending on heating and cooling requirements. The present study, which is in the framework of the GREEN PUMP project supported by the COOPERATION PROGRAMME INTERREG V-A, GREECE-BULGARIA 2014-2020, focus on the application of Geothermal Energy for heating and cooling purposes. More specifically, it is studied and calculated the possibility to use Geothermal Energy for heating and cooling proposes in 5th High School of Municipality of Drama with 2,800m^2 surface of buildings. The School is located near the Systems of municipal water pumps, whose measurements are monitored for the Programme. The evaluation results show that the School needs for the whole year 63629,35 Btu/h and taking into account this number it is resulted that the Geothermal Energy system is preferable to be vertical with four boreholes of about 100 meters depth each.

1. Introduction

Geothermal heat pumps (GHPs), usually referred as: GeoExchange, Earth-Coupled, Ground-Source, Water-Source heat pumps and they have been in used since the decade of the 40s. The main concept of Geothermal Energy is to use the almost constant temperature of the earth as the exchange medium instead of the temperature of outside air. The question if the geothermal energy is renewable one has been answered in more than 40 years ago since the scientist accepted the following definition: When the extracted energy is always replaced in a natural way by an additional amount of energy, and the replacement takes place on a similar time scale as that of the extraction. According to these, Geothermal Energy is renewable since it satisfy the above definition.

Although the temperature on the earth's surface is varied with the period of the season with the extreme values to be in a wide range up to 40 °C, few feet below the earth's surface the ground remains at a relatively constant temperature. The ground temperatures depend on latitude, within a range from 7°C to 21°C [1]. For the case of Greece, this temperature is in the range from 14.0 to 15.5 °C [2] and seems to be suitable for the use of Geothermal Energy for heating and cooling purpose. For example, the ground temperature is warmer than the air above during the winter and cooler than the air during the summer. Based on this advantage the GPHs exchange heat with the earth through a ground heat exchanger or the reverse process during summer.

The use of Geothermal energy is combined with many benefits regarding the environment. The main benefits of GE are: *a) It is a renewable one, b) Its use saves the energy required for heating and for cooling of a building, c) It is stable regardless of weather conditions, d) The absence of noise during its operation, e) It is en*vironmentally friendly, f) It helps to mitigate the effects of climate change, g) There is H*igh Energy Potential stored and h) It contributes to the achievement of the objectives for the environment according to the Kyoto Protocol.*

Also, the use of Geothermal energy is combined with many benefits regarding the society, which are: *a) An alternative source for heating, b) Creation of new jobs with workers specialized in the new technology of Geothermal (energy for heating). C) Educate citizens to select environmental friendly approaches to satisfy their everyday needs d) Geothermal Energy projects have an effect on energy security of Nations.*
In order to verify most of the above benefits it is studied the case of 5[th] High School of Drama. More specifically it is studied the possibility to provide, heating or cooling depending on the season, in this School by using Geothermal Energy. The results from calculations show that this case could be very interesting and hopeful for this energy source.

As far as the project participants is concerned, it is mentioned that the participants are: a) Aristotle University of Thessaloniki, Greece (lead partner), b) South-West University "Neofit Rilski", Bulgaria, c) International Hellenic University, Greece (incorporating initial partners Technological Educational Institute of Central Macedonia and Eastern Macedonia and Thrace Institute of Technology), d) Municipality of Pilea-Hortiatis, Greece, e) Municipality of Petrich, Bulgaria.

The targets of the project include: i)Elaboration of criteria for site selection (groundwater quality, aquifer depth, vicinity to prospective users, basement flooding risk, etc.), ii)Study of technical implementation details to existing and new buildings and cost estimation. iii)Construction of one complete pilot installation in Thessaloniki, Greece, and secondary water use ones in Blagoevgrad and Petrich, Bulgaria, and Pylaia, Greece, Iv) Recording of practical problems and possible pitfalls during the construction phase in densely populated areas, v) Elaboration of monitoring program for such systems and monitoring of the pilot installations. vi) Evaluation of the environmental and social benefits. Optimization of the design per user needs. vii) A policy document on the simplification of the legal procedures. In the following sections, we briefly present outcomes of the contribution of the team of the initial partner Eastern Macedonia and Thrace Institute of Technology.

2. **Study of Geothermal Heating of 5[th] High School of municipality of Drama**

Geothermal and water-source heat pumps could heat, cool, and with suitable mechanisms could supply the house with hot water. There are four basic types [3] of ground loop systems: Horizontal, Vertical, Pond /Lake and Open Loop System

The building in which the geothermal installation will be studied is the 5th High School of Drama (Figure 1) which is located in the Urban Web of the city and has a total area of about 2800 m^2. The prefecture of Drama is part of the climatic zone D [4*]. The choice of this building was based on the fact that it is located close to the system of pumps whose measurements we monitor (approximately 500m in a straight line from the pumps (figure 2)).

In this study, the first step was the calculation of the required depth of the drillings that will be needed. Then the length of vertical exchanger, the heat pump power and the diameter and the piping material were calculated. It was chosen to use a vertical heat exchanger and not horizontal ones because at great depths the ground temperature remains constant throughout the year and in addition the vertical heat exchanger requires a smaller installation area (about 10 times) compared to the horizontal heat exchangers. The calculation of the drilling depth is a very important element in the study because large depths require higher drilling costs, longer piping length and maintenance costs. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) methodology was used to calculate the drilling depth [5*]. According to the above methodology, the average annual heat flow in the soil q_a was first calculated, which is equal to:

$$q_a = (C_{fh} \times q_{lh} \times EFL_{hoursh} + C_{fc} \times q_{lc} \times EFL_{hoursc}) / T_a \quad (1)$$

where q_{lc} and q_{lh} are the nominal coolant (entered with a negative sign) and the thermal load of the school respectively expressed in Btu/h respectively. EFL_{hoursh} and EFL_{hoursc} are the equivalent hours in total heating and cooling load per year. They can be described as the number of hours a system designed for maximum heating and cooling load would operate at full load, respectively, and given by the ratios:

$$EFL_{hoursh} = E_h / q_{lh} \text{ and } EFL_{hoursc} = E_c / q_{lc} \quad (2)$$

where E_h and E_c are the annual energy consumptions in heating and cooling, C_{fh} and C_{fc} are correction factors related to the COP and EER characteristic coefficients of the heat pump. Choosing a heat pump with values of C_{fh} = 0.82 and C_{fc} = 1.2 [6,7], taking into account the required loads for heating (or cooling) and the final energy consumption according to the tables 1 and 2, it was calculated that the average annual heat flow in the soil is 63629.35 Btu/h. We consider that a heating cycle for he school requires 8 hours a day for a period from

Figure 1. 5[th] Secondury School of Drama.

Figure 2. Distance of the 5th Secondary School of Drama from a pump system

November 1 to April 15 excluding the Christmas holidays, i.e. a total of 5 months. The cooling cycle of the building is 8 hours / day for the period of June and 2 hours / day for the period from July 1 to September 15 (because the school is closed during these months).

Table 1 *Required loads for heating (or cooling) in 5[th] Secondary School of Drama*

Required heating/cooling loads (kWh/m^2)						
Months	Jan.	Feb.	Mar.	April	May	June
Heating	13,7	10,2	6,5	1,6	0	0
Cooling	0	0	0	0	0	1,1

Required heating/cooling loads (kWh/m^2)							Total
Months	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Heating	0	0	0	0	3,4	9	**44,4**
Cooling	0,4	0,4	0,6	0	0	0	**2,5**

Table 2 *Total Energy Consumption for heating (or cooling) in 5[th] Secondary School of Drama*

Total Energy Consumption (kWh/m^2)						
Months	Jan.	Feb.	March	April	May	June
Heating	28,5	21,3	13,5	3,3	0	0
Cooling	0	0	0	0	0	2,3

Total Energy Consumption (kWh/m^2)							Total
Months	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Heating	0	0	0	0	7,1	18,8	**92,5**
Cooling	0,8	0,8	1,3	0	0	0	**5,2**

In order to lay pipelines in the subsoil, it must be taken into account the geological data of the area where the school is located, i.e. the city of Drama. According to a study by the Institute of Geological and Mineral Research [8], the geological basin of Drama is the easternmost part of the Serres-Drama basin that was created during the Middle Ages. The main directions of the faults that affect the study area are NESW to ENE-WSW. The rocks found in the subsoil from the oldest to the newest are the following: Marbles, Pliocene marls, Chestnut-red clay, alternations of cobblestones with red sandy loams, cohesive cobblestone and cone deposits as well as alluvial deposits. All these are presented in Figure 3 [8*].

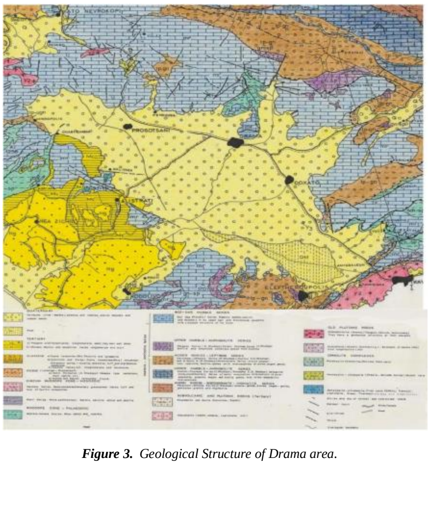

Figure 3. *Geological Structure of Drama area.*

Regarding the diameter of piping the calculation took place with the thermal load due to the fact that it is "worse scenario" than the cooling load. According to the calculations, there is a mass supply of water in the pipeline equal to 0.810Kgr / sec.

The volume flow will be equal to 0.810 * 10-3 m3/sec which will be divided into the boreholes that will be drilled and the loops that will be installed in each borehole. The number of drillings obtained based on the methodology that is applied, is equal to the load in RT, where 1RT = 12000,503Btu/h. By selecting a double loop in each borehole, the total flow will be divided into 8 heat exchangers and will be equal to 0.1013 * 10-3 m3 / sec. Selecting a type of U SDR11 1-1 / 2 " pipe from polyethylene, results a flow rate equal to 0.083 m / sec which is within the limits that are set. The relation gives the calculation of the required drilling depth according to the thermal load is [5]:

$$L_c = [q_a * R_{ga} + (C_{fh} * q_{lh}) * (R_b + PLF_m * R_{gm} + R_{gd} * F_{Sc})] / [t_g - (t_{wi} + t_{wo} / 2) - t_p] \quad (3)$$

where R_{ga}, R_{gm}, R_{gd} are the equivalent ground thermal resistances for annual, monthly and daily pulses respectively in h * ft * °F /Btu,
R_b is the thermal resistance of piping - drilling in h * ft * °F/Btu
PLF_m is the monthly part load factor,
F_{Sc} is the coefficient of heat loss of the piping circuit,
t_g is the soil temperature in °F,
t_{wi} is the inlet temperature of the liquid to the geothermal pump in °F,
t_{wo} is the outlet temperature of the liquid from the geothermal pump in °F and
t_p is a correction factor for ground temperature due to the interference of adjacent piping in °F.
According to numerical evaluations as well as reasonable values from bibliography for the above parameters as follows [9,10]:
R_{ga} = 0,21719 h*ft*°F/Btu, R_{gm} = 0,21694 h*ft*°F/Btu ,
R_{gd} = 0,25308 h*ft*°F/Btu.
PLF_m = 0,238, t_g,=60,44 °F, t_{wi} = 50 °F , t_{wo} =44,8 °F and t_p = -1,2 °F . Consequently the drilling depth is calculated at Lc = 2645.02 ft = 806.96 m. Having selected 4 boreholes with double loop, the depth of each borehole is calculated at 806.96 / 8 = 100.87 m. Based on the required thermal power, at least 806.96 / 3,699 = 218.56 m / RT or
3,699 * 1000 * 3,517 / 806.96 = 16.12W/m exchanger are required.
Concerning the cost and the time for the amortization of the investment, It is estimated that the cost of study of geothermal installation including the cost of relevant permissions and the equipment and installation cost is approximately 70,000.00 Euros excluding possible costs due to incompatibility of existing radiators with geothermal energy. Taking into account that the cost of electricity is about 0,25Euro/Kwh and the cost of oil is 1,10 Euro/lit, it is calculated that the annual cost of maintenance and operation of geothermal installation is 17,000.00 Euros while the corresponding annual cost for the heating and cooling needs of the school using oil and air-condition respectively is 27,000.00 Euros. It is expected to take up 8 years for the time of the amortization of the investment while the mean time of life of geothermal installation is from 20 to 50 years [1].

Taking into account that this installation will take place in the area of 5[th] Secondary School in Drama, this is very important for the education of students for the followings reasons:

a) They will gain experiential learning about renewable energy sources.
b) They will understand the importance of geothermal energy.
c) They will be able to do experiments and calculations for possible installation in their home.
d) They will be able to relate their knowledge from various subjects (such as geography, physics, mathematics etc) to Geothermal energy.
e) Some of them will be stimulated to engage later in geothermal energy and renewable energy sources.

3. Conclusions

In the present work it is presented the possibility to install a geothermal heat pump system in the area of 5[th] Secondary School in Municipality of Drama which is near the municipal water pumps. The surface of the building of the School is 2800 m^2, with a large area to be available for this installation. They were calculated the following parameters of the installations:

i) The required drilling depth to be 100 meters

ii) Number of boreholes to be 4 with double loop. Totally about 800 meters of drilling.

iii) Annual heat flow to be year 63629.35 Btu/h

iv) The minimum power of vertical exchanger to be 16.12W/m .

It was also calculated the time of the amortization of the investment of geothermal installation and we concluded that it is very cost-effective.

This installation is important for the education of the students since there are many reasons concerning to: experiential learning about renewable energy sources, understand the importance of geothermal energy, do experiments and calculations for possible installation in their home, relate their knowledge from various subjects (such as geography, physics, mathematics etc) to Geothermal energy, and engage later in geothermal energy and renewable energy sources.

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https://greenpump.eu/

Reference

1. http://apps1.eere.energy.gov/consumer/your_home/space_ heating_cooling/index.cfm/mytopic=12640
2. Papachristou, M., Mendrinos, D., Dalambakis, P., Arvanitis, A., Karytsas, C, and Andritsos, N., 2016, "Geothermal Energy Use, Country Update for Greece", Proc. European Geothermal Congress 2016, 19-24 September 2016, Strasbourg, France.
3. https://www.energy.gov/energysaver/geothermal-heat-pumps
4. TECHNICAL INSTRUCTION, TECHNICAL CHAMBER OF GREECE, T.O.T.E.E. 20701-1 / 2017.
5. Steve Kavanaugh, Kevin Raferty (1997): Design of geothermal systems for commercial and industrial buildings , ASHRAE, Atlanta.
6. B. Sanner, Guidelines, standards, certification and legal permits for ground source heat pumps in the European Union, 9th International IEA Heat Pump Conference, Zürich, Switzerland, 20 – 22 May, 2008.
7. H. Zeng, N. Diao and Z. Fang, Heat transfer analysis of boreholes in vertical ground heat exchangers. International Journal of Heat and Mass Transfer, 46 (23), pp. 4467-4481, 2003.
8. Geological map of Eastern Macedonia and Thrace at a scale of 1: 200000, Institute of Geological and Mineral Research, 1986.
9. VDI 4640 Part 1: 2010-06, Thermal use of the underground Fundamentals, approvals, environmental aspects, 2010.
10. B.Sanner (2011), Concept and Feasibility Studies. Geotrainet Training Manual for Designers of Shallow Geothermal Systems, Geotrainet, EGF, Brussels, p.21-24.