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ENERGY AND FINANCIAL BALANCE OF HEAT PUMP APPLICATION (OUTDOOR AIR-WATER) IN A FAMILY HOUSE

The content of the article is elaboration of tabular analysis of heat pump "outdoor air-water" in heating and domestic hot water system in family house. The object of analysis is comparison of conventional system with using gas boiler or electric boiler and application of heat pump "outdoor air-water". The part of analysis is energy performance of renewable energy source application as well as financial balance of savings in relation to conventional heat sources and pay-back period of investment in heat pump. Pay-back periods are determined for given boundary conditions and they were considered with rise in the price of energy too.

Keywords: heat pump, energy, financial balance, pay-back period, family house

INTRODUCTION

For our energy and financial balance the model family house was selected. It has 2 above-ground floors, double-sloping roof and the total heating floor area of the house is 170 m^2. The family house is designed for 4 householders. The radiant floor heating with additional radiators is designed in this house. Water temperatures in heating system are 50/40°C. Design heating load was calculated on the basis of building construction parameters, outdoor air temperature $\theta_e = -11$°C and design indoor air temperature $\theta_{int,i} = 20$°C. The calculation was done by technical standard [1] and the result value of building heat load is 12 kW what is 70.6 W/m^2 heating floor area.

1. CALCULATION MODEL

Heat demand for heating system in model family house is 26 300 kWh/year, heat demand for domestic hot water system is 3700 kWh/year and then the total heat demand is 30 000 kWh/year. In heating and domestic hot water system it is considered with two alternative heat sources in base case: gas boiler where the efficiency of heat generation is 90% [2] and electric boiler where the efficiency of heat generation is 99% [2]. Indirectly heated hot water storage vessel with volume 120 litres is designed in domestic hot water system (Fig. 1).

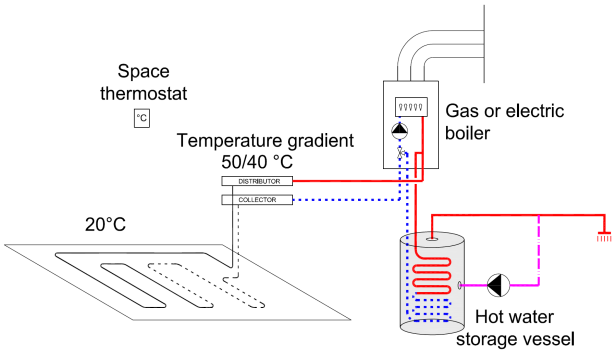

Fig. 1. The scheme of heating and domestic hot water system in base case

In the proposed base it is considered with application of electric heat pump "outdoor air-water" that is used as renewable heat source for heating and domestic hot water system (Fig. 2). The selected type of heat pump is done for outdoor installation and its part is additional electric coil with the power 9 kW. The other component of proposed heat pump system are heating buffer storage with volume 200 litres, indirectly heated hot water storage vessel with volume 200 litres, pump units, measurement and control, eventually other accessories.

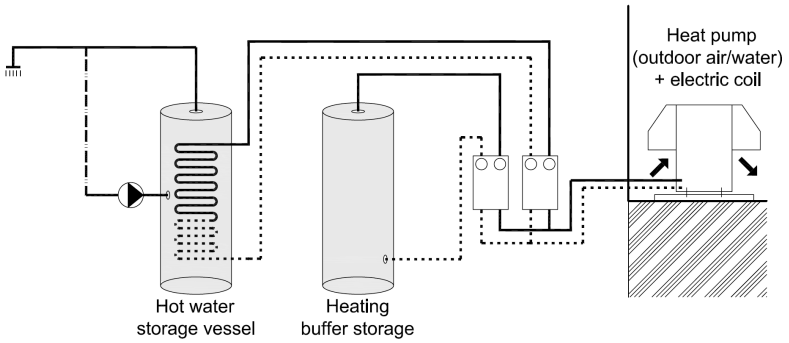

Fig. 2. The scheme of heating and domestic hot water system in proposed case

2. ENERGY BALANCE OF HEAT PUMP APPLICATION

In the first step of energy balance there is needed to set the heating capacity of selected heat pump for operational conditions of heating system in family house.

Capacity curve of selected heat pump together with its design is shown on a graph below (Fig. 3). The base operation conditions of system are design supply temperature, outdoor air temperature and design heating load.

It results from the graph that the heat pump heating capacity by outdoor air temperature (–11°C) is 7.5 kW. In the case of temperatures lower than –3°C (balance point temperature) the residual heating load will be delivered by back-up heater (electric coil).

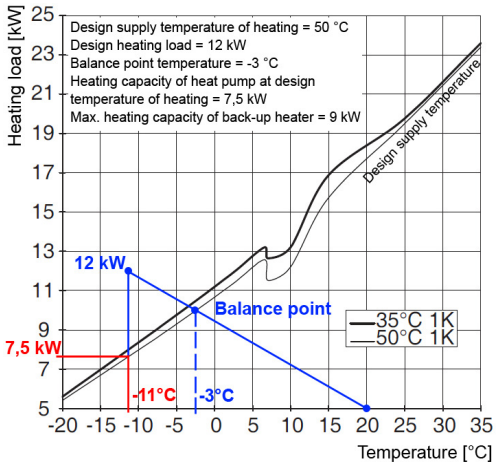

Fig. 3. Capacity graph of selected heat pump "outdoor air-water"

In order to calculate quantity of primary electric energy there is needed to determine COP factor of selected heat pump for operational conditions of heating system in family house in the next step. Partial values of COP factor for single outdoor air temperature at interval (–11°C to +13°C) and design supply temperature of heating 50°C were used in order to determine the result value of COP factor. This value was calculated as weighted average on the bases of annual frequency of the outdoor temperature [3] from mentioned interval. The result value of COP factor is 2.85 (Fig. 4).

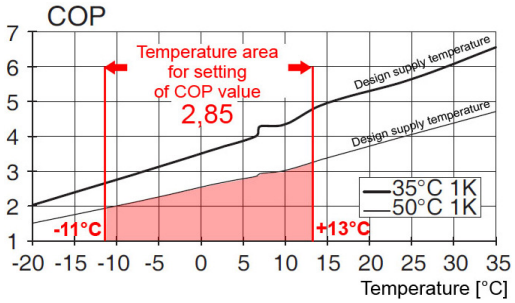

Fig. 4. COP factor graph of selected heat pump "outdoor air-water"

In the case of selected heat pump application in heating and domestic hot water system, delivered heat by heat pump is 28 714 kWh/year (around 95.7% cover of total heat demand) and delivered heat from back-up heater (electric coil) is 1286 kWh/year (around 4.3% cover of total heat demand).

In the base case (conventional system), the total energy consumption is 33 333 kWh/year by using of gas boiler and 30 303 kWh/year by using of electric boiler as heat source. In the proposed case where heat pump (COP factor 2.85) and back-up heat source (electric coil) are applied the total energy consumption is 11 374 kWh/year (Fig. 5 left).

3. FINANCIAL BALANCE OF HEAT PUMP APPLICATION

In order to elaborate correct financial balance of capital project (application of heat pump in heating and domestic hot water system in family house) it is needed to define individual input data. In this article there are elaborated two comparisons, heating and domestic hot water system with application of heat pump (proposed case) is compared with conventional system where the heat source is gas or electric boiler (base case).

In the base case with gas boiler the rate for energy is 0.0463 Euro/kWh and fixed monthly payment is 7.75 Euro/month by actual price list of natural gas supplier [4]. If the electric boiler is used in base case, the ending electric energy rate (by actual price list) is 0.1068 Euro/kWh and fixed monthly payment for supply point is 11.7163 Euro/month [5]. If the heat pump is applied as main heat source in heating and domestic hot water system, the consumer can gain better electric energy rate. In this case the ending energy rate is 0.124 Euro/kWh and monthly payment for supply point is 5.1686 Euro/month [5]. The total operation costs of heating and domestic hot water system for all cases and used heat sources are shown in a graph (Fig. 5 right).

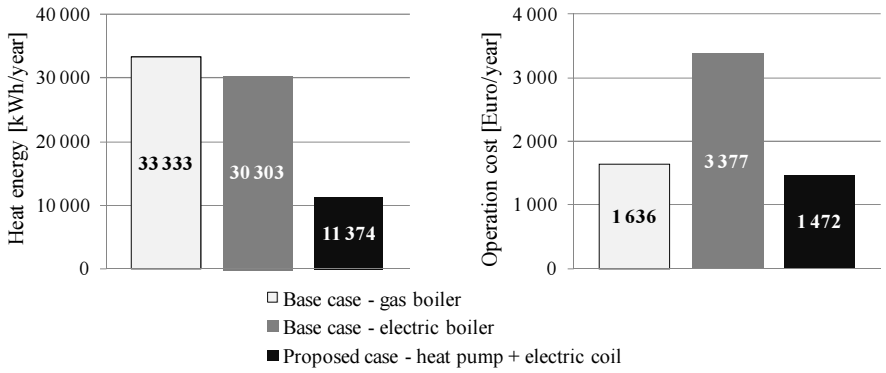

Fig. 5. Energy consumption (left) and operation costs (right) of heating and domestic hot water system in family house

Application of selected heat pump "outdoor air-water" in family house brings cost saving in the amount of 164 Euro/year in comparison with gas boiler or cost saving in the amount of 1905 Euro/year in comparison with electric boiler.

Total input investments in heat sources for all evaluated variants are calculated as follows:

- a set of gas boiler and indirectly heated hot water storage vessel = 1630 Euro,
- a set of electric boiler and indirectly heated hot water storage vessel = 1420 Euro,
- a set of electric heat pump with back-up heater (electric coil), heating buffer storage and indirectly heated hot water storage vessel = 12 260 Euro.

Lifetime of capital project (application of heat pump in heating and domestic hot water system) is 20 years for the purposes of next calculations in financial balance.

In the first step, the pay-back period of capital project is calculated from the input investment and achieved saving. The rise in the price of energy is not taken into consideration. In this case, the pay-back period of project is 5.7 years in comparison to base case with electric boiler (Fig. 6). In comparison to base case with gas boiler, the pay-back period of investment in heat pump is longer than its lifetime.

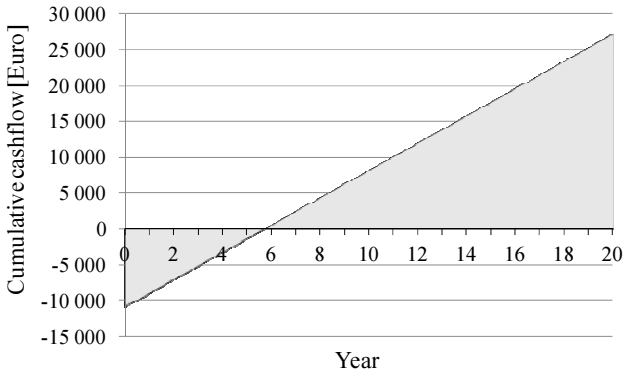

Fig. 6. The pay-back period of investment in comparison to electric boiler and without rise in the price of energy

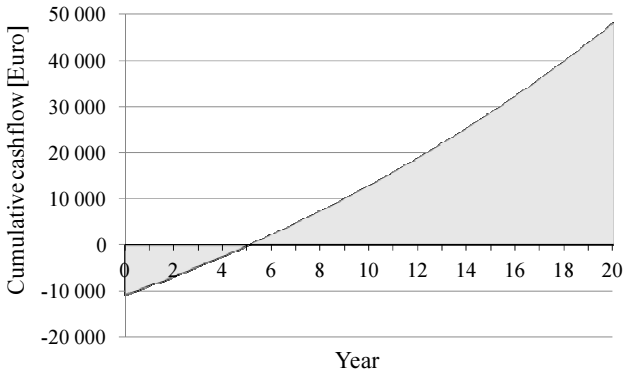

Fig. 7. The pay-back period of investment in comparison to electric boiler and with rise in the price of energy

In the second step, the pay-back period of capital project is calculated from the input investment and achieved saving but now the rise in the price of energy is taken into consideration. Average increase in prices of natural gases and electric energy for households was determined on the bases of data about their prices in years 2004-2012 that were made public by Statistical Office of European Union (EUROSTAT) [6]. The value of the rise in the price of natural gas for households is about 9% and the rise in the price of electric energy for households is about 4%. In this case, the pay-back period of project is 5.1 years in comparison to base case with electric boiler (Fig. 7). In comparison to base case with gas boiler, the pay-back period of investment in heat pump is longer than its lifetime.

CONCLUSION

The result from energy and financial balance of heat pump application in heating and domestic hot water system is the reduction of operation costs:
– 10% in comparison with gas boiler as heat source,
– 56% in comparison with electric boiler as heat source.

The calculated pay-back periods of input investment in heat pump system are adequate to achieved saving by application of heat pump in compare to conventional heat sources (gas and electric boiler). But we must say that if the rise in the price of natural gas or electric energy was not such high, the pay-back period would be longer.

Together with energy saving we can reduce the carbon dioxide emission in the amount of 5.9 tons per year in comparison with gas boiler or in the amount of 5.6 tons per year in compare with electric boiler as heat source. For better image, these amounts are equivalent to about 2450 litres unconsumed gasoline per year.

Acknowledgements

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ENERGETYCZNE I EKONOMICZNE UWARUNKOWANIA ZASTOSOWANIA POMP CIEPŁA (POWIETRZE-WODA) W BUDYNKACH MIESZKALNYCH

Tematem artykułu jest analiza zastosowania pompy ciepła powietrze-woda do ogrzewania i przygotowania ciepłej wody użytkowej w budynku mieszkalnym. Przedmiotem analizy jest porównanie konwencjonalnego systemu z wykorzystaniem kotła gazowego lub elektrycznego i niekonwencjonalnego z zastosowaniem pompy

ciepła powietrze-woda. Częścią przedstawionej analizy jest wyznaczenie energetycznych i ekonomicznych korzyści z zastosowania odnawialnych źródeł energii w stosunku do źródeł konwencjonalnych oraz okresu zwrotu nakładów poniesionych na tego typu inwestycję. Okres amortyzacji ustalono dla podanych warunków brzegowych z uwzględnione z wzrostem cen energii.

Słowa kluczowe: pompy ciepła, bilans energetyczny i ekonomiczny, czas zwrotu nakładów, budynki mieszkalne