

RESEARCH PAPERS

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MARKET IN WOOD BY-PRODUCTS IN POLAND AND THEIR FLOWS IN THE WOOD SECTOR

Wood by-products, i.e. waste from consecutive stages of roundwood processing in the production of wood materials and products, are significant in the rational management of raw wood material resources. They are a supplementary source of wood – an alternative to primary sources. This article presents results of research on the market of wood by-products in Poland in 2015, their resources and flows in various applications. Due to the lack of full and reliable information on the Polish market in those products, the research was based on a methodical solution using a model approach supplemented with a fragmentary survey and expert's knowledge. The research revealed that potential resources of wood by-products created in the wood sector in Poland amounted to more than 13 million m³ in 2015 (with imports included, the quantity was 14.8 million m³), of which it was estimated that 6.2 million m³ was intended for material processing, 5.8 million m³ for energy purposes, and approximately 1 million m³ for other purposes. It also showed that 61% of those resources (9.1 million m³) was directly used in the wood sector for both production and energy purposes.

Keywords: wood by-products, zero-waste economy, model approach, cascade wood consumption, wood supply, wood demand

Introduction

Sustainable development of the wood sector is more and more often considered within the context of a zero-waste economy and inter-industry flows – a model imitating the functioning of nature and connecting economic growth with an innovative approach to the management of available resources [Webster 2015;

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Geissdoerfer et al. 2017]. The imperative goal of such a model is to build an economy where the value of products, materials and resources is maintained as long as possible, and the creation of any type of waste is limited to a minimum [Dobbs et al. 2011; Bachorz 2016]. This phenomenon is also known as a zero-waste economy or a closed-loop economy [Fiedor et al. 2002; Mair and Stern 2017]. Contradictory to the model of linear economy (a model based on the principle: take-make-use-dispose [Kassenberg and Świerkula 2015]), whose premises do not account for the scarcity of resources and their reuse, circular economy assumes a closed flow of raw materials, it attributes various functions (also called utilities) to the environment (implications of the interactions between the economy and the environment), and the product is perceived as one of the elements of a cycle of processing and multiple use [Pearce and Turner 1990; Kozłowski 1991]. Therefore, a circular economy makes it possible to maintain the added value of wood products as long as possible and eliminate/reuse the waste created during manufacturing of those products [Communication 2011; European Commission 2014].

Poland is largely a self-sufficient country in terms of wood resources (it is one of the major European holders of wood resources¹). Nevertheless, the growing wood industry requires more and more raw material and recently there have been shortages of wood [Adamowicz et al. 2016]. The growing demand for raw wood material also stems from the necessity of fulfilling the international obligations concerning the development of renewable energy sources and thereby form a fierce competition for wood demonstrated by the power sector [Ratajczak and Bidzińska 2013; Gołos and Kaliszewski 2015; Mapping Study... 2016; Janeiro and Resch 2017]. Therefore, the importance of wood by-products (i.e. waste from consecutive stages of roundwood processing in the production of wood materials and products) increases when they are regarded as a significant, supplementary source of wood (an additional resource) and an alternative to primary sources [Szostak 1997; Ratajczak 2013; Szostak and Ratajczak 2003]. Those products create an additional market in raw materials, and their use brings not only ecological effects, but also considerable economic benefits [Wood Manufacturing By-Products 2005]. A modern approach to material and energy management regards traditional methods of collection and getting rid of post-production waste as prodigality that is accompanied by a high cost and often huge burden to the environment. It is thought that the rational management of post-production waste in the wood sector, should be based on the cascade use of raw materials model [Ratajczak 2013]. The model presents a simplified situation and stems from the idea of wood processing technology and input-output flows. After the production stage is over (i.e. the conversion of wood into wood materials and subsequently into final wood products is complete), the created wood by-products are 'turned back' to the technological

¹In terms of forest area, Poland is the sixth country in the European Union, in terms of raw wood material resources is the fourth, and in terms of wood removals is the fifth [Leśnictwo 2015].

process in situ or elsewhere (secondary production use). If they are unsuitable for this purpose, they are burnt with energy recovery (in situ or elsewhere) [Odegard et al. 2012; Sokka et al. 2015; Vis et al. 2016].

In Poland, the management of wood by-products may be deemed rational. The market in wood by-products in Poland was the subject of research conducted by various scientific institutions, as well as the Wood Technology Institute [Ratajczak and Szostak 1994; Danecki and Rodzeń 1997; Szostak 1997; Cichy and Prączyński 1999; Szostak and Ratajczak 2003]. Despite that research, there is still a cognitive gap mainly concerning the current volume of wood by-product resources and their flows, as well as research methods and tools allowing a comprehensive analysis of this market. The current reporting system in Poland does not allow the determination of the actual supply of and demand for wood by-products.

This article presents the results of research on the market in wood by-products in Poland, supported by a methodological approach, carried out at the Wood Technology Institute in 2016. The aim of the research was to determine the supply of wood by-products in 2015 (taking into consideration their types, forms, and main sources, i.e. places where they are created) and also to define their flows in the wood sector, inter alia, for production (material) and energy purposes [Szostak et al. 2016].

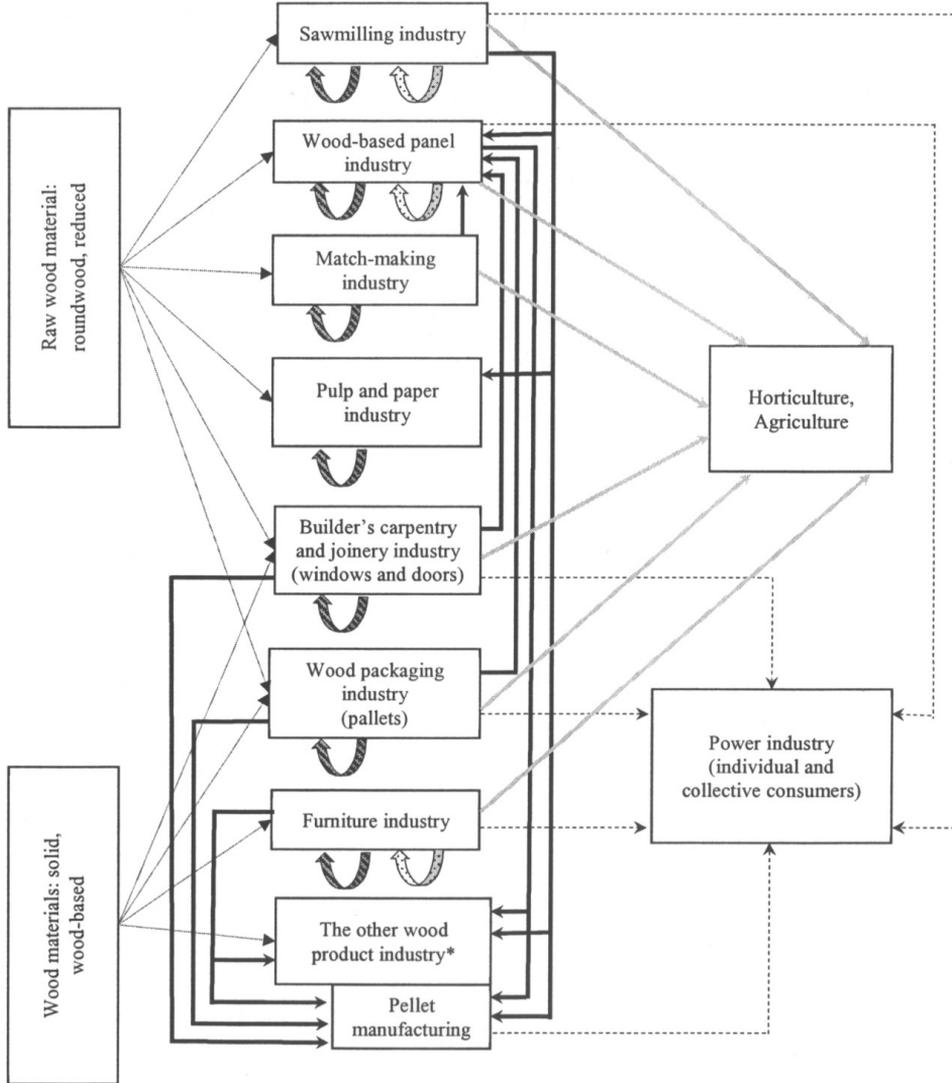
Research methodology

The research on the Polish market of wood by-products in terms of their flows focused on two economic categories, i.e. supply (by source, type and form) and consumption (management) in basic applications, i.e. the use for material purposes (for secondary production in situ and elsewhere), for energy purposes (for a company's own purposes and for sale), as well as for other purposes. The research was based on a premise that the material use of wood by-products is a priority.

The subject of the research were wood by-products originating from the wood sector, i.e. a field of manufacturing where wood and its derivatives are comprehensively processed. According to the idea of a production sequence, where industries are distinguished by the raw wood material they use, the wood sector considered in the research encompassed the following industries: sawmilling, wood-based panels, builder's carpentry and joinery (windows and doors), wooden packaging, furniture, match-making, and pulp and paper. Figure 1 presents the strength and directions of the wood by-products flows. These flows are very diverse and result from the nature of supply and demand, they can also be intra-industry, inter-industry and outside of the sector.

The potential resources of wood by-products were determined using a model approach where the supply was a derivative of the production volume of individual wood materials and products and the raw material/material efficiency

of technologies used for the processing of wood and wood materials. The approach required the adoption of detailed assumptions concerning [Szostak et al. 2016]:



* E.g. the producers of wooden accessories, toys, games, sports equipment etc.

Flows of wood by-products:

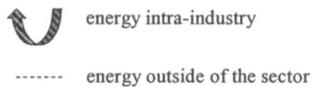
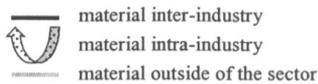


Fig. 1. Flows of wood by-products created in the wood sector in Poland

Source: own compilation of the authors' team

- the volume and assortment structure of the production of basic wood materials and major products in individual industries of the wood sector,
- the raw material/material efficiency of the production of major wood materials and products resulting each time from, inter alia, the raw material type and quality, production assortment and modernity of techniques and technologies used for wood processing,
- the volume of production losses during the processing of wood at individual processing stages,
- the type of wood by-products and their percentage in individual wood industries.

The model approach was also a useful methodical solution in the case of the demand for wood by-products. It was assumed that their potential consumption for the secondary material processing resulted primarily from the production volume and the production process technology, which determined as to what level the wood by-products might have been used as a raw material (i.e. what were the possibilities of substituting wood by-products for roundwood without any effect on the quality or dimension parameters of the product). Therefore, it was necessary to define in detail [Szostak et al. 2016]:

- the percentage of wood by-products consumed for companies' own production purposes in individual industries,
- the percentage of wood by-products created in individual wood industries and sold for production purposes,
- the technological conditions of the structure of the raw material feed in the production of basic wood materials,
- the type (including the form) of wood by-products consumed for production purposes in individual wood industries,
- the scale and scope of possible raw material substitution (wood by-products for roundwood) in the production of basic wood materials.

On the other hand, the consumption of wood by-products for energy purposes was determined using the method of the 'rest' based on the premise that only products not used for production purposes may be consumed for energy purposes (the priority of the processing of wood by-products for material purposes). Additional assumptions concerned:

- the percentage of wood by-products used for companies' own energy purposes in individual wood industries,
- the percentage of wood by-products created in individual wood industries and sold on the power market,
- the type (including the form) of wood by-products consumed for energy purposes.

In the case of the wood by-product flows for other purposes, (apart from production and energy) its volume was determined by the method of the 'rest', also used in the methodical approach to the determination of the consumption for energy purposes. Additional assumptions concerned:

- the proportion of wood by-products created in wood industries and sold to consumers from outside the wood sector,
- the type (including the form) of wood by-products consumed for other purposes (apart from production and energy).

To characterise the market in wood by-products in Poland and estimate the self-sufficiency of the wood sector in terms of supply in that type of raw material, the authors employed a useful analytical tool – ‘balance’, which is a juxtaposition of the supply sources and volume on one side with the places and volume of consumption on the other. On the supply side, the ‘balance’ allowed for imports of wood by-products, whereas on the consumption side it allowed for exports [Parobek et al. 2014].

In the case of the potential supply of wood by-products and their consumption, the detailed assumptions of the model approach were based on the results of research in this field (most often fragmentary) carried out in Poland [Ratajczak and Szostak 1994; Szostak 1997; Danecki and Rodzeń 1997; Szostak and Ratajczak 2003] as well as abroad [Forest Products... 2010; Mantau et al. 2010; Mantau 2012; Saal et al. 2017]. The research results were supplemented by the opinions of experts and specialists in the investigated field and by a direct survey of Polish wood producers (a mail query). The questionnaires, tailor-made for each producer group, contained questions (closed, half-open, one-option and multi-option), whose scope in the part pertaining to the supply of wood by-products concerned issues such as the indices of wood material consumption in production; the volume, types and assortments of raw wood material consumed in production; the volume, types and forms of wood by-products created during production. The part of the survey pertaining to the management of wood by-products concerned issues such as: their percentage consumed for companies’ own production and energy purposes (considering their types and forms); the percentage of wood by-products sold for production and energy purposes and for other purposes (also considering their types and forms). Respondents for the survey (477 in total) were selected using purposive sampling due to a large dispersion of often numerous and hard to identify groups of producers of individual wood materials and products. The main criterion of the respondent selection was their type of business according to NACE classification. Approximately 13% of the respondents sent their answers back.

Results of the research

The research revealed that in 2015 the industries of the wood sector in Poland created more than 13 million m³ of wood by-products, which was 32% in relation to domestic removals of roundwood. Inclusive of imports (approximately 1.8 million m³ in 2015) the total resources of wood by-products were estimated to have been 14.8 million m³ (table 1).

Table 1. Resources of wood by-products in Poland in 2015

Sources of wood by-products	Wood by-products			
	in total	of which:		of which:
		solid	wood-based	bark
thous. m ³				
Sawmilling industry	6259.0	5883.5	–	375.5
Wood-based panel industry	2406.0	520.0	1144.5	741.5
Match-making industry	6.5	5.0	–	1.5
Builder's carpentry and joinery (windows and doors)	328.5	299.0	29.5	–
Wooden packaging industry (production of pallets)	1150.0	1011.0	–	139.0
Furniture industry	1582.0	134.0	1448.0	–
Pulp and paper industry	657.5	65.5	–	592.0
In total	12389.5	7918.0	2622.0	1849.5
<i>Wood by-products from the production of wood materials and products omitted in the model approach¹</i>	<i>620.0</i>	<i>396.0</i>	<i>131.0</i>	<i>93.0</i>
In total	13009.5	8314.0	2753.0	1942.5
<i>Imports</i>	<i>1778.5</i>	<i>1778.5</i>	–	–
IN TOTAL	14788.0	10092.5	2753.0	1942.5

¹Random factor (index of error of the estimate) determining the scale of possible error of the estimates concerning the period in question (it was assumed that the error was 5% of the calculated supply of wood by-products created in the wood sector in Poland in 2015). Calculations had to allow for the error due to the complexity of the process of estimation of the supply of wood by-products, resulting especially from the significant diversification of a considerable and hard to identify group of wood materials and products and their material structures, as well as from the inaccessibility of some of the required data.

Source: calculations based on the adopted detailed methodical assumptions and data by the Central Statistical Office.

The sawmilling industry, as well as the wood-based panel industry and the furniture industry are major sources of wood by-products in Poland. The estimated share of the sawmilling industry within the total resources of wood by-products (imports included) was over 42% in 2015 (48% of their volume was created in the Polish wood sector, without imports) and the shares of the other two industries were more than 16% and 11%, respectively (18% and 12%, respectively, without imports). The structure of the resources of wood by-

Table 2. Applications of wood by-products created in the wood sector in Poland in 2015

Sources of wood by-products	of which for:							
	In total	production purposes			energy purposes			other ¹ sale
		in total	company's own	sale	in total	company's own	sale	
thou. m ³								
Sawmilling industry	6259.0	3880.5	375.5	3505.0	1970.0	1338.5	631.5	408.5
Wood-based panel industry	2406.0	935.5	248.5	687.0	939.5	623.5	316.0	531.0
Match-making industry	6.5	-	-	-	6.5	6.5	-	-
Builder's carpentry and joinery (windows and doors)	328.5	17.0	-	17.0	311.5	148.0	163.5	-
Wooden packaging industry (pallets)	1150.0	448.5	-	448.5	687.5	300.0	387.5	14.0
Furniture industry	1582.0	607.5	114.0	493.5	941.5	500.5	441.0	33.0
Pulp and paper industry	657.5	-	-	-	657.5	657.5	-	-
In total	12389.5	5889.0	738.0	5151.0	5514.0	3574.5	1939.5	986.5
<i>Wood by-products from the production of wood materials and products omitted in the model approach²</i>	<i>620.0</i>	<i>295.0</i>	<i>37.0</i>	<i>258.0</i>	<i>276.0</i>	<i>179.0</i>	<i>97.0</i>	<i>49.0</i>
IN TOTAL	13009.5	6184.0	775.0	5409.0	5790.0	3753.5	2036.5	1035.5

¹E.g.: agriculture, horticulture, tanning etc.

²Random factor (index of error of the estimate) determining the scale of possible error of the estimates concerning the period in question (it was assumed that the error was 5% of the calculated consumption of wood by-products created in the wood sector in Poland in 2015). Calculations had to allow for the error due to the complexity of the process of estimation of the consumption of wood by-products, resulting especially from the significant diversification of a considerable and hard to identify group of wood materials and products and their material structures, as well as from the inaccessibility of some of the required data.

Source: calculations based on the adopted detailed methodical assumptions and data by the Central Statistical Office.

purposes were sawdust and chips (37% of the estimated volume of wood by-products consumed as energy carriers) as well as pieces (33%). The structure of by-products used for other purposes was dominated by bark (79% of the number of wood by-products consumed for other purposes). Research revealed that the highest quantities of wood by-products in the form of pieces were used for companies' own production purposes in the sawmilling industry

Table 3. Balance of supply and consumption of wood by-products in Poland in 2015 – self-supply of the wood sector industries in products created by them

Industry	Supply of wood by-products	Consumption of wood by-products				Balance
		in total	own		purchased	
			for:			
			production purposes	energy purposes	production purposes	
thou.m ³						
Sawmilling	6259.0	1714.0	375.5	1338.5	–	+4545.0
Wood-based panel	2406.0	5108.5	248.5	623.5	4236.5	-2702.5
Match-making	6.5	6.5	–	6.5	–	0.0
Builder's carpentry and joinery (windows and doors)	328.5	148.0	–	138.0	–	+180.5
Wooden packaging (pallets)	1150.0	300.0	–	300.0	–	+850.0
Furniture industry	1582.0	614.5	114.0	500.5	–	+967.5
Pulp and paper	657.5	769.5	–	657.5	112.0	-112.0
In total	12389.5	8661.0	738.0	3574.5	4348.5	+3728.5
<i>Wood by-products from the production of wood materials and products omitted in the model approach¹</i>	<i>620.0</i>	<i>433.0</i>	<i>37.0</i>	<i>179.0</i>	<i>217.0</i>	<i>+187</i>
In total	13009.5	9094.0	775.0	3753.5	4565.5	+3915.5

¹Random factor (index of error of the estimate) determining the scale of possible error of the estimates concerning the period in question. Calculations had to allow for the error due to the complexity of the process of estimation of the consumption of wood by-products, resulting especially from the significant diversification of a considerable and hard to identify group of wood materials and products and their material structures, as well as from the inaccessibility of some of the required data.

Source: compilation based on tables 1-2.

Having taken into consideration the inter-industry flows, imports, exports and consumption for material purposes in the economic sectors other than the wood sector, it was concluded that in 2015 the calculative supply of wood by-products in Poland exceeded the calculative demand by 3.8 million m³ – table 4.

connected with the operation of the wood sector, and recently also of the power sector, because wood by-products are an alternative to wood from the forest, and thus they contribute to forest wood savings (especially in the periods of raw material shortages). They are also an important energy carrier. Their rational use brings significant economic and ecological benefits conducive to the protection of natural environment and the quality of human life, which is the basis of the sustainable development idea and is also in line with the idea of a circular economy, i.e. a zero-waste economy featuring a closed loop.

Despite the great importance of wood by-products for the operation of both the wood sector and the power sector, and despite broad research of this market, there is still an information barrier in Poland concerning the current volume of wood by-product resources and their flows in the wood sector and outside of the sector. There is also a cognitive gap regarding research methods that would allow comprehensive analyses of this market. Hitherto, in Poland we have faced the lack of full, systematically delivered, up-to-date and reliable information on the volume and structure of wood by-products supply and demand. Data obtained from public statistical reporting are scarce and fragmentary, therefore, they cannot be used alone as a basis for comprehensive analyses of this market.

In this situation, the determination of potential wood by-products flows require one to work out their own methodical approach that would additionally allow for expert's knowledge and possibly for results of direct research. Expert knowledge and direct research are especially important for broadening and verifying the knowledge about the resources of wood by-products, taking into consideration where they are created, in what form and type, and what their functional properties are. They are also significant with regards to the determination of wood by-products applications and verification of the assumptions behind the models of assessment of these by-products' potential and possible options of their management.

It is assumed that the supply of wood by-products is primarily a derivative of the quantity of wood material consumed in production and the raw material efficiency of the production process. On the other hand, the potential consumption of wood by-products (from various sources and in various types and forms) primarily stems from the production volume of wood materials and technological conditions of the production processes which determine the possible level of use of wood by-products as an alternative to traditional raw material.

The market in wood by-products in Poland, as well as their flows in the wood sector, is largely determined by a significant diversification of the sector industries and the assortment structure of manufactured materials and products. The market is an implication of the volume of production of wood materials and products, the diversity of the production processes, the assortment of tailor-made products and different stages of modernity of techniques and technologies of wood processing and of the production of wood materials and products.

The research shows that in 2015 in Poland:

- 13 million m³ of wood by-products might have been created in the wood sector in Poland, which was 32% in relation to domestic roundwood removals from the forest; 48% of them were used for production purposes, 44% for energy purposes and approximately 8% for other purposes (agriculture, horticulture etc.); it is estimated that 35% of their volume was consumed directly in situ, i.e. by the wood sector industries (for their own production and energy purposes), whereas 65% was sold,
- wood by-products were primarily created in the sawmilling industry, whose share within their supply from the wood sector was 48%; the highest amounts of wood by-products were consumed in the wood-based panel industry, whose consumption of them for material and energy purposes was estimated to have been 39% of the resources originating from the wood sector,
- the potential resources of wood by-products from the wood sector were dominated by solid products, whose share was 64%, wood-based by-products accounted for 21%, and bark for 15%; by-products were mainly in the form of pieces – 47% of the estimated supply from the wood sector, and sawdust and chips – 30%,
- wood by-products in the form of pieces were primarily used for production purposes (68% of the total estimated amount of wood by-products used for this purpose), sawdust and chips as well as wood by-products in the form of pieces were used for energy purposes (37% and 33%, respectively, of the volume of wood by-products consumed for energy generation); bark accounted for the highest percentage of wood by-products used for other purposes (79% of the volume of wood by-products consumed this way),
- the calculative supply exceeded the calculative demand by more than 3.8 million m³, taking into consideration the flows of wood by-products for material and energy purposes in the wood sector (intra-industry and inter-industry), the volume of their imports and exports, and the consumption for material purposes in the economy sectors other than the wood sector (exo-sectoral flows); that meant that the surplus could have been used as an energy carrier in the power sector (outside the wood sector); however, according to the estimates, the power sector's demand for wood biomass is considerably higher,
- 70% of wood by-products (considering the internal flows of wood by-products (consumption by the industries which created them) and their external flows (without imports and exports), i.e. the flows to consumers from other processing industries or other economy sectors) were used in the wood sector industries and the rest could have been used by other consumers from outside the wood sector.

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