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Energy consumption and costs of heating a detached house with wood briquettes in comparison to other fuels

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ABSTRACT

This paper presents the consumption of energy needed to heat a detached house located in the north-east of Poland, as well as the cost of heat generation by combustion of wood briquettes compared to other biomass fuels and fossil fuels. The annual average consumption of briquettes during three heating seasons was 6.93–7.42 t/year and the annual consumption of fuel energy was 121–130 GJ/year. Expressed as energy per unit area of the house, the consumption of heat ranged from 0.40 to 0.42 GJ/m^2/year. The average annual consumption of heat per person was 20.22–21.65 GJ. The annual cost of production of heat from briquettes for a house ranged from €772 to €986 during the three seasons under study. The cost of energy production from this fuel was much lower compared to fuel oil, natural gas, coal and pellets, but was higher compared to willow chips. Briquettes, which are produced in Poland in piston briquetting presses and which can be used as fuel in automatic boilers, is a prospective and promising feedstock for generating heat for family houses. The high price of new automatic biomass boilers is the main barrier in the modernisation of boiler houses.

1. Introduction

A considerable portion of the EU population lives in houses, which usually need individual solutions to satisfy their demand for thermal energy. According to statistical data, about 58% of the population of the EU-28 countries lived in houses in 2013, with 34% living in detached houses and 24.1% – in semi-detached houses. The remaining 41.1% of the population lived in flats and 0.1% – in other residential facilities. Of the EU-28 countries, the largest portion of the population lived in houses in Croatia (70.9%), followed by Slovenia (66.5%). In Poland, 55.4% of the population lived in houses, with 50.1% living in detached houses and 5.3% – in semi-detached houses. The remaining 44.5% of the population lived in flats and 0.1% – in other residential facilities [1]. Therefore, it appears that the portion of the population living in houses in Poland is growing. Obviously, the structures of residential conditions in towns and villages differ. Multi-family residential buildings dominate in towns and detached houses – in villages. In towns, 78.9% of flats were in multi-family residential buildings and 21.1% – in detached houses, whereas detached houses accounted for 84.2% of residential facilities in villages [2].

Although the amount of energy consumed in detached houses built nowadays is much lower than in older ones, they still consume a considerable portion of heat for household heating (37.01%) and electricity for lighting and electrical devices (18.96%) used in Poland [3]. Therefore, energy used by households accounted for the greatest portion of the final consumption of energy (33%). During the period between 1993 and 2012, the portion of the total heating energy in the final energy consumption for heating was very high, but it decreased steadily from 73.1% to 68.8% (Fig. 1). A decrease in the consumption of heating energy in recent years has resulted from replacing low-efficiency coal-fired boilers with more efficient devices. Moreover, measures related to thermo-modernisation and use of stricter construction standards have been intensified. Energy consumed for heating water accounted for 14.8%. About 8.3% of energy was consumed for preparing meals; electrical devices and lighting used 6.6% and 1.5%, respectively. The doubling of electricity consumption during the period between 1993 and 2012 resulted from houses being increasingly well-equipped with electrical devices and changes in user behaviours [4].

Due to the high share of energy consumed for heating, the cost of heat is still a large burden for households. An average of 20.1% of a

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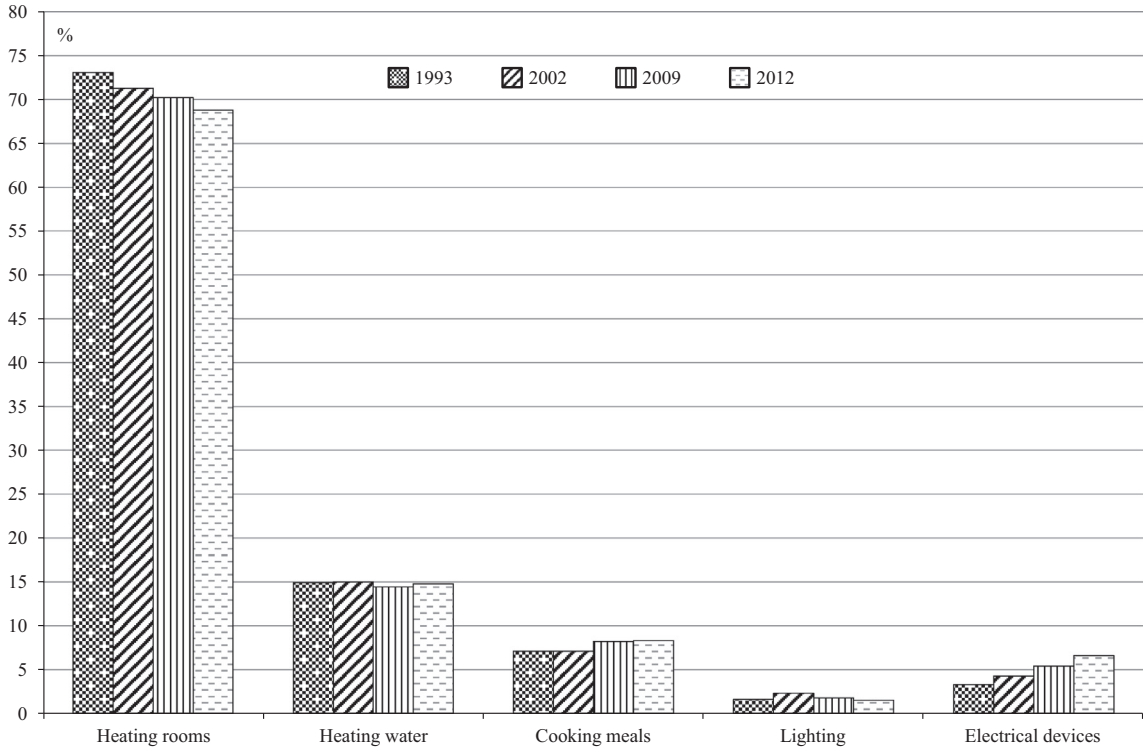

Fig. 1. The structure of consumption of energy in Polish households by type of use in the years 1993–2012 (%) [4].

household budget is spent on energy and accommodation in 2014 in Poland and it was the second largest cost borne by households, just after food and beverages (24.4%) [5]. On the other hand, the cost of housing, water, electricity and other fuels in the EU in 2012 accounted for 24.1% of all the expenses, while in selected countries, such as Sweden, Finland, Portugal, Greece, it accounted for 27.0%, 27.1%, 16.2% and 23.8%, respectively [6]. Therefore, seeking a possibility of reducing the cost of heat in households is still a valid task. This aspect is of particular importance in northern Europe, including in the climatic conditions of north-eastern Europe, where the heating season can last as long as 230 days a year.

There are about 7.3 million detached houses in Poland [7], which accounts for 63% of all households. Moreover, there are an estimated 5.5 million detached houses which are heated by solid fuel boilers, fired mainly with coal. Solid fuels, mainly hard coal (29%), are the most important in the structure of energy consumption in Poland. For comparison, this index in the next coal user, Ireland, is 7%, and the European average is 3% [2]. On the other hand, it should be emphasised that – as opinion polls have shown – coal is the most popular fuel used to heat houses in Poland, but Poles would gladly replace coal with renewable sources of energy. Therefore, the aim of this study was to evaluate the consumption and cost of the generation of heat for a detached house from wood briquettes compared to other renewable and fossil fuels.

2. Materials and methods

2.1. Location and scope of the experiment

This study was carried out in a detached house situated in the north-east of Poland, in the town of Olsztyn (53°47′N, 20°30′E). The materials used in the construction of the building and the boiler house were characterised in detail in a previous paper [8]. In autumn 2012, the house was expanded, which involved adding one room, a utility room and a garage. In consequence, the total area of the house following the expansion increased to 307 m^2, including the slightly heated utility room (9 aluminium ribs of a convector radiator for the area of 40 m^2) and an unheated garage with an area of 20 m^2. The materials used in the expansion work were the same as those used in the original construction work. The heating system remained the same, except that only 14 radiator ribs were added; therefore, there are 214 aluminium convector radiator ribs altogether. The area of the house before it was enlarged was 247 m^2 [8], its area after enlargement increased by 60 m^2 to 307 m^2. Of the entire area of the house, 80.5% (247 m^2) is heated for the residents' full comfort. 13.0% of the house area is slightly heated and 6.5% is not heated at all. Six people lived in the house before and after it was enlarged.

The study at the building was started in October 2006 [8]. Heat was generated (to heat water for central heating and to produce domestic hot water) by burning briquettes made from pure sawdust of broadleaved and coniferous trees, further in this paper is referred to as briquettes. This study analyses in detail three consecutive heating seasons after the house was enlarged: 2012/2013, 2013/2014 and 2014/2015. Moreover, the discussion section contains an evaluation of the use of the boiler room and generating heat before the house was enlarged (six heating seasons) and in total for the whole period of nine consecutive heating seasons from 2006 to 2015.

2.2. Fuel quality

The quality and amount of briquettes used for heat generation was analysed. The briquettes were made by the same manufacturer during the years of the study. The fuel quality was assessed three times, after each delivery in 2012, 2013 and 2014. As in earlier studies, the quality of pellets produced from a mixture of oak and pine sawdust, willow chips from field-grown willows and hard coal (pea coal, 20–30 mm grade) as an alternative fossil fuel for renewable fuels was evaluated in order to compare briquettes to other fuels. Representative samples were taken from each fuel for laboratory analyses in consecutive years of study. Subsequently, the bulk