Economic Analysis of Geothermal Heat Source for Residential Area Project

S.Poberžnik, D. Goricanec, J. Krope

[1]***Abstract*** **-** The article discusses the economic analysis of heat source for residential area project. The energy source is geothermal energy. Every house has its own borehole heat exchanger (BHE) and heat pump in basement. In this system low temperature floor and wall heating was carried out. The economic analysis was performed as a pilot study for real system with all installation needed to run the system. The analysis has been done using the method of the net present value. In the research the coefficient of profitability and the period of time in which the investment is going to return itself were established. The system has been compared to the conventional system that uses fossil fuel (Liquidized naphtha gas- LNG) to heat the building and domestic hot water.

Key-Words **-** Geothermal energy, borehole heat exchanger, heat pump, heating system, economic analysis, net present value

I. INTRODUCTION

THE European Union (EU) energy policy is an important part of the strategy for sustainable development.

The ultimate objective of the strategy paper is the security of energy supply, encompassing environmental principles. The priority of the energy supply field lies in the reduction of global atmosphere warming with emphasis on efficient energy use, on renewable energy sources (RES) [1], and on availability of low-cost energy devices. The goal of the EU is to reach a 12 % share of energy produced from RES in the total energy output by 2010.

As to this goal, the development and use of heat pumps in EU industrialized countries are in constant growth, as they represent the devices of the near future, especially for the purposes of heating and cooling [2, 3]. They are far more efficient in heat or cold production than the traditional technologies based on combustion of fossil fuels or electricity, and as a result open up infinite possibilities of helping to protect the environment and reducing the damage caused by continuous global warming.

II. PILOT PROJECT PRESENTATION

The decision regarding exploitation of geothermal energy was also made in Maribor, where a geothermal energy is going to be used to heat houses in a new settlement near centre of the town. Investor has a vision to build up a first settlement based on ground source heat pump (GSHP) in this part of Slovenia.

The company’s former projects regarding houses and domestic hot water heating were traditional, based on fossil fuel. Investor’s skilled employees are very experienced in the real estate market, investments and selling prices of such houses.

It was necessary to calculate the cost of investment for a settlement of houses with GSHP and low temperature floor and wall heating.

In the first phase the designer made project for a house with such heating system. The fitter of heating system evaluates the price to install such heating system.

Houses are to be built according to Rules on Thermal Insulation and Efficient Energy Use in Buildings. Expected annual heating energy consumption is 60 kWh /m^2/a. Maximum allowable value is 80 kWh/ m^2/a.

Based on calculations made, 10 cm wall insulation was considered as optimal.

Using geothermal alternative energy source, houses reach the decrease in energy consumption for heating and better market value.

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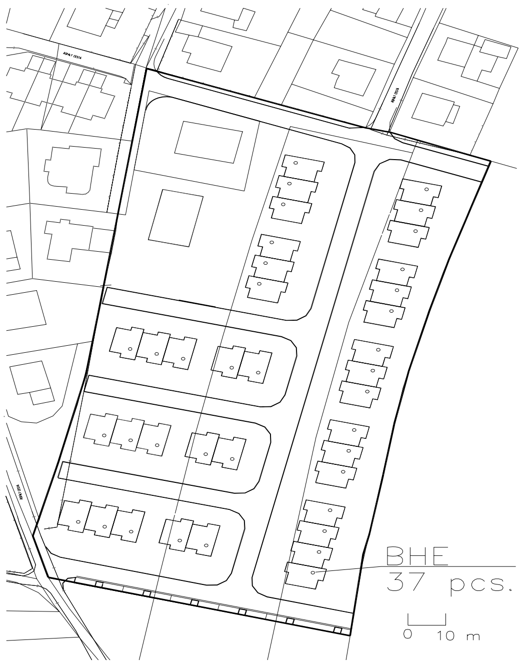

Fig. 1 proposition of BHE arrangement for residential area project

The heating system project anticipates the floors and walls as heating surfaces.

The important feature of this system is also that it enables to achieve the same comfort as with radiator heating system at 1°C lower indoor temperature. 1°C lover indoor temperature contributes 5÷7 % lower energy consumption per year.

The above described system operates at low water temperature, which means 40°C is sufficient to heat the building.

A. Heat pump system with BHE

The heat pump system with borehole heat exchanger (BHE) consists of borehole with two pairs of PE pipes as heat exchanger in it and heat pump which converts heat energy to usable temperature (30÷40°C).

Our pilot heat pump is positioned in the basement under the ground level. The borehole is drilled few meters away form the heat pump. Hence, the distance between them is small. The borehole is drilled after the ground plate in the basement is done, before mounting the ground plate for the ground floor. Features of the described system are:

- The heat pump and the bore hole are in the same place in the basement.
- The pipe connection between them is short.
- All heating elements are in/under the house
- The ground heat energy exploitation influence on plants is low

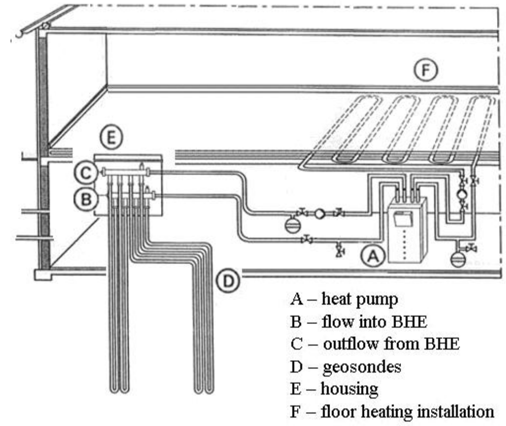

Fig. 2 BHE and heat pump [4]

BHE

The decision on using BHE instead of horizontal heat exchanger is the area of parcels of land. Parcels have the area of 23 x7,6, which comes to 174,8 m^2.

The distance between two nearest energy sources for heating system (BHE) is 7,4 m.

Double U-pipe BHE is made of 2 plastic pipes forming U-shape in the borehole, so that fluid is driven down to the bottom and than back up. Typical outer pipe diameter is 25 to 40 mm. Filling material is introduced between the pipes and borehole wall in order to ensure good thermal contact with the ground.

Typical borehole diameter is 10 ÷ 15 cm and depth of 30 ÷ 300 m.

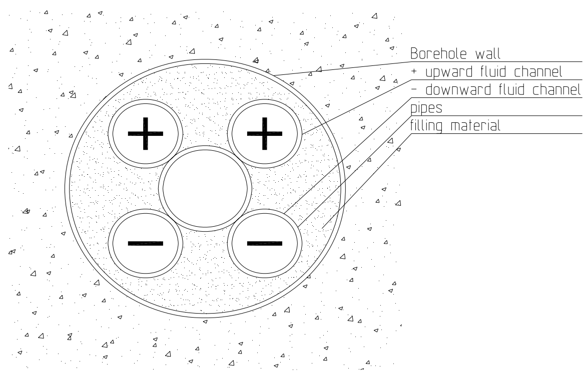

Fig. 3 schematic cross section of typical Double U-pipe BHE [7]

The amount of energy depends on BHE diameter and depth, and also on the quality of soil.

If there are no geological tests done, the number of BHEs and their depths are chosen according to VDI 4640.

In our example, no geological tests were done jet; therefore the calculations are made according to standard data [5]:

- Wet compacted soil with λ=1,5 ÷ 3,0 W/m K
- Specific heat for BHE: 50 W/m
- BHE length for 1 kW - heating: L=14 m.

Before drilling the holes for the whole settlement, it is necessary to make BHE response test. Depending on this test's result, the right BHE depth can be calculated.

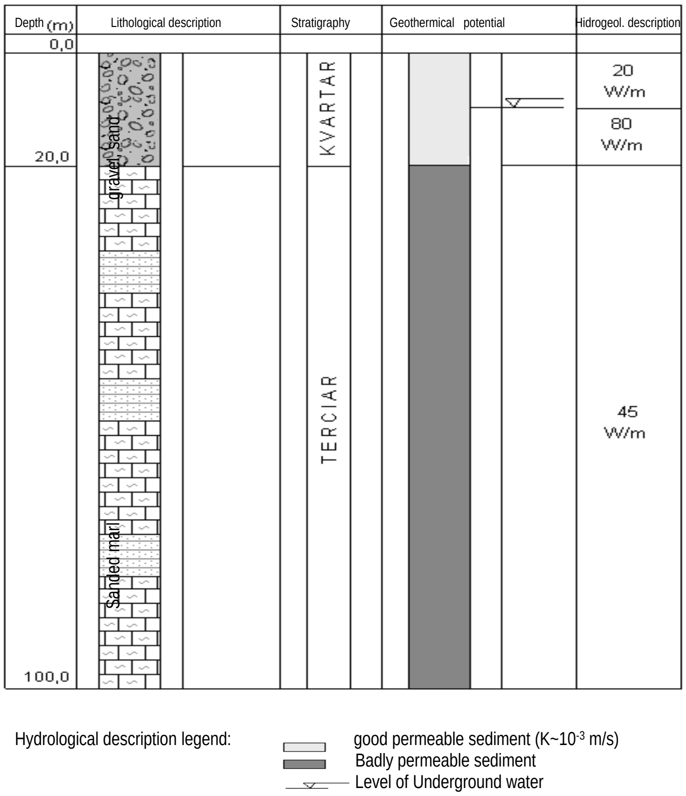

Fig. 4 geological prognosis of ground

Fig. 4 presents geological profile of the place near by.It can be taken into account only as information. For exact values geological test is got to be done.

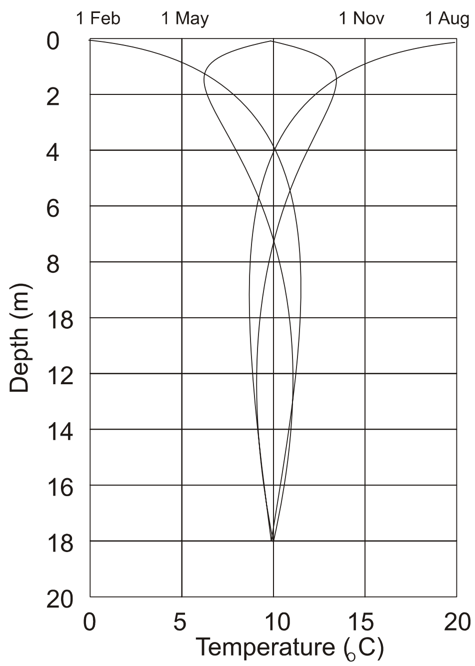

Fig. 5 range of temperatures in the Earth over the year depending on depth [5], [6]

Heat pump

Heat pump is a device, which pumps low temperature energy from soil to higher temperature level using electric energy to move the compressor.

The designing parameters are:

- house heating needs,
- sanitary hot water (SHW) heating needs,
- temperature regime for SHW and heating
- coefficient of performance,
- heat flow of condenser and evaporator,
- energy consumption of compressor,

In the summer water from BHE can be lead directly into system of floor/wall heating to cool the building. The only costs appear to run small circulation pump. Cooling demands rises in summer. Cold water from BHE is not enough any more. Than working principle of heat pump changes. Heat pump starts with active cooling.

Cooling with BHE is not a subject of this article.

III. TWO HEATING SOURCE PROFITABILITY EVALUATION [7]

Every economic analysis is based on two presumptions:

- the investment, which represents the amount of money needed for the realization of a project, and
- the surplus, which represents the difference between incomes and operating expenses.

The economic analysis of the project represents the value determination of both mentioned presumptions using methods, which differ in complexity and accuracy. The choice of method depends on the stage of development of a project in a certain moment. The profitability of the heat pump investment can be evaluated with the method of the net present value (NPV), while taking into consideration the annual inflation rate.

The net present value is very commonly used in preparing investment projects in later phases of project development, when a sufficient amount of data is available. The net present value is the sum of present value of all cash flows. When deciding about a certain investment based on the NPV, the rule is that the investment is accepted, when the NPV is larger than zero, and rejected when the NPV is negative.

Investment costs represent costs for BHE and heat pump of heat pump system, while investment costs for boiler represent costs of conventional system with boiler, chimney, LPG station and LPG pipeline system in public road.

The investment costs can be covered by one's own funds, bank loans, subsidy, or by the combination of all of them. The present value of investment costs C_{INV} is determined without discounting annual installments according to the equation:

$$C_{INV} = C_0 \qquad (1)$$

The maintenance costs of a heat pump CS are estimated at 2% of the purchase price. The NPV of the costs, while taking into consideration inflation, is determined by the equation:

$$C_S = \sum_{j=0}^{N} \frac{0.02 \cdot C_{TČ} \cdot (1+r_j)^j}{(1+r_j+r)^j} \quad (2)$$

The NPV of the electricity costs for the running of a compressor CPS is determined by the equation:

$$C_{PS} = \sum_{j=0}^{N} \frac{C_E \cdot P_E \cdot t_1 \cdot dayK \cdot (1+r_j)^j}{(1+r_j+r)^j \cdot \Delta T} \quad (3)$$

The NPV of the costs of the investment, maintenance, and electricity needed for the running of a compressor, is determined by the equation:

$$C_{NPV} = C_{INV} + C_S + C_{PS} \quad (4)$$

The NPV of heating system with wall hanged boiler is determined by the equation (4).

The present value of investment costs C_{INVB} is determined by discounting annual installments according to the equation:

$$C_{INVB} = C_{0B} \quad (5)$$

The maintenance costs of a boiler C_{SB} are estimated at 2% of the purchase price. The NPV of the costs, while taking into consideration inflation, is determined by the equation:

$$C_{SB} = \sum_{j=0}^{N} \frac{0.02 \cdot C_B \cdot (1+r_j)^j}{(1+r_j+r)^j} \quad (6)$$

The NPV of the LNG consumption C_{PSB} is determined by the equation:

$$C_{PSB} = \sum_{j=0}^{N} \frac{C_{LNG} \cdot Q_T \cdot t_1 \cdot dayK \cdot (1+r_j)^j}{(1+r_j+r)^j \cdot \Delta T \cdot H_{LNG}} \quad (7)$$

The NPV of the investment, maintenance, and LNG costs needed to burn in boiler is determined by the equation:

$$C_{NPVB} = C_{INVB} + C_{SB} + C_{PSB} \quad (8)$$

The successfulness of an investment is determined with the coefficient of profitability:

$$K = \frac{C_{NPV}}{C_{NPVB}} \quad (9)$$

The coefficient of profitability K represents the ratio between the NPV of two different systems.

TABLE 1
DATA FOR ECONOMIC ANALYSIS OF A TWO STAGE HEAT PUMP

Name of mark	Value	Units
One's own funds – C_o	100	%
Price of a heat pump – C_{tc}	10000.0	EUR
Price of a boiler – C_b	2500.0	EUR
Number of years for paying of a heat pump – n_1	10	years
Discount rate – r	0.07	/
Discount rate of annual installments – r_a	0.07	/
Inflation rate – r_j	0.012	/
Power used by a compressor P_E	1825	W
Heat pump/boiler heating capacity – Q_T	7300	W
Price of electricity – C_E	0.1	EUR/kWh
Price of liquidized naphtha gas – C_{LNG}	2,366	EUR/kWh
Heating value (LNG) – H_{ILNG}	26.094	kWh/m^3
Operational life of a heat pump – N	20	years
Maintenance costs – heat pump – C_s	$0.02{\cdot}C_{TČ}$	EUR
Maintenance costs – boiler – C_{sb}	0.02 Cb	EUR
Operational time of a heat pump per day – t_1	18	h/day
Heating season	3300	days K
Exterior temperature	-13	°C

Heat pump system with subsidy:
Cinv = 10000 EUR – heat pump and BHE
Csub = 2100 EUR – subsidy
Cs = 2333 EUR – maintenance cost of heat pump
Cps = 3810 EUR – costs for running a compressor
Cnpv = 14060 EUR – NPV heat pump

Boiler system:
Cinvb = 2500 EUR – boiler
Csb =583 EUR – maintenance cost of boiler
Cpsb = 13230 EUR – liquidized naphtha gas consumption
Cnpvb = 16320 EUR – NPV boiler

K = Cnpv/Cnpvb = 1,16 – successfulness of an investment

Heat pump system without subsidary:
Cinv = 10000 EUR – heat pump and BHE
Cs = 2333 EUR – maintenance cost of heat pump
Cps = 3810 EUR – costs for running a compressor
Cnpv = 16160 EUR – NPV heat pump

K = Cnpv/Cnpvb = 1,01 – successfulness of an investment

IV. DISCUSSION

Economic analysis of energy source for residential area project was made.

The first source was heat pump with BHE and the second was conventional wall mounted LNG boiler. The comparison was made for house with 10 cm heat isolation. Both models had the same room heating system - floor and wall heating. In economic analysis all costs were considered: investment, subsidy, operational and maintenance costs. Under normal running condition, compressors lifetime is about 20 years.

Table 1 presents the data needed for analysis taken from Slovenian market at beginning of 2007. It was taken into consideration that in near future the mentioned settlement is not planned to be connected to earth gas. Therefore the analysis is made for liquidized naphtha gas.

Investment comparison of two heating sources is shown in the Figure 6. HP-S indicates the heat pump with subsidy; HP-BS indicates the heat pump without subsidy and B - the boiler.

Based on presented diagram, it can be concluded that investment in GSHP is better choice than boiler system with LNG. Calculating all costs in 14 years net present value is the same and after GSHP is the cheaper alternative.

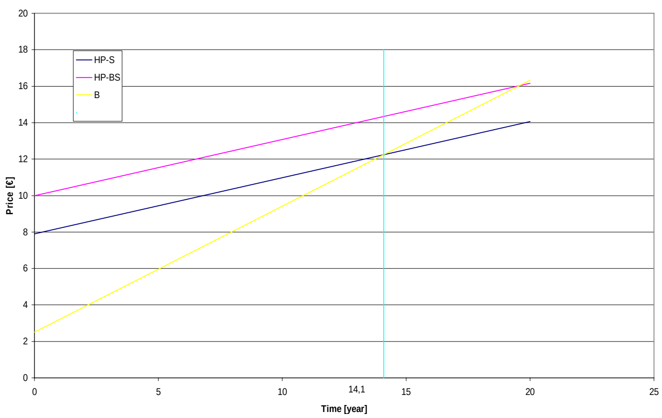

Fig.6 two heat sources investment comparison

V. CONCLUSION

The presented study shows the economic analysis of geothermal heat source for residential area project. It shows comparison between two heating sources for the same kind of building (conventional and renewable energy). Floor and wall heating is the secondary system in the house for both heating sources.

Investment in system with liquidized naphtha gas as a source of energy is lower than investment in renewable energy. Maintenance costs are also lower.

Investment in renewable energy sources is supported with subsidy of 2100 €.

Taking into account a period of 20 years and net present value cheapest system is the one with borehole heat exchanger. The most expensive system in 20 years is a system with boiler and LPG as heating medium.

Period of 20 years shows different results as to investment without NPV.

Investor has to pay a bit more for building with BHE, but he can sell the same building for higher price.

Renewable energy is good for longer period of time.

NOMENCLATURE

Cinv – price of heat pump and BHE
C_0 – Investor's own resources for system with BHE
Csub – subsidy
Cs – maintenance cost of heat pump
Cps – costs for running a compressor
Cnpv – NPV for system with heat pump
Cinvb – price of boiler
C_{0B} – Investor's own resources for boiler system
Csb – maintenance cost of boiler
Cpsb – liquidized naphtha gas consumption
Cnpvb – NPV for boiler system
K – successfulness of an investment
$C_{TČ}$ – price of heat pump
r_j – inflation rate
r – discount rate
C_E – price of electricity
P_E – power used by a comressor
T_1 – operational time of a heat pump
dT –temperature difference between temperature at standard condition and room temperature
C_B – price of boiler
C_{LNG} – price of liquidized naphtha gas
Q_T – heat pump/boiler capacity
H_{LNG} – heating value of LNG
λ - thermal conductivity

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