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To cite this article: G Komitov *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **595** 012046

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# Determining the expenses for heating of a residential building using different energy sources

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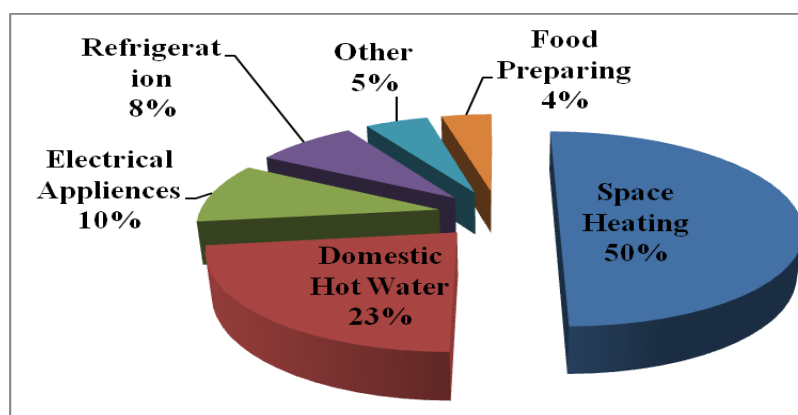
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**Abstract:** The heating of residential and industrial buildings is important for creating a good microclimate in them and for their normal functioning. This article defines the thermal losses of an energy model of a residential building according to the energy efficiency legislation in force in the Republic of Bulgaria. The advantages and disadvantages of using different energy sources for buildings heating are considered. Various types of energy sources- conventional and alternative (electricity, pellets, HHO gas, LPG, natural gas – CNG, gas oil) are used. Comparison and analysis of the expenses, energy and environmental impact of their implementation has been done.

## 1. Introduction

The heating of residential and industrial buildings is important for creating a good micro-climate in them and for their normal functioning. The analysis shows that the largest share of household energy consumption is represented by heating (50%) and hot water (23%) (Figure 1) [1, 2].

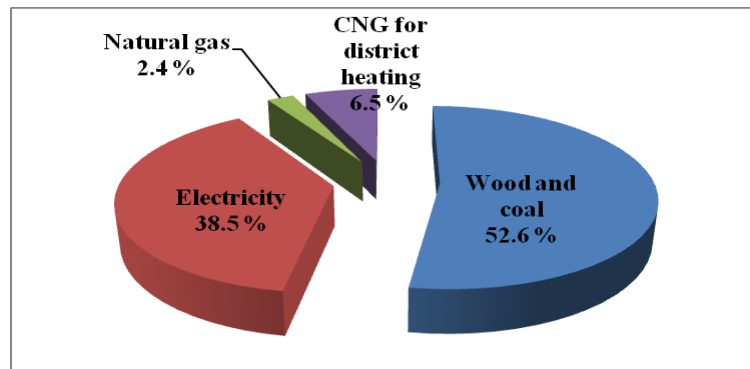


**Figure 1.** Structure of energy consumption in a household.

Energy consumption for heating and domestic hot water accounts more than 70% of the total energy consumption of the household, so the type of energy source and the efficiency of energy

conversion systems is of utmost importance.

The final consumption of energy sources for heating in Bulgaria is as follows (Figure 2): wood and coal - 52.6%, electricity - 38.5%, natural gas - 2.4%, natural gas for district heating - 6.5% [2]. The large share of wood and coal use (around 52.6%) is clearly visible. In domestic heating with non-efficient stoves and solid fuel boilers and the use of coal containing ash and sulphur and wet wood, pollutants such as sulphur dioxide, nitrogen dioxide, carbon monoxide and fine particulate matter are the main problem in cities [3-7]. Analyses indicate that this type of heating causes at least 85% of fine particulate emissions, so measures to improve air quality are mostly targeted in this area [2].

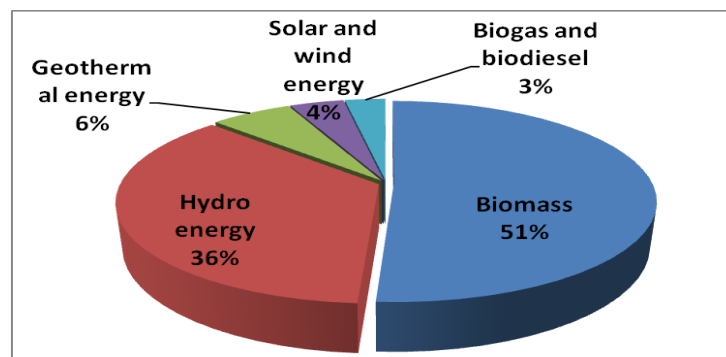


**Figure 2.** Energy consumption for heating in Bulgaria.

Fig. 2 shows also that the use of electricity for home heating stands in second place with a share of 38.5%. The problem in this case is that nearly 1/3 of electricity is lost, until it reaches the end user. Except of that the electricity distribution system is significantly burdened and, at the same time, there is energy dependence of households on the electricity distribution companies [1-2]. The use of renewable energy sources is negligible, but more and more people living at houses choose pellets as heating fuel for their homes.

The European Union is addressing the issue of introducing of renewable energy as a means of reducing greenhouse gas emissions and compliance with the Paris agreement on climate change. Increased use of renewable energy also plays an important role in sustainable energy production at affordable prices, technological development and innovation [8].

In many countries, more rational use of energy and development of renewable energy sources (RES) is planned to be replaced part of the fossil fuels used to satisfy their energy needs (Figure 3) [1-2, 8-11].



**Figure 3.** Distribution of energy from renewable energy sources (RES).

The perspectives for energy saving and the development of new energy sources are related to economic models geared to sustainable development at regional and local level [1].

The most efficient and secure way to meet the energy needs of households is decentralized generation of renewable energy, including in our homes. It concentrates complex benefits because: avoids losses in energy transportation, avoids costs for building the transmission network, and uses clean and inexhaustible resource [12].

An alternative to houses heating is the use of oxy-hydrogen gas (HHO gas). Yull Brown has patented an electrolyze technology for HHO gas generation [13]. A number of researchers have investigated the existing generators of HHO gas and their applicability in practice [14-16], the possibility of using HHO gas as a fuel in internal combustion engines [17-20], in food industry [21], for electricity generation [22] or for heating purposes [23-24].

The purpose of this paper is to determine the costs for heating of a residential building using 7 different sources of energy – conventional and alternative and to compare them.

## 2. Materials and Methods

In our case, a residential building with a heated area of 514 m<sup>2</sup> and a heated volume of 1285 m<sup>3</sup> was chosen for a model. The building is located in the city of Plovdiv and depending on its energy consumption falls in energy class "B" [25]. To determine the energy required for heating the model building, a methodology based on the energy efficiency legislation in force in Bulgaria is used [25]. For the purpose of the comparative study seven different energy sources for building heating are used: HHO gas heating (Brown gas), electric hot water boiler [26], pellet boiler - class A1 [27], gas oil boiler [28-29] and natural gas condensing boiler [30]. The calculated energy demand for heating of the model building is  $Q_Y = 36,788$  kWh per year. The number of heating days per a year in the region of Plovdiv is  $d = 165$  days and it is determined according to [25]. The energy distribution according to the number of heating days per a year  $Q_{H,d}$  is obtained after dividing the required amount of energy  $Q_Y$  by the number of heating days according the equation (1).

$$Q_{H,d} = \frac{Q_Y}{d} = 223 \text{ kWh/day} \quad (1)$$

The energy required to heat the building for 1 hour is obtained after dividing the required energy for one day  $Q_{H,d}$  by the number of hours per day (2):

$$Q_h = \frac{Q_{H,d}}{h} = 9.29 \text{ kWh} \quad (2)$$

Table 1 presents data for the calorific value and the prices of the investigated energy sources [31].

**Table 1.** Data on the calorific value and the prices of the investigated energy sources.

Nº	Energy sources	Calorific value - $Q_{PS}$			Price of energy source - $p_{PS}$		
1	HHO gas	$Q_{HHO}$	6.26	Wh/l	$p_E$	0.11	€/kWh
2	Electricity	$p_E$	1.00	kWh	$p_E$	0.11	€/kWh
3	Wood pellets	$Q_W$	5.28	kWh/kg	$p_W$	0.26	€/kg
4	Agro pellets	$Q_A$	3.33	kWh/kg	$p_A$	0.13	€/kg
5	Natural gas - CNG	$Q_{CNG}$	9.89	kWh/m <sup>3</sup>	$p_{CNG}$	0.44	€/m <sup>3</sup>
6	LPG	$Q_{LPG}$	13.9	kWh/kg	$p_{LPG}$	1.12	€/kg
7	Gas oil	$Q_G$	11.63	kWh/kg	$p_G$	1.09	€/l

Bulgaria has a fixed exchange rate of BGN to the EURO and 1 EURO = 1.95583 BGN [32].

Considering the wide variety of energy sources and the different price of each of them, the comparison between the energy sources from table 1 consists in determining the value that the end user pays for model building heating for one hour. The HHO gas, also known as Brown's gas, is an alternative source of energy while at the same time it is nearly ecological. The Brown's gas is produced by electrolysis of distilled water and a certain amount of potassium hydroxide solution (Fig. 4). In course of an electrochemical reaction, HHO gas is released. The energy potential of the HHO gas according to different sources is  $Q_{HHO} = 6.26$  Wh/l [33].



**Figure 4.** Principal scheme for generating of HHO gas.

The quantity of HHO gas required to ensure the heating of the building for 1 hour is calculated according to the equation (3):

$$D_{HHO} = \frac{Q_h}{Q_{HHO}} = 1484 l_{HHO} \quad (3)$$

On the other hand, according to our experiments for generation of 1 liter HHO gas is required  $E_{HHO} = 1.006$  Wh electric energy. Therefore, for heating of the model building for 1 hour, the required amount of energy is (4):

$$q_{HHO} = D_{HHO} \cdot E_{HHO} = 1.49 \text{ kWh} \quad (4)$$

According to the electricity prices of electricity company EVN-Bulgaria, the average price of electricity is 0.21 BGN/kWh (to 01.01.2019) [31] or 0.11 €/kWh. The cost of the model building heating can be expressed by equation (5):

$$C_{PS} = q_{PS} \cdot p_{PS} \quad (5)$$

where  $q_{PS}$  is the amount of energy required for building heating with the particular energy source.

In the option of heating with hot water electric boiler, the boiler "Ecothermal", model „10 MRL“ is selected [26]. It is an electric boiler with a power of 10 kW and a power supply of 400 V. The value of electricity used for heating in this case is determined by dependence (6):

$$C_E = Q_h \cdot p_E \quad (6)$$

The amount of energy  $q_{PS}$  required for building heating with energy sources - pellets, gas oil, CNG or LPG is determined by equation (7):

$$q_{PS} = \frac{Q_h}{Q_{PS}} \quad (7)$$

where  $Q_{PS}$  is the calorific value of the particular energy source.

The cost of heating by using different energy sources  $C_{PS}$  for one hour is determined from the equation (8):

$$C_{PS} = q_{PS} \cdot p_{PS} \quad (8)$$

where  $p_{PS}$  is the price of each energy source.

According to the measures taken by the Paris Greenhouse Gas Reduction Agreement, the use of coal is limited to all EU countries and therefore the authors do not recommend their use.

Heating with automated pellet boilers can be considered as renewable energy source heating, especially if the pellets are made from waste from agricultural produce, such as branches, plant stems, scales, etc. The boiler burning pellets used in this publication is "Burnit" boiler, model "UB 27" with a rated output of 27 kW [27]. The boiler is automated and is suitable for burning wood and agro pellets as well as solid fuel.

### 3. Results and Discussion

The results for determining the cost of building heating using different energy sources are summarized

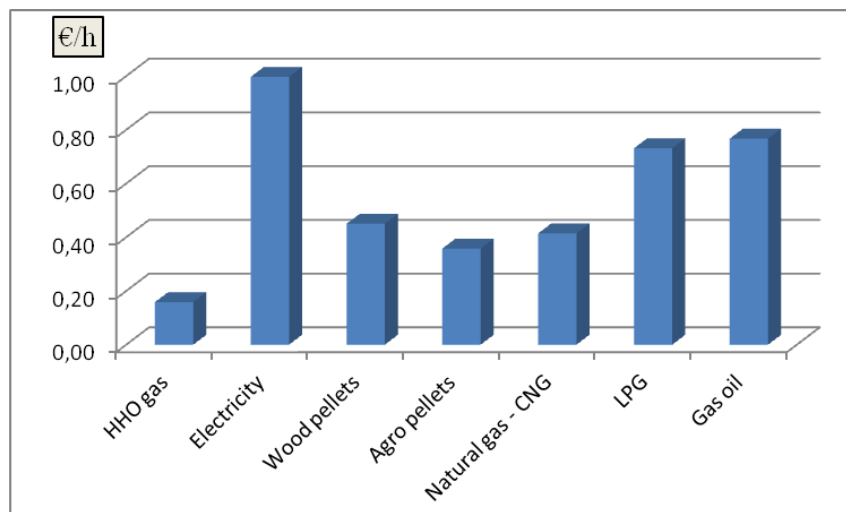
in Table 2 and graphically presented in Figure 5.

**Table 2.** Value of heating per an hour at different energy sources.

Nº	Energy sources	Energy requirement - $q_{ps}$			Cost of heating $C_{ps}$
1	HHO gas	$q_{HHO}$	1.49	kWh	0.16 €/h
2	Electricity	$q_E$	9.29	kWh	1.00 €/h
3	Wood pellets	$q_W$	1.76	kg	0.45 €/h
4	Agro pellets	$q_A$	2.79	kg	0.36 €/h
5	Natural gas - CNG	$q_{CNG}$	0.94	m <sup>3</sup>	0.41 €/h
6	LPG	$q_{LPG}$	0.67	kg	0.73 €/h
7	Gas oil	$q_D$	0.70	l	0.77 €/h

The results of Table 2 only make sense to determine the required for building heating amount of a specific energy source in natural terms in order to limit its use or its preservation in nature. Considering that electricity is one of the cleanest energies, the use of an energy source different from electricity can lead to a significant increase in the fine dust particles. At the same time, in the production of a unit of electricity, 3 times more primary energy is consumed and, therefore, more is the CO<sub>2</sub> released into the atmosphere. Therefore, the result of Table 2 could be used for environmental and economic research on the use of the type of energy carrier.

Figure 5 shows the cost of heating of model building at seven different energies.



**Figure 5.** Cost of heating at different energy sources.

According to data from Table 2 and Figure 5 heating the building using HHO gas is cheapest. In this case one-hour heating of the model building costs 0.16 €/h. There is almost no harmful emission and the costs are for water and electricity necessary for the decomposition of water. Therefore, heating with HHO gas is suitable for all heated buildings with a separate boiler room.

On the other hand, the most expensive heating of the model building is heating with an electric hot water boiler - 1.00 €/h. This type of heating is suitable for use of buildings with limited space.

The use of green energy from biomass for heating is quite acceptable option at a relatively low price of heating -  $0.36 \div 0.45$  €/h depending on the type of pellets. The cost of pellets can be reduced by properly planning the purchase of the pellets. At the end of the heating season, the price of pellets drops by almost half. The emissions from the boiler for automatic pellet burning are minimal and are controlled by the combustion process. This type of heating is suitable for all heated buildings.

Economical option for building heating is heating with a boiler burning CNG (0.41 €/h). The



heating with CNG relies on a gas supplier and this will lead to energy dependence. The heating with the CNG is simply to the type of the installation and is a practical option in the absence of free spaces for the boiler.

The value of building heating using LPG and gas oil as energy source varies within the range of  $0.73 \div 0.75$  €/h. The prices of these types of energy source directly depend on the oil price. Again there is energy dependence on oil companies. It is practical and justified to use these energy sources in hard-to-reach areas and those that do not require year-round heating. Such buildings can be mountain chalets and villas.

#### 4. Conclusions

This article defines the thermal losses of an energy model of a residential building according to the energy efficiency legislation in force in the Republic of Bulgaria. The advantages and disadvantages of using different energy sources for buildings heating are considered. Various types of energy - conventional and alternative (electricity, pellets, HHO gas, natural gas, LPG and gas oil) are used. Comparison and analysis of the energy and environmental impact of their implementation has been done.

The most economical heating of the model building with the required heat output of 9,29 kW is that of HHO gas. The value of this heating is 0.16 €/h if electricity is used to generate the HHO gas. This type of heating is suitable for all heated buildings that have a boiler room.

Biomass energy for heating the model building shows relatively good results, depending on the type of biomass (pellet). The value of heating the model building with biomass varies from  $0.36 \div 0.45$  €/h, but it can be reduced by properly planning its purchase.

The use of natural resources leads to energy dependence on the supplier of the energy sources.

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