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# Agricultural vs forest biomass: production efficiency and future trends in Polish conditions

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**Abstract.** Biomass is one of the main sources of renewable energy with rapidly growing trend in the European Union countries. The technical potential of biomass energy in Poland is one of the highest in Europe, estimated at approximately 900 PJ/year. Solid biomass is the primary Polish RES and the share in the structure of production in Poland amounted to almost 77% in 2015. The most common types of biomass are waste raw materials from crop fields and forests.
The paper presents current potential of the biomass of two basic types, i.e. agricultural and forest material, based on the analyses developed with the scenario forecast of future use in Poland. Detailed considerations include differences in efficiency of agricultural and forest biomass production. To develop the efficiency aspects some indices were proposed to compare potential of energy production basing on different kind of biological material.

**Key words:** solid biomass, renewable energy, energy efficiency.

## INTRODUCTION

The objective of this article is to show future potential of energy usage of the most common types of biomass available in Poland: agricultural and forestry wood wastes.

According to statistic data, energetic potential of agricultural waste in Poland is $10^7$ tons annually[1] only from straw (cereal straw understand as stalks of threshed grain, especially of wheat, rye, oats, or barley) which could covers approximately 4% of country primary energy demand.

Apart from straw, wood wastes coming from the forestry production[2] and the wood industry determined types of energy sources that comprise woodchip and the smallest fractions of wood that usually being used in the form of briquettes or pellets.

On account of the minimum price and the greater availability, the most common used biomass in energy power plants in Poland is the one of forest origin. Taking into consideration the contribution of forestry biomass and remaining types of biomass, consuming wood wastes constitutes about 70% of the total volume. Consumption per input of energy transformations in 2015 accounted for 34.29% of national consumption,

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[1] Total mass after harvesting.

[2] Defined as any material wastes from forestry, logging, timber trade, and the production of forest products, timber/lumber and primary forest.

with 86.77% of the consumption falls on power plants and power generation plants (ARE, 2015).

The pie chart (Fig. 1) compares the share of biomass consumption in Polish energy sector. The largest share occurs to forest biomass which increases to over 49%. The smallest part, has a biomass energy crops, which results from a small area of plantations in Poland. In the coming years, there may be an increase in the consumption of this type of biomass, but it will be up to a few percent.

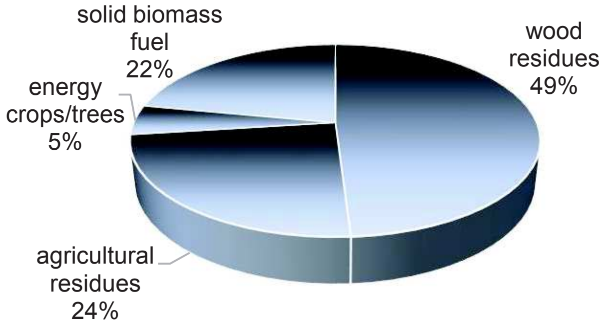


**Figure 1.** The structure of average biomass consumption in Polish energy sector (ARE, 2015).

The main features of biomass are as following (Strzelczyk & Wawszczak, 2008):

– modulus and respective deformations;
– the low calorific value – ranges: 6 MJ kg$^{-1}$ (waste), 15–16 MJ kg$^{-1}$ (wood chips, straw), 18 MJ kg$^{-1}$ (pellet);
– high moisture content in the raw biomass (45–60%) strongly reduces its calorific value, and negatively affects the efficiency of the combustion process.

The main determinant of calorific value for every types of biomass is humidity which in case of fresh straw varies between 12–22% and for fresh woodchips 50–60% (Table 1).

**Table 1.** Selected properties comparison – straw and woodchips

| Parameter | Unit | Straw | Woodchips |
|---|---|---|---|
| Humidity contain | wt% | 20 | 40 |
| Ash contain | DM | 3–4 | 0.6–1.5 |
| Carbon contain | wt% | 42–43 | 50 |
| Flue dust | wt% | 70–73 | 70 |
| Gross calorific value | MJ kg$^{-1}$ | 15.4–16 | 10.4 |
| Net calorific value | | 18.2–18.7 | 19.4 |

*Source: Hołubowicz-Kliza, 2007.*

Recent changes in national legislation, which could serve was observed in the years 2014–2015 in the field of renewable energy sources (RES), environmental protection and waste management, provide problem of new opportunities of biomass management and possibilities for energy plant development. Responsibilities of the state to maintain the growth of the share in use of energy from renewable sources in the primary energy consumption does not allow only the actions of market mechanisms.

## MATERIALS AND METHODS

The base for all calculation was data about annual crop production in Poland since 2009, for basic types of crops: wheat, rye, barley and triticale (Fig. 2). As it can have been seen below (Fig. 2) accumulated value of production fluctuates in time, which generates difficulties in estimation method selection.

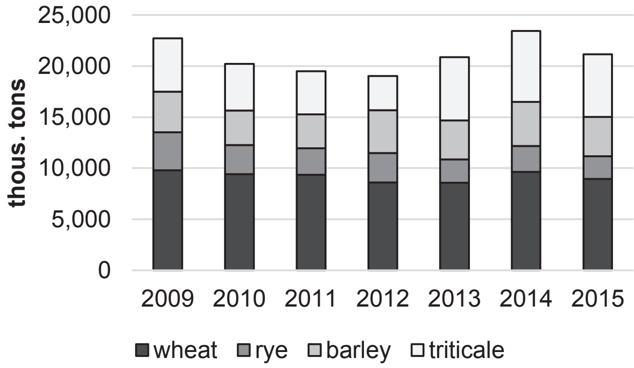


**Figure 2.** Annual crops production in Poland. (*Source: own elaboration based on (GUS, 2015–2009)*).

Estimation of wheat production was prepared according to crops purchase (Table 2) with three year move using linear regression:

$$Y \approx f(X, \beta) \qquad (1)$$

Linear regression calculates an equation that minimizes the distance between the fitted line and all of the data points. The statistical measure of fitted the data to regression line – coefficient of determination $R^2$ was relatively high amounted to 0.82.

**Table 2.** Annual value of crops purchase

| Year | Wheat | Rye | Barley | Triticale | Total |
|---|---|---|---|---|---|
| | Thousand tons | | | | |
| 2009 | 5,614.1 | 1,295.4 | 785.6 | 705.2 | 8,400.3 |
| 2010 | 5,603.2 | 940.6 | 850.9 | 777.7 | 8,172.4 |
| 2011 | 5,674.7 | 661.7 | 756.9 | 516.3 | 7,609.6 |
| 2012 | 5,689.6 | 1,004.9 | 1,046.0 | 610.5 | 8,351.0 |
| 2013 | 5,040.0 | 1,280.3 | 948.3 | 681.1 | 7,949.7 |
| 2014 | 6,805.5 | 1,101.6 | 811.6 | 1,007,2 | 9,725.9 |

*Source: own elaboration based on (GUS, 2015–2010).*

Next step was to carry out the multiple regression with independent variables (Eq. 2), i.e. rye ($x_1$), barley ($x_2$), and triticale ($x_3$) annual production volumes and dependant variable – wheat annual production what give $R^2$ = 0.80 and equation like below:

$$y = 0.974x_1 + 0.059x_2 + 0.497x_3 \qquad (2)$$

Independence of observation was checked using Durbin-Watson statistic test.

All parameters in the study were distributed normally. Data were expressed as mean ± standard deviation. Differences were tested by two-tailed t-test. Pearson's correlation was used to analyse the association between all studied parameters. The values $P < 0.05$ were considered statistically significant.

To evaluate the potential of straw for energy purposes the total amount of harvest straw has to be reduced by its consumption in agriculture (firstly, straw must cover the needs of animal production (litter and feed) and maintain a sustainable balance of soil organic matter (fertilization).

Following formula was used for calculation:

$$N = P - \left(Z_s + Z_p + Z_n\right)[t] \tag{3}$$

where: N – straw surplus for energetic use; P – straw total production; $Z_s$ – demand for bedding; $Z_p$ – demand for litter; $Z_n$ – demand for mulch.

Results of the calculation is shown on Fig. 3 and as it can be seen its quantity varies in the time in relation to total volume as well as single crop's straw type.

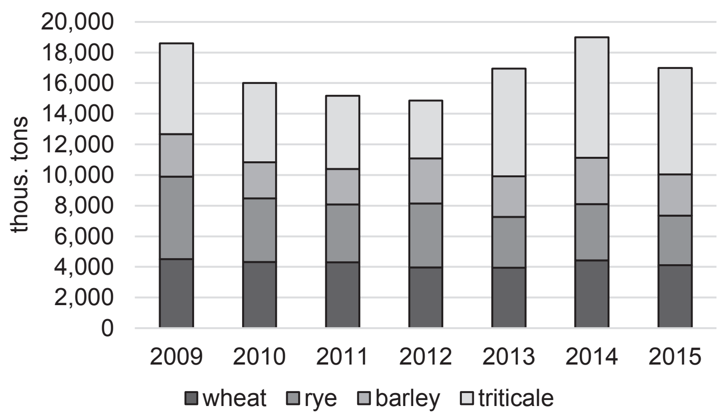


**Figure 3.** Annual production of crop's straw. (*Source: own elaboration*).

Results of prognosis for forestry biomass was assumed in accordance with (Gołos & Kaliszewski, 2013). To estimate potential amount of wood for energy purposes, data on the share of wood assortments, which formally can be used to produce energy from renewable sources were used by authors. According to the Regulation of the Ministry of Economy of 18 October 2012. (Dz. U. of 2012., Pos. 1229) as a defective wood can be treated as firewood.

To sum up the matter of wood and agricultural wastes energy potential comparison the forecasted volumes was multiply by average calorific value of selected types of biomass used in Polish energy sector (Table 3).

**Table 3.** Average calorific value of selected types of biomass used in energy sector in 2015

| Biomass types | Average calorific value, MJ kg$^{-1}$ |
|---|---|
| Forestry wastes | 9.99 |
| Agricultural wastes | 14.51 |

*Source: own elaboration based on (ARE, 2015).*

In spite of fact that wood production is less energy intensive than agricultural unitary energy potential cumulated in the first type of biomass is minor.

## RESULTS AND DISCUSSION

Results of all calculation are presented below in accordance with the methods presentation.

The outcomes of agricultural wastes forecast are highly possible which confirmation is presented on Fig. 4 that shows coverage of predictions and real values – example for wheat.

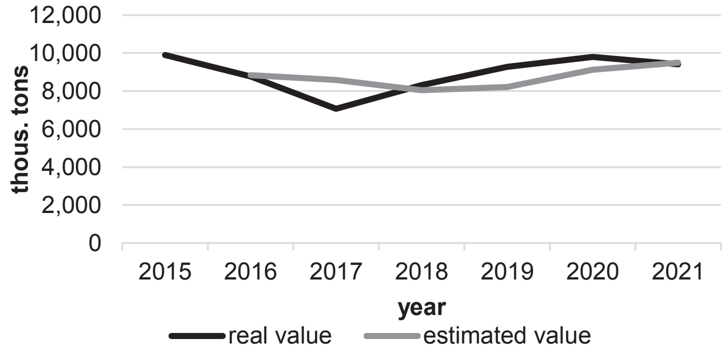


**Figure 4.** Wheat – results of forecast. (*Source: own elaboration).*

Rotary changes in historic crop production affects results of forecast (Fig. 5). The amount of energy straw production varies between 6,969 thousand tons in 2018 and maximum value 8,035 in 2021.

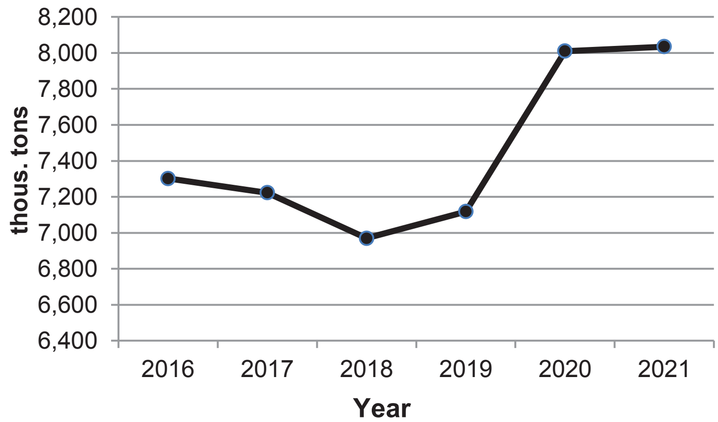


**Figure 5.** Estimation of energetic straw production. (*Source: own elaboration).*

Presented result of wood wastes forecast (Table 4), which was covered by (Gołos & Kaliszewski, 2013), shows that in 2021 total expected amount of small timber and woodchips is 4.53 million cubic meters.

Comparison of total energy potential calculated for 2021 for wood and agricultural wastes exhibits:

**Table 4.** Selected types of forestry biomass used in energy sector in Poland – historic and estimated volumes

| Assortment | 2011 | 2021 |
|---|---|---|
| | m $m^3$ | |
| Small timber | 2.14 | 2.45 |
| Woodchips | 1.82 | 2.08 |
| Total | 3.96 | 4.53 |

*Source:* Gołos & Kaliszewski, 2013.

large possibilities for agricultural wastes usage in energy sector because estimated amount is 116.583 PJ,

– poor potential of wood wastes – 27.393 PJ in 2021.

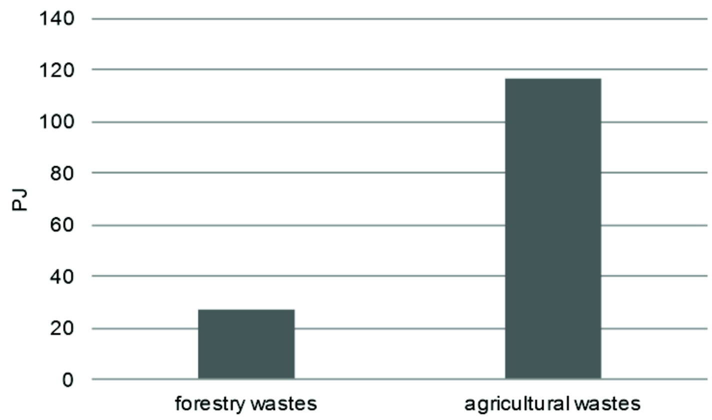


**Figure 6.** Energetic potential of forestry and agricultural biomass in 2021. (*Source: own elaboration*).

The calculations concerning biomass production as well as energy production coming from the straw show expected values to compare them with energetic potential of forestry biomass. On the other hand, the expected values can be verified in practice by many factors deciding about effectiveness of energy production (Komorowicz et al., 2009). There can be relation of energy content variations of straw to the fraction size, humidity, composition and environmental impact (Kalinauskaitė et al., 2013). Importance of humidity is considered in comparisons on agricultural and forestry biomass in the process of pellets and agri-pellets production (Vlădut et al., 2010). Basing on the results of detailed data it is possible to compare energetic value of many agricultural biomass sources (Niedziółka & Zuchniarz, 2006).

## CONCLUSIONS

Comparison of energetic potential of forestry and agricultural biomass show considerable differences in amount of accessible biomass for energy production, so it can be important information concerning future needs in the field of technical operation and management of particular kind of biomass.

Differences in annual amount of produced straw constitute significant data to expect and balance demand and supply in the energy market including some additional sources of energy.

Authors own experience and agriculture market observation allow to draw the conclusion about annual fluctuation in cereal crops production. All the changes in total end-volumes ground on complex agri-economic factors that indicate Polish market.

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