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Professional paper

THE CONTRIBUTION OF HEAT PUMPS TO REDUCTION OF CARBON DIOXIDE GENERATION DURING THE PROCESS OF COMBUSTION

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The aim of the paper is to propose a method of heating and hot water preparation using a heat pump based on the analysis of the heat losses calculated for the purposes of an office building, which is a part of a medium-sized production plant. In this respect, the original gas boilers will be replaced with alternative energy devices, which will lead to heat and power savings and reduction of carbon dioxide emissions released into the atmosphere.
Key words: heat pump, heating, heat source, natural gas, CO_2 generation.

Doprinos toplinskih pumpi smanjenju proizvodnje ugljičnog dioksida tijekom procesa izgaranja. Cilj rada je predložiti metodu zagrijavanja i pripreme tople vode primjenom toplinske pumpe na temelju analiza toplinskih gubitaka izračunatih za potrebe poslovne zgrade, koja je dio proizvodnog pogona srednje veličine. U tom smislu, izvorni plinski kotlovi bit će zamijenjeni alternativnim energetskim uređajima, što će dovesti do uštede topline i energije te smanjenja emisija ugljičnog dioksida otpuštenog u atmosferu.
Ključne riječi: toplinska pumpa, toplina, izvor topline, prirodni plin, produkcija CO_2.

INTRODUCTION

Nowadays, in view of the increasing environmental pollution, we attempt to use the alternative energy sources, which are more environmentally friendly especially from the point of view of emissions generation. Lower energy consumption and the resulting operating costs belong to their main advantages. Despite the fact that the initial costs are relatively high, it is possible to save due to the lower operational costs related to the operation of the alternative energy source over time.

The aim of the paper is to point out an option of optimizing the heating system by using alternative technologies in a medium-sized production plant. The first part of the paper addresses state of the art of the issue and provides the reader with a brief description of the technological devices placed in the boiler room and the heating system. Next, the issue of heating and preparation of hot water for the purposes of the office building by means of alternative energy sources is discussed. In this section, the thermal losses of the building, the need for heat for purposes of hot water preparation and the resulting heat demand of the building are presented as well. The proposal of the heat pumps design was carried out on the basis of the aforementioned data. The conclusion of the paper focuses on the assessment of the proposal in terms of energy efficiency and reduction of carbon dioxide emissions.

THE DESCRIPTION OF THE HEATED BUILDING AND ITS BOILER ROOM

The building which should undergo the replacement of the heating source is a three-storey office building. The toilets intended for the employees are placed on the ground and first floors; there are mostly offices on the second floor. The building consists of internal reinforced concrete pillars and the cladding is made up of masonry walls of thickness of 500 mm and 400 mm. The front cladding of the building is insulated by means of the Degussa MultiTherm II thermal insulation system, which uses the EPS boards of thickness of 80/50 mm. The partitions are made of concrete masonry blocks. The building is covered with a reinforced concrete roof together with dross and cement screed. The floors are made of concrete, whereas the surface is adjusted to the purpose of the room. The windows are made of plastic with glazing. The doors leading to the office building and the locker rooms are made of plastic too; the office doors are wooden and the ones in the production plant are steel.

A boiler room is a part of the building; there are three Viessmann Paromat-Triplex-Z 720kW gas boilers of 2160 kW output each placed. The boilers are used to heat up process water, heating water and hot water to the temperature of 80° C. The boilers are not in operation simultaneously because it usually is not necessary to supply 100 per cent output for the building. This leads to decreasing the overload of the system and prolongs maintenance-free and failure-free operation.

The water is transported from the boilers to a distributor and then it continues to the particular branches of systems. After the heat has been transferred, the water returns back to the collector from all branches; at this point the return water branch is conducted to the boiler.

THE PROPOSAL OF THE HEATING DEVICES

The proposal of the heating system was based on the heat losses calculations of the office building. The calculated heat loss in accordance with [1] is 81.54 kW, which means that the heating device, the heat pump in this case, must be of an equivalent or higher output compared with the heat loss of the building under the conditions of the monovalent operation. In the case of the bivalent operation, the heat pump can be supplemented by the existing gas boilers. The required output of the heat pump concerned is determined on the grounds of the calculations of the heat input for heating [2].

Since the heat losses of the building concerned are relatively high, it is necessary to design a heat pump of output matching this heat demand. The proprietor of the office building was in favour of the Stiebel Eltron WPL 47 heat pumps, which they found the most suitable alternative due to their favourable heat output among the air-water heat pumps offered by the aforementioned producer.

These heat pumps are intended for ensuring the heating needs of the building, whereas they are installed outdoors. The heat pump aggregate is equipped with a hermetic compressor, starter release, condenser, evaporator, safety devices such as the high/low pressure controls and anti-freeze control. The electronic expansion valve is used to optimize the output. The external casing is corrosion protected. The heat pump uses the R 407C refrigerant. The heating system and hot water preparation circuit for the purpose of the building will be designed at the temperature gradient of 55/45 ° C. The issue of heating systems is more detailed in [3-4].

Technical specifications of the heat pump

The Stiebel Eltron WPL 47 heat pump will be connected into the heating system. In order to satiate the heat demand and balance the heat losses of the building, three heat pumps of the aforementioned type will be needed. The technical data of the heat pump at the outlet temperature of 55° C is listed in the table below.

Table 1. Technical data WPL 47 [5]
Tablica 1. Tehnički podaci WPL 47 [5]

Ambient temperature (°C)	**Heating output (kW)**	**Input (kW)**	***COP* (-)**
-20	15.40	9.20	1.70
-15	17.90	9.30	1.90
-7	22.80	10.20	2.20
2	25.40	10.50	2.40
7	26.10	9.70	2.70
10	27.30	9.80	2.80
15	30.40	10.00	3.00
20	32.30	10.20	3.20

The three heat pumps operation will be of the bivalent nature, in particular connected in a parallel way at the bivalent point of -9.3 ° C. This point is sketched in Fig. 1. This means that the heat pumps will operate up to the outdoor ambient temperature of -9.3°C. In case of dropping the temperature below this value, the heat pumps will automatically switch off and the heat demand will be covered by means of the backup source, in particular the gas boilers.

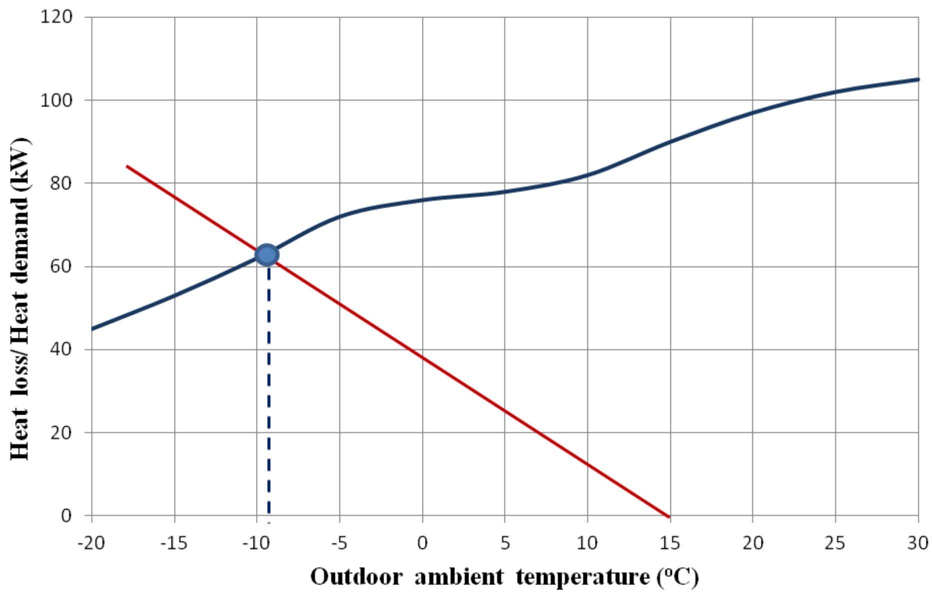

Figure 1. Diagram of bivalent point of the heat pump
Slika 1. Dijagram bivalentne točke toplinske pumpe

The heat pumps will cover up to 97.5% of the heat demand of the building during the heating period and the backup source, the gas boilers, will cover the remaining 2.5% of the heat demand of the building as it is projected in Fig. 2. The heat pumps cover the supply of 210,490 $kWh \cdot y^{-1}$ of thermal energy during the heating season (year), whereas the gas boilers ensure the supply of 5,488 $kWh \cdot y^{-1}$ of thermal energy.

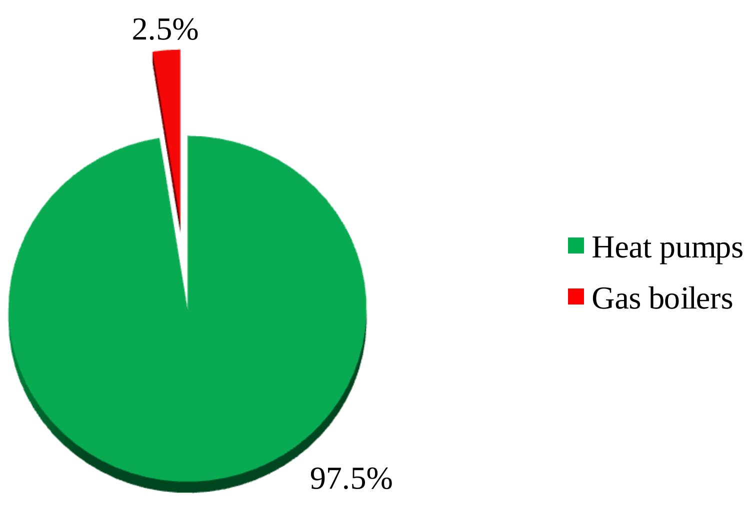

Figure 2. Diagram of the heating energy generation by the source used
Slika 2. Dijagram produkcije toplinske energije po izvoru koji se koristi

The heat pumps are planned to be located in front of the office building and connected to the existing pipelines inside the building. The advantage of this method is the heat losses reduction during the heat transportation by the pipelines.

Assessment of the proposal of the heat pump WPL 47

As it has been mentioned above, commissioning of three heat pumps is needed to cover the heat demand of the building which was calculated based on the heat losses of the building. The diagram comparing the share of each method used in heat generation throughout the year is in Fig. 3. In Fig. 4 there is a comparison of each method's share in consumed energy throughout the year. The data was provided by manufacturer's the sizing software. Given that the temperature of the return water of the heating system is very high, in particular 55° C, the heat pump's average *COP* is 2.72. The value of natural gas consumption was calculated at the value of the gas boiler's efficiency, 90%, and converted to $kWh.y^{-1}$.

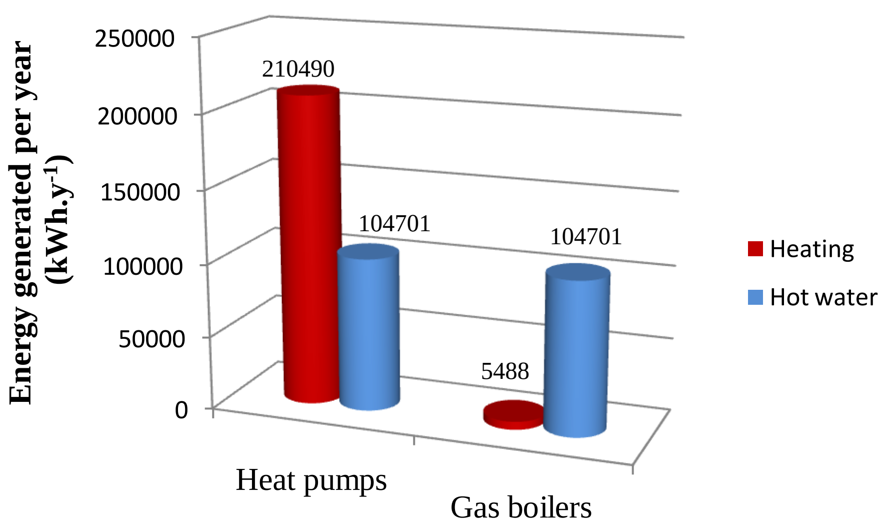

Figure 3. Generated energy by the type of source used
Slika 3. Proizvedena energija prema vrsti korištenog izvora

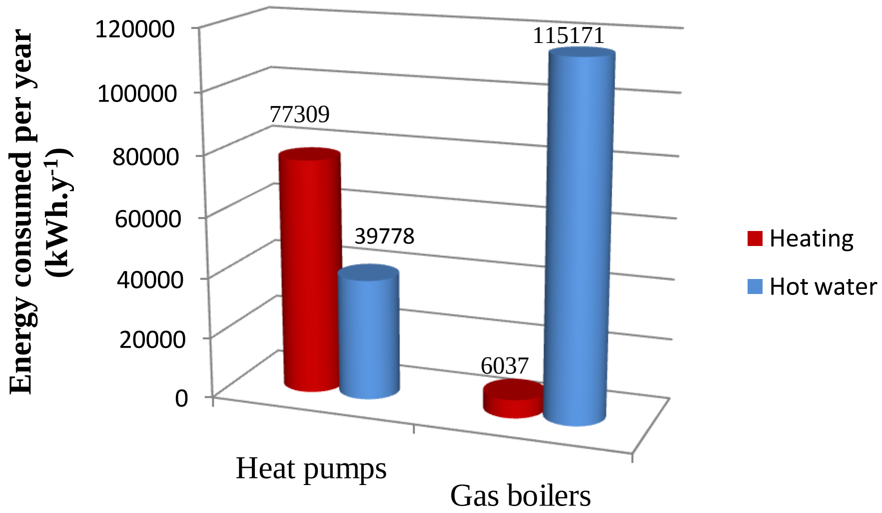

Figure 4. Consumed energy by the type of source concerned
Slika 4. Potrošena energija prema vrsti dotičnog izvora

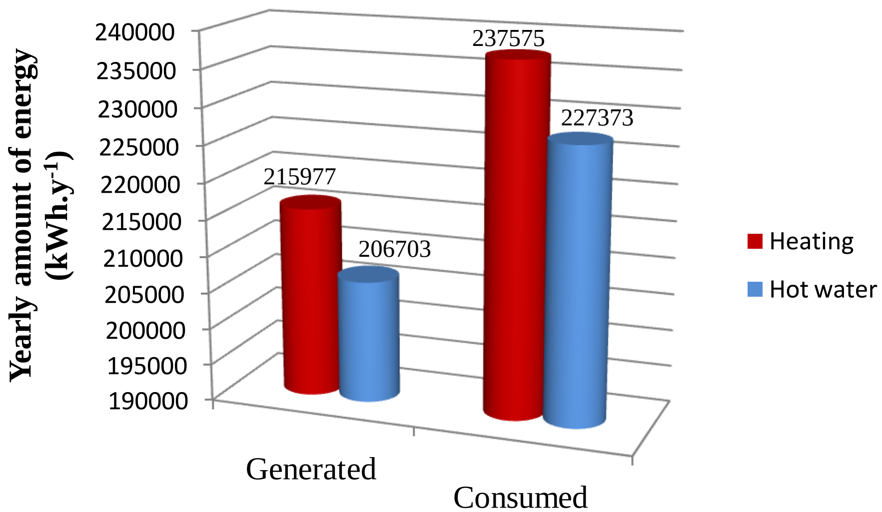

Figure 5. Generated and consumed energy by the gas boilers
Slika 5. Proizvedena i potrošena energija plinskim kotlovima

CALCULATION OF CARBON DIOXIDE EMISSIONS

The value of carbon dioxide generation is primarily dependent on the type of energy carriers used, whereas the input quantity for its determination is the energy delivered expressed in the partial values based on the type of the energy carriers concerned. The emission factors were read from [6] by the type of carrier. The resulting amount of emissions is determined according to the formula [6]:

$$E_{CO_2} = \sum_j Q_{\sup,j} \cdot K_j$$

$(kg \cdot m^{-2} \cdot y^{-1})$

where:

E_{CO2} –value of carbon dioxide emissions $(kg \cdot m^{-2} \cdot y^{-1})$

$Q_{sup,j}$ – supplied energy by the type of the carrier of energy $(kWh \cdot m^{-2}.y^{-1})$

K_j – carbon dioxide emission factor by the type of carrier of energy $(kg \cdot kWh^{-1})$

Calculation of carbon dioxide generation for the purpose of the WPL 47 heat pump design:

$$E_{CO_2} = 91.5 \cdot 0.293 + 94.7 \cdot 0.277 = 53.03$$

$(kg \cdot m^{-2} \cdot y^{-1})$

Calculation of carbon dioxide generation for the purpose of the gas boilers design:

$$E_{CO_2} = 365.56 \cdot 0.277 = 101.3$$

$(kg \cdot m^{-2} \cdot y^{-1})$

It follows from the aforementioned results that the proposed heating and hot water preparation systems with heat pumps commissioned generate less carbon dioxide emissions per year compared to the current situation. The difference between the proposed system and the old one makes up of almost 48%.

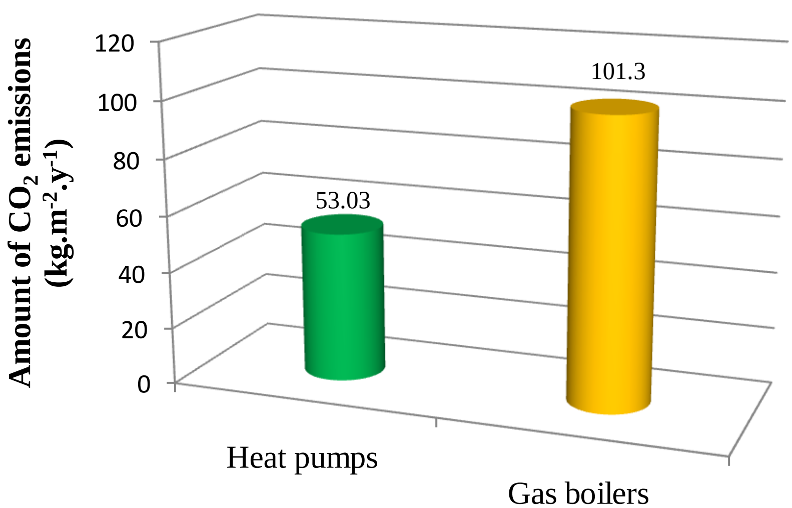

Figure 6. Yearly carbon dioxide emission generation
Slika 6. Godišnja emisija ugljičnog dioksida

CONCLUSION

The aim of this paper was to point out the options of reducing emissions generated by using fossil fuels while optimizing the heating system by means of alternative energy sources. In this case, the heating and hot water preparation systems for the purpose of the office building were assessed with the heat pumps contained.

Based on the calculated heat loss of the building, three heat pumps of the Stiebel Eltron WPL 47 type were chosen. They use the ambient air as the source of heat. Due to the high heat demand, these heat pumps will be used mainly for heat supply and to some extent for hot water preparation, whereas the gas boilers will be used as a complementary source of energy.

From an energy point of view, the operation of heat pumps is beneficial. On the other hand, the economic profit of the project will depend on various factors. In particular, it will be crucial for assessment of the profitability of the project to know whether the technology used in the proposal is subsidised by the member state of the EU in which the device is commissioned [7]. Thus, it is possible to obtain the subsidy at purchase of the facility. Moreover, the operator of the device may apply for being granted a preferential electricity tariff for the operation of an alternative heat source. Under such circumstances, it is possible to considerably decrease the initial costs of the investment in this cutting-edge technology. In the case of the aforementioned investment in heating technology for the purposes of the office building, this investment will be approximately 52500 €.

Despite the high investments, the environmental aspect of this project could be considered to be the advantage of commissioning the heat pumps since less carbon dioxide is produced during their operation compared to the operation of the gas boilers. This difference represents almost 48 per cent, which is the main benefit of the solution to the environment in the long run.

Acknowledgement

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