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Single family house: Heat Pump or Gas Boiler?

Tautvydas Antanas Aleksandravičius[1],

Feliksas Zinevičius[2]

[1] *Šilumos Mašinos UAB,*
16A Žilvičių Street, Garliava,
LT-53273 Kaunas Region,
Lithuania

[2] *Kaunas Regional Energy Agency,*
3B Breslaujos Street,
LT-44403 Kaunas, Lithuania
E-mail: info@krea.lt

The article deals with the investigation of Heat Pump and Gas Boiler Systems both installed in the same single family house. The measurement and registration of systems operational data during three heating seasons gave a possibility to calculate the running costs and to compare the systems from an economic point of view.

Key words: ground source heat pump, heat produced using heat pump, gas boiler heating system, comparison of costs for gas boiler and heat pump systems

INTRODUCTION

In Lithuania investigations of heat pump applications were initiated at the Lithuanian Energy Institute. Thermal and hydrodynamic experimental data and their analysis are presented in the monograph [1] and other publications [2–9].

Ground Source Heat Pumps (GSHP) are a modern technology for heating and cooling of buildings. They make use of geothermal energy (the heat stored beneath the earth surface) almost anywhere throughout Europe.

In such countries like Sweden, Switzerland, France, Germany, Austria, GSHP are already a routine option for residential houses. In the countries of East Europe – Lithuania, Latvia, Estonia – now GSHP market development shows evident growth rates (in Lithuania the installed capacity increased 10 times in the period from 2004 to 2009 – from 2.88 MW to 31.2 MW), but the society is still faced with lack of information, especially from an economic point of view.

So, the aim of this study is to compare the Heat Pump System with the Gas Boiler System both installed in the same single family house.

INSTALLATION FOR INVESTIGATIONS AND METHODOLOGY

The heat pump allows transformation of heat from a lower temperature level to a higher one, by using external energy (e. g. to drive a compressor). Ground Source Heat Pump Systems consist of three main components: ground side, heat pump itself, and building side.

The Heat Pump (heating capacity – 13.0 kW, power – 2.6 kW, refrigerant – R407C) and Gas Boiler (capacity – 24 kW) were installed for heating purposes and investigations in a single family house (180 m^2) located in a suburb of Kaunas, Kaunas Region, Lithuania (Fig. 1). The main component of the ground side of the GSHP System is a heat collector. The installed collector consists of 8 loops made from plastic pipes (polythene PA, D32×3).

Inside the loops we have a mixture of water and antifreeze liquid (approx. 400 litres) the freezing temperature of which is –12 °C. The flow resistance Δp in the soil collector was calculated by $\Delta p = \lambda q v^2 l / 2d_{ekv}$.($N/m^2$) where $\lambda = 0.316/Re^{0.25}$. For the heat collector the top earth layer was removed, the pipes were laid (in the depth of 1.8 meters), and the soil (loam) was distributed back over the pipes.

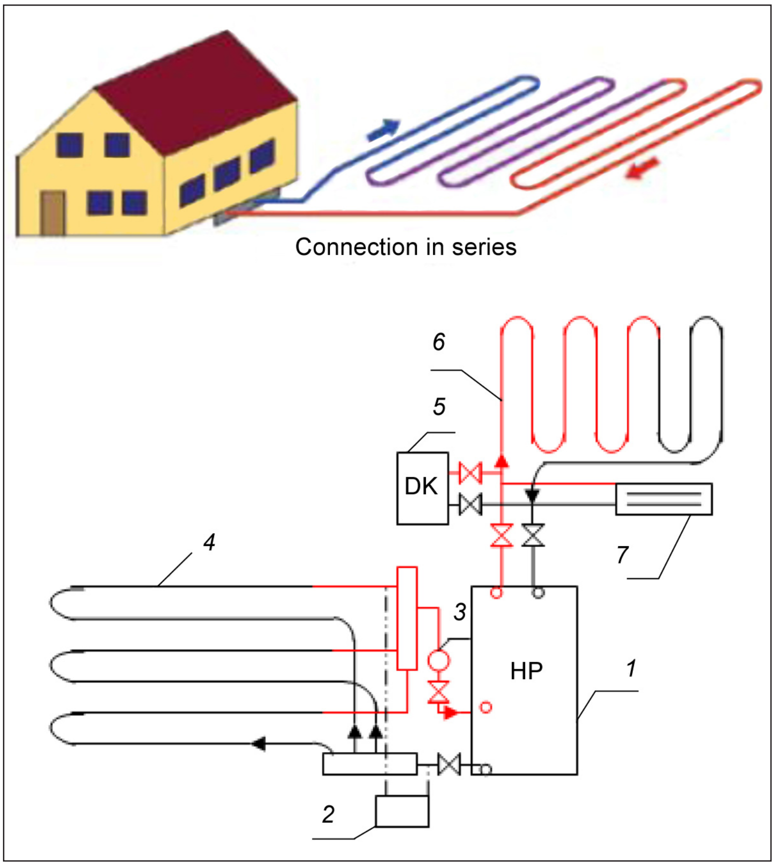

Fig. 1. The heating scheme with two systems – Heat Pump and Gas Boiler (*1* – heat pump, *2* – temperature meter, *3* – water flow meter, *4* – horizontal ground heat exchanger, *5* – gas boiler, *6* – floor heating, *7* – fan coil)

The main component of the building side of the Heat Pump System is also a heat exchanger which consists of tubes (diameter 12 mm, temperature 25–30 °C) installed in the floor and covered by concrete and tiles. The pressure inside the soil collector and inside the floor heating system was 0.8–1.25 bar. Indoor temperature during the heating season was kept 18–22 °C, and the outside temperature in the heating season changes from –10 °C up to +12 °C.

When the Heat Pump was in operation, the Gas Boiler was switched off and vice versa. A fan coil may be used, in case of need, to raise indoor temperature in a short time.

The measurement and registration once per 24 hours of temperatures (of water flows in loops, also indoor and ambient), volumes (of water circulating (m^3/h) and natural gas used), pressures (in loops) and electricity consumption gave a possibility to calculate the operating costs and the coefficient of performance (COP) of the heat pump over the heating season.

RESULTS

The house in Fig. 1 and the HP soil collector are shown for more visualisation of the HP System only.

The changes of the ambient temperature and the soil temperature from October 2007 to April 2008 are presented in Fig. 2.

The average ambient temperature was –4.64 °C. The electricity consumption within the month of the HP was 732 kWh or 24 kWh per day. The COP was 3.95.

Table. **Comparison of expenses of the Gas Boiler System and Heat Pump (HP) System**

	Operating cost per year									
	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
Boiler investment 1 100 EUR	4 835.1	8 570.2	12 305.3	16 040.4	19 775.5	23 510.6	27 245.7	30 980.8	34 715.9	38 451
HP investment 9 372 EUR	9 866.9	10 361.8	10 856.7	11 351.6	11 846.5	12 341.4	12 836.3	13 331.2	13 826.1	14 321

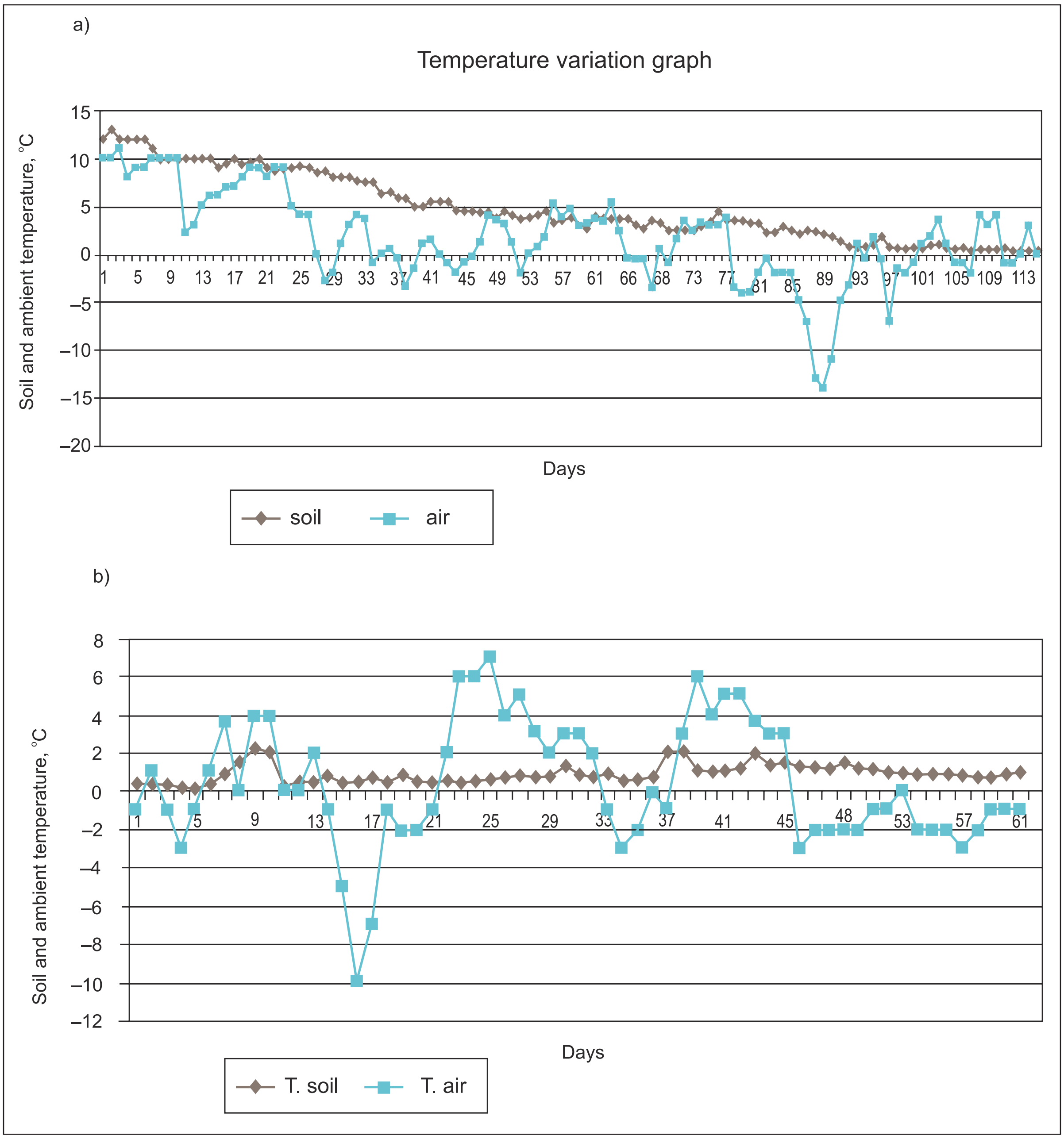

Fig. 2. The changes of soil and air temperature: a) from the start of the heating season to 1 February, b) from 1 February to 1 April

When the heating season started, the temperature of the soil was 12–13 °C, the lowest ambient temperature was from minus 10 and the highest temperature was up to 12 °C.

The soil temperature goes down with the time because the heat was constantly taken off from the soil.

The temperature decrease of the soil was not less than 0 °C. It shows that the soil and the fluid which is inside of the pipes buried in the soil have no possibility to freeze. When the Heat Pump for the weekend was switched off, the room temperature went down from 20–22 °C to 15–17 °C and the temperature of the soil went up to 1–2 °C. The Gas Boiler consumed 24.46 m^3 of natural gas per day.

The calculations (carried out using the prices of the natural gas, electricity and equipment of the year 2012) show that the operation cost of the Heat Pump System is 494.9 EUR/year and that of the Gas Boiler System is 3 735.1 EUR/year.

The comparison of the foreseen expenses for every of 10-year exploitation (in case of the same operation cost every year) of each system are separately presented in the Table.

Installation costs. Private investment: the total cost of the Heat Pump Heating System is 9 372 EUR; the total cost of the Gas Boiler Heating System is 1 100 EUR.

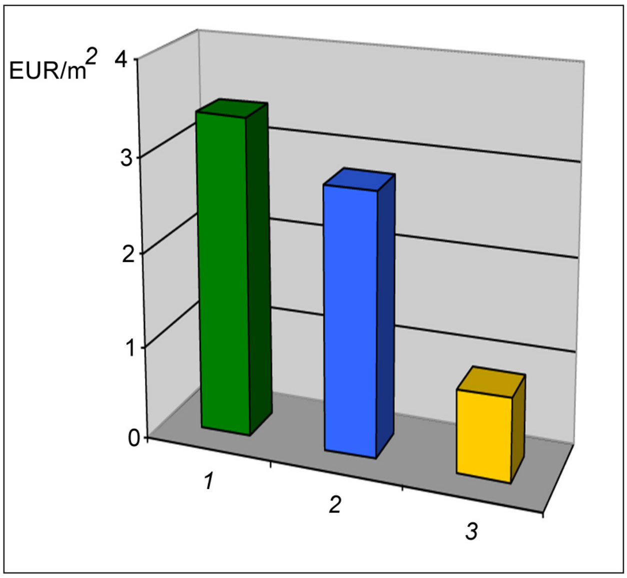

Fig. 3. Costs of Gas Boiler and Heat Pump Systems operation (*1* – gas boiler, 3.4 EUR/m^2; *2* – gas boiler switched off for 6–8 hours per night, 2.8 EUR/m^2; *3* – heat pump, 0.885 EUR/m^2)

In the first year we have a sum of investment and operation costs. During next years the expenses are rising due to operation costs. The total expenses per 10 years for the Gas Boiler System are 2.61 time higher than for the Heat Pump System.

CONCLUSIONS

1. Heat Pump System is clean and easy to maintain.
2. The average COP was 3.95.
3. If in the short run the Gas Boiler System seems more financially attractive, in the long run (10 years) it requires 2.6 times higher expenses.
4. It is possible to reduce considerably the expenses for heating by switching off the boiler for 6–8 hours per night.

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Tautvydas Antanas Aleksandravičius, Feliksas Zinevičius

INDIVIDUALUS GYVENAMASIS NAMAS: ŠILUMOS SIURBLYS AR GAMTINIŲ DUJŲ KATILAS

Santrauka

Straipsnyje analizuojami šilumos siurblio ir gamtinių dujų katilo, instaliuotų tame pačiame name, eksploatacijos rezultatai. Pateiktas žemės šilumą naudojančio šilumos siurblio sistemos aprašymas, bendra pastato šildymo sistemos schema.

Tyrimų laikotarpis – trys šildymo sezonai, tačiau straipsnyje pateikti vieno sezono (2007/2008 metų) tyrimo duomenys. Temperatūra, debitai, slėgis, suvartota elektra buvo registruojama kartą per 24 val.

Gauti rezultatai leido nustatyti šilumos siurblio transformacijos koeficientą (COP) – 3,95. Atlikti ekonominiai skaičiavimai, remiantis 2012 m. kainomis.

Pateiktas šilumos siurblio ir gamtinių dujų sistemų kaštų palyginimas 10 metų laikotarpiu. Nustatyta, jog pagal instaliavimo kaštus pigesnės gamtinių dujų sistemos dešimtmečio bendrosios išlaidos yra 2,6 karto didesnės, palyginti su šilumos siurblio sistemos bendrosiomis dešimtmečio išlaidomis.

Raktažodžiai: žemės šilumą naudojantis šilumos siurblys, gamtinių dujų katilo šildymo sistema, gamtinių dujų katilo ir šilumos siurblio sistemų kaštų palyginimas

Таутвидас Антанас Александравичюс, Феликсас Зинявичюс

ИНДИВИДУАЛЬНЫЙ ЖИЛОЙ ДОМ: ТЕПЛОВОЙ НАСОС ИЛИ КОТЕЛ НА ГАЗОВОМ ТОПЛИВЕ

Резюме

В статье анализируется результаты эксплуатации теплового насоса и котла на газовом топливе – оба смонтированы в том же доме. Представлено описание системы теплового насоса, использующего теплоту земли; представлена общая схема теплоснабжения дома.

Эксперименты проводились в течении трёх отопительных сезонов. В статье представлены данные только одного отопительного сезона 2007/2008 года. Температуры, дебиты, давления, потребление электроэнергии регистрировались раз в 24 часа.

Полученные результаты позволили установить коэффициент трансформации тепла (COP) теплового насоса – 3,95. Экономические расчёты проведены используя цены 2012 года.

Представлено сравнение стоимости систем теплового насоса и котла в течении 10 лет. Установлено, что с точки зрения разходов инсталляции более дешевая система газового котла через 10 лет эксплуатации нуждается в 2,6 раза больших общих финансовых расходов чем система теплового насоса.

Ключевые слова: тепловой насос, использующий тепло земли, теплота, полученная при использовании теплового насоса, система отопления дома котлом на газовом топливе, сравнение стоимости систем теплового насоса и котла на газовом топливе