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RENEWABLE SOURCES OF ENERGY FOR HOUSE HEATING AND USABLE WARM WATER PRODUCTION

An original installation for house heating and warm water production has been presented. The system relies on three independent sources of heat, taken advantage of both for utilitarian and research purposes.

Heat sources integrated together, but working independently, are as follows: solar collectors, a fireplace with water jacket and a low power gas boiler.

The installation was instrumented and measured in a way that enables continuous measurement of characteristic temperatures, heat streams and energy generated by an individual source. The role of the original software consists in registration of the parameters, compilation of statistics, diagram generation as well as observation and Internet data transmission. Experimental results for the whole year 2005 have been gathered and analyzed.

The total annual production of energy used for a semi-detached house heating and usable warm water production was equal to 22.568 kWh, with 50% of this amount representing renewable energy.

1. INTRODUCTION

The biggest threat to natural environment, viewed globally or locally, are the by-products of power industry, such as dust, gases and unburned hydrocarbons. Energy is one of the basic factors determining life and living standards. An increase in energy demand results not only from rapid population growth, but mainly from the pursuit of improvement of life conditions and comfort. The tendency towards an increase in energy demand will intensify and more and more people will live in towns. The latter are frequently old historical towns, which are invaluable treasures of culture and art of the past ages.

Industrial wastes, generated during production of energy, such as sulphur dioxide, nitrogen oxides or dusts, permanently damage museum collections, books or paint-

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ings. That is why in the last decades intensive search for ecologically clean energy sources has taken place. These include renewable energy sources [1], that is, energy coming to the Earth from the Sun. In European countries belonging to the same climatic zone as Poland, the biggest part of energy consumed by population, besides transport, is energy for house heating and production of warm water.

2. HEATING SYSTEMS WITH THREE INDEPENDENT HEAT SOURCES, TWO OF THEM UTILIZING RENEWABLE CARRIERS

An original system was designed and constructed [2], [3], as shown in figure 1. The installation was based on cooperation of solar collectors, a wood-fired fireplace with a water jacket and a low power gas boiler.

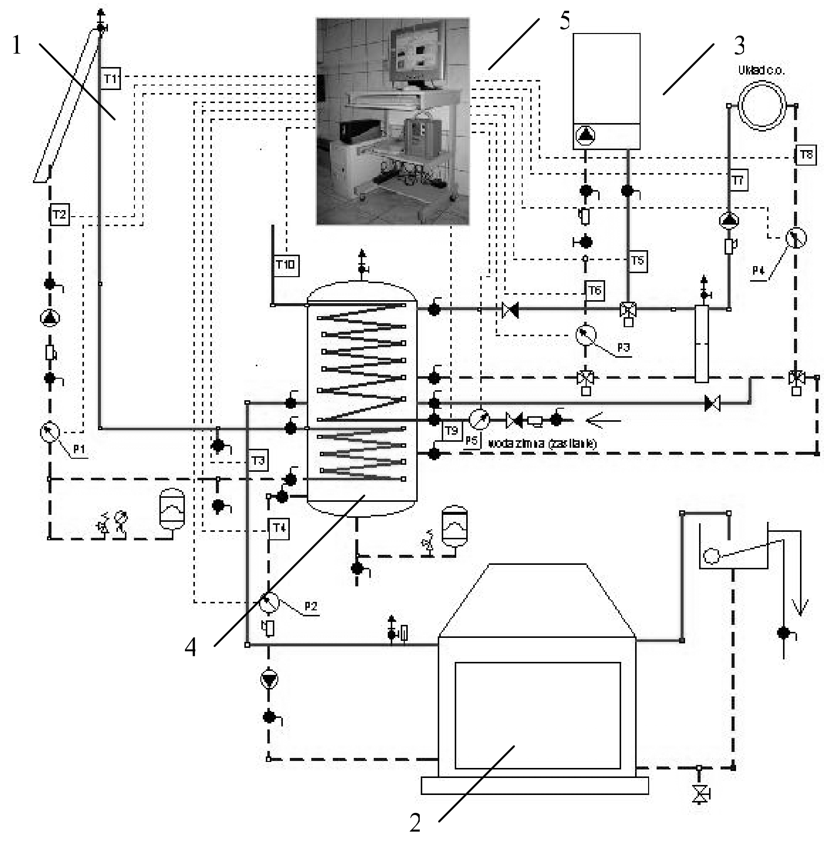

Fig. 1. Heating system: 1 – solar collectors; 2 – fireplace with water jacket; 3 – gas boiler; 4 – storage bin; 5 – measuring system

The system was instrumented and measured [4] in such a way as to enable continuous registration of work parameters, data acquisition and creating data archives, as well as diagram generation and Internet data transmission. The installation has been operating flawlessly from the beginning of the year 2005, heating a semi-detached house of about 300 m^2 usable floor area and producing warm water for its residents.

Sample plots showing the variability of temperature, the amount of energy generated and warm water used are given in figures 2, 3 and 4.

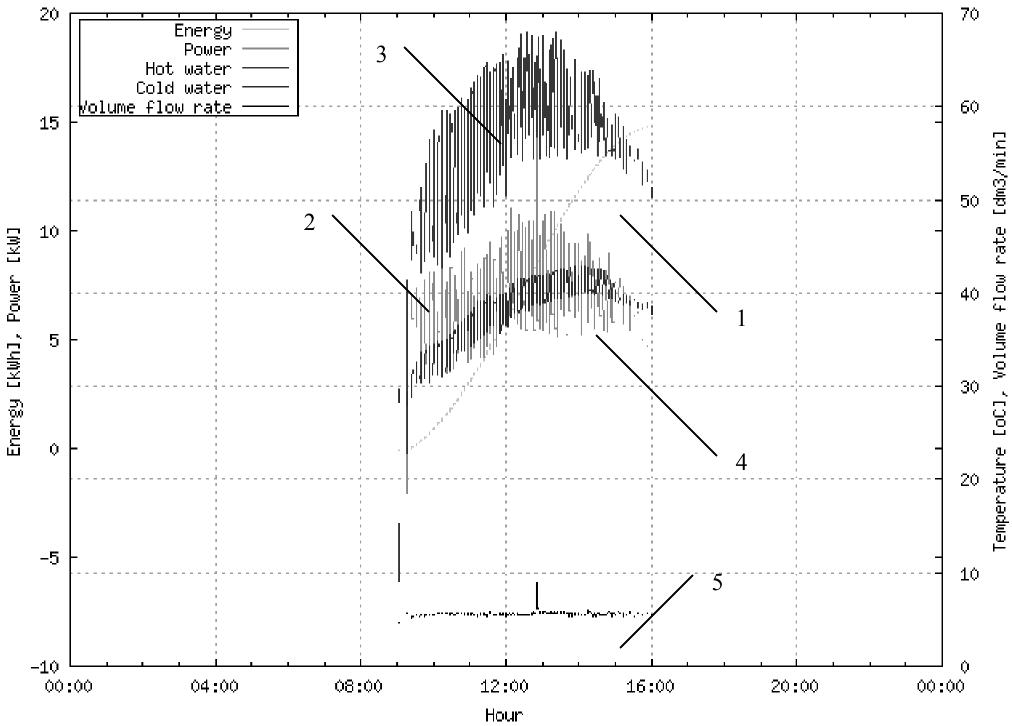

Fig. 2. Operating parameters of solar collector on 2nd March 2005

Based on the data collected it was possible to define the structure of energy produced daily in the year 2005, as well as the structure of energy consumption.

Figure 4 shows the automatically controlled system to operate well, because each time the supply of heat energy from the solar collector or fireplace was sufficient, the gas boiler did not switch on.

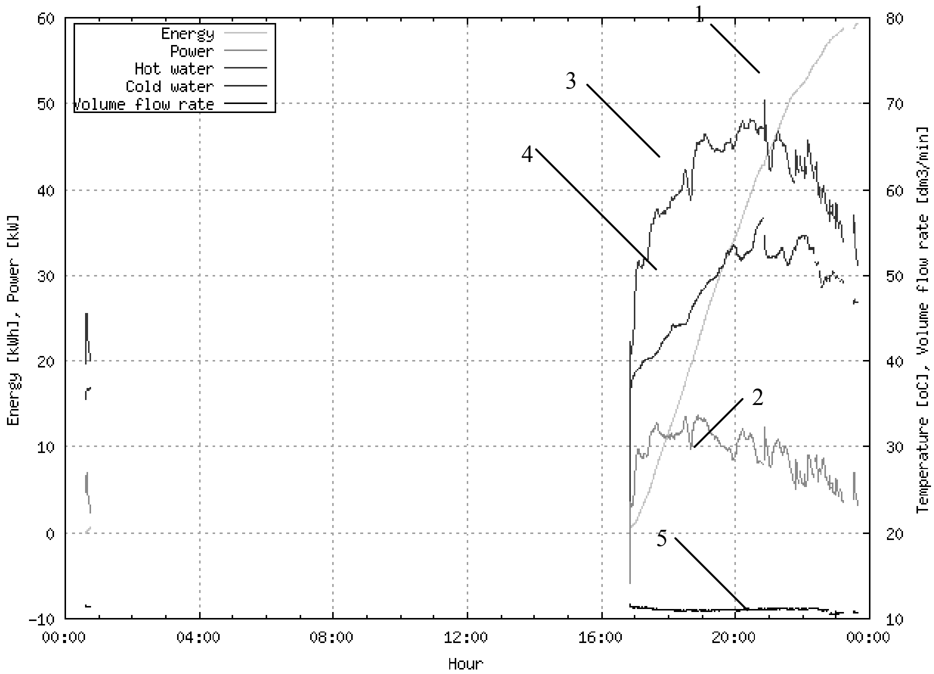

Fig. 3. Operating parameters of fireplace with water jacket on 2nd March 2005

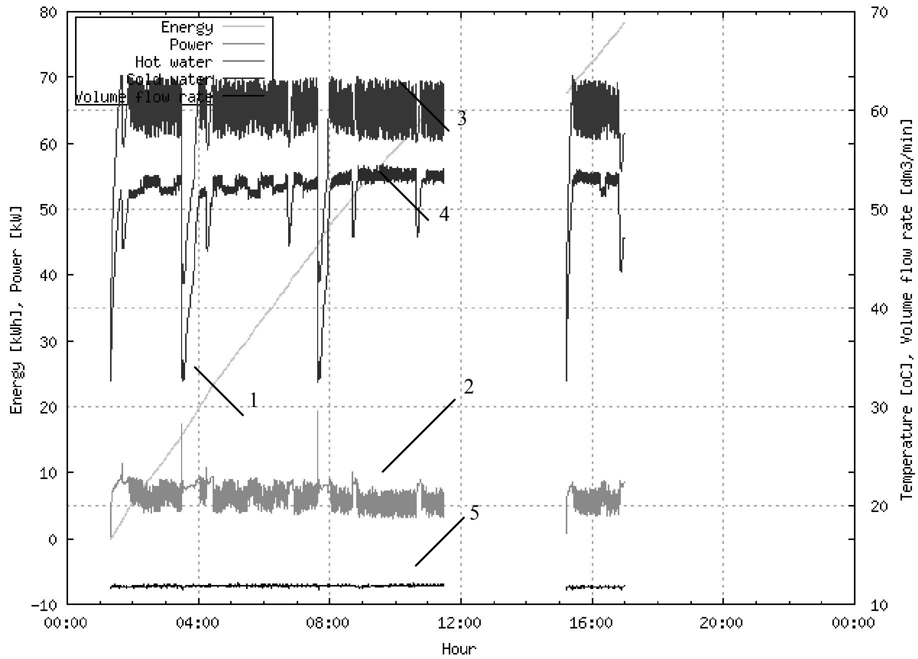

Fig. 4. Operating parameters of gas boiler on 2nd March 2005

In table 1, the data collected each month in one year, showing the structure of energy supplied, are given.

The data enable daily and weekly statistics to be produced. In figure 5, the distribution of energy supplied on 2nd March 2005 is shown.

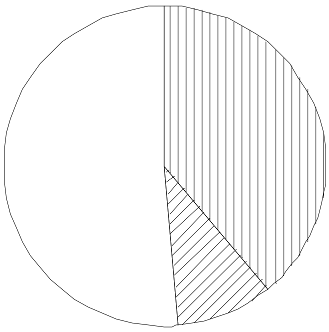

Fig. 5. Distribution of energy supplied on 2nd March 2005

Table 1

Heat energy supplied from different sources in the year 2005

Month	Solar collectors [kWh]	Fireplace [kWh]	Collectors and fireplace [kWh]	Gas boiler [kWh]	Total energy production [kWh]	Percentage of solar collectors [%]	Percentage of renewable sources [%]	Energy used for heating [kWh]
January	38.62	1661.98	1700.6	1646.80	3347.40	1.15	50.80	2797.14
February	91.37	1487.20	1578.57	2319.57	3898.14	2.34	40.50	3126.01
March	222.89	1433.98	1656.87	1960.03	3616.90	6.16	45.81	2717.74
April	251.90	221.01	472.91	787.54	1260.45	19.98	37.52	722.41
May	341.88	36.07	377.95	445.94	823.89	41.50	45.87	479.43
June	298.43	79.98	378.41	18.19	396.60	75.25	95.41	19.48
July	245.03	0.00	245.03	17.15	262.18	93.46	93.46	0
August	271.97	109.85	381.82	4.50	386.32	70.40	98.84	1.3
September	256.61	142.52	399.13	0.00	399.13	64.29	100.00	36.78
October	252.93	870.16	1123.09	85.96	1209.05	20.92	92.89	703.17
November	90.99	1383.34	1474.33	1224.20	2698.53	3.37	54.63	2030.43
December	15.78	1552.62	1568.4	2702.95	4271.35	0.37	36.72	2877.9
Total	2378.4	8978.71	11357.11	11212.83	22569.94	10.54	50.32	15511.79

The supply of energy from solar collectors was changing each day of the year and was dependent on insulation. However, the amount of energy supplied by the fireplace depended on a day and intensity of burning. Gas boiler was treated as a third stage and secure full energy supply.

The data in table 1 should not be considered universal. Probably the amount of heat energy consumed by the residents of this house and the amount of warm water consumed are not representative of a family. However, the energy supplied by fireplace is somehow coincidental and depends on individual behaviour, the latter referring to the frequency and intensity of wood burning. The measurements of wood mass, its humidity and the amount of heat energy produced in this way allow the efficiency of this heat source to be calculated.

Making the energy balance, i.e., comparing energy production and consumption, one obtains inequality. The total amounts of energy produced and consumed in one or several days may differ significantly because of the fact that the storage bin (heat exchanger of 1 m^3 in volume) can accumulate excess energy and give off energy accumulated previously.

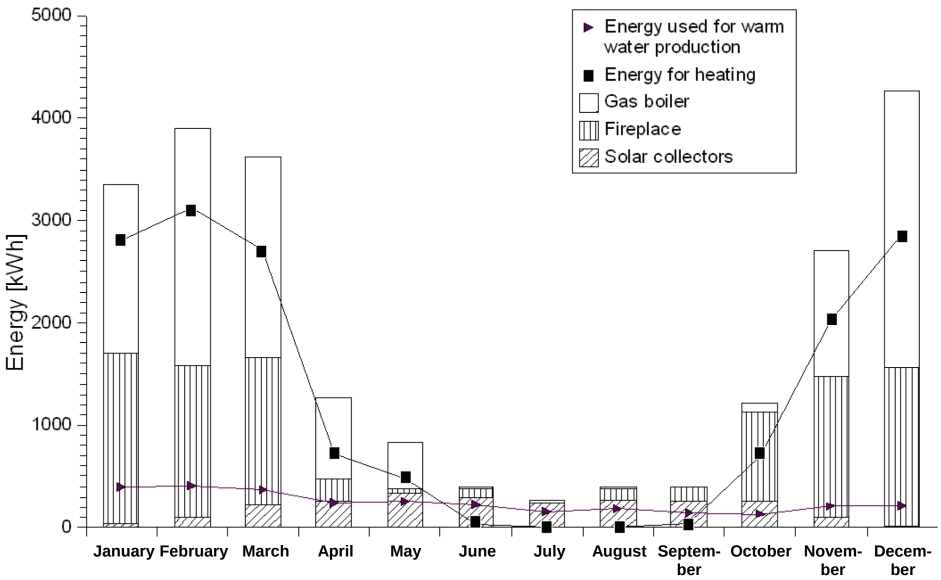

Fig. 6. Energy balance for the period from 1st January to 12th December 2005

Part of the energy produced was then dissipated. This heat energy dissipation during the heating period can be treated as energy transfer for heating the building in other way than by heaters. Otherwise, e.g., during summer, it is a useless heat loss. The loss can be reduced using good insulation of storage bin – heat exchanger, pipes and fittings. It follows from table 1 and figure 6, presenting the total energy generated by three sources during the whole year 2005, that from June to September the whole energy was used to produce warm water.

The ratio of energy from solar collectors in energy balance for one year equals about 10%, but in January, February, November and December this figure is really small. The ratio of energy produced by renewable sources, i.e., solar collectors and burned wood during the year, exceeded 50%.

3. ECONOMIC AND ECOLOGICAL EFFECT

During 2005, heat energy produced in the system amounted to 81.3 GJ, of which 10% came from solar collectors, 40% from wood burning in fireplace and 50% from gas burning in gas boiler.

The annual mean results can be used to calculate the cost of energy production. Assuming the cost of 1kWh of heat from natural gas in the year 2005 (for individual consumer) at PLN 0.15 in Poland and assuming the efficiency of gas boiler to be 0.80, it is possible to calculate the cost of energy from gas in 2005 and the cost of energy if the only source (100%) were natural gas.

Table 2

Costs of heating in 2005

Month	Gas [PLN]	Wood [PLN]	Energy from wood calculated for gas price [PLN]	Wood economy [PLN]	Profit from collectors [PLN]	Gas only [PLN]
January	275.25	141.35	277.79	136.44	6.46	559.49
February	387.70	126.48	248.57	122.09	15.27	651.55
March	327.61	121.96	239.68	117.72	37.25	604.54
April	131.63	18.80	36.94	18.14	42.10	210.68
May	74.54	3.07	6.03	2.96	57.14	137.71
June	3.04	6.80	13.37	6.57	49.88	66.29
July	2.87	0.00	0	0.00	40.96	43.82
August	0.75	9.34	18.36	9.02	45.46	64.57
September	0.00	12.12	23.82	11.70	42.89	66.71
October	14.37	74.01	145.44	71.44	42.28	202.08
November	204.62	117.65	231.22	113.57	15.21	451.04
December	451.78	132.05	259.51	127.46	2.64	713.93
Total	1874.14	763.62	1500.73	737.11	397.53	3772.40

The total cost of heating in 2005 amounted to PLN 2637.76.

Economy (profit) coming out from fireplace and collectors usage: PLN 1134.64.

The economy account takes into consideration profits stemming from lower CO_2 emission to the atmosphere, because of the fact that 50% of energy comes from renewable sources.

The cost G (in PLN) of natural gas burning was calculated according to the equation:

$$G = \frac{E_g \cdot C_g \cdot 3.6}{W_g \cdot \eta_g}, \quad (1)$$

where:
E_g – energy from natural gas [kWh],
C_g – price of 1m^3 of gas [PLN/m^3],
W_g – gas calorific value [MJ/m^3],
η_g – gas boiler efficiency.

The cost D (in PLN) of wood burning was calculated according to the equation:

$$D = \frac{E_d \cdot C_d \cdot 3.6}{W_d \cdot \eta_d}, \quad (2)$$

where:
E_d – energy from wood [kWh],
C_d – price of wood per 1 kg [PLN/kg],
W_d – wood calorific value [MJ/kg],
η_d – fireplace efficiency.

For calculation purposes we assume the following:
C_g – 1.30 [PLN/m^3],
W_g – 35 [MJ/m^3],
η_g – 0.8,
C_d – 0.178 [PLN/kg],
W_d – 12.6 [MJ/kg],
η_d – 0.6.

The savings on energy from wood and solar collectors in comparison to the price of energy from natural gas did not include amortization costs.

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ODNAWIALNE ŹRÓDŁA ENERGII W OGRZEWANIU BUDYNKÓW I PRODUKCJI CIEPŁEJ WODY

Przedstawiono oryginalną instalację do centralnego ogrzewania i produkcji CWU. System opiera się na trzech niezależnych źródłach ciepła i jest wykorzystywany zarówno w celach naukowych, jak i użytkowych. Źródła ciepła są zintegrowane, lecz pracują niezależnie jako kolektory solarne, kominek z płaszczem wodnym i kocioł gazowy. Instalacja została oprzyrządowana i opomiarowana w sposób, który umożliwia ciągły pomiar charakterystycznej temperatury, strumieni ciepła i energii generowanej w poszczególnych źródłach. Oryginalne oprogramowanie komputera rejestruje parametry, tworzy statystyki i wykresy oraz umożliwia transmisję danych przez Internet. Przeanalizowano dane eksperymentalne za cały rok 2005. Całkowita roczna produkcja energii potrzebnej w domku bliźniaczym (CWU i centralne ogrzewanie) wynosi 22,568 kWh, 50% tej wielkości stanowi energia odnawialna.