Rational Use of Primary Energy in Single-Family Residential Houses

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Abstract. This work presents results of the primary energy use for heating residential single-family house. Analysis includes domestic hot water system (DHW) and heating, ventilation and air condition system (HVAC). During researches the conventional and alternative energy sources (natural gas, biomass, fuel oil, bituminous coal, lignite, or electric energy obtained from electric power system – EPS) were used in DHW and HVAC systems. Furthermore in the article, the analysis of sulfur dioxide emission to the atmosphere during energetic combustion of energy source was performed.

Keywords: primary energy, energy politick, sulfur dioxide emission, single-family residential house.

1 Introduction

Dynamic industrial development of European Union Countries makes the issues of effective utilization of fuels as essential task in the immediate future [4, 6, 7]. Example of this initiative is the ruling of Kioto Protocol [21] (implemented in 2005) determining the international agreement concerning limitations of pollutants emission to the atmosphere through the increase in renewable energy utilization.

The consequence of these decisions are numerous regulations in terms of effective energy utilization, introduced both by the European Parliament [2, 15–17] and by the all member states of the European Union – including Poland [10–14].

Constantly growing energy demand [20] causes a great number of problems concerning environmental pollutions and creates difficulties related to the energy balancing. Depending on the source type of generated power (electrical, thermal, nuclear, etc.), further appear inconveniences associated with the optimal delivery of energy raw material for energy production.

Analyzing the usage of primary energy sources in Poland, the dominant role of coal as a primary resource can be noticed. This is due to substantial deposits of this material in Poland, located mainly in the southern part of the country. This arrangement results in the location of the power plants majority almost exclusively in the areas of energy resource deposits occurrence (Fig. 1). Such situation creates another issue related to the necessity of electricity transmission to other parts of the country.

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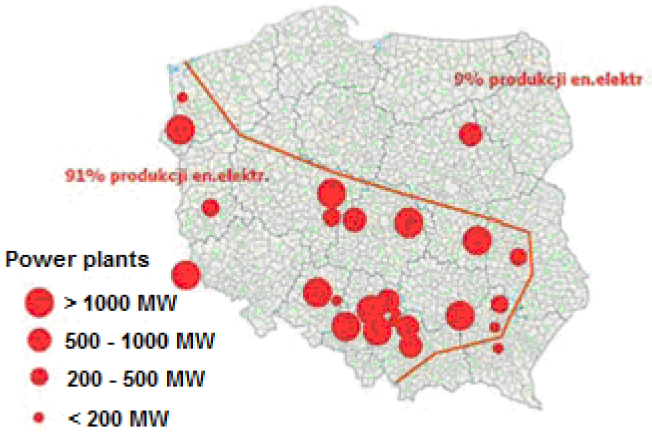

Fig. 1. Distribution of system power plants in Poland (source: [9])

It should be noted that in the 50 % Polish area the 91 % of total energy from system plants is generated. Existing imbalance prompts the obvious loss of energy resulting from the transport over long distances (Table 1).

Table 1. Values of electric energy consumption and losses in Poland over the last decade [5, 20]

Value [GWh]	2005	2007	2008	2009	2010	2011
Domestic consumption:	131,186	139,584	143,700	136,996	144,453	147,668
Household consumption:	26,565	27,713	28,425	28,684	29,774	29,383
Energy losses:	14,563	14,416	11,255	12,533	11,851	10,638

The analysis of data presented in Table. 1 shows that approx. 7.2 % of domestic electric energy consumption accounts for the losses associated with the generation, transmission, control and storage. Hence, they are so essential that could satisfy approx. 36.2 % of the total electric energy consumption of all the households in Poland. Such a significant share of losses, on a global scale, means that the issue of energy effectiveness is currently of particular importance. Instances are inter alia: new regulations placed on residential building including single family houses. These requirements are of particular concern to the need of reducing the consumption of non-renewable energy, used for the purpose of exploitation.

Currently, most of household energy consumption (from 60 % to 90 %) is associated with the operation of systems: domestic hot water system and heating, ventilation and air condition system. Therefore, the analyses of those systems are performed further in the article.

2 Analysis of Annual Energy Demands and Sulfur Dioxide Emissions to the Atmosphere in a Single-Family Residential Building

2.1 The Assumptions and Analysis Range

Fig. 2 presents the scheme of single-family residential building used as a base for the simulations and further analysis. In this research, to supply the domestic hot water system (DHW) and heating ventilation and air condition system (HVAC), were used traditional energy sources such as: bituminous coal, lignite, natural gas, fuel oil, electric energy as well as environmentally friendly biomass.

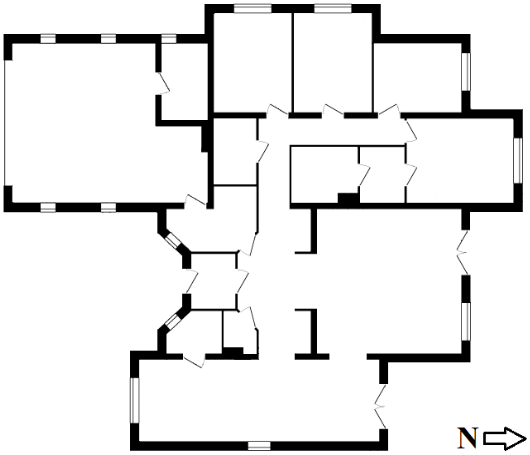

Fig. 2. Scheme of single-family residential building used in the research

Table 2. Summary of the building parameters used in the analysis

Surface:	216.2 m^2
Cubature:	535.1 m^3
Place	Gdansk (1st climatic zone)
Type of cooling system:	non
Type of ventilation system:	gravitational
Citizens:	5

Moreover, it was assumed that the object of the research is located in the first climatic zone in Gdansk and is inhabited by five citizens (very important information due to calculations of annual energy consumption). Table 2 presents the statement of the building parameters used in the analysis, as: cubature, type of cooling and ventilation systems, or number of inhabitants.

2.2 The Calculation of Annual Sulfur Dioxide Emissions and Building Demands for Primary Energy

The calculation methodology results from the adoption of normative value of losses on building heating and ventilation – according to requirements of EN 13790:2008 [3, 18, 19] standard. In the next step the primary energy was obtained, in accordance to current methodology pertain to determining the energy efficiency of buildings. The value of this energy depends mainly on the total surface of the building (Af), as well as total energy consumption for each subsystem ($Q_{P,W}$ for HVAC system and $Q_{P,H}$ for DHW system).

$$EP = \frac{Q_{P,W} + Q_{P,H}}{A_f} \tag{1}$$

The amount of annual emission of sulfur dioxide mainly depends on fuel ratio (B_w, B_K), emissions of sulfur dioxide ratio ($SO_{2,W}$, $SO_{2,H}$) and normalization coefficient (m_W, m_K) [18].

$$SO_2 = B_W \cdot SO_{2,W} \cdot m_W + B_K \cdot SO_{2,K} \cdot m_K \tag{2}$$

This method allows to estimate the total primary energy consumption in residential buildings and the total annual sulfur dioxide emission to atmosphere. This approach also enables to determine the benefits of utilize the non-conventional energy sources.

3 Results of the Analysis

Table 3 presents results of the above mentioned analysis, taking into account: annual energy demand for HVAC system ($Q_{K,H}$), annual energy demand for DHW system ($Q_{K,W}$), total annual emissions of sulfur dioxide to the atmosphere from selected energy source (SO_2) and total annual demand for primary energy of the object (EP).

Table 3. Summary of the analysis results

Energy source	$Q_{K,H}$ [kWh·a^{-1}]	$Q_{K,W}$ [kWh·a^{-1}]	SO_2	EP
Biomass	24,154.94	3501.56	4.46	25.58
Bituminous coal	18,558.06	3501.56	55.01	112.23
Lignite	18,558.06	3501.56	522.88	112.23
Fuel oil	17,098.44	3501.06	17.47	104.81
Natural gas	17,098.44	3501.06	0.00	104.81
Electric energy	12,171.58	2433.03	132.90	202.65

Due to the similar nature of HVAC and DHW systems the analyses results of final energy demand for bituminous coal and lignite energy sources are the same (for natural gas and fuel oil the approach is analogical).

In order to better present the annual primary energy demand and total annual sulfur dioxide emission, depending on use of different energy source, Fig. 3 and Fig. 4 illustrate summary those analysis results.

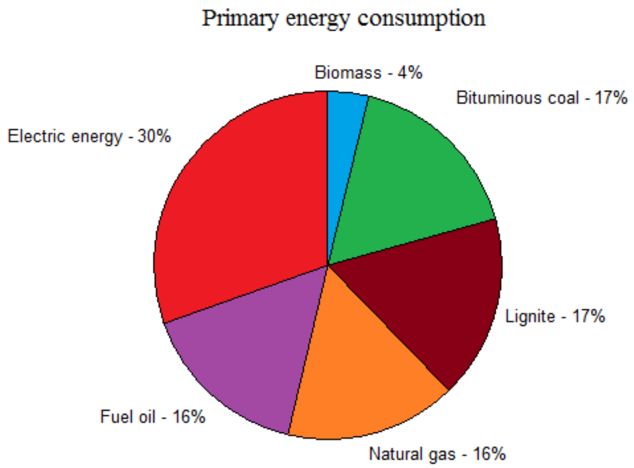

Fig. 3. Summary of primary energy consumption for the referential object

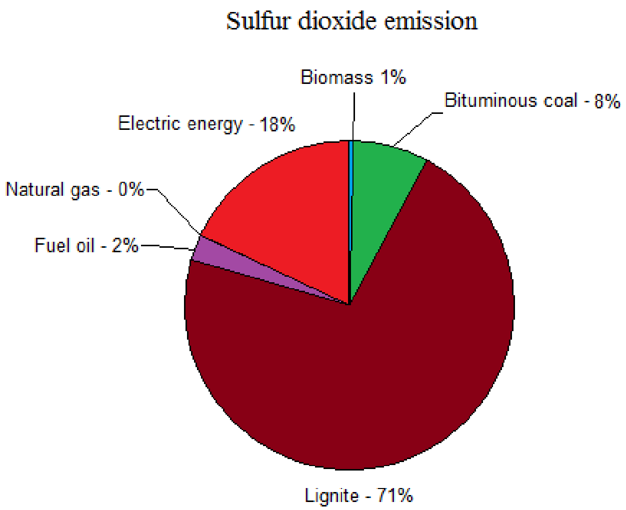

Fig. 4. Summary of sulfur dioxide emission to the atmosphere for the referential object

The results clearly show that primary energy consumption is greatest when HVAC system and DHW system utilize electric energy obtained from the EPS as an energy source. Simultaneously, the results show on biomass as the lowest primary energy consumption source of energy.

This information is very important on the grounds of planning energy development strategy, because it shows how to limit the consumption of raw materials. Evidence to support that thesis is possibility to utilize biomass as an energy source to reduce primary energy demands by up to 87 %, compared to the worst scenario (electric energy obtained from electrical power system). Taking into account this fact, the utilize of non-conventional energy sources is particularly important, especially for areas distant from the power plants, or/and heating plants. Due to utilize biomass as energy source, energy losses associated with its transmission can be sharply reduced. Also it should be noted that in Poland the bituminous coal is the main energy raw material which during the energetic combustion emits great amounts of carbon and sulfur dioxide to the atmosphere.

Definitely the greatest sulfur dioxide emission to the atmosphere was in the case of lignite used as a source of energy. Furthermore biomass and natural gas were characterized by the lowest sulfur dioxide emission to the atmosphere.

The analysis clearly shows superiority pro ecological solutions over conventional solutions (bituminous coal, lignite, fuel oil, or electricity) in view of environmental impact. The worst results was gained for lignite and electrical energy obtained from EPS.

4 Conclusions

The mentioned above issues, in the light of current topics of primary energy ergonomic use, take on special meaning especially when referring to the current European Union guidelines and to the problems related to environmental protection. Thus it is particularly valuable to conduct diverse forms of support for any thermomodernization projects, especially for those which seek to use renewable energy sources. An example of government policy in this area is undoubtedly the law act of supporting thermomodernisation projects that, following an energy audit, allow for applying for a 20% refund of the contracted for this purpose investment loan amount.

It should be noted also that although the presented results refer to a specific type of residential building, they can be considered as representative of the majority of residential buildings. The differences in primary energy consumption for other buildings, will result most of all from the application of other than the assumed in the analysis technological solutions – including the efficiency of certain devices.

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