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Spatial Diversity in the Share of Local Sources of Biomass in Meeting Heating Needs in the Rural Areas of Lubelskie Voivodship

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Abstract

An analysis of heat consumption and the potential of biomass energy was made in particular counties of Lubelskie Voivodship and its spatial diversity was analyzed. Demand for heat in the rural areas of the voivodship runs at a level of 12993 GWh/year while potential biomass that can be used for energy is 5333 GWh/year. On this basis it is estimated that biomass' share in the voivodship energy sources for heating needs can amount to 43%. To estimate spatial diversity in the share of biomass in covering demand for heat within the voivodship fuzzy sets were used. The highest biomass participation in meeting heat demand needs appears in the eastern and southern counties of the voivodship (Parczewski, Hrubieszowski, Janowski, Biłgorajski, Kraśnicki, Włodawski counties), while the lowest potential was noted in the counties in the north-west (łukowski, opolski and łęczyński) and these being in the neighbourhood with town counties, including Lublin and Zamość.

Keywords: final energy consumption for heating, biomass potential energy, fuzzy sets

Introduction

According to the Law of 10 April 1997 known as the 'Energy Law' the Minister of the Economy prepared the document known as the Polish Energy Policy through the year 2030 accepted by the Council of Ministers on 10.11.2009, where the national strategy was presented to answer the most important challenges that face the Polish power industry, in the short-term perspective, as well as in perspective the year 2030. Under the ecological obligations set by the European Union (EU) through the year 2020 the quantitative aims, known as "3×20%," are to reduce heating gas emission by 20% in comparison to those of 1990, to reduce energy consumption by 20% in comparison with forecasts for the EU through the year 2020, and augmentation of the share of renewable sources of energy to 20% of the total energy consumption in the EU. The energy law[1] legislates local government as the main planner and organizer responsible for implementation of the energy policy of the EU. The law of local government[2] establishes the tasks of the local powers which include provision of heat, electric current and gas fuel. In the range of energy planning the local government units are to determine the size of energy needs and possibilities to meet these needs in particular by using local, unconventional and renewable sources of energy. Determining heating needs for houses within a given region is one of the key inputs in energy planning (Szul and Trojanowska 2003). To cover the public housing needs for heat that is within its range including the housing sector, social and economic infrastructures and the needs of farms is one of the basic energy challenges. Energy consumption within this sector is about 45% of total EU energy needs (Ballarini and Corrado 2009). In Poland the housing sector consumes about 42% of the country's initial energy and above 80% of it goes to the heating of houses and heating usable

1. See: Ustawa z dnia 10 kwietnia 1997 r. – Prawo energetyczne, DzU z 1997 r. nr 54 poz. 348.
2. See: Ustawa z dnia 8 marca 1990 r. o samorządzie terytorialnym, DzU z 1990 r. nr 16 poz. 95.

water (Trojanowska and Szul 2008). No less important of a factor in a plan for supplying energy is determination of potential renewable sources of energy within a given territory. Among all the types of renewable energy sources the greatest technical potential for quick use appears in biomass, and especially in biomass of primal energy resources such as those found in wood, straw, hay and energy plants. Housing dispersion and territory extent is a characteristic feature of the rural sites. You can characterize potential energy resources such as biomass using such features, and in this case there appears a spatial dispersion of places where the energy resources come from. Therefore, in drafting plans to supply energy within a given region it is necessary to study how local biomass sources can meet the heating needs of consumers, and its spatial diversity to guarantee systematic resource supply.

1 Objective

The target was to analyze the spatial diversity of meeting fuel needs, using the local biomass technical potential of rural areas within Lubelskie Voivodship. Thus, for particular communes within the counties of the voivodship, the final energy consumption and energy potential of wood, surplus of straw, hay and plants from energy farming was determined. Counties were grouped considering biomass' share in supplying fuel for heat.

2 Results and analysis

The calculations of final energy consumption for heating aims were done for 193 rural communes and rural areas of town-village communes grouped into 22 counties of the voivodship. According to the methodology of evaluating energy consumption in rural territories found in the works of Trojanowska and Szul, based on the statistical data for local government entities in the local data bank of the Main Statistical Office,[3] the structures within the communes were divided into three sectors., i.e. housing, public utilities and covered plants. The calculations were done on the base of the statistical data for 2013 updating the results in previous works (Szul 2011a, 2011b). The calculation results are shown in table 1.

Within the analyzed rural territories of the Lubelskie Voivodship, demand for heat is very diverse and it fluctuates from 307 GWh/year in the Parczewski County to 1 645 GWh/year in the Lublin County. Average consumption of final energy runs to 650 GWh/year at the variability rate of these needs which runs to 51%. The total heat consumption within the rural areas of the voivodship amounts to 12 993 GWh/year. The biggest consumer is the housing sector responsible for 86% of the total energy consumption.

Technical potential of solid biomass usable for energy was calculated in accordance with methodology presented in the works of Kowalczyk-Juśko (2010) accepting data of biomass productivity from the works of Frączek (2010), Kościk (2003), Szydeł (*Raport o stanie środowiska…* 2002, 152–164), Zajączkowski (2013). Calculations were made for wood biomass (from forests, orchards, wooden industry and afforestations), straw and hay, and energy plantations. Technical potential of biomass (expressed in energy units) with division for particular counties is compared in table 2.

The quantity of biomass possible for energy purposes in particular counties fluctuates from 100,7 GWh/year in the Opolski County to 563,2 GWh/year in the Bialski County. Technical potential of solid biomass possible for energy use amounts to 5 333,6 GWh/year. Average value for particular counties amounts to 266,6 GWh/yearat the variability factor of 52%.[4]

After calculating consumption quantity of final energy and biomass technical potential in particular counties of the voivodship, we could define the degree of coverage of fuel needs using the local biomass resources which is presented in Drawing 1. The degree coverage is very diverse and

3. See: http://stat.gov.pl/bdl/.

4. [In the journal (in both Polish and English texts) European practice of number notation is followed—for example, 36 333,33 (European style) = 36 333.33 (Canadian style) = 36,333.33 (US and British style). Furthermore in the International System of Units (SI units), fixed spaces rather than commas are used to mark off groups of three digits, both to the left and to the right of the decimal point.—Ed.]

Tab. 1. Final energy consumption in the counties of Lubelskie Voivodship in 2013 (GWh/year)

County	Housing sector	Public sector	Covered plants sector	Together in the county
Bialski	907	113,9	8,9	1 029
Biłgorajski	616	104,2	9,8	730
Chełmski	720	77,4	7,4	805
Hrubieszowski	498	49,7	9,8	557
Janowski	308	54,6	0,7	363
Krasnostawski	520	22,8	13,9	557
Kraśnicki	566	61,9	5,7	633
Lubartowski	597	62,7	5,7	666
Lubelski	1 299	157,9	188,8	1 645
Łęczyński	342	56,2	17,1	416
Łukowski	654	96,9	4,9	756
Opolski	416	43,9	34,2	494
Parczewski	257	44,8	4,9	307
Puławski	563	67,6	21,2	651
Radzyński	438	45,6	4,9	489
Rycki	292	32,6	13,9	339
Świdnicki	287	21,2	4,1	313
Tomaszowski	649	92,8	9,8	752
Włodawski	265	56,2	1,7	323
Zamojski	980	73,3	114,8	1168
Total	1 1174	1 336,0	482,0	12 993

fluctuates from 20% in the Łukowski and Łęczyński counties to 69% in Parczewski County. The average for the 20 counties of the voivodship is about 43% at a variability factor of 39%.

The diversity of demand for heat and the possibilities of meeting it through biomass was examined by grouping counties, using elements of the theory of fuzzy sets (Chojcan 2001; Höppner et al. 1999, 37–49; Jajuga 1984; Jefmański 2009; Kacprzyk 1986; Trojanowska 2003).

The question of fuzzy classification can be expressed as follows (Jajuga 1984): A set Ω is formed, that counts n objects $P_1,P_2,...,P_n$, that are described by values m fuzzies $X_1,X_2,...,X_m$. Within the set Ω one ought to define the fuzzy classes of family $S_1,S_2,...,S_k$ $(1 < k < n)$, to fulfill circumstances:

$$0 \leq f_{sj}(P_i) \leq 1 \quad i = 1, 2, \ldots, n; \; j = 1, 2, \ldots, k, \tag{1}$$

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

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

In the fuzzy classification the object belongs to different classes with different degrees of affiliation. The objects that have a great affiliation degree to the same class are very similar, and objects with a large degree of affiliation to different class are not much alike. In this analysis the iterative method was applied using the conception of a fuzzy center of gravity (Höppner et al. 1999, 37–49; Jefmański 2009; Trojanowska 2003) making three fuzzy clases S1, S2, S3 in which the counties with little, medium and great biomass share in the coverage for fuel demand were gathered. Using the fuzzy classification of grouping counties respecting supply of fuel needs with biomass made it possible to obtain more information about particular classes thanks to analysis of the diversity of degrees of affiliation to fuzzy classes which is shown in table 3 and represented in the figure 2.

Tab. 2. Technical potential of solid biomass in counties of Lubelskie Voivodship (GWh/year)

County	Fuel logs from forests	Scraps from wood industry	Wood scraps from orchards	Logs from afforestations	Straw	Hey to use for energy aims	Biomass of perennial energy	Altogether in county
Bialski	107,4	62,2	3,2	6	279,4	27,3	77,7	563,2
Biłgorajski	93,1	53,9	2,6	2,2	219,8	7,7	56,0	435,3
Chełmski	47,5	27,5	1,4	3,1	252,8	17,9	87,3	437,5
Hrubieszowski	23,8	13,8	0,6	2,8	226,9	7,2	93,8	368,9
Janowski	42,2	24,4	2,2	1,9	137,8	2,2	14,9	225,6
Krasnostawski	22,0	12,8	2,2	2,1	176,2	4,5	53,5	273,3
Kraśnicki	29,9	17,3	7,7	1,9	253,5	2,1	54,2	366,6
Lubartowski	38,6	22,3	1,3	2,5	28,9	10,9	51,4	155,9
Lubelski	26,4	15,3	3,7	3,9	264	4,4	73,5	391,2
Łęczyński	12,6	7,3	1,0	1,5	10,9	6,2	48,7	88,2
Łukowski	38,9	22,5	28,8	2,4	4,0	17,4	40,9	154,9
Opolski	25,2	14,6	1,2	1,7	19,2	9,4	29,4	100,7
Parczewski	33,4	19,3	0,5	1,8	72,5	6,8	79,4	213,7
Puławski	29,8	17,2	2,5	2,1	69,2	4,3	37,2	162,3
Radzyński	29,4	17,0	1,4	2,5	83,2	11,2	49,1	193,8
Rycki	17,1	9,9	0,9	1,4	52,4	4,7	16,2	102,6
Świdnicki	7,0	4,1	2,1	1,3	99,1	1,7	55,5	170,8
Tomaszowski	46,6	27,0	0,7	3,1	196,9	4,9	82,4	361,6
Włodawski	72,6	42,0	1,5	2,0	4,5	14,2	42,8	179,6
Zamojski	60,2	34,8	1,4	3,1	187,1	10,4	90,9	387,9
Total	803,7	465,2	66,9	49,3	2 638,3	175,4	1 134,8	5 333,6

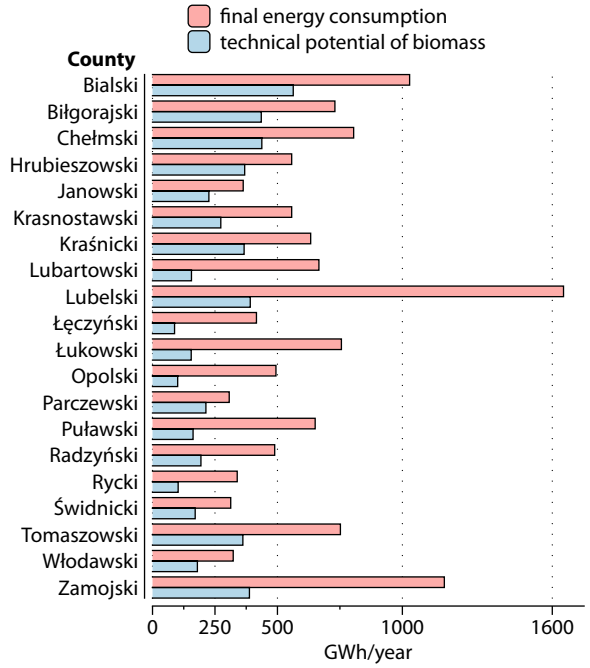

Fig. 1. Heat consumption and technical potential of biomass for energy purposes in the counties of the Lubelskie Voivodship

Tab. 3. Grades of membership of objects to fuzzy clusters (the essential grade of membership to the cluster is a magnitude of at least 0,3)

	Degree of affinity to a class		
County	**S1**	**S2**	**S3**
Bialski	0,000	0,726	0,274
Biłgorajski	0,000	0,568	0,432
Chełmski	0,000	0,764	0,236
Hrubieszowski	0,000	0,503	0,497
Janowski	0,000	0,539	0,461
Krasnostawski	0,000	0,882	0,118
Kraśnicki	0,000	0,664	0,336
Lubartowski	0,573	0,427	0,000
Lubelski	0,568	0,432	0,000
Łęczyński	0,703	0,297	0,000
Łukowski	0,719	0,281	0,000
Opolski	0,709	0,291	0,000
Parczewski	0,000	0,298	0,702
Puławski	0,549	0,451	0,000
Radzyński	0,602	0,398	0,000
Rycki	0,421	0,579	0,000
Świdnicki	0,000	0,732	0,268
Tomaszowski	0,000	0,998	0,002
Włodawski	0,000	0,674	0,326
Zamojski	0,532	0,468	0,000

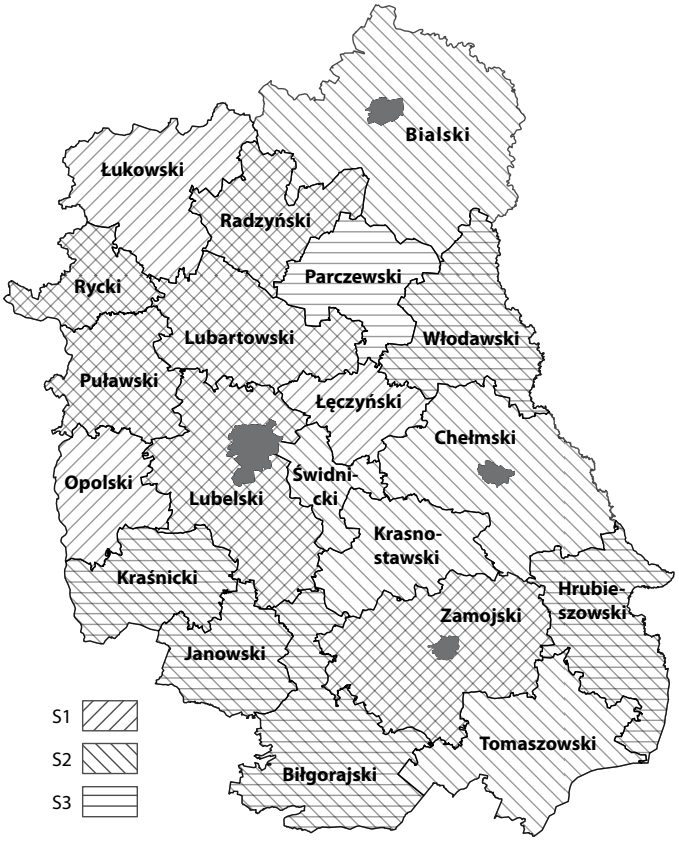

Fig. 2. Diversity of the biomass share in meeting demand for heating fuel in Lubelskie Voivodship

Parczewski County, where biomass participation is greatest in the voivodship, belongs to class S3. Counties with a significant degree of affiliation to the same class include: hrubieszowski, janowski, biłgorajski, kraśnicki and włodawski. In the class S2 the highest degree of affiliation is noted in counties: tomaszowski, krasnostawski, chełmski, świdnicki and bialski. Three counties in the voivodship belong to class S1. They are: łukowski, opolski, lubartowski. A significant degree of affiliation to this class is found in counties: nowosolski, radzyński and lubartowski. More than half of the counties have significant degrees of affiliation to two classes.

Analyzing the spatial diversity of counties one can notice that the highest biomass share is in the eastern and southern counties of the voivodship, while the lowest in the northwest counties and counties located around the largest towns of the region (Lublin, Zamość).

Conclusions

Final energy consumption for heating in the rural areas runs from 307 GWh/year in the Parczewski County to 1 645 GWh/year in Lubelski County. The total heat consumption within the rural areas of the voivodship is 12 993 GWh/year. Technical biomass potential for energy in the particular Counties includes in the interval form 100,7 GWh/year in Opolski County to 563,2 GWh/year in Bialski County. Technical potential of solid biomass is 5 333,6 GWh/year. The degree to which fuel demand is met through local sources of biomass depends on a county, ranging from 20% to 69%. Average for the 20 counties of the voivodship is about 43%. The highest share of biomass for heating fuel is in the east and south counties of the viovodship (Parczewski, Chrubieszowski, Janowski, Biłgorajski, Kraśnicki, Włodawski) while the lowest in the northwest (Łukowski, Opolski and Łęczyński) neighbouring with town counties such as Lublin and Zamość.

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