Tomasz SZUL
Krakow University of Agriculture, Faculty of Powering and Automation of Agricultural Processes
ul. Balicka 116B, 30-149 Kraków, Poland
e-mail: Tomasz.Szul@ur.krakow.pl

DIFFERENTIATION OF THE SHARE OF SOLID BIOMASS IN MEETING THE HEATING DEMAND IN RURAL AREAS OF THE LUBUSKIE REGION

Summary

An analysis of heat consumption and energy potential of biomass and its differentiation in individual districts of the Lubuskie Province was performed. The demand for heat in the province's rural areas amounts to approx. 18.6 PJ, while the potential of biomass which can be used for energy generation purposes is 8.5 PJ. On this basis, it is estimated that the share of biomass in meeting the heat demand in the province can amount to 45%. To be able to define the spatial differentiation of the share of biomass in meeting the heat demand in the Lubuskie Province, the fuzzy set theory was used. The highest share of biomass in satisfying the heat demand occurs in western districts of the province, while the lowest in land districts situated around the region's largest cities.
Keywords: *Final energy consumption for heating, biomass, fuzzy sets*

ZRÓŻNICOWANIE UDZIAŁU BIOMASY STAŁEJ W POKRYCIU POTRZEB CIEPLNYCH NA OBSZARACH WIEJSKICH WOJEWÓDZTWA LUBUSKIEGO

Streszczenie

Przeprowadzono analizę zużycia ciepła i potencjału energetycznego biomasy w poszczególnych powiatach województwa lubuskiego oraz przeanalizowano jego zróżnicowanie. Popyt na ciepło na obszarach wiejskich województwa kształtuje się na poziomie ok. 18,6 PJ, zaś potencjał biomasy, która może być wykorzystana na cele energetyczne wynosi 8,5 PJ. Na tej podstawie szacuje się, że udział biomasy w pokryciu potrzeb cieplnych na terenie województwa może wynieść 45%. Aby móc określić przestrzenne zróżnicowanie udziału biomasy w pokryciu zapotrzebowania na ciepło na obszarze województwa lubuskiego wykorzystano teorię zbiorów rozmytych. Najwyższy udział biomasy w zaspokojeniu potrzeb cieplnych występuje w zachodnich powiatach województwa, najniższy zaś w powiatach ziemskich zlokalizowanych wokół największych miast regionu.
Słowa kluczowe*: zużycie energii końcowej na ogrzewanie, biomasa, zbiory rozmyte*

1. Introduction

Recently, the European Union has defined the purposes of its energy policy and has set the deadline for achieving them. Until 2020, the effectiveness of energy consumption is supposed to increase by 20%, the share of renewable energy sources in the energy balance is supposed to reach 20%, and CO2 emissions are to be reduced by 20%, as compared to 1990.

The local government act defines local authorities' tasks which include, amongst other things, provision of heat, electric power and gas fuels [13], and the Energy Law [14] makes the local government the main planner and organizer in this scope, so it is also responsible for implementing the objectives of the EU energy policy. Within energy planning, local governments are supposed to determine the size of energy needs and the possibility of satisfying them, especially using local sources of energy, including unconventional and renewable ones. Among all sources of renewable energy, biomass is characterized by the greatest technical potential that can be used quickly and, in particular, in the biomass of primary energy resources, i.e. in wood, straw, hay and in energy crops. To define the degree of meeting the heat demand, it is necessary to estimate the size of this demand in a given region and the local energy potential beforehand, especially that biomass resources are spatially differentiated and the concentration of raw material is one of elements guaranteeing the regularity of its deliveries to the recipients over a longer period of time.

2. Aim of the study

The study was aimed at assessing the possibility of meeting the demand for heat with the use of the local technical potential of biomass in rural areas of the Lubuskie Province and, in particular, its spatial differentiation.

To achieve the aim of the study, the consumption of final energy for heating purposes was defined as well as the energy potential of: wood, surplus straw, hay and energy crops. Districts were categorized according to share of biomass in meeting the demand for heat.

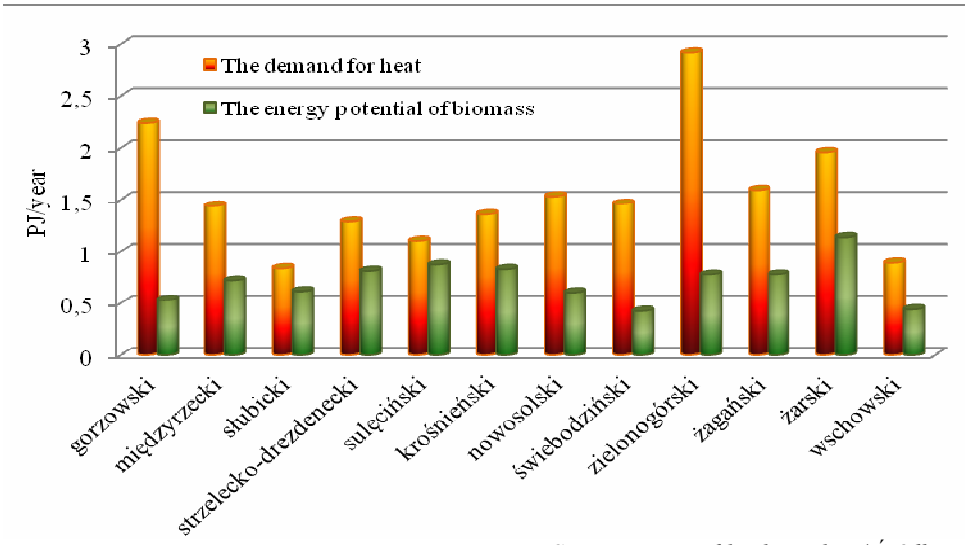
3. Results of research and their analysis

The use of final energy for meeting the heat demand in rural areas of the province was developed on the basis of the study [9], based on statistical data for local government units contained in the “local data bank” of the Central Statistical Office” [1]. The technical potential of solid biomass (wood, surplus straw and hay and energy crops) which can be used for energy purposes was calculated on the basis of the study [8]. The technical potential of biomass with the division into individual districts is presented in Table 1 while a comparison of final energy consumption with the biomass potential is presented in Figure 1.

Table 1. Technical potential of solid biomass in the Lubuskie Province
Tab. 1. Potencjał techniczny biomasy na cele energetyczne w województwie lubuskim

Specification / District	wood and wood waste PJ	energy crops PJ	straw PJ	hay PJ	total PJ
Gorzów	0.37	0.038	0.103	0.018	0.53
Międzyrzecz	0.5	0.027	0.174	0.013	0.71
Słubice	0.48	0.025	0.098	0.01	0.61
Strzelce-Drezdenko	0.7	0.014	0.087	0.013	0.81
Sulęcin	0.76	0.027	0.071	0.015	0.87
Krosno	0.74	0.016	0.060	0.015	0.83
Nowa Sól	0.48	0.014	0.098	0.01	0.60
Świebodzin	0.3	0.007	0.109	0.009	0.42
Zielona Góra	0.6	0.017	0.144	0.017	0.78
Żagań	0.64	0.009	0.121	0.009	0.78
Żary	0.99	0.011	0.120	0.013	1.13
Wschowa	0.32	0.003	0.109	0.009	0.44
total PJ	6.88	0.208	1.294	0.151	8.53

Source: prepared by the author on the basis of [8] / Źródło: opracowanie własne na podstawie [8]



Source: prepared by the author / Źródło: opracowanie własne

Fig. 1. Comparison of final energy consumption for heating with the technical potential of solid biomass in individual districts of the Lubuskie Province
Rys. 1. Zużycie energii końcowej na ogrzewanie i potencjał techniczny biomasy na cele energetyczne w powiatach województwa lubuskiego

In the rural areas of the Lubuskie Province, the demand for heat is heavily differentiated and it ranges from 0.84 PJ in the Słubice District to 2.92 PJ in the Zielona Góra District, with the coefficient of variation of this demand amounting to 37% (Fig. 1). The total heat consumption in rural areas of the province is 18.63 PJ.

The amount of biomass which can be used for energy purposes in individual districts ranges from 0.42 PJ in the Świebodzin District to 1.13 PJ in the Żary District. The technical potential of solid biomass for energy use is 8.53 PJ, with the coefficient of variability of 34%. It allows for meeting approx. 45% of the demand for heat of inhabitants in the districts under analysis.

The differentiation of the demand for heat as well as the possibility of meeting this demand by using biomass for energy purposes were examined using the fuzzy set theory [2, 5, 7, 10].

The fuzzy classification can be formulated in the following way [4].

The Ω set containing n objects is given: P_1, P_2,....., P_n, which are described by m values of variables: X_1, X_2,....., X_m.

The family of fuzzy classes S_1, S_2, ..., S_k ($1 < k < n$) should be defined in the Ω set to meet the following conditions:

$$0 \le f_{sj}(Pi) \le 1 \quad (i = 1, \ldots, n;\ j = 1, \ldots, k) \tag{1}$$

$$\sum_{j=1}^{k} f_{sj}(Pi) = 1 \quad (i = 1, \ldots, n) \tag{2}$$

Where: $f_{sj}(Pi)$ means the degree of affiliation of the P_i object to the S_j.

In the fuzzy classification, the object belongs to various classes with various degrees of affinity. Objects for which the degrees of affinity to the same class are high are very similar, while there are few similarities between objects for which the degrees of affinity to various classes are low.

The iteration method was employed in the study, using the notion of the fuzzy centre of gravity [3, 6, 11] creating three fuzzy classes S1, S2, S3 in which districts with a small, medium and large share of biomass in meeting the demand for heat. The use of fuzzy classification while grouping districts in terms of meeting the heat demand by using biomass for energy generation allowed for obtaining more comprehensive information about the individual classes, owing to the differentiation of the degree of affinity to the individual classes. The results of calculations in which the degrees of affinity to fuzzy classes were defined are presented in Table 2 and illustrated in Figure 2.

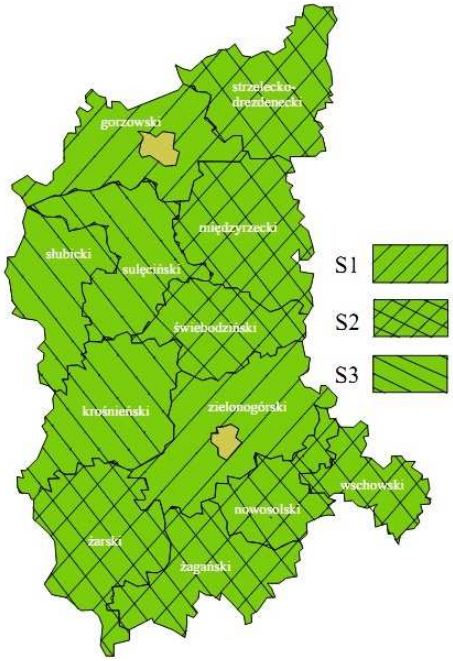


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Fig. 2. Differentiation of the share of biomass in meeting the demand for heat in the area of the Lubuskie Province
Rys. 2. Zróżnicowanie udziału biomasy w pokryciu zapotrzebowania na ciepło na obszarze województwa lubuskiego

Class S3 includes three districts, i.e. Krosno, Sulęcin and Słubice in which the share of biomass for meeting the heat demand is the highest in the province. The Żary District also has a significant degree of affinity to this class. The Wschowa, Międzyrzecz, Żagań and Strzelce-Drezdenko Districts are characterized by the highest degree of affinity in class S2. Two districts in the province belong to the class S2, and these are the Gorzów and Zielona Góra Districts, the Nowa Sól and Świebodzin Districts have a significant degree of affinity to this class. Over a half of districts have significant degrees of affinity to two classes.

While analysing spatial differentiation of districts, it can be noticed that the highest share of biomass in meeting the heat demand occurs in western districts of the province, while it is the lowest in land districts situated around the region's biggest cities (Gorzów Wielkopolski and Zielona Góra) or in ones in their direct vicinity.

Table 2. The degree of affinity of objects to fuzzy classes*
*Tab. 2. Stopnie przynależności obiektów do klas rozmytych**

District	Degree of affinity to a class		
	S1	S2	S3
Gorzów	0.777	0.223	0.000
Międzyrzecz	0.004	0.996	0.000
Słubice	0.000	0.287	0.713
Strzelce-Drezdenko	0.357	0.643	0.000
Sulęcin	0.000	0.184	0.816
Krosno	0.000	0.296	0.704
Nowa Sól	0.678	0.322	0.000
Świebodzin	0.633	0.367	0.000
Zielona Góra	0.709	0.291	0.000
Żagań	0.011	0.989	0.000
Żary	0.000	0.317	0.683
Wschowa	0.006	0.994	0.000

*a value of at least 0.3 was regarded as a significant degree of affinity

Source: prepared by the author / Źródło: opracowanie własne

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