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The potential opportunities for using wood biomass in energy production

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Abstract. This paper presents results of a meta-analysis on the theoretical and economic aspects of using wood biomass for the production of energy in Poland. The source data used in the analyses were obtained from various official sources and statistics as well as previously published scientific studies. The results lead to the conclusion that the wood biomass supplied for energy production in the year 2012 amounted to a total of 18 million cubic meters, of which forestry supplied 6.8 million m^3, the wood industry 6.5 million m^3 and public utilities provided 4.5 million m^3.

Keywords: bioenergy, fuel wood, forest residues, energy plantation

1. Introduction

The use of renewable energy sources is at present one of the most interesting topics, which has become the main subject for many scientific papers. Current research concerns biomass, which is a renewable natural resource and one of the most environmentally friendly energy sources. Biomass is a substance that results from the metabolic activity of living organisms. It can serve as an energy source at every step of its transformation (Jabłoński, Wnuk 2009). The definition of biomass is given in the second paragraph of the regulation issued by the Minister of Economy on October 18, 2012 (Dz. U. 2012, 1229). Current research explores the biomass defined in statistics as solid biofuel (Energy from renewable sources in 2012), and more specifically it researches wood. Wood biomass for energy purposes mainly originates from forestry and the wood industry (wood processing, cellulose, paper as well as furniture production). Other sources of biomass include agriculture and municipal public waste (Fig. 1).

The goal of the current research is to explore theoretical and economic aspects of using wood biomass for energy purposes in Poland. It is important to emphasize that energy value may have different interpretations. Theoretical energy value of renewable energy sources is defined as the theoretically possible production of energy from biomass (Fig. 2). Technical energy value is the amount of energy that during one year could be obtained from national resources using the best technologies of energy production starting with renewable sources and ending at final energy ports. From the other side, economic energy value is a part of technical value, which could be utilized according to existing economic conditions. Technical energy value is defined in relation to actual possibilities of energy use in current economic conditions. In the case of waste wood, its whole technical value is assumed to be its economic value. In the case of energy plantations, their economic value is calculated taking into account environmental limitations and limitations related to access to the given area without restricting national food self-sufficiency. And finally, the market value is estimated according to the degree to which economic value could be used efficiently with the existing support system. In the case of dry waste wood biomass, its market value is equal to its economic value.

One of the main limitations affecting biomass resources' availability for energy purposes is legislative protection of environmentally valuable areas (national parks, reserves, landscape parks, areas of protected landscape, geological documentary sites, ecological sites, nature and landscape complexes, as well as natural monuments; Niedziółka 2012,

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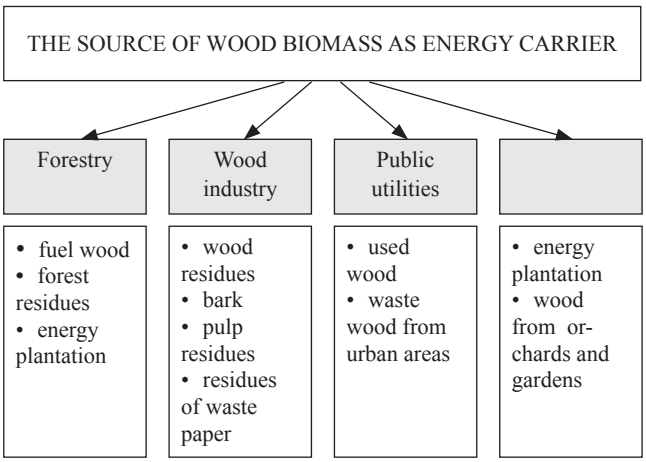

Figure 1. The place of creation and kinds of wood biomass for energy production
Source: Ratajczak, Bidzińska 2013

EC BREC 2007). According to statistical sources, the area of such sites varies from 18.6% in theDolnośląskie Province to 64.5% in the Świętokrzyskie Province (Ochrona Środowiska 2013).

2. Methods

Evaluation of potential use of wood biomass (theoretic, technical and economic) for energy purposes was based on data about natural resources, their economic capacity and utilization based on technologies available on the market, and not on support systems, which deform market state especially when plantations of fast-growing trees are involved. Due to this reason, the current work did not take into consideration the market potential.

Potential use of wood biomass for energy purposes was calculated for the whole area of Poland in 2012 with division into four main places of their origin: forestry (which presented a main study area), wood industry, municipal solid waste and agriculture.

In the case of forestry, calculations included fuel wood, volumes of which were obtained from statistical sources (Leśnictwo 2004–2013), as well as wood residue. It would be important to note that paragraph 2 of the Regulation of the Minister of Economy from October 18, 2012 (Dz. U. 2012, 1229) introduced the new definition which is "full value wood", which includes wood with qualities described in standards accepted for large-diameter broadleaf wood, large-diameter coniferous wood and also medium-diameter wood from the groups described as S1, S2, S3 as well as wood products obtained as a result of cutting those types of wood. According to the above regulation, such wood cannot

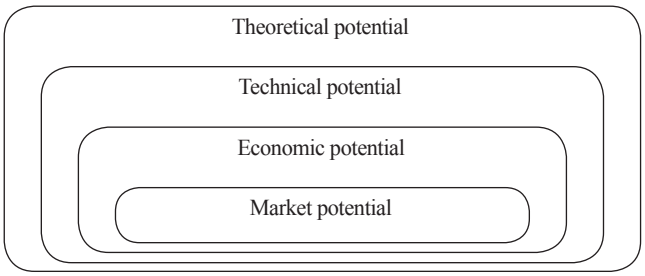

Figure 2. Estimated value of renewable energy resources
Source: Determination of energy value for renewable energy sources in Poland 2011, EC BREC 2007

be formally used for energy production. Therefore, only fuel wood S4, low-diameter wood and tree stumps could be used for energy purposes.

Theoretical potential of forest residue used for energy purposes was calculated according to assumed percentage shares of the following fractions (Płotkowski, Piekutin 2007):

- OZN (logging residue) – 6%,
- DTN (thinning residue) – 4%,
- BK (stump and root biomass) – as 10% of dendromass,
- BD (wood available from wood biomass balance).

BD is a hypothetically available biomass estimated from the difference between annual increment and harvest volume multiplied by established share of OZN, DTN and BK fractions. The current annual harvest reaches about 60% of the annual increment (Raport o stanie lasów w Polsce 2012).

Technical potential depends on the quality of available logging equipment and technology, which allows the utilization of the following amount of each fraction (Płotkowski, Piekutin 2007 according to Karjalajnen et al. 2004):

- OZN – 75%,
- DTN – 45%,
- BK – 20%,
- BD – 25%.

Additionally, the OZN and DTN fractions were reduced by 50% following the assumption about manual method of harvesting.

Economic potential of forest residue is defined as the amount of biomass that could be truly harvested within current economic conditions. Biomass coming from tree stumps is not economically efficient. That is why harvesting in forests reached 0.1–0.3 thousand m^3 and any increase in harvesting of this type of biomass for energy purposes is not being foreseen. Tree stumps are extracted only in certain circumstances such as clearing of area for road construction. In line with this, estimated volume of such biomass is very low – about 1 thousand m^3. However, OZN and DTN fractions were at the level of their technical potential. The BD

fraction was estimated at its technical potential but without consideration of stump and root biomass.

The supply of biomass from the wood industry in Poland was estimated according to the research by Ratajczak and Bidzińska (2013). As indicated in the above study, wood residue generated from the manufacture of wood products amounts to 95% of forest biomass, while used wood 70%.

Information on biomass potential from energy plantations was obtained from the study "Estimating energy potential of renewable energy sources for different regions of Poland".

3. Results

Research indicates that the largest forest biomass resources could be found in western and northern provinces of Poland, where main forest areas are located. According to the data of the Main Statistical Office from December 31, 2012, the area of forests in Poland was 9370 thousand hectares, which corresponds to 29.3% forest cover and in relation to land area of Poland this number was 30.6% (Leśnictwo 2013). In order to estimate the volume of wood available as energy resource along with forest area it would also be important to enclose information on forest property structure. Public forests dominate in Poland (81.2%) with State Forests covering 77.3% of the total area. Coniferous species grow on 69.9% of the forest area. The third age group dominates the age division covering an area of more than 26%.

Forest growing stock with the division by provinces is presented in Fig. 3. Zachodniopomorskie Province with almost 223 thousand m^3 and Podkarpackie Province with more than 201 thousand m^3 have the most vast forest resources. Those provinces also contain forest stands with the largest volume per hectare or 276 m^3 and 300 m^3, respectively. Total forest resources of Poland in 2012 were about 2.5 million m^3 of timber (over bark) with average volume per hectare being 263 m^3 (over bark per hectare of forest area).

Timber harvesting can also reflect the state of forest resources. In 2012, timber harvesting in Poland was 37045 million m^3, from which 95% was harvested in the State Forests. The share of merchantable size timber was about 94%. The share of fuel wood harvested in the State Forests is presented in Table 1 and on average is equal to 7.5% of harvested merchantable timber and 67% of small-diameter timber, which for the total harvest gives a share of 11.3%. The annual average volume of fuel wood harvested from private forests is about 185 thousand m^3, which presents 14.7% of large-diameter timber (Table 2).

Table 3 presents total removal of timber by provinces with the assumption that the removal of low-diameter timber in

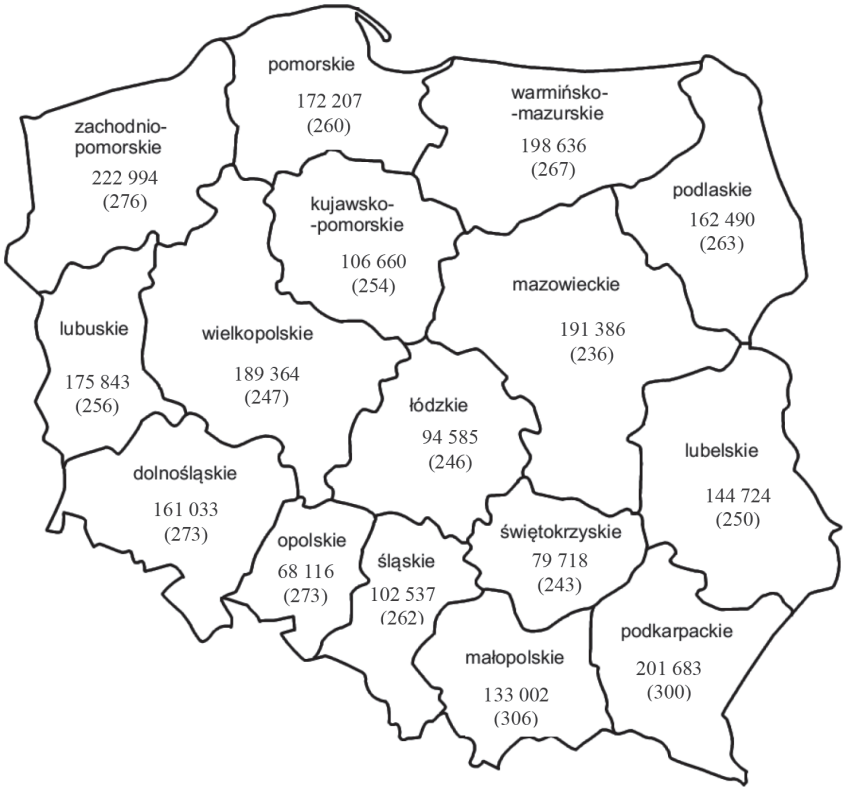

Figure 3. Growing stock of forest in Poland (in thous. m^3) and resources in 2012 (m^3)
Source: Forestry 2013

Table 1. Removals of fuel wood in The State Forests National Forest Holding in 2003–2012

Years	Timber [thous. m^3]		Slash [thous. m^3]		Fuel wood [%]
	total	fuel wood	total	fuel wood	
2003	27 134	2 094	2 086	1 284	11.6
2004	28 698	1 817	2 294	1 315	10.1
2005	28 164	1 855	2 207	1 305	10.4
2006	28 700	2 025	2 142	1 326	10.9
2007	32 314	2 086	1 777	1 109	9.4
2008	30 695	2 277	1 854	1 260	10.9
2009	31 188	2 496	1 916	1 379	11.7
2010	31 882	2 418	1 888	1 398	11.3
2011	32 789	2 822	2 286	1 770	13.1
2012	33 212	3 085	2 055	1 609	13.3
Average annual	30 478	2 298	2 051	1 376	11.3

Source: Forestry 2004–2013

Table 2. Removals of fuel wood in private forests in 2003–2012

Years	Timber [thous. m^3]		Fuel wood [%]
	total	fuel wood	
2003	1 151	142	12.3
2004	1 269	151	11.9
2005	1 124	149	13.3
2006	1 098	158	14.4
2007	1 349	172	12.8
2008	1 248	171	13.7
2009	1 089	177	16.3
2010	1 244	210	16.9
2011	1 633	277	17.0
2012	1 349	244	18.1
Average annual	1 255	185	14.7

Source: Forestry 2004–2013

private forests is at the same level as in the State Forests (coefficient of 1.06 in relation to merchantable timber). In 2012, in the State Forests timber harvesting from thinning operations accounted for about 52% and from final harvest almost 44%. From the data included in Table 3 it could be observed that total timber harvest in Poland was more than 38 million m^3. The largest timber removal was in the Zachodniopomorskie Province and was equal to more than 4.3 million m^3.

Table 4 presents potential volumes of wood biomass that could be obtained from the forest sector. From the data above it could be seen that theoretical potential is equal to more than 16.9 million m^3, while technical potential is only 4.2 million m^3 and economic potential available for removal is only 1.8 million m^3 (in addition to more than 4.9 million m^3 of fuel wood as indicated in statistical data). Therefore, the total volume of energy wood in 2012 in Poland was almost 6.8 million m^3. The largest volumes could be found in Zachodniopomorskie and Warmińsko-mazurskie Provinces, and the lowest in Łódzkie, Świętokrzyskie and Małopolskie Provinces. In addition to the above sources, more than 6.5 million m^3 of residue from the wood industry could also be used for energy purposes. This volume includes 2.9 million m^3 of wood from sawmill operations and more than 1.7 million m^3 from furniture production (Table 5). However, the largest part of used wood available for energy purposes is contributed by used furniture and wood elements originat-

Table 3. Removals from forestry and trees and shrubs in 2012 by voivodships (timber + slash)

Voivodship	Public forests	Private forests	Trees and shrubs	Total
	thous. m^3			
dolnośląskie	3 005.2	12.4	53.8	3 071.5
kujawsko-pomorskie	1 748.0	37.4	67.0	1 852.5
lubelskie	1 576.1	178.5	109.7	1 864.3
lubuskie	3 028.0	16.9	32.2	3 077.1
łódzkie	1 072.2	87.0	76.2	1 235.4
małopolskie	1 048.0	210.6	72.0	1 330.6
mazowieckie	2 054.7	182.7	194.9	2 432.4
opolskie	1 275.9	13.5	22.4	1 311.8
podkarpackie	2 443.9	119.9	55.5	2 619.4
podlaskie	1 730.8	124.8	49.5	1 905.0
pomorskie	2 943.9	103.9	35.1	3 082.9
śląskie	1 668.4	120.1	46.6	1 835.2
świętokrzyskie	1 160.7	79.9	23.6	1 264.3
warmińsko-mazurskie	3 517.7	47.3	60.4	3 625.4
wielkopolskie	3 094.8	83.3	87.3	3 265.4
zachodniopomorskie	4 278.6	11.1	42.8	4 332.5
Poland	35 647.1	1 429.3	1 029.3	38 105.6

Source: Own elaboration on the basis Forestry 2013 (coefficient 1.06)

Table 4. Estimated value of biomass from forest sector (forest residues)

Voivodship	Biomass potential [thous. m^3]		
	theoretical	technical	economic
dolnośląskie	1 363.7	335.5	147.9
kujawsko-pomorskie	822.5	202.3	89.2
lubelskie	827.8	203.6	89.8
lubuskie	1 366.2	336.1	148.2
łódzkie	548.5	134.9	59.5
małopolskie	590.8	145.3	64.1
mazowieckie	1 080.0	265.7	117.2
opolskie	582.4	143.3	63.2
podkarpackie	1 163.0	286.1	126.2
podlaskie	845.8	208.1	91.8
pomorskie	1 368.8	336.7	148.5
śląskie	814.8	200.4	88.4
świętokrzyskie	561.3	138.1	60.9
warmińsko-mazurskie	1 609.7	396.0	174.6
wielkopolskie	1 449.9	356.7	157.3
zachodniopomorskie	1 923.6	473.2	208.7
Poland	16 918.9	4 162.0	1 835.5

Source: Own elaboration (on the basis of removals amounting to 38 105.6 m^3 – from table 3)

ing from house construction, which amounts to almost 0.8 million m^3 (Table 6).

According to the authors of the study "Estimating energy potential of renewable energy sources in various regions of Poland", theoretical area available for permanent energy plantations in 2013 was 6.11 million ha (Table 7). However, after eliminating areas located on sites with low precipitation where underground water is not constantly available, protected or valuable due to their biodiversity areas, the remaining area is equal to about 2.18 million ha. Yet, economic potential is equal to only 641 thousand ha. This occurs due to benefits received for biomass production, which were set to be equal to production for food purposes as well as bonuses for risk related to new production. It was implemented through prices offered by the energy sector established at the level of 21 PLN/GJ (on field). From the data presented in Table 7, it could be seen that the largest economic potential could be found in Lubelskie, Mazowieckie and Podkarpackie Provinces, where more than 38% of the total national production is located. It would be important to notice that in 2012 the area of long-term energy plantations in Poland was only about 10.5 thousand ha.

Using the assumption that wood density of poplar and willow (the main species for energy plantations) in a fully dry state is 400 kg/m^3 (poplar density is used; Dzurenda et al. 2011), the economic potential of energy plantations could amount to about 14.8 million m^3 of wood. Therefore, the economic potential of the calculated area of energy plantations will be 641 thousand ha. However, currently only 10.5 thousand ha are used for that purpose, which transfers into 243 thousand m^3 of wood biomass supply (971 thousand t of dry matter).

Therefore, the total estimated wood biomass supply in 2012 in Poland reached the level of 18 million m^3 (Table 8).

Assuming that the energy value of wood is about 9 GJ/m^3, the energy potential of wood biomass in 2012 would be 162 PJ.

4. Discussion

The advantage of biomass in comparison to other renewable energy sources opens up the possibility to shape that resource depending on the accepted national energy policy, such as introducing changes to plantation structure towards various energy species or improving the efficiency of agricultural and forestry residue utilization. Dzurenda et al. (2011) report that depending on tree species, the percentage share of wood in wood biomass varies between 60 and 80%, bark – 10–20%, and green biomass 10–20%. While the data should be treated with certain caution, it could be assumed that wood comprises 60% of the total biomass harvested in forest and the remaining part includes above-ground parts of trees,

Table 5. Estimated supply of biomass from wood sector in Poland in 2012

Specification	Biomass [thous. m^3]	%
Wood industry	4 056.9	62.8
of which:		
sawmill	2 855.3	44.2
wood-based panels	981.9	15.2
building joinery	219.7	3.4
Furniture manufacturing	1 724.8	26.7
Pulp and paper industry	678.3	10.5
Wood sector	6 460.0	100

Source: On the basis Ratajczak. Bidzińska 2013

Table 6. Estimated supply of biomass from public utilities in Poland in 2012

Specification	Biomass [thous. m^3]
Used wood	4 460.0
of which:	
used furniture (20%)	952.0
elements of used buildings (16%)	761.6
used packages (13%)	618.8
used windows and doors (12%)	571.2

Source: On the basis Ratajczak. Bidzińska 2013

Table 7. Estimated supply of biomass from long-term power plantations

Voivodship	Theoretical potential		Technical potential		Economic potential	
	[tys. ha] [k ha]	[tys. t s.m.] [k t dm]	[tys. ha] [k ha]	[tys. t s.m.] [k t dm]	[tys. ha] [k ha]	[tys. t s.m.] [k t dm]
dolnośląskie	250.9	2 301.0	103.7	926.2	36.6	352.5
kujawsko-pomorskie	374.0	3 434.0	154.2	1 412.9	51.6	485.1
lubelskie	555.4	5 133.8	201.0	1 831.2	104.9	984.3
lubuskie	248.6	2 184.8	63.3	564.3	14.0	124.9
łódzkie	489.7	4 621.4	163.8	1 542.3	23.6	216.2
małopolskie	111.1	1 102.8	55.6	535.2	35.1	348.0
mazowieckie	984.5	9 032.0	307.1	2 827.8	72.9	647.1
opolskie	149.6	1 530.1	68.6	682.6	7.9	90.8
podkarpackie	203.2	1 911.4	85.9	780.1	70.0	626.7
podlaskie	481.2	4 184.2	166.2	1 455.7	40.3	321.3
pomorskie	313.3	2 989.9	115.0	1 083.8	23.9	230.9
śląskie	162.2	1 593.1	53.3	517.1	22.5	214.4
świętokrzyskie	232.2	2 110.7	85.7	772.0	30.7	280.0
warmińsko-mazurskie	419.7	3 845.6	162.2	1 476.2	35.8	336.6
wielkopolskie	717.7	6 511.8	255.1	2 324.9	24.3	205.5
zachodniopomorskie	417.4	3 914.2	144.2	1 335.1	46.5	454.0
Poland	6 110.6	56 401.1	2 184.8	20 067.4	640.7	5 918.1

Source: Determination of energy value for renewable energy source in Poland

Table 8. Estimated supply of biomass for energy production in Poland in 2012

Specification	Biomass [m m^3]
Forestry	6.8
Wood industry	6.5
Public utilities	4.5
Plantation	0.2
Total	18.0

Source: Own elaboration

stump and roots, which are not commercially used. Therefore if the annual harvest of merchantable timber is around 38 million m^3 (with about 25 million m^3 left behind in the forest), theoretically the wood available for energy purposes would amount to 30 million m^3 (with 4.9 million m^3 of fuel wood being currently harvested).

From the data presented in the State of Forests in Poland report from 2012 it could be seen that the share of harvested annual increment in different countries is quite diverse. For example, in the Czech Republic it equals to about 75%, in Sweden and Slovak Republic it is above 80% and in Austria reaches more than 90%. Thus, increase in timber harvest in Poland (which would also increase the amount of harvested fuel wood) should not result in negative consequences.

Sites available for energy or forestry plantations could be supplemented by abandoned or requiring recultivation areas. These areas are anyway in no current use, while they could make a significant input for increase of energy wood potential as their area is more than 530 thousand ha (Rocznik Statystyczny Rolnictwa 2012). Large part of unused areas is located within the Mazowieckie (more than 62 thousand ha) and Podkarpackie Provinces (more than 50 thousand ha).

Jabłoński and Wnuk (2009) estimate that the theoretical potential of biomass that could be produced in Poland without causing losses in food production and with inclusion of fields that are currently lying dormant, flooding and contaminated areas may amount to about 360–400 PJ/year. It is understandable that economic potential would be relatively low and use of contaminated areas for energy wood production is questionable. Meanwhile Pisarek and Hunder (Sokólska 2001) assess that in Poland technical potential of biofuel is about 684.6 PJ per year, from which 407.5 PJ comes from solid biofuel (similar estimates are presented by EC BREC and IBMER 2000), which could be divided into groups of surplus biomass received from:

• agriculture – 195 PJ (straw from cereal plants – 147 PJ, straw from rapeseed – 23 PJ and hay – 25 PJ),
• forestry – 101 PJ,
• gardening – 57.6 PJ,
• residue from wood industry – 53.9 PJ.

Szczukowski and Stolarski (2013) present somewhat different estimates of the area potential of agricultural lands available for energy purposes. Their work indicates that in Poland almost 1 million ha could be set aside for farming of energy plants. Most of them are located in the Zachodniopomorskie and Mazowieckie Provinces, covering an area of more than 100 thousand ha. The largest share could be found in the Podkarpackie Province and is equal to more than 10%. The authors emphasize that in 2010 long-term energy plantations in Poland covered only 10200 ha, which is about 0.06% of the total agricultural area.

The European Commission predicts the increase of renewable energy use, which will affect land management. Using land area for biomass production could conflict with other goals such as protection of environmental sustainability, biotypes, soil and water protection, or organic farming (Rode, Schlegelmilch 2006). Therefore, the use of areas for biomass production will be competitive to agricultural and food production or nature protection. They could also have a negative effect on the protection of the natural environment and landscape. In the case of forestry, such a risk is related to excess of plantations of fast-growing species, reduction in final harvest age, inappropriate site conditions, exceeding planned harvesting volumes or over-removal of snags.

5. Summary and conclusions

Based on the implemented analysis, it could be stated that in 2012 the estimated volume of wood biomass for energy purposes in Poland was about 18 million m^3 (economic potential). Forestry provided 6.8 million m^3, including more than 4.9 million m^3 of fuel wood S4 with more than 1.8 million m^3 of forest residue. The volume obtained from wood industries was estimated to be 6.5 million m^3, with the largest shares coming from sawmill operations – 44.2% and furniture production – 26.7%. Municipal services supplied around 4.5 million m^3 of wood biomass, which included 20% coming from used furniture and 16% of wood elements coming from building construction. The economic potential of energy plantations was evaluated to be 14.8 million m^3, while in 2012 only 0.2 million m^3 of wood biomass was received from that source. However due to the fall in the biomass market, the increase of energy plantation area is not foreseen in the coming years.

Yet it is obvious that the whole existing wood biomass cannot be used for energy purposes as other products originate from it. Production of bioenergy should consider other more preferential utilization methods of wood biomass, which should be used wisely and sustainably.

Conflict of interests

The author declares absence of potential conflicts.

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