SOLAR ASSISTED GROUND SOURCE HEAT PUMP SYSTEM FOR AN OFFICE BUILDING IN Gödöllő, HUNGARY

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ABSTRACT

The objective of the project was to find the most suitable solution for heating and cooling a conference room in an office building in Gödöllő, Hungary. Ground source heat pump system assisted by four solar photovoltaic cells for electric energy generation was installed in 2009. For a collector system two 100 m deep U-type-tubes were placed in separate boreholes. The system works in heating and cooling mode. The heat pump is not used for cooling. The excess heat is delivered to the soil by a heat exchanger situated in a depth of 15 m. Monitoring of the performance of the system was made for a period of 20 days in the winter of 2010 and the performance of it was analyzed for 24 hours and is given in this publication. Electric energy consumption of one year was 12679.2 MJ (compressor 10368 MJ, circulation pump 1728 MJ, fan-coil units 583.2 MJ). By using a traditional heating system with a boiler and climate control this number could be 4.6 times bigger which saves about 45236 kg on carbon emissions and the cost of € 135 708 in one year. It is more friendly to the environment and economic. The installed system works without disorders and is a successful project.

KEYWORDS

Ground source heat pump, solar energy, heating and cooling

INTRODOCTION

The price of fossil fuel and a need for an independent and pollution free energy source motivates businesses and households looking for alternative energy sources in Hungary especially for heating and cooling. Heat pumps are suitable for the weather in Hungary as it can provide heating in the winter and cooling for the summer and soil conditions in this geographical area are suitable for collecting high temperatures from the ground. The disadvantage of heat pumps is that they require external power and as a solution it is possible

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to combine it with a solar system for electricity generation. A solar assisted ground source heat pump system is installed in one of the office buidings in Gödöllő. The obstacle of this project was to find a cheaper, cleaner and more independent heat energy source.

DESIGN AND INSTALLATION

A solar assisted ground source heat pump system is installed for heating and cooling 100 m^2 conference room of an office building in Gödöllő in 2009. The heat pump requires electricity and to provide cheaper and more environmental friendly energy solar collectors are used for power generation. The system consists of a heat source - ground collector system, water-to-water heat pump which raises the temperature of the collected heat and transfers it in form of the water to a buffer tank and further to a heat distribution system – water is transferred from the buffer to fan-coil units. The collector system consists of two 100 m deep boreholes. A location of boreholes and a floor plan of conference room are shown in Figure 1.

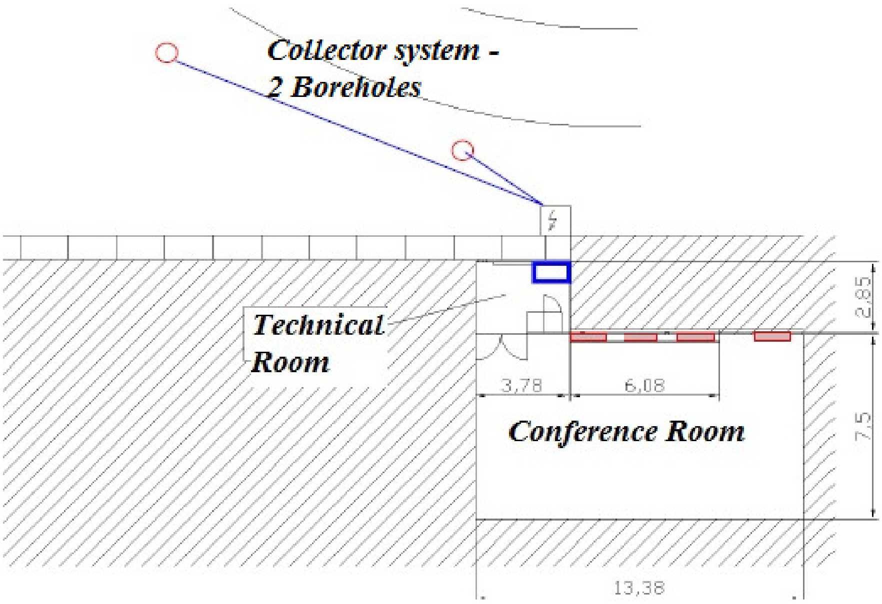

Figure 1 Floor Plan of a Conference room and borehole locations

There are two different types of ground source heat pump systems – a direct expansion system where a refrigerant is circulated through the heat pump and the collector system; and an indirect system where a mix of water with antifreeze circulates through the collector system and the refrigerant circulates only in the heat pump. In this case it is an indirect system. An extra heat exchanger is situated on a U-type-tube in depth of 15 m and it is used directly for cooling in the summer without even running the heat pump which reduces electricity bills. The distribution heat system of the conference room consists of four series connected fan-coils – the heat exchanging units in which water is circulated and heated or cooled air is transferred to the room by a fan.

The system is assisted by four solar photovoltaic cells for electricity generation to run the circulation pump. System is shown in Figure 2.

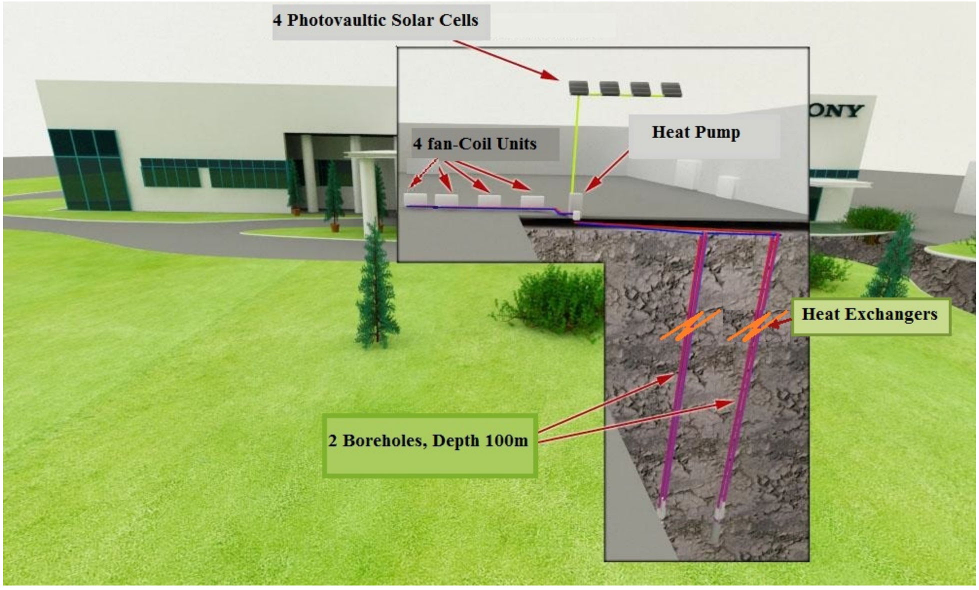

Figure 2 Solar assisted heat pump system

THE COMPONENTS OF THE HEAT PUMP SYSTEM

The system consists of two parts - primary and secondary side which are separated by the heat pump. The primary side consists of a vertical ground collector system with the heat exchanger and the secondary part consists of a heat distribution system - four fan-coils. A compressor of the heat pump works periodically by turning on and off. To maintain a correct and equable flow a buffer tank is used in this system. In cooling mode summer heat exchanger is used without using heat pump. Figure 4 and Figure 5 shows a schematic and components of the installed heat pump system.

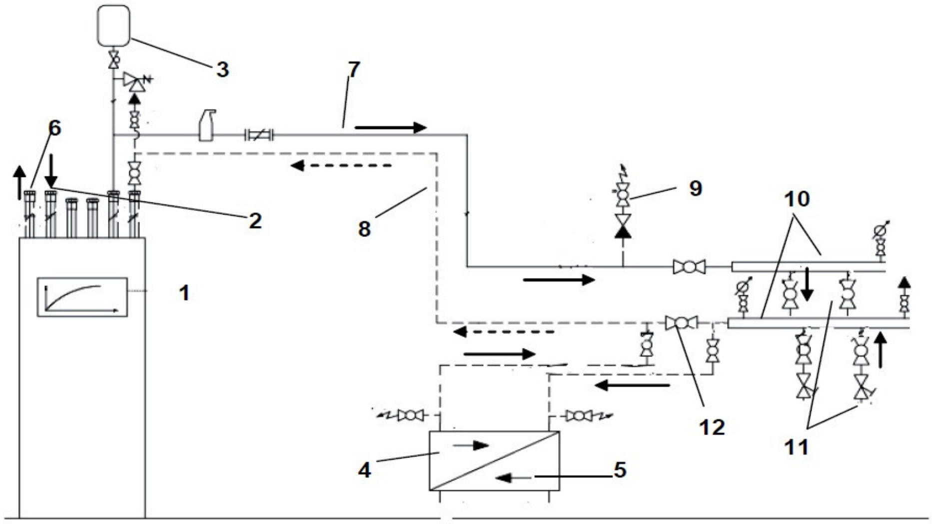

Figure 3 Primary side

1. Heat pump 2. The secondary side (going in) 3. Compensator container 4. The primary side of a refrigeration heat exchanger 5. The secondary side of a refrigeration heat exchanger 6. The secondary side (going out) 7. The branch of the primer side (going out) 8. The secondary side (going in) 9. Recharging tap 10. Boreholes going in 11. The boreholes going out 12. Relay tap in case of refrigeration in summer

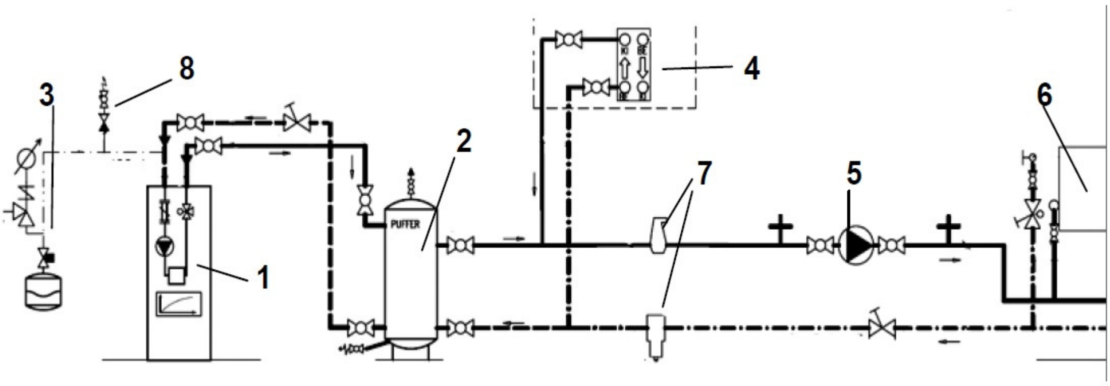

Figure 4 Secondary side

1. Heat pump 2. Puffer 3. Compensator container 4. Heat exchanger for refrigeration in the summer 5. Circulation pumo 6. Fan-coil units

In the heating mode heat is collected from the soil by a liquid – a mix of the water and glycol running through U-type-tubes situated in boreholes. In the heat pump heat is transferred to a refrigerant by heat exchanger and the temperature of it is increased by a compressor and the heat is transferred to the secondary loop by the heat exchanger and is delivered to a buffer tank where the heated water is stored. It equates the flow of the water because the compressor works periodically. The water flow is circulated by a pump and transferred to four fan-coils. In the cooling mode the process is reversed but a ground heat exchanger is used for giving the heat to the soil instead using the heat pump. The heat exchanger is in the depth of 15 m because from 15 m up to 100 m depth the temperature of the soil is almost constant. By using cooling heat exchanger a demand of power is reduced.

Figure 3 shows designed temperatures.

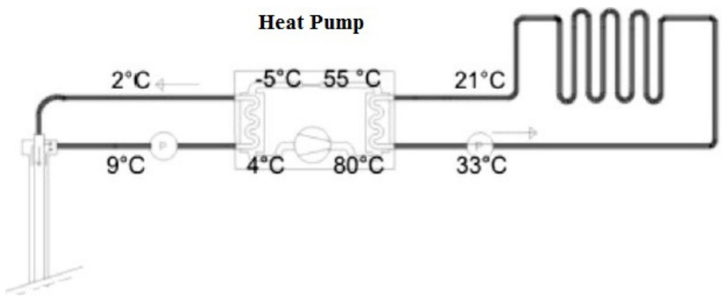

Figure 5 Heat pump designed temperatures

Figure 6 Installed Heat Pump

MONITORING AND RESULTS

To analyze the performance of the system monitoring was carried out. Measurements were made for a period of 20 days starting from 30th October 2010 to 18th November 2010. Temperatures in 16 different points were measured. Most significant results of minimal, maximal and average temperatures of 24 hour measurement in 6th November are shown in Table 2.

	Max T °C	Min T °C	Average T °C
Temperature of the soil (16m deep)	13,4	11,7	12,6

From the heat pump (out)	37,5	24,92	27,72
Back to the heat pump (in)	30,12	24,92	27,12
Air temperature in the room	23,40	25,00	24,29

Table 1 Measured temperatures

Temperatures are closed to design ones. The difference between the heat pump minimal and maximal temperature is because the compressing process of the heat pump doesn't happen constantly. Measurements for temperatures were made every 10 minutes. Diagram 1 shows 24 hour (144 × 10 min) temperature of the temperature variation of outgoing and returning water of the buffer of the heat pump system (variation of the soil temperature (16 m deep).

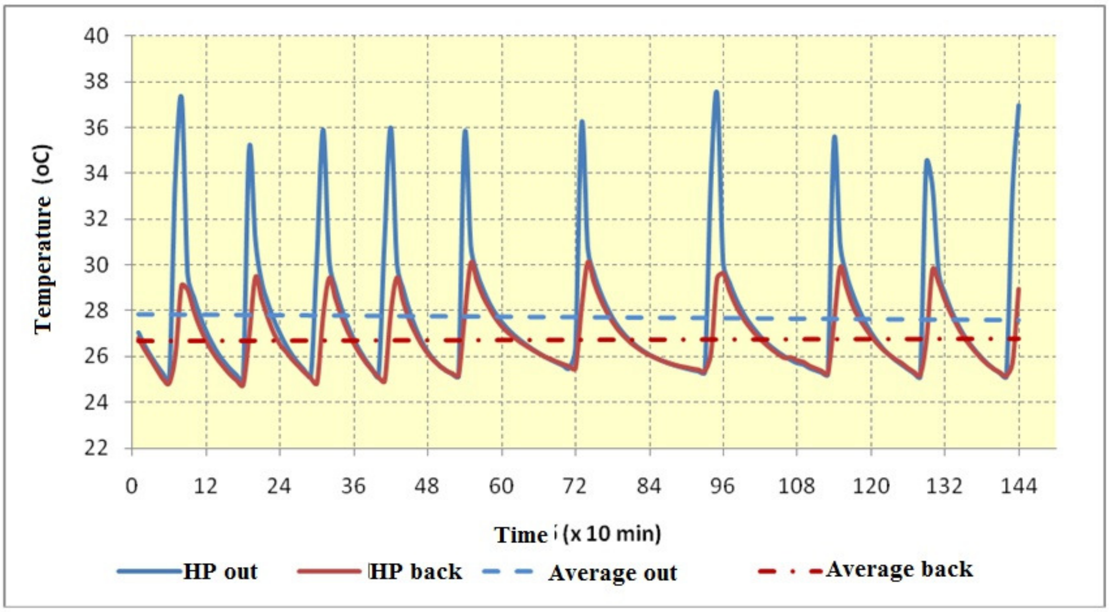

Diagram 1 Outgoing and returning water temperatures of the Buffer

Temperatures of collected and returned heat are shown in Diagram 2 during 24 hour period. The green line shows the soil temperature16 m deep which varies from 11,8 to 13,4°C.

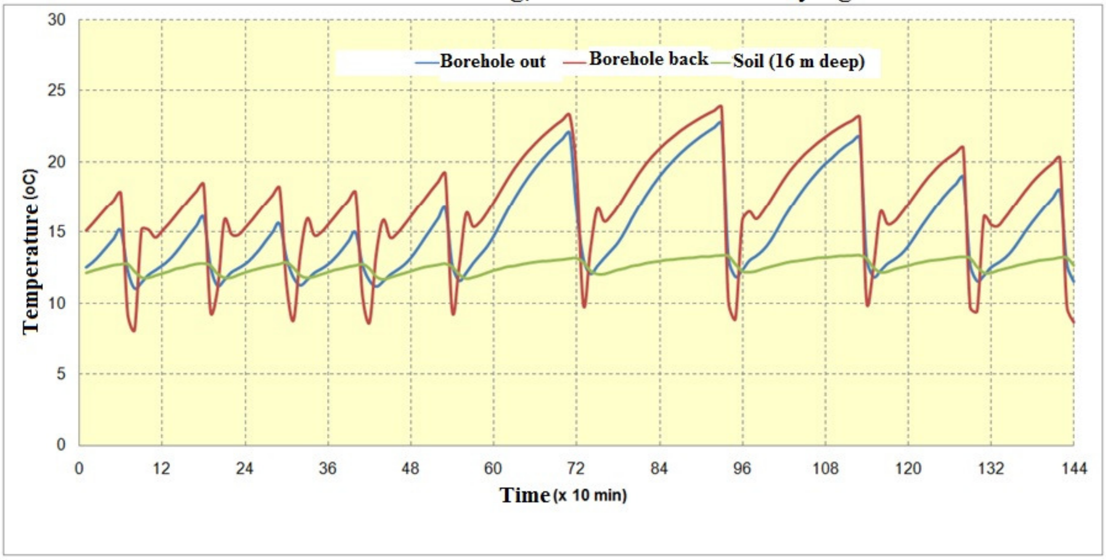

Diagram 2 Collected and returned heat (in the U-type-tube out and back), Temperature of the soil

To analyze the performance of the hall system it is significant to analyze the consumption of the electricity. The system provides electrical energy for the compressor, fan-coil units and the circulation pump. Performance of the system in a cold winter day when average outdoor temperature is -3 °C is shown in Diagram 3.

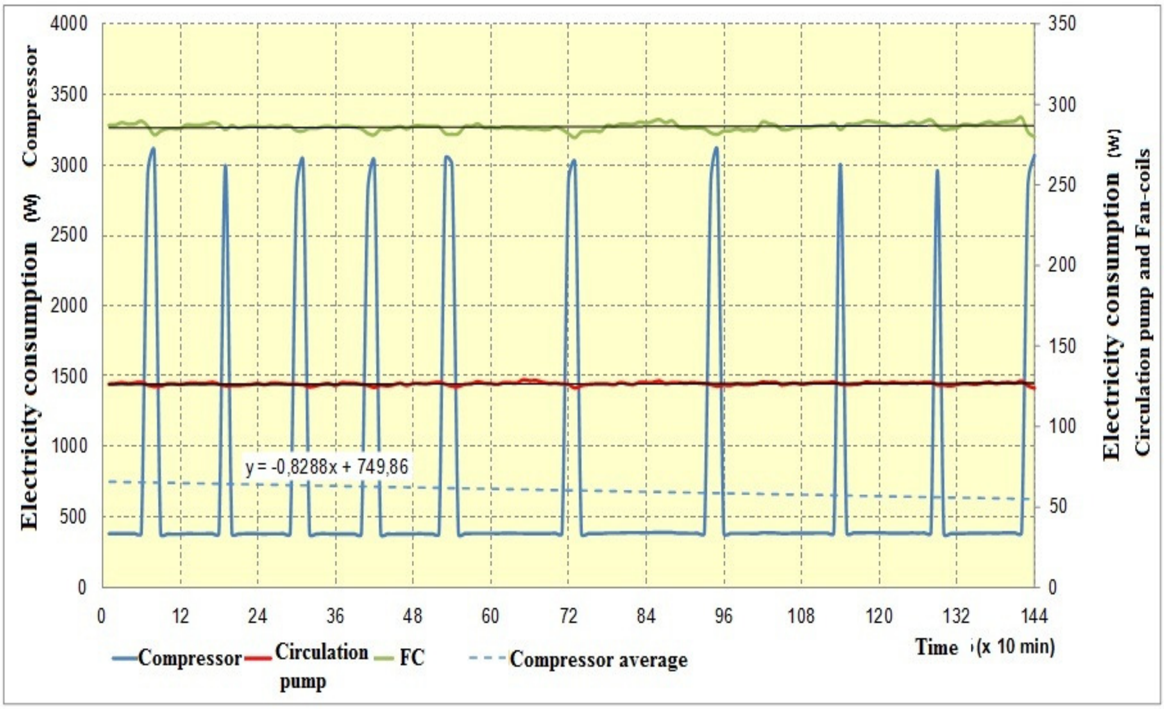

Diagram 3 Electricity consumption of the system

During a 24 hour period the compressor of the heat pump works with interval 17 – 25 min. when the compression is not required compressor will consume only around 380 W but during compression this number will raise up to 3 100,5 W. Electricity consumption of fan-coils varies from 279,7 W to 292,2 W and for the circulation pump from 126,5 W to 129,9 W.

A variation of the supplied water temperature to fan-coils and the supplied air temperature to the room is shown in Diagram 4. The supplied water temperature varies from 24,5 °C to 31,5 °C. And the supplied air temperature varies from 21,0 °C to 23,8 °C which is very high temperature.

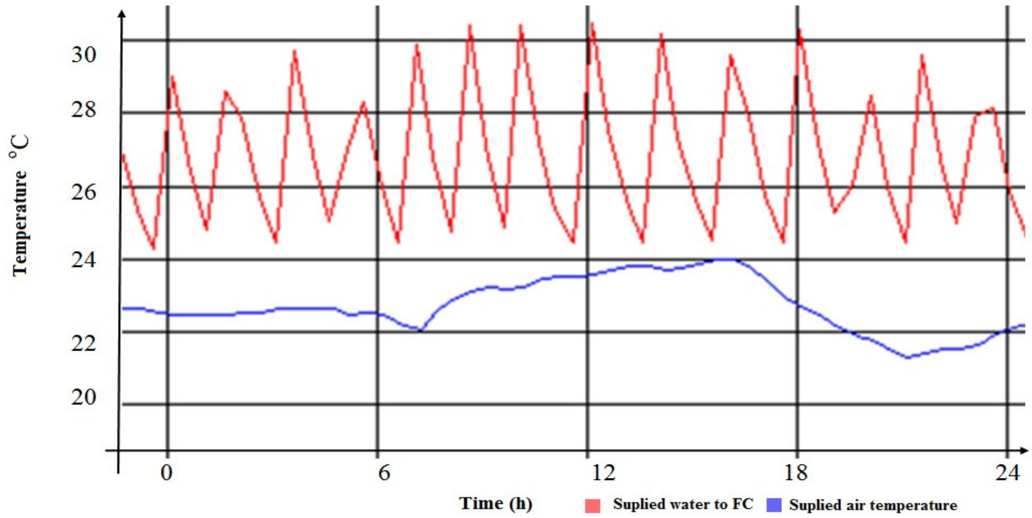

Diagram 4 Fan-coil performance

Measured data shows that the project system is successful and works without any disorders. Measured temperatures are close to designed temperatures and a comfort temperature +22 °C (+/- 2°C) are provided in the room all year around even in the coldest months of the year.

ASSESSMENT OF ECONOMY

Energy consumption of the running system – heat pump, circulation pump and fan-coils is shown in Table 2. It is compared with energy consumption of a natural gas boiler heating system combined with a separate climate control which would be required to heat and cool the same room. Savings of energy and carbon emissions of one year are shown in the table.

	kWh/year	MJ/year		kWh/ year	MJ/ year
Natural gas burner	11550	51975	Heat pump	2880	10368
Split clime	1650	5940	Circulation pump	480	1728
			Fan-Coils	162	583,2

Together	13200	57915	Together	3522	12679,2

Saving	**45236**	MJ/year
CO_2 Saving	**3871**	kg/year

Table 2 Energy consumption of the heat pump system compared to the energy consumption of a traditional system

In one year the consumption of energy was 12679,2 MJ (Heat pump 10368 MJ, circulation pump 1728 MJ, fan-coil units 583,2). By using a traditional heating system with boiler and climate control this number could be 4,6 times bigger which saves about 45236 kg carbon emissions and € 135 708 in one year. Energy consumed by a circulation pump is provided by solar panels on the roof.

Figure 7 Solar panels situated on the roof

Parameters and the performance of solar panel such as size, collected energy of one m^2 and a factor of a performance, working hours of a year and produced energy in one year are shown in Table 3.

m^2	kW/m^2	η	h/year	kWh/year
1,8	1000	0,16	2100	604,8

Table 3 Performance of solar panels

As shown in table solar panels provide 604 kWh/year but the circulation pump requires only 480 kWh/year. Cost of the heat pump system was € 13 868 (1 drilling of 100 m deep borehole in Hungary costs € 2190).

CONCLUSIONS

By installing a ground source heat pump system the energy consumption and CO_2 emissions are reduced. This solution for heating and cooling provides comfort for users as temperatures are easy to regulate and the system does not require maintenance. The system works error free and provides heating and cooling, just by changing a position of a switch. The consumed energy is reduced by 4,6 times which makes up to € 135 708 savings in one year (according to the electricity and natural gas tariff in 2011) making the system environmental friendly and cost effective for the business. The results of measured data shows that system works without any disorders and appropriate to designed parameters.

RESOURCES

1. Ochsner K., (2007), Geothermal heat pumps: a guide for planning and installing, London
2. Sarbu I. and Bura H., (2011), Thermal tests on borehole heat exchangers for ground–coupled heat pump systems, *International Journal of Energy and Environment,* Iraq
3. Komlós F.: Épület - Energia - Élettér - Ember: hőszivattyús technika. Magyar Épületgépészet, XLVI. évf. (1997) 12. szám, p. 5 – 7
4. Steimle, F.: Wärmepumpentechnik - Einführung. Gas Wärmepumpen Praxis - Wärmepumpentechnologie, Band IV.
5. Büki G.: Magyar energetika a századfordulón számokban. Magyar Energetika, 2001/1. szám, p. 3 – 11
6. Tóth.L, Fogarasi L, Bihercz G, Ménesi A: (2008): Utilization of Geothermal Heat for Air-Conditioning of Different Small Buildings. Journal of Agricultural Machinery Science. Volume 4, Number 3. 241-246. p. ISSN: 1306-0007
7. Sembery P-Tóth L.: 2005. Hagyományos és megújuló energiák, Szaktudás Kiadó Ház. Budapest, 522 p.