

JANUSZ MAGIERA\*, SEBASTIAN PATER\*

## BIVALENT HEATING INSTALLATION WITH A HEAT PUMP AND SOLAR COLLECTORS FOR A RESIDENTIAL BUILDING

Solar energy systems and heat pumps are two promising means of reducing the consumption of fossil energy resources and the cost of delivered energy for residential heating. The integration of these two installations presents a novel combined heating system, so-called bivalent system, operating more economically. The major objective of this paper was to analyze the possibility of construction and benefits of a bivalent system composed of a heat pump and solar collectors for heating and cooling residential buildings.

### 1. INTRODUCTION

Until 2005, approximately one third of final energy in Poland consumed households [1]. For a typical Polish family it was connected with destiny of about 11.7% of their household budget on building heating and domestic hot water (DHW) producing [2]. One of the ways to reduce sizeable costs of energy production is the use of free and inexhaustible thermal energy stored in the surrounding environment. The main source for the Earth's solar radiation is a stream of 173 000 TW [3]. Moreover,  $3.9 \times 10^{24}$  J of energy from the sun during the year reaches the Earth, which corresponds to  $1.08 \times 10^{18}$  kWh [4]. This amount of energy is more than 10 000 times higher than all primary energy consumed during that time on Earth [4]. Suitable devices which use solar energy or the one that comes from wind, sea waves, biomass and heat of the Earth may satisfactorily reduce the rate of non-renewable resources exploitation and environmental degradation.

Heat pumps were known to specialists from heating industry for several decades, however, high costs of purchase and low prices of conventional energy sources made them unattractive. In recent years, when the price of gas, coal and fuel oil has in-

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\*Cracow University of Technology, Institute of Chemical and Process Engineering, ul. Warszawska 24, 31-155 Cracow, Poland; e-mail: jmagiera@pk.edu.pl

creased substantially, and device prices decreased, the introduction of heating systems with heat pumps became more and more willing be considered by investors [5].

Another example of utilizing an alternative energy source is the solar collector. It converts solar radiation in an absorber into heat and passes it to liquid heat carrier, which then due to the heat exchanger or other device, releases heat to cold water [5].

## 2. BIVALENT COOPERATION OF RENEWABLE ENERGY SOURCES

Installation with the heat pump to heat a residential building and produce DHW can cooperate successfully with gas, oil, or biomass boilers. A heating system with an additional heat source beside the main one is called a bivalent or integrated system [6]. This kind of cooperation can be carried out in:

- parallel – heat pump operates in the whole range of external temperatures and an additional device is switched on at a specific temperature (called a bivalent point) below which the pump needs support,
- alternatively – either heat pump works, or an additional device, which activated operates independently [6].

A special case is assisting the heat pump by solar collectors. Such cooperation is not a classic example of a bivalent parallel system because of the vagaries of weather. Energy is fed into the system not when installation needs it, but when the sun provides a direct energy. Because of that, the system must be supported with an additional source of heat supplying missing energy during the inclement weather such as electric heater, or a biomass boiler [6].

The possibility of construction, cost effectiveness and benefits of a bivalent heat pump system and solar collectors for heating and cooling of residential buildings have been the subject of many projects since 1970. Unfortunately, at that time, these systems have not been enthusiastically adopted [7]. As part of the European Programme ENDOHOUSING (Endothermic Technology for Energy Efficient Housing in the EU) supporting projects popularizing heat pump systems with solar collectors, five demonstrative installation had been done between latitudes from 35° to 62° in Cyprus, in Northern and Southern Italy, in Central Germany and Sweden [7]. Studies conducted in a facility located in Sandviken in Sweden proved that the installation of heat pump supported by solar installation for a period of approximately two years (2006–2008) in a satisfactory manner meets the building energy needs [7]. In another installation, in October 2004, for a period of about 11 months of operation, the coefficient of performance (COP) of the heat pump was maintained at 3.75 [8]. There is also the notion that providing energy to the ground by a vertical probe of bottom heat source for heat pump (BHS) causes drying of the soil around it, and thus decrease of its thermal conductivity.

Therefore the fundamental objective of the heat pump and solar collectors bivalent system is to obtain a higher COP as compared to the heat pump alone and also the

direct use of excess thermal energy supplied by solar collectors [7]. Integrating these two installations also brings quantifiable benefits in:

- regeneration of bivalent heating system (BHS),
- power reduction of heat pump and thus financial savings,
- unloading of the heat pump during the heating season and in this way extending its life.

It should be mentioned that such cooperation of two installations also contributes to an even greater reduction of environmental pollution, because by increasing the COP consumption of electricity is reduced by the heat pump aggregate [9].

A question arises whether it is not better to install a heat pump which may provide full coverage of the heating needs rather than complicate the installation. The first and most common obstacles are economic considerations. Upon increasing power of a heat pump, its cost increases, approximately 1000 ZLP for every 1 kW of heating energy. Another barrier occurs during designing BHS. The problem is explained on the example of the house with the net area of 200 m<sup>2</sup> on a plot of 600 m<sup>2</sup>. It was assumed that for its heating and DHW preparation, the maximum output of heating power of 12 kW will be needed. The heat pump of such power requires a horizontal ground collector surface area of approximately 500 m<sup>2</sup> which is almost 85% of the property. In such a situation another solution should be found, e.g. a vertical collector, being however much more expensive than the horizontal one, the exploitation of a deep well of sufficient capacity and water parameters or a bivalent system [6].

### 3. FACILITY ANALYSIS

As the object of the analysis located in a village Lewniowa about 13 miles south from Brzesko (in the Małopolska province) was selected a residential building of a net surface area of 186 m<sup>2</sup>, single-family, detached, one-story with usable attic and partial basement and a garage in the form of extensions. House is directed about 18° to the south-west. Currently, five persons live there, including three children.

Central heating system of the building is a two-pipe one, with bottom distribution and heating manifolds, utilizing as a heating elements plane floor heaters in wet technology, except for the bathrooms, where the mixed heating was used: radiator–floor heating. Assumed flow temperature of heating medium (water) is 40 °C, and return flow is 30 °C.

The annual demand for energy to heat the building calculated in Purmo OZC program in version 4.01B is 11 132 kWh/year (40.07 GJ/year) with the period of the heating season amounting 222 days. The conversion of this value to the seasonal demand index for heat  $E_A$  provides 60.3 kWh/(m<sup>2</sup>·year) (217.0 MJ/(m<sup>2</sup>·year)); and cubature indicator of seasonal demand for heat  $E_V = 16.8$  kWh/(m<sup>3</sup>·year) (60.4 MJ/(m<sup>3</sup>·year)). These results placed the considered building in the category of energy-efficient buildings [10].

The annual heat energy demand for DHW was calculated in accordance with the Minister of Infrastructure [11] and is equal to 6608 kWh/year. The total heat energy demand of the concerned building reached 17 440 kWh/year, of which 37.2% stand for energy needed for DHW system, while 62.8% of the total energy is allocated for home heating.

#### 4. PROJECT ASSUMPTIONS

In winter, the heat pump is intended to provide heat for central heating (CH) and for DHW, while in summer, the working of CH where is not required, the heat pump will run, if necessary, as a device supporting the work of solar installation warming DHW. By using a reversible heat pump, passive cooling of the building premises will be possible. This has the double advantage: there will be regeneration of heat source exploited by heating season and the temperature comfort in the building during the hot days will improve.

A heat pump type brine/water with ground heat exchanger have been selected for installation due to absence of deep well or water reservoir on plot for pump type water–water and the variation within a wide range of heating power of air–water pumps depending on outside air temperature. Due to the location of the analyzed residential building on the plot and future plans of the investor it is not possible to use the horizontal ground heat exchanger as a BHS for heat pump. The BHS was chosen in the form of vertical probes, which will be drilled on a parcel at a suitable distance from the building foundation.

All year round, solar installation with vacuum tube solar collectors, on sunny winter days will play a supporting role, providing energy primarily for DHW and excess energy will be directed to CH. It was assumed that during the year the installation will provide approximately 60% of energy for DHW, and the rest 40% for the heat pump.

The southern roof surface is an ideal place to mount collectors in the building. The roof is tilted at the angle of  $40^\circ$ , which is an optimum value for whole year running installation in the Polish latitude. Unfortunately, the roof surface is not ideally directed in a southern direction, but slightly to the southwest ( $18^\circ$ ).

#### 5. CALCULATIONS AND SELECTION OF DEVICES

##### 5.1. HEAT PUMP INSTALLATION

The calculations of the heat pump system were made using the guidelines given in [12]. Examined house is classified as a new building, in which the heating temperature

limit is equal 15 °C [12]. For this temperature, pump running time is around 1700 h/season [12]. BHS heat output ( $Q_{o1}$ ) was calculated from the formula [12]:

$$Q_{o1} = \frac{Q_h}{b_h} + d = \frac{(11\,132 + 0.4 \times 6608) \text{ kWh} \cdot \text{year}^{-1}}{1700 \text{ h} \cdot \text{year}^{-1}} + 0 = 8.1 \text{ kW} \quad (1)$$

where:  $Q_h$  – the annual energy demand supplied by the heat pump [kWh/year],  $b_h$  – operating hours of the heat pump [h],  $d$  – addition grant of absence of electricity supply.

Cooling power of BHS ( $Q_{c1}$ ), assuming that the COP of heat pump is at the level of 4, was calculated from the formula [12]:

$$Q_{c1} = Q_{o1} - \frac{Q_{o1}}{4} = 6.0 \text{ kW} \quad (2)$$

It is recommended choosing a heat pump with the heating power 10–20% lower than that calculated, and complementary application of an additional electric heater, which in most currently manufactured pumps is mounted as a standard one [12]. Electric heater can be used for:

- heating newly created object,
- covering the highest demand for heat in very cold days, which during the year are relatively rare,
- periodic heating the DHW to 65 °C (by legionella protection function).

According to recommendations heating ( $Q_o$ ) and cooling power ( $Q_c$ ) was reduced to the value:

$$Q_o = Q_{o1} - 0.2Q_{o1} = 6.48 \text{ kW} \quad (3)$$

$$Q_c = Q_{c1} - 0.2Q_{c1} = 4.8 \text{ kW} \quad (4)$$

The ground temperature under normal conditions is about 6–8 °C but in the case of application of a vertical collector, it is reduced at the end of the heating season to 3–6 °C [12]. It was assumed that the temperature of brine in the BHS will be ca. 5 °C.

Based on the above calculations, using Vaillant's selection chart, a heat pump geoTHERM VWS 64/2 was chosen, which for the parameters of the installation has the heat output of 6.6 kW and 4.8 kW cooling, and its COP is equal to 4.13 (Fig. 1). Selecting a heat pump with such a reduced heating power reduces the costs of purchase to about 2 000 ZLP.

The heat pump working time to prepare circulating water of CH in the year is [12]:

$$\tau_{CH} = \frac{Q_{CH}}{Q_{HP}} = \frac{11\,132}{6.6} = 1686.7 \text{ h/year} \quad (5)$$

where:  $Q_{CH}$  – annual energy demand for CH [kWh/year],  $Q_{HP}$  – heat pump heating power [kW].

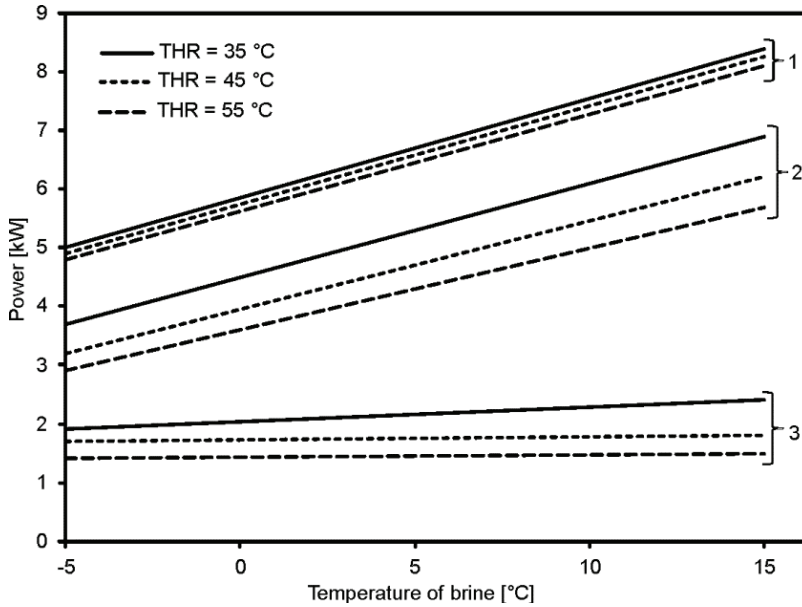


Fig. 1. Power plot of the heat pump Geotherm VWS 64/2: consumption of heating (1), cooling (2) and electric (3) power; THR – temperature of heat receiver [12]

Heat pump's working time to prepare DHW in the year was defined (according to [12]) by the formula:

$$\tau_{DHW} = \frac{Q_{DHW}}{Q_{HP}} = \frac{2643}{6.6} = 400.4 \text{ h/year} \quad (6)$$

where:  $Q_{DHW}$  – the annual energy demand for DHW [kWh/year].

Therefore the planned working time of the pump will be 2087.1 h/year. According to earlier assumptions ( $b_h$  in Eq. (1)), the heat pump was supposed to work for approximately 1700 h/year. The increase in heat pump's working time is not harmful because it is better for it to work longer than to work more frequently in short periods. This fact will contribute to extension of trouble-free period operation of the pump.

Due to the lack of information about the soil layers located below 2 m, the safe level of ground thermal efficiency was accepted at 45 W/m. This value is slightly smaller than the average 50 W/m for normal sediment at the operation time equal to 1800 h/year. The total depth of boreholes ( $l_s$ ) was established from the formula [12]:

$$l_s = \frac{Q_{HP} - \frac{Q_{HP}}{COP}}{W_g} = \frac{6600 - \frac{6600}{4.13}}{45} = 111 \text{ m} \quad (7)$$

where:  $W_g$  – ground thermal efficiency [W/m].

A common mistake at this stage of design is to calculate the length of probes relative to the total heat pump heating power. It should be remembered that part of the heating power also includes power generated by the heat pump compressor which should not be included in the calculation. As the ground thermal performance factor was assumed approximately, during the execution of a borehole it is necessary to verify the length of the ground probes, taking into account information about the ground provided by geologists or experienced staff.

Because of the restrictions on the length of the probes (maximum 120 m) and of the cost reduction, two ground probes were performed in the form of a double U-tube, each 55 m long, which gives summarily 110 m. The distance between the boreholes will be 7 m and diameter of each will vary in the range from 115 to 220 mm. At the end of each borehole a head with ca. 150 cm long and 10 cm in the diameter was mounted to change the direction of the brine flow in the probe. In order to facilitate the introduction of the probe in the borehole, steely ballast was used. The Tichelmann system was selected as the hydraulic connection of probes because the number of cycles did not exceed 4. This type of connection is characterized by lower costs in comparison with the system using a combination of heating manifold as well as summary collector and no need to use the wells, because tees or bends with the branches permanently remain in the ground [12].

As the medium used to fill the heat pump installation a mixture of 1,2-propanediol and water in the ratio of 1:2 was used. Its freezing point was  $-15^\circ\text{C}$ .

As a buffer tank in installation Reflex PHW 500 of the capacity of  $500 \text{ dm}^3$  was used; it can be loaded with thermal energy from the solar collectors through a coil of the heating surface of  $1.88 \text{ m}^2$ . This tank is designed for active and passive cooling systems through a complete thermal insulation of the thickness of 90 mm. Due to usage of 8 spouts on the sides of the tank and one on the top, future expansion of the installation is possible [13].

## 5.2. INSTALLATION OF SOLAR COLLECTORS

According to the fact that Lewniowa village lies near Tarnów, meteorological data of this city [14] was used, relating to a typical meteorological year, based on the information collected over 30 years, since 1971. The data on the intensity of daily radiation was recognized for  $45^\circ$  incline and southern direction. Dimensioning of the collectors surface in relation to winter radiation is groundless in Polish latitude; for this reason only the intensities of daily radiation from March to October were taken into

account (Fig. 2). During this time period, the collectors should provide the maximum amount of energy for DHW.

Intensity of daily solar radiation to a greater extent depends on the month. The highest values were observed during the summer (from May to August). It is important to emphasize that the intensity of radiation in a given month is not constant. It acquires values differing up to ten times (e.g. 1 March – 720.9 Wh/(m<sup>2</sup>·d), and 11 March – 6796.9 Wh/(m<sup>2</sup>·d)). This state of affairs is due to stochastic changes in weather.

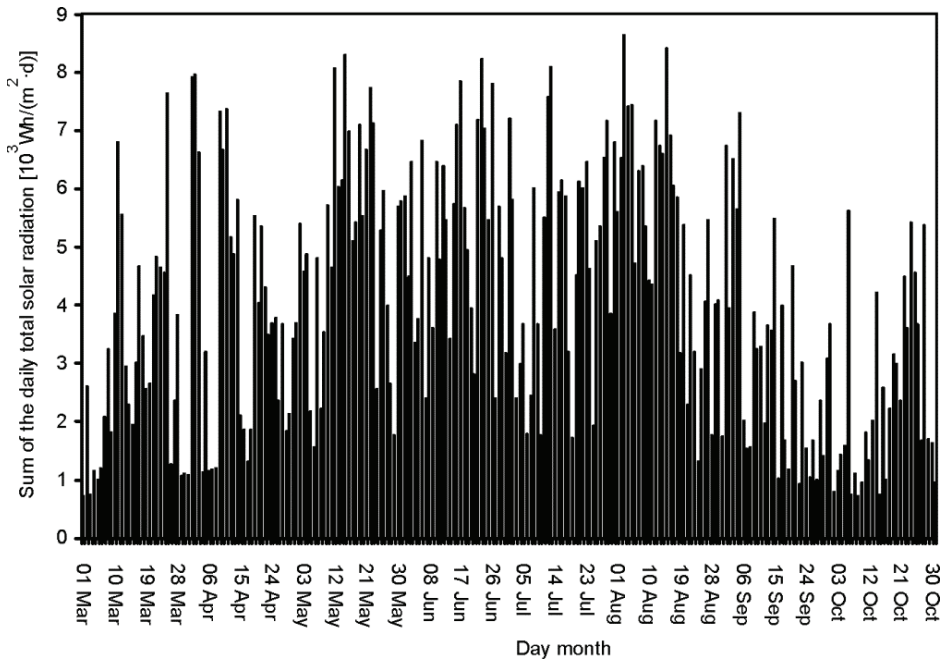


Fig. 2. Daily radiation for inclination of 45° and the southern direction in the period from March to October for Tarnów [14]

Knowing the daily solar radiation, the solar surface was calculated [15]:

$$A_k = \frac{E_{\text{col}}}{S_D \eta_1 \eta_2 \eta_3} \quad [\text{m}^2] \quad (8)$$

where:  $E_{\text{col}}$  – calculated daily energy demand for DHW ( $6\,608\,000 \times 0.6/365 = 10\,862$  Wh/d),  $S_D$  – the sum of the daily total solar radiation [Wh/(m<sup>2</sup>·d)],  $\eta_1$  – average efficiency of the vacuum collector (0.6) [2],  $\eta_2$  – factor related to the impact of deviations from the southern direction of the collector (0.96) [15],  $\eta_3$  – factor related to the inclination of the collector (1) [15].



From the results presented in Fig. 3, due to the applying the trend line, it seems that from early May to late August, the surface area of vacuum collectors in the range 4–6 m<sup>2</sup> will be sufficient to cover the energy demand for DHW in 60%. For the remaining months, the solar cover will be smaller, but it protects systems in the summer from frequent failures caused by overheating because of oversizing collectors surface area.

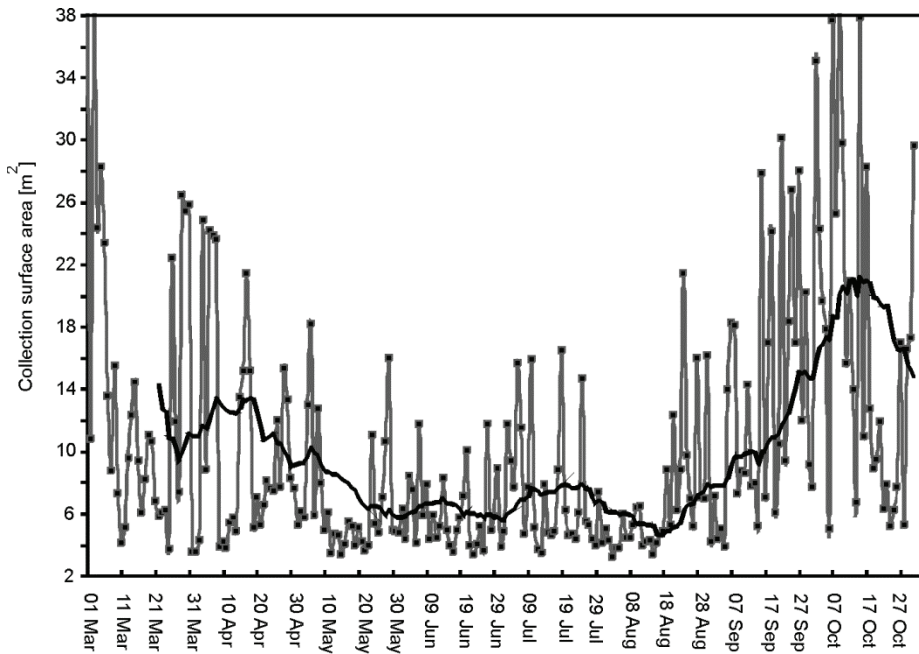


Fig. 3. Area of the vacuum collectors calculated from the daily radiation for the period of March–October for Tarnów

In order to meet the requirements for the collectors surface area amounting to 4–6 m<sup>2</sup>, 3 vacuum collectors WATT CPC 9 were chosen. Each of them was made of 9 vacuum tubes of the absorption surface area equal to 1.92 m<sup>2</sup>, which gives the total surface of 5.76 m<sup>2</sup>. The efficiency of solar collectors is certified by Solar Keymark [16].

To reduce the pressure decrease in the solar circuit, the flow rate in copper pipes should not exceed 1.5 m/s [17]. In order to achieve optimum heat transfer, in a parallel connection of collectors and the nominal flow rate of 1 dm<sup>3</sup>/min for the WATT CPC 9, the total flow of the working medium by the collectors ( $\dot{V}_{col}$ ) should be:

$$\dot{V}_{col} = 3 \times 1 \text{ dm}^3/\text{min} = 3 \text{ dm}^3/\text{min} = 5.00 \cdot 10^{-5} \text{ m}^3/\text{s} \quad (9)$$

Because of possible periodic high-temperature solar fluid, pipes made from copper were used in the system, instead of plastic ones. Selection of the pipes was made

based on Table 1. Knowing the flow rate of the solar medium, the optimum pipe outer diameter 15 mm and wall thickness of 1 mm were chosen.

Linear flow velocity of solar medium ( $u_s$ ) in copper pipes with the internal diameter of 13 mm ( $d_i$ ) was calculated using the formula:

$$u_s = \frac{4\dot{V}_{col}}{\pi d_i^2} = 0.377 \text{ m/s} < 1.5 \text{ m/s} \quad (10)$$

Table 1

Optimum diameter of the solar installation pipes [18]

Flow rate		Flow velocity [m/s]						
		Pipe outer diameter×wall thickness [mm]						
m <sup>3</sup> /h	dm <sup>3</sup> /min	12×1	15×1	18×1	22×1	28×1.5	35×1.5	42×1.5
0.125	2.08	0.44	0.26	0.17	0.11	0.07	0.04	0.03
0.15	2.50	0.53	0.31	0.21	0.13	0.08	0.05	0.03
0.175	2.92	0.62	0.37	0.24	0.15	0.10	0.05	0.04
0.2	3.33	0.70	0.42	0.28	0.18	0.11	0.06	0.05
0.25	4.17	0.88	0.52	0.35	0.22	0.14	0.08	0.06
0.3	5.00	1.05	0.63	0.41	0.27	0.17	0.09	0.07
0.35	5.83	1.23	0.73	0.48	0.31	0.20	0.11	0.08
0.4	6.67	1.41	0.84	0.55	0.35	0.23	0.13	0.09
0.45	7.50	1.58	0.94	0.62	0.40	0.25	0.14	0.10
0.5	8.33	1.76	1.04	0.69	0.44	0.28	0.16	0.12
0.6	10.00	2.11	1.25	0.83	0.53	0.34	0.19	0.14
0.7	11.67	2.46	1.46	0.97	0.62	0.40	0.22	0.16
0.8	13.33	2.81	1.67	1.11	0.71	0.45	0.25	0.19
0.9	15.00	3.16	1.88	1.24	0.80	0.51	0.28	0.21
1.0	16.67	3.52	2.09	1.38	0.88	0.57	0.31	0.23
1.5	25.00	5.27	3.13	2.07	1.33	0.85	0.47	0.35
2.0	33.33	7.03	4.18	2.76	1.77	1.13	0.63	0.46
2.5	41.66	8.79	5.22	3.45	2.21	1.41	0.79	0.58
3.0	50.00	10.55	6.27	4.15	2.65	1.70	0.94	0.70

The length of the system of flow and return pipes placed inside the building will be around 18 m, whereas the length of the pipes connecting the three parallel vacuum collectors will be 3 m giving the total of 21 m copper pipes. To minimize heat losses through the pipes, one should insulate them with a layer of synthetic rubber foam 19 mm thick for the internal pipes and 32 mm for the external ones.

A minimum volume of the DHW tank with the daily consumption of 50 dm<sup>3</sup> water/person, with 5 persons and the multiplicity coefficient of daily demand for DHW at 1.5 gives the volume of storage equal to 375 dm<sup>3</sup>. Polish company Sunergy Solar

Technology DHW storage WS-400.2 has been selected. This storage of the dimensions of  $70 \times 185 \text{ cm}^2$  has the volume of  $400 \text{ dm}^3$ . It is equipped with two coils for solar and heat pump systems, the surface area of the former being  $1.6 \text{ m}^2$ , and the of the latter –  $9 \text{ m}^2$ . In addition, three precisely positioned temperature slots were used, which allows highly efficient collaboration with solar control systems. Foam insulation 70 mm thick ensures low heat losses to the environment [19].

The installation as a closed circuit with a forced flow of heating medium is characterized by the invariable flow resistance. The total flow resistance is the sum of:

- solar collectors ( $\Delta p_{\text{col}}$ ),
- hot water storage coil ( $\Delta p_{\text{sc}}$ ),
- pipes and fittings ( $\Delta p_p$ ),
- pump set ( $\Delta p_{\text{ps}}$ ).

In the present installation the summary flow resistance ( $\Delta p_{\text{is}}$ ) equalled:

$$\Delta p_{\text{is}} = \Delta p_{\text{col}} + \Delta p_{\text{sc}} + \Delta p_p + \Delta p_{\text{ps}} = 12 + 120 + 88 + 50 = 270 \text{ mbar} \quad (11)$$

Thus, the minimum lifting pump height should be 2.75 m of water column.

A pump set Grundfos UPS 15-80 has been selected. The pump in this set is characterized by high reliability, freedom from maintenance, low noise and power consumption. It is recommended for solar installations, where the maximum lifting height is up to 8 m. The pump has three gears, and the body is made with iron. Maximum working pressure is 10 bar. In addition, the pump set includes a pressure gauge, two temperature gauges, and two safety valves [20].

For installation expansion a vessel Reflex S with the nominal capacity of  $18 \text{ dm}^3$  has been selected.

Simulation of working solar vacuum installation carried out in Polysun 4 shows that the average, annual energy yield from  $1 \text{ m}^2$  of solar collectors is about 421 kWh, while the coverage of energy demand for DHW called Solar fraction is equal 74.9%. This value is satisfactory, whereas in the project assumptions installation consisting of 3 WATT CPC 9 is intended to provide only 60% of energy for DHW. The degree of energy demand coverage for DHW calculated by the Polysun program at the level of ca. 75% does not automatically mean that this value will be obtained in the installation. It is largely dependent on weather fluctuations in a given year. However it could be with highly probability adopted that the solar installation will provide the proposed 60% energy.

As is seen in Fig. 4, the coverage degree does not fall below 97% from May to August. This corresponds to a smaller amount of a deficiency energy that the heat pump during these months will have to provide to the system (Fig. 5). Less efficient exploitation of BHS during the summer period will allow the faster regeneration and better preparation it for the next heating season. The highest coverage of energy demand for DHW was obtained in July (99.5%), and lowest in December (22.0%).

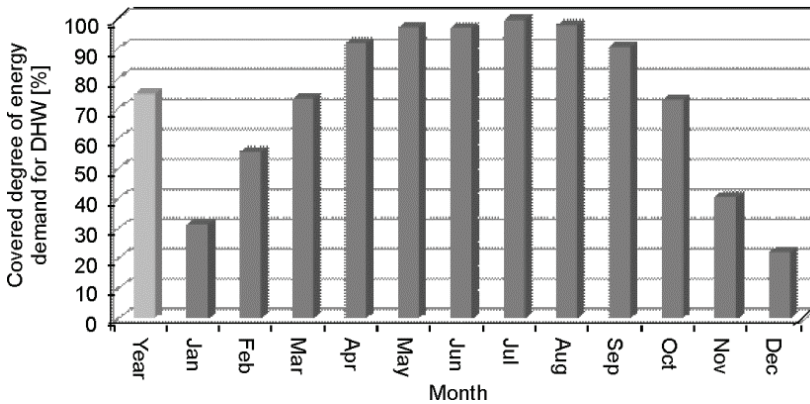


Fig. 4. The coverage degree of energy demand for DHW during the year by solar installation

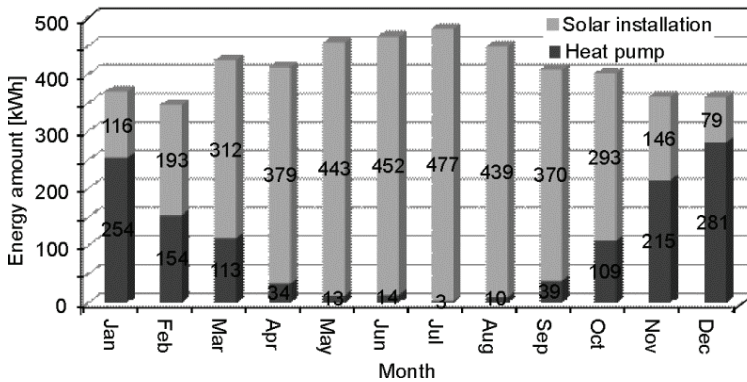


Fig. 5. The energy supplied by the solar and heat pump installation for DHW during one year

## 6. REGULATION AND CONTROL OF INSTALLATION

Designed installation requires a driver that would integrate work of the heat pump and solar installation so that their action will be more effective. Perfectly in this role verifies the DigiENERGY driver, which according to the manufacturer can bring 20–30% savings in operating installation, through optimum management of energy [21]. Installation service is user very friendly because DigiENERGY visualize all the activities and conditions. Countless numbers of charts, diagrams, give an excellent overview of the installation work, and thus it is easy to evaluate its performance [21]. Tight control of circulating pumps and switching them only when it is necessary improve the economy of installation [21]. Via the Internet on your PC, the appropriate game console, and even a modern mobile entire installation can be operated in real

time [21]. Moreover, if a fault occurs, the system sends you information by email or SMS that the installation is damaged [21]. Scheme of installation with DigiENERGY driver was shown in Fig. 6.

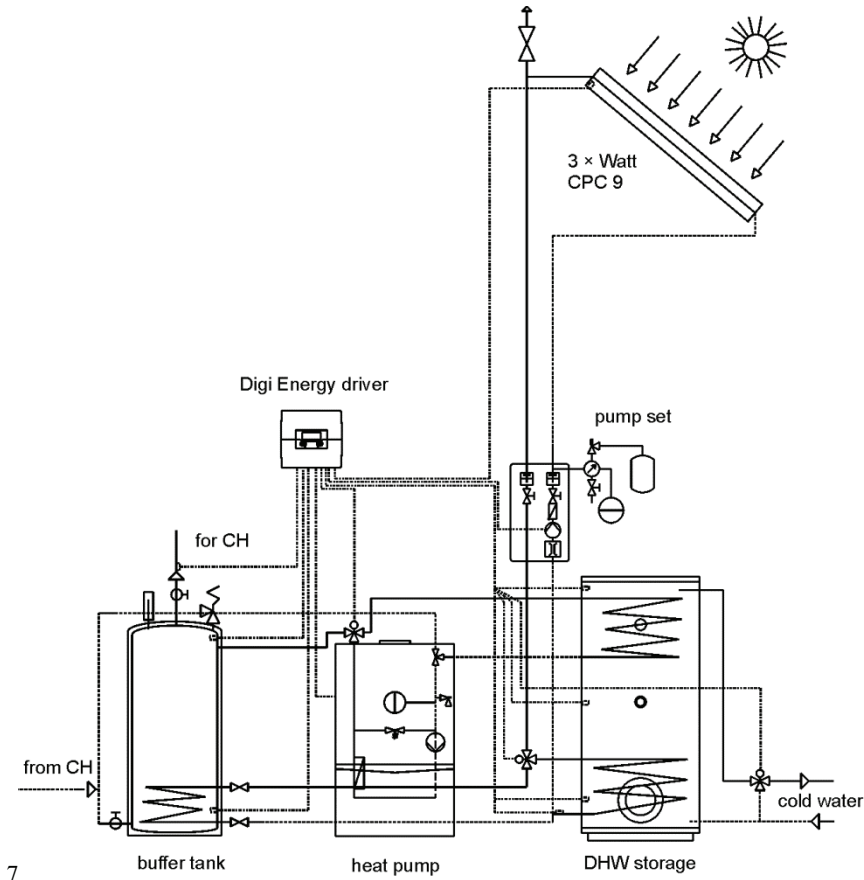


Fig. 6. Scheme of installation

## 7. CONCLUSIONS

Bivalent installation of CH and DHW with a heat pump and solar collector is able to provide 100% coverage of energy needs for the analyzed building.

The combination of a heat pump and solar collector system would appear to reduce many of the disadvantages that each has when operating separately or alone. Combined heating system operated more economically [22].

Solar installation cooperating with a heat pump discharges it in the summer and thus prolongs its life by reducing the frequent on/off. Additionally, the excess solar

energy heat can be directed to the BHS ground collector contributing to the increase of the heat pump COP.

Designing heat pump with the heating power of 10–20% lower than that calculated reduces the cost of its purchase. As a power complement is used auxiliary electric heater, which turns on at the time of peak demand for heating power (e.g. very cold days).

The optimum solution is to choose the surface area of solar collectors which will provide ca. 60–70% of energy for DHW per year.

Modern and ecological installation with a heat pump and solar collectors is associated with a very high comfort of usage and reducing emissions of harmful substances into the atmosphere. Cooling the building is also possible by using a reversible heat pump.

#### REFERENCES

- [1] WNUK R. et al., *Effectiveness of the energy use in the years 1995–2005*, ZWS, Warsaw, 2007 (in Polish).
- [2] MAGIERA J., GLUSZEK A., *Polityka Energetyczna*, 2008, 11 (2), 41.
- [3] SZARGUT J., ZIĘBIK A., *Fundamentals of Thermal Energy*, PWN, Warsaw, 1998 (in Polish).
- [4] NEUPAUER K., MAGIERA J., *Czasopismo Techniczne*, 2009, 106 (4), 57.
- [5] MAGIERA J., *Pol. J. Environ. Stud.*, 2004, 13 (2), 118.
- [6] OSZCZAK W., *How to Obtain Cheaper Heat in the House*, Wydawnictwo Komunikacji i Łączności, Warszawa, 2005 (in Polish).
- [7] STOJANOVIĆ B., AKANDER J., *Appl. Therm. Eng.*, 2010, 30 (2–3), 188.
- [8] TRILLAT-BERDAL V., SOUYRI B., FRAISSE G., *Energ. Buildings*, 2006, 38 (12), 1477.
- [9] CHUA K.J., CHOU S.K., YANG W.M., *Appl. Energ.*, 2010, 87 (12), 3611.
- [10] ŻURAWSKI J., *Izolacje*, 2008, 123 (2), 26.
- [11] *Journal of Laws* No. 156, pos. 1118, Regulation of the Minister of Infrastructure dated 6 November 2008 on the methodology for calculating the energy performance of buildings and dwelling or part of a building constituting an independent whole technical-utilitarian and the preparation and models of certificates of energy performance (in Polish).
- [12] Vaillant Company, *Project Materials 2009, bottom heat sources, pumps price list, hydraulic schemes and geoTHERM heat pumps*, unpublished (in Polish).
- [13] *Reflex buffer tanks for heating and cooling installations*, Reflex Company.
- [14] Ministry of Infrastructure, *Typical meteorological years and statistical climate data for the Polish territory (Tarnów) for energy calculations of buildings*, 2008 (in Polish).
- [15] KOCZYK H., *The Practical Heating. Designing, installation, operation*, SYSTHERM SERWIS, Poznań, 2005 (in Polish).
- [16] *Vacuum solar collector WATT CPC 9*, WATT Company (in Polish).
- [17] *The startup manual of solar installation which supports domestic hot water heating*, Vaillant Company (in Polish).
- [18] *Which pipes in the solar installation?*, Polskie Centrum Promocji Miedzi, 2009, 14 (1), 1 (in Polish).
- [19] *Solar storage tanks*, Sunergy Company (in Polish).
- [20] *Heating systems in residential buildings*, Grundfos Company (in Polish).
- [21] *Flyer DigiENERGY Heizungs & Solarregler*, Digitronic Automationsanlagen Company, unpublished.
- [22] KAYGUSUZA K., AYHANB T., *Energ. Convers. Manage.*, 1999, 40 (13), 1377.