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ENERGY PERFORMANCE OF A BUILDING WITH HEAT PUMP SYSTEM – A CASE STUDY

ANALIZA ENERGETYCZNA BUDYNKU Z ZASTOSOWANIEM POMPY CIEPŁA

Odpowiedzialność za poprawność językową ponoszą autorzy

A b s t r a c t

The content of paper is a case study of building energy certification by application of heat pump for heating and domestic hot water system. The aim is to apply a methodical process of relevant standard STN EN 15316-4-2 and to evaluate the impact of heat pump application on energy balance of heating system and domestic hot water system.

Keywords: renewable heat source, heat pump, energy performance

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

Tematem artykułu jest analiza pod kątem certyfikatu energetycznego budynku, w którym została zastosowana pompa ciepła do ogrzewania oraz podgrzewania ciepłej wody użytkowej. Celem jest przedstawienie procesu zgodnie z normą STN EN 15316-4-2 oraz oszacowanie wpływu zastosowania pompy ciepła na bilans energetyczny systemu grzewczego oraz ciepłej wody użytkowej.

Słowa kluczowe: odnawialne źródła ciepła, pompa ciepła

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1. Introduction

Using renewable energy in all forms for energy-optimal economic operation of buildings is now a requested item. Today's systems make it possible to use different types of renewable energy, whether solar energy, wind, water, earth or other energy forms. An integral part of the use of green energy is the positive approach of people to our human environment, the whole planet Earth. In our conditions the most are used solar systems, which use solar radiation as renewable energy source. Solar collectors are applied mainly in domestic hot water systems, further as a support for the heating system of buildings or for heating water in the pool. Furthermore, there are heat pumps in various modifications, for example. water-water, ground water, air-water, which are now constantly innovated. As a result, increases their efficiency by using different forms of energy, e. g. groundwater, soil, energy from deep wells, or ambient air.

In our example we concerned with the determination of energy efficiency of the office building using heat pump system design in water/water. In determining the energy performance of heat pump will be used a methodical procedure according to STN EN 15 316-4-2 (Heating systems in buildings – Method for calculation of system energy requirements and system efficiency – Part 4-2: Space heating generation systems, heat pump systems). In addition to these technical standards will be applied to other standards, dedicated to the issue of energy efficiency and building certification No. 311/2009 Ordinance Code and the Law No. 555/2005 Coll SR. The result wills the determination of delivered and primary energy building.

2. Example of the administrative building's model

The 3-floor office building with a flat roof was chosen as a model example. The floor area is 890.8 m^2 and the building is located in the city of Kosice. The first floor (ground floor) is used as an area for clients; the second and third floor is designed as cellular offices. In the building is designed combination hot water heating, with a separate circuit for floor heating on the first floor and convection heating circuit with the plate radiators on the second and third floor. The system has hydraulic control and regulation by outside-air temperature; the thermostatic heads are fitted on the radiators including space thermostats on the first floor. Heat source is an electrically driven heat pump in design water/water with suction and absorbing well, a storage tank for heating water of volume 500 litres. In case of need, the required heat output will be increased involvement of electric coil into a storage tank. Domestic hot water system is decentralized; the sampling locations are equipped with electric heaters. The solution of forced ventilation, cooling and air conditioning system is not considered. The subject of the evaluation is heating and domestic hot water system. Lighting system, forced ventilation, cooling and air conditioning is not assessed, as reflected in determining the range of energy classes.

Domestic hot water system – in a model example is considered with local water heating in the direct electrical heated domestic water heater. The energy demanol is relevant to heating the necessary amount of water in the house. Distribution and accumulation system is not evaluated (no).

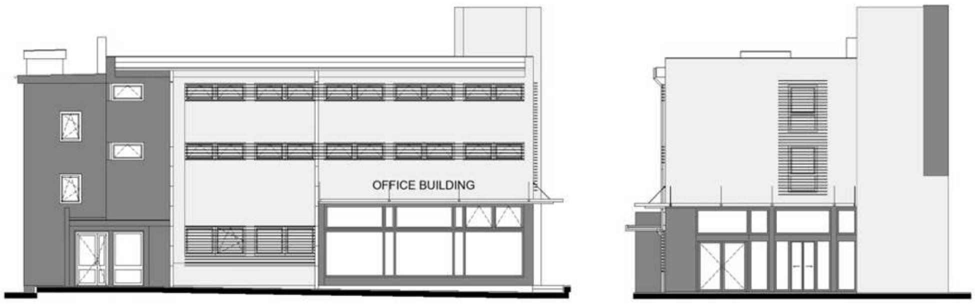

Fig. 1. Model of an administrative building

Rys. 1. Model budynku administracyjnego

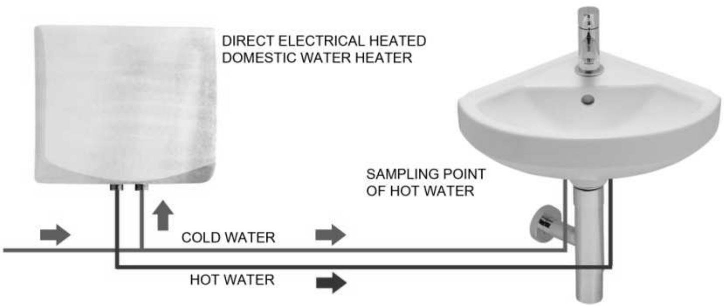

Fig. 2. Scheme for training of local hot water

Rys. 2. Schemat przepływu lokalnej ciepłej wody

Under Decree No. 311/2009 Coll SR it is based on the quantity of needed heat of hot water for a category of buildings: office buildings – 6 kWh/(m^2·year), delivered energy domestic hot water system is 5345 kWh/year] or 6 kWh/(m^2·year). Energy class of domestic hot water system – B.

Heating system – for example, the model is considered with a combined heating, convective with plate radiators and radiant floor. Temperature gradient is designed for 55/45 °C. The source of heat is electric heat pump in design water/water. The temperature of groundwater is based on measurements of between 12 to 14°C. In the model example we consider the ground water temperature of 10°C. In determining the delivered energy of the heating system has been analyzed: the emissions subsystem (transfer), heat distribution subsystem and the accumulation of heat. Heat generation subsystem is the subject of primary energy. Fig. 4 shows the monthly balance of the delivered energy heating system. The delivered energy heating system is 76 691 kWh/year or 86 kWh/(m^2·year), which classifies the heating system in energy class – D. The following illustration shows a functional diagram of a heating system in the office building.

The balances of the total delivered energy of building have been established based on the sum of delivered energy domestic hot water and heating system. The evaluated office building was classified into energy class C.

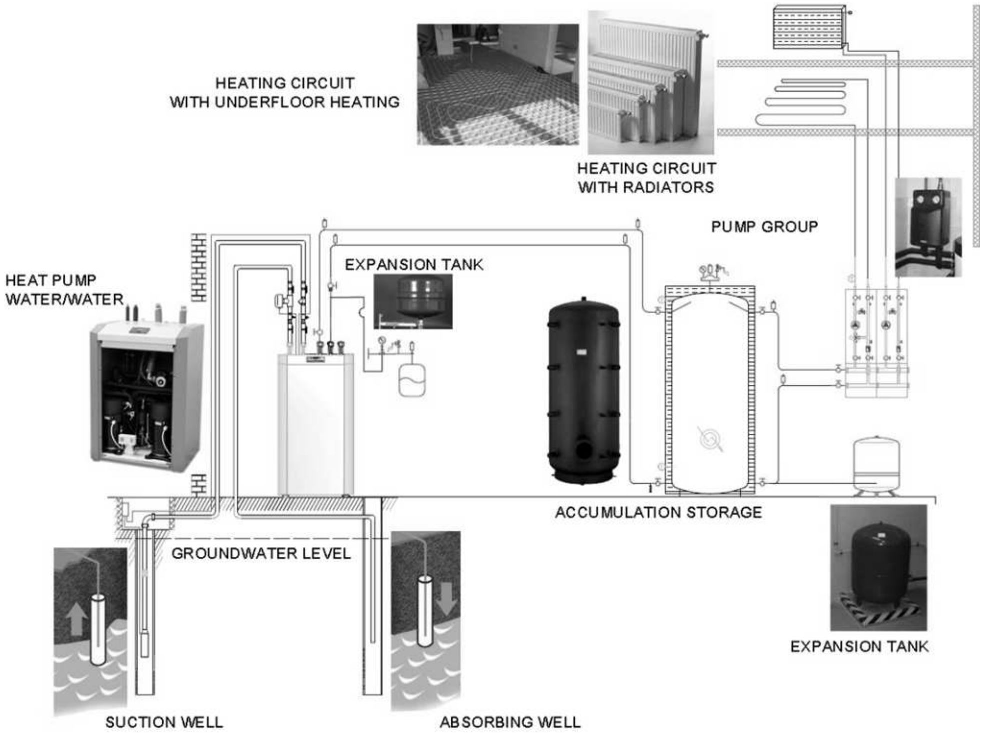

Fig. 3. Scheme of heating system in the administrative building

Rys. 3. Schemat podgrzewania w budynku administracyjnym

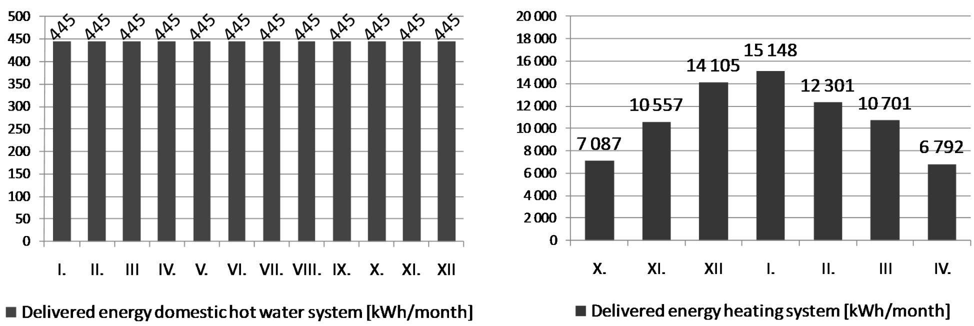

Fig. 4. Monthly balance of power system supplied hot water and heating

Rys. 4. Miesięczny bilans energii uzupełniającej ciepłą wodę i ogrzewanie

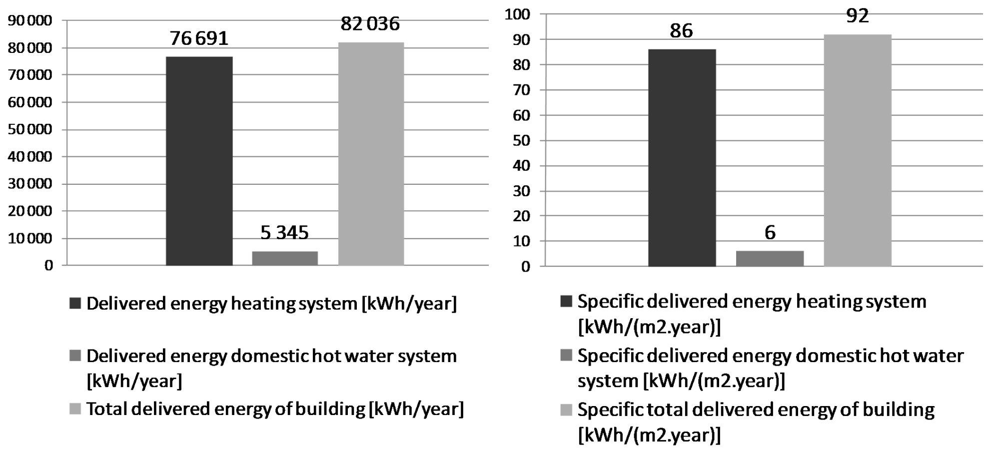

Fig. 5. Total delivered building energy

Rys. 5. Całkowita dostarczona energia

Table 1

Energy class

Parameter	Space Heating	DHW	Space Heating + DHW
Total delivered energy [kWh/year]	76 691	5345	82 036
Floor area [m^2]	890,8	890,8	890,8
Total delivered energy per 1 m^2 floor area [kWh/(m^2.year)]	86	6	92
Energy class	**D**	**B**	**C**

Based on the instructions of the decree No. 311/2009 Coll SR and methodological guidelines, the efficiency of energy production including factor of primary energy by type of used energy is taken into account by determination of primary energy. In the case of domestic hot water system was calculated with the production effective of 99% and with the factor of primary energy for electricity in the value 2,81. In assessing the energy performance of heat pump was used STN EN 15 316-4-2. The average monthly data about the heating capacity of heat pump and the COP factor were established on the ground of content standards and its procedures. These were taken into account the technical parameters of the heat pump, which were obtained during testing of the product manufacturer. The presented data are calculated by linear interpolation between two closest points, characterizing curves of heating capacity and factor COP. In the calculation was include the change in volume flow of heating water in compare with the volume flow of heating water during the test of the heat pump. On this basis was calculated the average heating capacity and factor COP of the heat pump in a given month, Figure 6. The heat pump was designed to cover the required thermal input power of evaluated object at the outside-air temperature –6°C. The electric coil will involved at the outside-air temperature below –6°C and its operation is assumed 10 days in duration 22 hour per day. Period of 10 days is the average time with the outside-air temperature lower than –6°C. Calculated COP factor was used in determination of the primary energy heat pump, the factor of primary energy for electricity – 2.81. It takes into account the need for suction pump with 99% efficiency.

Correction of the COP characteristic for the temperature spread at the heat pump condenser.

$$COP_{\Delta\theta} = COP_{standard} \cdot \left[1 - \frac{\dfrac{\Delta\theta_{standard} - \Delta\theta_{op}}{2}}{\left\{ T_{si} - \dfrac{\Delta\theta_{standard}}{2} + \Delta T_{si} - (T_{so} - \Delta T_{so} \right\}} \right] \tag{1}$$

where:

$COP_{\Delta\theta}$	–	COP corrected for a different temperature spread [W/W],
$COP_{standard}$	–	COP derived from standard testing (e.g. according to EN 14511) [W/W],
$\Delta\theta_{standard}$	–	temperature spread on the condenser side due to standard test conditions [K],
$\Delta\theta_{op}$	–	temperature spread on the condenser side in operation due to the design of the heat emission system [K],
T_{si}	–	sinks temperature [K],
ΔT_{si}	–	average temperature difference between heat transfer medium and refrigerant in condenser [K],
T_{so}	–	source temperature [K],
ΔT_{so}	–	average temperature between heat transfer medium and refrigerant difference in evaporator [K].

Linear interpolation of the heating capacity in direction of the source temperature

$$\phi_{hp,h,sin_{(so,in,W35)}} = \frac{\phi_{hp,h,sin_{(B5/W35)}} - \phi_{hp,h,sin_{(B0/W35)}}}{5°C - 0°C} \cdot (\theta_{so,in} - 0°C) + \phi_{hp,h,sin_{(B0/W35)}} \tag{2}$$

Linear interpolation of the heating capacity in direction of the sink temperature

$$\phi_{hp,h,sin_{(\theta so,in,\theta si,out)}} = \frac{\phi_{hp,h,sin_{(\theta so,in/W45)}} - \phi_{hp,h,sin_{(\theta so,in/W35)}}}{45°C - 35°C} \cdot (\theta_{si,out} - 35°C) + \phi_{hp,h,sin_{(\theta so,in/W35)}} \tag{3}$$

where:

$\Phi_{hp,h,sin(\theta so,in,\theta si,out)}$ – heating capacity of the heat pump for $\theta_{so,in}$ and $\theta_{si,out}$ [kW].

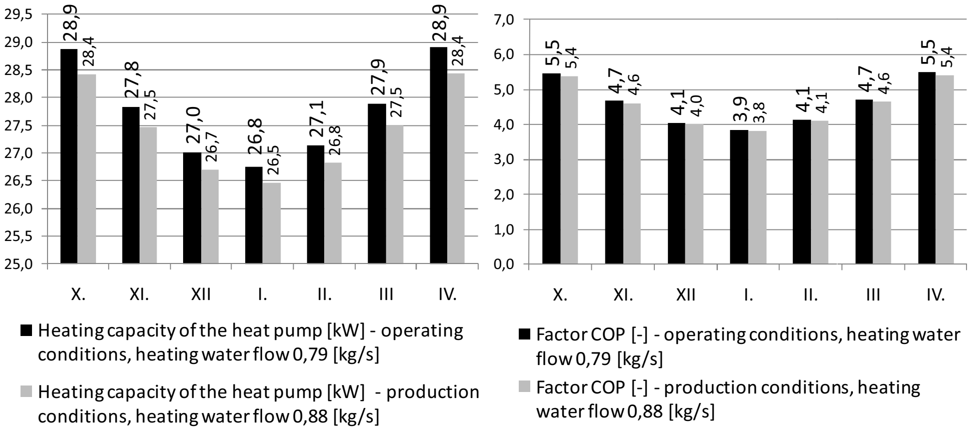

Fig. 6. Correction of heat pump COP factor for operating conditions

Rys. 6. Korekta pompy cieplnej COP dla warunków operacyjnych

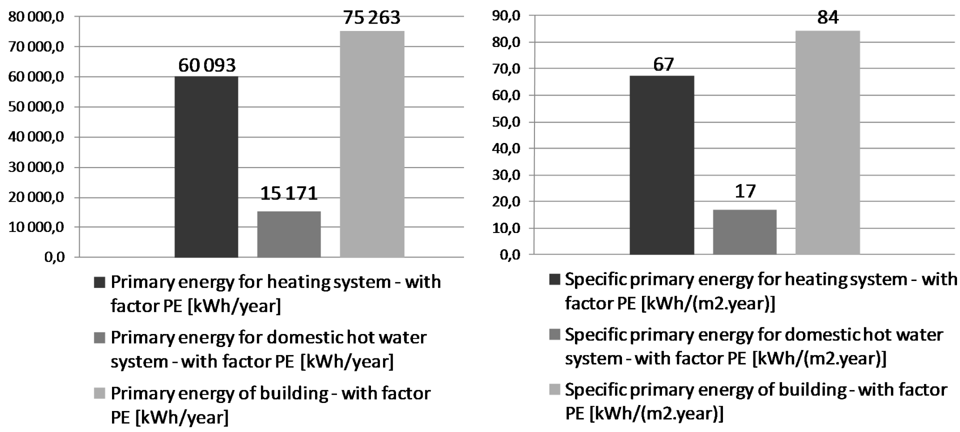

Fig. 7. Total primary energy of building

Rys. 7. Całkowita podstawowa energia budynku

Table 2

Determination of primary energy

Place	COP [–], efficiency [%]	Primary energy factor	Primary energy [kWh/year]	Primary energy [kWh/(m^2·year)]
Heat pump	by Fig. 6	2,81	49 015	54
Suction pump	99	2,81	5929	7
Electric coil	99	2,81	5151	6
DHW	99	2,81	15 171	17

The total primary energy was specified for each energy system in building on the basis of primary conversion factor and efficiency or factor COP of individual devices, according to Table 2 and Fig. 7.

3. Conclusions

The total delivered energy per 1 m^2 area of evaluated office building is 92 kWh/(m^2·year). This value is basic for the classification of building into energy class C. Energy Decree No. 311/2009 Coll SR required minimum energy class B, or maximal value of total primary energy for office buildings after conversion to 1 m^2 of floor space – 240 kWh/(m^2·year). In our example, the first condition is not satisfied, but the resulting primary energy 84 kWh/(m^2·year) is less than 240 kWh/(m^2·year), which is evaluated the building classified as satisfactory.

The aim of the present contribution was to apply the standard for determining the energy performance of heat pump and to determine factor COP. In our case, we set the average monthly value of the factor COP by considering, that the supplemental heat source (electric coil) is in operation at the outside temperature below –6°C. Finally, we note that for the evaluation of heat pumps would be more accurate to consider the calculation interval = 1 day. This approach requires information on daily ambient temperatures, thereby more accurately determine the operating time when running an additional source of heat – electric coil.

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