The state and the perspectives of the eco-energy infrastructure development in Biała Podlaska County (Poland). Part II Estimation of solid biomass resources for energy purposes

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Abstract. The paper estimates the possibility of obtaining solid biomass for energy purposes in the Biała Podlaska County (Lublin Voivodeship, Poland). The estimates were based on data on: forest area, orchards and tree stands, land use, crop structure, animal population, and marginal land area in the County. It was found that in most communes, there are great possibilities of obtaining biomass for energy purposes. The largest resource is straw (243,501 Mg per year), which should first be used in agriculture as animal litter and organic fertilizer. Only its surplus can be intended for the combustion and production of pellets and briquettes. In the County, large areas of poor quality land were inventoried, on which perennial energy plants with low requirements can be grown. Up to 113,595 Mg of biomass can be obtained there. The basic condition for the development of targeted energy crops is the emergence of a biomass market: installations that convert biomass into fuels or produce energy on a local scale and sell it to power plants. Currently, a commonly used resource is wood biomass from forests and wood processing, which is used as fuel in domestic boilers, as well as for the production of pellets and briquettes.

1 Introduction

Solid biomass is currently the dominant component of the Polish energy matrix [1]. Its importance results on the one hand from large resources, compared to other Renewable Energy Sources (RES), on the other hand, from the possibility of using it on a different scale: from wood-fired home boilers with a few kW to specialized boilers in power plants, including boilers with fluidized bed fed with ground biomass of several dozen MW. Besides, wood biomass from forests, which account for about 30% of the area in Poland [1], is mostly in the hands of the state institution: State Forest National Forests Holding, which facilitates trading in raw materials.

Poland's biomass market is not well organized, which is not conducive to the establishment of energy plantations. The hopes that were placed in the development of the energetic use of biomass at the beginning of the 21st century have largely failed [2]. Farmers do not decide on the cultivation of energy crops like perennial species without the guarantee of collecting raw material. On the other hand, power plants and combined heat power plants do not conclude contracts with small biomass producers. In this situation, the needs of energy producers are met by importing biomass, especially from agriculture (so-called agro-biomass) [3]. This is unfavorable due to environmental pollution caused by transport, as well as preventing the implementation of one of the essential aspects of renewable energy: the revival of the national economy, the creation of jobs, and new markets for the sale of agricultural produce. Meanwhile, local biomass resources are plentiful and diverse: wood biomass from forests, orchards and woodlots, straw and hay, whose surpluses are recorded in forestry and agriculture [4-6]. In the situation of a real increase in demand for domestic biomass, it is also possible to increase its supply by establishing energy plantations. Especially, perennial plants, whose biomass has a high calorific value, and the requirements allow for cultivation on low-quality land [7]. The last factor is becoming more and more relevant because the strategic documents of the European Union shape energy policy in such a way as to prevent conflicts between food production and agro-energetics [8]. The primary function of agriculture is food production. In contrast, energy production (in various conversion processes) should be limited to by-products, waste, and crops grown on land unsuitable for food and feed plants [9,10].

The study aimed to assess local solid biomass resources, both currently available and obtainable in the near future, in a selected County with a typically agricultural character. The quantity and energy value of wood biomass from various sources (forests, wood processing, orchards, woodlots), straw and hay, as well as plants that could hypothetically be cultivated on low-quality lands, were estimated.

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2 Materials and methods

The article is part of the research carried out in the Biała Podlaska County (Lublin Voivodeship, Poland), the results of which, including the characteristics of the area and the diagnosis of the state of infrastructure producing energy from renewable sources, were published in the article Listosz et al. [11]. This article covers the analysis of solid biomass resources that are useful for use for energy purposes directly after harvesting (such as fireplace wood) or after initial processing into bales, pellets or briquettes. For each biomass (wood, straw, hay), the use for non-energy purposes (agricultural, industrial, food, feed) was first assumed. Surplus biomass can be treated as a potential energy resource. Methods of estimating energy biomass resources were used, described by Kowalczyk-Juśko [12]. After estimating the amount of biomass from each source, its energy value was determined. The following calorific values for biomass in working conditions were adopted: wood from forests, orchards and tree stands – 8.1 $MJ \cdot kg^{-1}$, wood waste from processing – 11.3 $MJ \cdot kg^{-1}$, straw and hay – 13.9 $MJ \cdot kg^{-1}$, biomass from special purpose crops – 14.1 $MJ \cdot kg^{-1}$. These values are averaged results from own research as well as numerous literature. Estimates were carried out at each Commune level, and the results were added for the County.

Source data came from Local Data Bank [1], Agency for Restructuring and Modernization of Agriculture, Biała Podlaska County Authority Office, and 17 offices of rural communes and 2 municipal offices, which are part of this county. These data included: forest area, timber harvesting, tree growth, orchard area, length of roads, crop structure, cereal yields, animal population, soil complexes, the share of unused meadows.

2.1 Identification of marginal soils for energy crops

It is not advisable to allocate good quality land for energy purposes, which should be the basis for food and feed production. Soils for agricultural use complexes 5, 6, 8, 9, and 3z are most useful for growing energy crops. The analysis was carried out based on soil complexes as indicators of soil quality assessment. The balance sheet includes restrictions resulting from organizational and logistic conditions. Therefore it was assumed to use 10% of the calculated area of marginal land to cultivate perennial plants for the production of solid biomass. In 3 communes, over 30% of the commune area is covered by various forms of nature protection, this percentage was reduced to 5%. It was calculated that in the Biała Podlaska County, at least 12,211 ha of perennial energy crops can be allocated.

2.2 Land use structure

Agricultural land (67.1%) dominates in the land use structure of the analyzed county and includes: arable land (66.6%), meadows (20.1%), pastures (7.9%), and orchards (1.4%). Due to the county's agricultural nature, the basic energy raw material could be by-products formed in agriculture and the agri-food industry, as well as biomass from special-purpose crops. However, the low utilization of biomass resources from agriculture means that in practice, wood biomass, mainly derived from forests, which constitute 27.4% of the county area, is more important.

3 Results

3.1 Estimation of wood biomass resources

3.1.1 Forest biomass resources

Wood from forests and the industrial processing this raw material is currently the most important source of biomass used in boiler rooms of individual houses as well as in combustion and co-combustion processes in power plants and combined heat power plants. The resources of this raw material are limited because, in Poland, rational and sustainable forest management has been conducted for many years, allowing the use of forest resources while maintaining the sustainability of forests and leading to an increase in the forest cover of the country. Uncontrolled logging from forests can have negative effects on complex, multi-species forest ecosystems [13].

Forest biomass resources, which can be used for energy purposes in the Biała Podlaska County, amount to almost 35,000 Mg, which is the equivalent of over 282,000 GJ per year (Table 1). The following municipalities have a significant share in the biomass resources of the county: rural Biała Podlaska (12.4% of the total forest biomass resources), Drelów (11.6%), and the rural commune of Międzyrzec Podlaski (9.7%). The municipalities of Terespol (17 Mg per year) and Międzyrzec Podlaski (85 Mg per year) have a low technical potential of wood biomass from forests, which results from their low afforestation.

3.1.2 Waste wood resources from wood processing

Significant resources of waste wood arise during the processing of raw material in wood processing and processing plants. These are sawmills, woodworking craft factories, furniture industry plants (production of panels and furniture), paper and pulp industry factories. There are 26 wood processing plants in the county [11]. Wood waste resources were assessed based on the volume of timber harvested from the state and private forests located in the Biała Podlaska County. It was assumed that wood waste (sawdust, sawdust, chippings, chips, etc.) constitutes on average 20% of the initial mass intended for processing [14,15].

The analysis showed that the estimated amount of wood waste that can be obtained annually in the Biała Podlaska county is about 12,000 Mg (Table 1). The energy value of this waste is over 142,000 GJ. The limitation in using these resources is that a significant part of the waste generated during the processing of

Table 1. Technical and energy potential of biomass from various sources in the communes of the Biała Podlaska County

Territorial Unit (commune)	Unit	Wood			Straw	Hay	Special purpose crops
		forest	wood processing	orchads and trees			
Międzyrzec Podlaski*	Mg	85	31	18	1 961	130	0
	GJ	689	350	146	27 258	1 807	0
Terespol*	Mg	17	6	16	465	64	0
	GJ	138	68	130	6 464	890	0
Biała Podlaska	Mg	4 312	1 560	154	29 224	1 851	15 758
	GJ	34 927	17 628	1 247	406 214	25 729	222 188
Drelów	Mg	4 037	1 461	85	13 273	1 971	6 599
	GJ	32 700	16 509	689	184 495	27 397	93 046
Janów Podlaski	Mg	1 135	411	82	12 589	968	3 143
	GJ	9 194	4 644	664	174 987	13 455	44 316
Kodeń	Mg	2 162	782	80	7 859	824	7 896
	GJ	17 512	8 837	648	109 240	11 454	111 334
Konstantynów	Mg	1 047	379	110	11 966	207	1 702
	GJ	8 481	4 283	891	166 327	2 877	23 998
Leśna Podlaska	Mg	754	273	50	12 541	496	5 282
	GJ	6 107	3 085	405	174 320	6 894	74 476
Łomazy	Mg	2 517	911	104	20 007	1 183	13 718
	GJ	20 388	10 294	842	278 097	16 444	193 424
Międzyrzec Podlaski	Mg	3 378	1 222	107	29 944	1 355	11 824
	GJ	27 362	13 809	867	416 222	18 835	166 718
Piszczac	Mg	2 500	905	65	17 992	897	8 835
	GJ	20 250	10 227	527	250 089	12 468	124 574
Rokitno	Mg	2 229	807	59	7 526	485	4 994
	GJ	18 055	9 119	478	104 611	6 742	70 415
Rossosz	Mg	1 051	380	27	8 087	508	2 483
	GJ	8 513	4 294	219	112 409	7 061	35 010
Sławatycze	Mg	275	100	87	7 039	602	3 455
	GJ	2 228	1 130	705	97 842	8 368	48 716
Sosnówka	Mg	1 887	683	67	14 649	1 080	5 747
	GJ	15 285	7 718	543	203 621	15 012	81 033
Terespol	Mg	1 079	391	87	4 619	1 156	3 302
	GJ	8 740	4 418	705	64 204	16 068	46 558
Tuczna	Mg	2 313	837	61	19 021	1 116	7 728
	GJ	18 735	9 458	494	264 392	15 512	108 965
Wisznice	Mg	1 590	575	147	15 069	1 466	5 901
	GJ	12 879	6 498	1 191	209 459	20 377	83 204
Zalesie	Mg	2 485	899	77	9 702	737	5 227
	GJ	20 129	10 159	624	134 858	10 244	73 701
Biała Podlaska County	Mg	34 853	12 610	1 482	243 501	17 096	113 595
	GJ	282 309	142 493	12 004	3 384 664	237 634	1 601 690

*urban commune

wood in processing plants is used for the heating needs of these plants. Besides, waste is a raw material for the production of chipboard. Part of the raw material in the processing process is subjected to chemical substances and is thus useless for further energy purposes. Sawdust, which is used for the production of briquettes and pellets, is an important raw material generated during sawmill processing. Two plants are producing this type of solid fuel in the county [11].

3.1.3 Waste wood resources from orchards, woodlots and roadsides

Woodlots are productive and protective clusters of trees and shrubs outside the forests. They occur along communication routes and watercourses, as well as among agricultural crops, next to houses and outbuildings. To ensure road safety, constant care of roadside trees is necessary. Waste wood from fruit growing arises during the liquidation of old plantations and annual sanitary cuts (trees infected with diseases, pests, broken trees). Liquidation of the old orchard occurs on average 25 years after planting trees, and natural defects account for an average of 2% of the forest stand annually.

The estimated amount of waste wood from cleanouts, sanitary and renovation cuts, and roadside trees in Biała Podlaska County, obtained as a result of calculations, is about 1,500 Mg per year and energy value of over 12,000 GJ (Table 1). In practice, wood from branches,

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cleanouts and refurbishment cuts is used by households as a raw material for burning in boilers. Part of this resource is burned directly in the field and has no energy use. Only large orchards are of interest to companies involved in obtaining biomass for power plants. Waste wood from the cleaning of roadside tree care is often shredded and left at the place of harvest for natural decomposition. For now, obtaining this type of wood can be troublesome, but the proper organization of work can bring benefits in the form of an energy resource that can meet the needs of, e.g., local boiler rooms.

3.2 Straw and hay resources for energy purposes

Cereal straw potential is considered to be the most considerable untapped energy potential in agriculture. Most often, this raw material is used for agricultural purposes, including litter, fodder, or plowed as fertilizer. Its surpluses can be a valuable raw material for energy production. The reason for the creation of surplus straw is the decreasing number of livestock, with a simultaneous increase in the share of cereals in the crop structure. The decrease in the number of cattle and sheep, as well as changes in the animal feeding system, were the reason for abandoning the use of part of the permanent grassland area (meadows and pastures) or mowing them without harvesting. A rational way to use these surpluses is to burn them in boilers adapted for compressed straw or to produce briquettes and pellets. This will reduce the burning of straw in the fields, which is an environmentally hazardous activity (currently prohibited in Poland) and will also provide the valuable raw material for the power industry.

In the first place, straw should cover the demand for animal production (litter and fodder) and maintain a balanced sheet of soil organic matter (fertilization by plowing). Agriculture has a high demand for straw, therefore, by estimating the amount of straw that can be used for energy purposes, its demand in agriculture was calculated based on head-count and structure of sown crops, according to the methodology [12].

Hay resources from unused meadows were also estimated. It has been assumed that in Poland, the average hay yield from meadows where particular care is not carried out is 4.5 $Mg \cdot ha^{-1}$.

Analyzing the amount of straw technical potential in individual communes of the Biała Podlaska County, it was found that the largest occurs in the rural communes of Międzyrzec Podlaski and Biała Podlaska (about 30,000 Mg per year). Significant straw resources (about 20,000 Mg per year) can be obtained from the Łomazy and Tuczna communes (Table 1). The total potential of straw that can be used in the County is annually over 243,000 Mg. The potential of hay that can be used for energy purposes in the County is over 17,000 Mg per year.

The management of surplus hay and straw for energy purposes would allow obtaining over 3,622,000 GJ of energy. In addition to the significant benefits of managing agricultural surplus biomass, one should take into account the difficulties arising from their acquisition. These resources are fragmented, in the case of hay, often difficult to access in wetlands, and the quality of these raw materials is very diverse and depends on the humidity and content of mineral impurities, which are ash and negatively affect the operation of power boilers [16].

3.3 Plant biomass resources for energy purposes

Renewable energy development strategies in Poland tend to reduce the use of biomass from forests in favor of agro-biomass. In addition to waste biomass from agriculture, energy crops may also be found in the consumption structure of this biomass. Such plantations are established on more deficient soils where it is difficult to obtain satisfactory crops for feed and food. Especially perennial species, such as, for example, fast-growing grasses (*Miscanthus giganteus*, *Miscanthus sacchariflorus*, and *Spartina pectinata*) or *Sida hermaphrodita* are suitable for permanent planting. High-yielding varieties of *Salix viminalis* can be planted in excessively humid places due to high water requirements. Energy plantations are not very common in the Lublin Voivodeship. However, it is possible to approximate the potential of land and the biomass obtained from it, which will be an energy raw material.

10% of their area was assumed to be a safe level of use of marginal land suitable for energy crops. According to this estimation, the total area of energy crops in the Biała Podlaska County may amount to about 12.2 thousand ha. The technical potential of biomass to obtain from these lands, with an assumed yield of 9.3 Mg/ha, is over 113,000 tonnes, and its energy value exceeds 1,601,000 GJ (Table 1).

3.4 Total solid biomass potential in the Biała Podlaska County

The calculated potential of solid biomass in the Biała Podlaska County is differential in Communes (Fig. 1) and amounts over 423,000 Mg per year, whose energy value is 5,670,000 MJ (Fig. 2). Agricultural waste biomass in the form of surplus straw for energy purposes has the largest share in this potential (59.69%). An important source of solid biomass in the County may be the biomass of perennial energy crops (28.24%), grown on marginal lands. This potential is theoretical, because plantations of perennial energy plants in the County, according to information from commune offices, occupy a total area of only 32 ha. The establishment of these plantations depends on the emergence of a real biomass market and the profitability of its production. Wood biomass (from forests, wood processing, orchards, mid-field, and roadside tree stands) accounts for 7.88% of the total energy potential of the County. However, in fact, wood in various forms is the most-used biomass raw material.

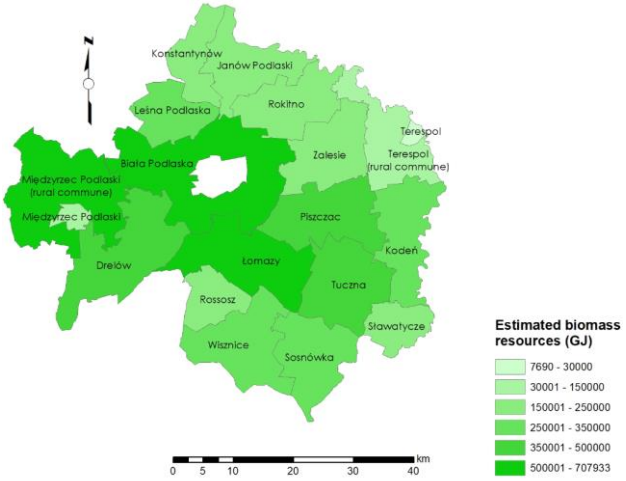

Fig. 1. Estimated biomass resources (GJ) in communes of Biała Podlaska County.

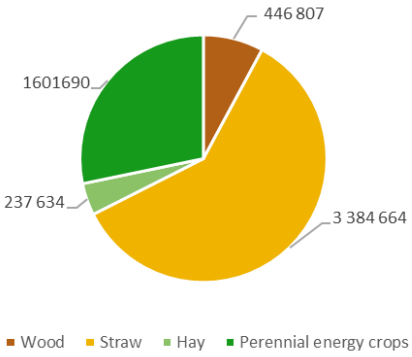

Fig. 2. Potential of energy (GJ) in the Biała Podlaska County.

4 Conclusions

1. An initial estimate of the potential of solid biomass, which can be obtained in the Biała Podlaska County (Poland), for energy purposes indicates that it amounts to about 423,000 Mg per year. The most energy can be obtained from crops (mainly straw – about 59.69% of the total biomass potential in the county), and then from plantations that could be established on poor quality agricultural land.
2. It is estimated that over 5.67 million GJ of energy stored in available solid biomass resources can be obtained annually in the Biała Podlaska County without compromising the food security of the region or country.
3. Until the spread of energy crops, solid biomass from forests is the basic raw material for energy.
4. The estimated biomass energy potential gives a great understanding of the problem on a county scale. An indication of the biomass potential is essential because of the low unit weight, increasing transport costs. The most rational solution is to use biomass on a local scale, e.g., for heating communal buildings, individual residential buildings, or local boiler rooms.

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