BUDOWNICTWO
CZASOPISMO TECHNICZNE
TECHNICAL TRANSACTIONS
CIVIL ENGINEERING
WYDAWNICTWO POLITECHNIKI KRAKOWSKIEJ
1-B/2009
ZESZYT 5
ROK 106
ISSUE 5
YEAR 106

FRANTISEK VRANAY, ZUZANA VRANAYOVA, MARTIN KOVAC*

SMART BUILDINGS VERSUS GROUND ENERGY AND INDOOR TECHNOLOGIES

BUDYNKI INTELIGENTNE WOBEC ZIELONEJ ENERGII I TECHNOLOGII WEWNĘTRZNYCH

A b s t r a c t

It is argued that heat pumps as one of renewable energy sources are very energy efficient, and therefore environmentally-friendly. Under favourable conditions, the energy from low--potential heat, in other way unusable, is used as a source of energy for a heat pump performance. The applicability of this system supports the utilisation of electric energy at a low tariff rate, which is also valid for the operation of other electrical appliances. This article determines operative production costs for heating and operation of other electrical appliances and indicates new ways of using it in combination with low-temperature heating systems.

Keywords: *heat pump*, *building heating*, *energy balance*

S t r e s z c z e n i e

Pompy ciepła, jako źródło energii odnawialnej, są bardzo efektywne energetycznie i z tego powodu przyjazne dla środowiska naturalnego. W dobrych warunkach energia pozyskiwana ze źródła dolnego, nieużyteczna w inny sposób, jest efektywnie wykorzystywana za pośrednictwem pompy ciepła. Używanie takiego systemu może być dodatkowo atrakcyjne przez zastosowanie taniej taryfy energii elektrycznej. To dotyczy również użytkowania innych urządzeń elektrycznych. W artykule określono koszty ogrzewania i użytkowania innych urządzeń elektrycznych i wskazano nowe sposoby ich stosowania w kombinacji z niskotemperaturowymi systemami ogrzewania.

Słowa kluczowe: *pompa cieplna*, *ogrzewanie budynku*, *bilans energetyczny*

* Ing. Frantisek Vranay, as. prof. Zuzana Vranayova, Ing. Martin Kovac, Institute of Building and Environmental Engineering, Civil Engineering Faculty, Technical University of Kosice, Slovakia.

Denotations

HP – heat pump
COP – coefficient of performance

1. Introduction

The EU and the world are at a cross-roads concerning the future of energy. Climate changes, increasing dependence on oil and other fossil fuels, growing imports, and rising energy costs are making our societies and economies vulnerable. These challenges call for a comprehensive and ambitious response. The heating and cooling sector accounts for approximately 50% of overall EU final energy consumption and offers a largely cost-effective potential for using renewable energies, notably bio-mass, solar and geothermal energy. However, with renewables today accounting for less than 10% of the energy consumed for heating and cooling purposes, this potential is far from being exploited [1].

It is argued that heat pumps are very energy efficient, and therefore environmentally-friendly. Under good conditions, the energy from low-potential heat, in other way unusable, is used as a source of energy for heat pump performance. The applicability of this system supports utilisation of electric energy at low tariff rate, which is also valid for operation of other electrical appliances. This article determines operative production costs for heating and operation of other electrical appliances.

1.1. Heat pump general description

The working principle of the heat pump (HP) has been known for more than 100 years. Nowadays, its usefulness is clearly demonstrated by relatively low cost of the system and the competitive prices of other energy sources. The heat pumps can be thought of as a heat engine which operates in reverse, as, for example in food refrigerators or freezers, air conditioners and reversible-cycle heat pumps providing thermal comfort. Rich energy sources can be found in our immediate surroundings (water, air, ground). Their utilisation is efficient when the energy at a low temperature level is overdrawn by HP to a higher temperature level. The useful heat consists of the energy extracted from the source (in this case the groundwater at 10°C is cooled down) and the heat which is equal to the delivered electrical energy. Basing on these energies, one can define the coefficient of performance ($E_1 + E_2$). The term coefficient of performance (COP) is used to describe the ratio of the output heat of the supplied work

$$\mathrm{COP} = \frac{E_1 + E_2}{E_2} \tag{1}$$

where:

E_1 – energy extracted from the source (water temperature ranging from 10°C to 6°C),
E_2 – delivered electrical energy for HP.

This figure is space-less and it is the main indicator of quality, particularly with respect to the source. The COP depends on operating conditions. On the input side, there are the cooled down water temperature and the HP quality and working order, while on the output side, there is the temperature of a heated medium (water for heating or heated water). When the temperature difference between the heated and cooled medium is smaller, the COP is higher. On the contrary, with the higher temperature difference, the COP goes down, e.g.: with COP = 5 the output energy is 5 kWh and electrical energy input is 1 kWh. Therefore, the most efficient seems to be the low temperature heating systems.

2. Analysed system description

The system is designed for an administrative building with the heat loss of 140 kW without water heating. Hot water is heated by an electrical flow water heater. The source of heat is the ground water at the temperature of 11–13°C. The heating system consists of hot water conventional radiators with the temperature drop of 60/50° and the outdoor temperature of 15°C. The whole building is electrified.

– Heating with the HP.
– Water heating by an electrical flow water heater.
– Lighting and other appliances.

During the operation we used the tariff BENEFIT-EKO-MAXI. Following outputs result from the operating costs.

2.1. Calculation methodology

The calculations are done on the basis of the real-measured, average day temperatures and their frequency during the heating season 2006/2007. Every outdoor temperature is related to a heating water temperature (heated medium temperature) which has an influence on the COP. The HP must heat water for heating to the required temperature.

Figure 1 shows the performance of the HP relative to the outdoor temperature. It is possible to cover the building heat loss by the HP up to the exterior temperature of –11°C. Below this temperature an external heat source is needed. The engine room is connected to the heat exchanger plant where it is possible to raise the heating water temperature in case of need. The COP value for central heating is 2.4–5.3, i.e. on average – 3.5. The COP also covers other electrical appliances (pumps, regulation, etc.).

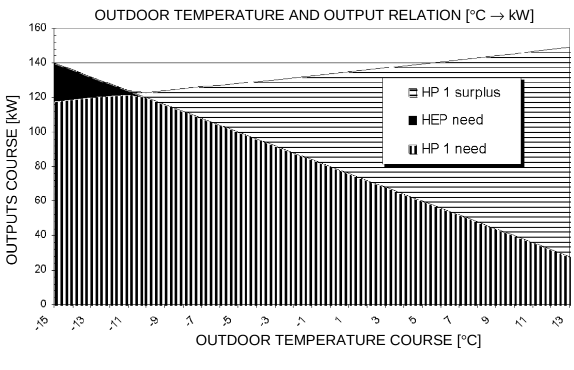

Fig. 1. Presents HP performance relative to exterior temperature (heat loss = 140 kW, HP performance = 118 kW, outdoor temperature –15°C)

Rys. 1. Wydajność pompy cieplnej w zależności od temperatury zewnętrznej (straty ciepła = = 140 kW, wydajność pompy = 118 kW, temperatura zewnętrzna –15°C)

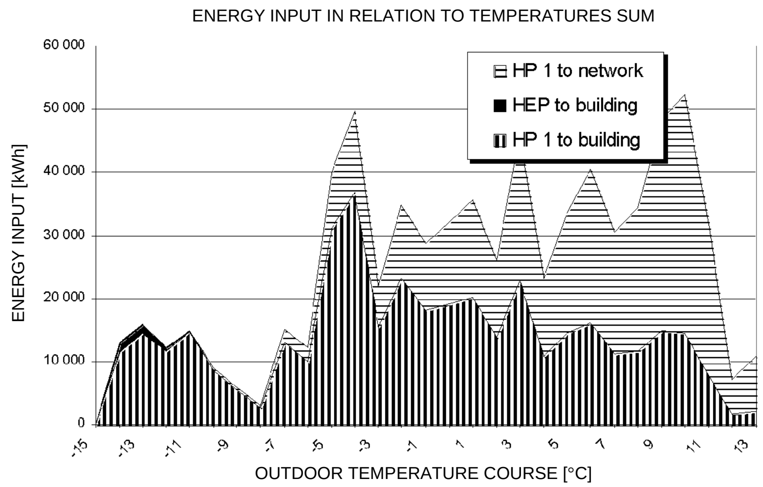

Fig. 2. The period of delivered energy for heating according to frequency of heating season with related exterior temperature

Rys. 2. Dostawa ciepła do ogrzewania w zależności od występowania danej temperatury zewnętrznej w sezonie grzewczym

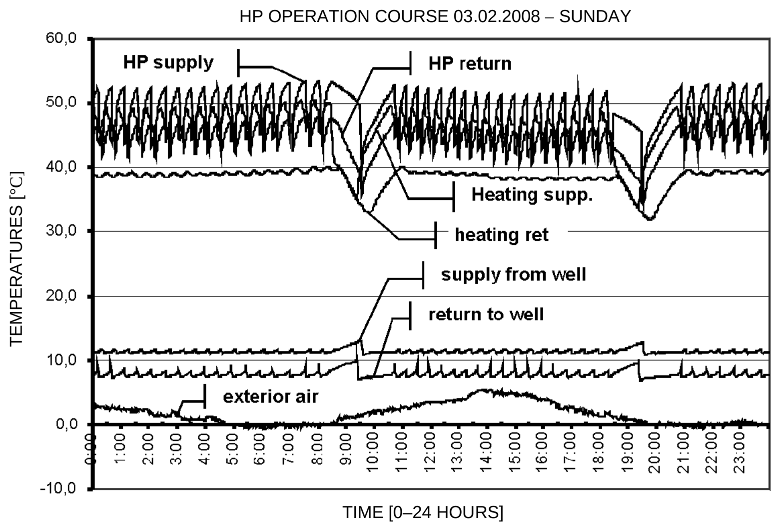

Fig. 3. The period of measured temperatures during the heating on one typical day

Rys. 3. Pomierzone wartości temperatury podczas jednego typowego dnia okresu grzewczego

Figure 2 presents a specification of heating needs in relation to heating season and energy consumption. The derived energy supply used for heating relative to the outdoor temperature ranging from –15°C to +13°C. The heat pump performance is only 85% of the maximal heat loss. The HP can cover up to 99% of the required energy for central heating depending on the frequency and average temperature of heating days. The external heater is needed only for 1% of energy consumption. The pie slice 2 in Fig. 2 shows the available heat quantity to be supplied to another customer. When the outdoor temperature rises above –11°C the system generates a surplus, which can be used to supply energy to another customer. In this case, 53% of the heat is consumed within a given building and 47% is given to the distribution network.

In chart 3 one can see the shape of temperatures, charging the energy to the tank and the HP running time. To achieve the HP efficiency, it is turned off during the electrical energy high tariff periods, i.e. between 8^{30}–9^{30} and 18^{30}–19^{30}. This one-hour pause in heating is compensated by the accumulation of building heat and has no influence on thermal balance.

3. Conclusions

The low tariff rate for the HP has been applied for the whole building. The COP = 3.5 has been used for the HP operation, which determines the electrical energy demand for the HP as 100 000 kWh, compared to the delivered heat for central heating equalling 350 000 kWh. The HP operation is preferable. The evaluation of other cases depends on the well prices (injection and extraction well). The balance involves only the heat for the building, therefore it is necessary to re-evaluate all factors which have influence on the realisation.

The substitution of the heat from the fossil fuel combustion (gas, coal) by using a heat pump aimed at the emission decrease. With a yearly heat production of 6000 GJ, the assumed decrease for the reference building is respectively:

SO_2 = 413,846 kg/year

NO_x = 34,26 kg/year

TZL = 19,67 kg

CO = 10,00 kg

CO_2 = 151,15 t/year

In the next part of our research we would like to concentrate on the applicability of capillar mats technology to heating/cooling, using a radiant heat part with the decrease of the operational water temperature to 40°C – possible heat pump efficiency increase to the ratio 1:5,5 up to 1:6 for a suction water well at 12–14°C as well as the utilisation of the accumulated energy as heat/cool in the building construction interaction and finding a smart regulation of dynamical parameters. Our focus of attention will be the technology providing solutions for the heat supply during a heating season and at the same time, the cool supply in a summer season.

The article was created with solution of grant project ITMS "26220120018".

R e f e r e n c e s

[1] Renewable Energy Road Map, Renewable energies in the 21st century: building a more sustainable future, COM Brusel, 2007.

[2] L i s A., *Czynniki wpływające na potrzeby cieplne budynków*, [in:] *Zborník z medzinárodnej konferencie*: *Zagadnienia współczesnego budownictwa energooszczędnego o zoptymalizowanym zużyciu potencjału energetycznego*, Częstochowa, Poland, 2003, 148-155.

[3] P u r c z P., *Communication complexity and speed-up in the explicit difference method*, Parallel Processing Letters, vol. 16, no. 3, 2006, 313-321.

[4] L u k á č P., *Niektoré možnosti energetických úspor pri prevádzke ústredného kúrenia v CZT*, Acta Mechanika Slovaca 3-A/2004, 631-636.