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RESIDENTIAL BUILDING HEATING COSTS USING THE ENERGY FROM GRAIN COMBUSTION

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Summary. The analysis of cost-effectiveness of residential building heating using the energy from grain combustion in comparison to the energy from bituminous coal was performed. It was proven that the grain combustion is more cost-effective in the variant of grain production in the intensive technology or purchasing grain in conditions of low market prices. Meanhile, the combustion of grain obtained from production in extensive technology or purchased at high market is not cost-effective.

Key words: grain combustion, heating costs, renewable energy sources

INTRODUCTION

Till today, grain cultivation was limited to the production of grain for consumption and feed purposes. In recent years, a concept of using the grain for energetic purposes was established, the more so, because the farmers have the experience in grain cultivation as well as necessary machines and tools.

Since many years, grains have been used for heating purposes in Scandinavia as well as in Canada and the USA [Internet1]

The first example of oat grain combustion in Poland is the farm in the Brzuchania village, near Miechów (Malopolskie voivodship). In the opinion of the owner, the new technology is cost-effective, nearly entirely automated (requires only the supplementation of grain in the container) and the ash, resulting from combustion can be used as a fertilizer [Internet1].

Grain combustion meets a few obstacles, mainly coming from mentality (combustion of food source) , however the factors in favour of grain combustion are the rising prices of the conventional energy sources and variable grain prices, not always guaranteeing the profitability of production in case of selling the grain on the market [Rynek rolny, 2005-2009].

THE AIM AND SCOPE OF RESEARCH

The aim of research was to analyse the heating costs of a residential building in a farm, of 150 m^2, with the energy acquired from the combustion of oat, rye, corn and bituminous coal of „eco pea coal" type.

In case of grain combustion, the performed analyses regarded the costs of energy acquisition from the grains produced in the farm as well as purchased on the market.

The economic analyses were performed for two technologies of grain production: intensive (obtaining of high grain crops) and extensive (obtaining crops at lower production costs).

METHODOLOGY OF RESEARCH

The demand for thermal energy of a residential building was estimated on the basis of the individual demand, which, in Polish conditions for buildings comprising to the insulation standards, is 100 $kWh \cdot m^{-2}$ of area for the entire time of heating period [Internet3]. Therefore, assuming the building area to be of 150 m^2, the demand for thermal energy would be about 15000 kWh annually. In order to estimate the energy carriers' costs, their calorific value, expressed in $MJ \cdot kg^{-1}$ was converted into kWh, noting that 1 kWH is 3600 kJ [Internet3]. Because of that, the individual cost of energy in the analyses was expressed in $PLN \cdot kWh^{-1}$. The cost of building heating was calculated by multiplying the individual cost by the building's demand for the energy.

The costs of grain plants production were calculated on the basis of the dependency carried out according to the literature [Kalkulacje kosztów... 1998, Klepacki, Gołębiewska 2003]:

$$K_{PROD} = \left(K_{NAW} + K_{SOR} + K_{NAS} + \sum_{i=1}^{n} K_{ui} + K_{R} + K_{pos} \right) - D_{BZP},$$

where: K_{PROD} – production costs [$PLN \cdot ha^{-1}$], K_{NAW}- fertilization costs [$PLN \cdot ha^{-1}$], K_{SOR}- cost of used pesticides [$PLN \cdot ha^{-1}$], K_{NAS}- costs of purchased grains [$PLN \cdot ha^{-1}$], K_R –labour costs [$PLN \cdot ha^{-1}$], K_u – cost of a unit performing a given service [$PLN \cdot ha^{-1}$], n – the number of treatments in a given crop, K_{pos} – indirect costs (crop insurance, agricultural tax, etc.) D_{BZP} – direct farming subsidies [$PLN \cdot ha^{-1}$].

The production costs were estimated for grain production in intensive and extensive technology. The technologies were diversified by the level of fertilization and number of pesticide and fertilization treatments [Chotkowski and others 1994].

The crop amount for oat in the intensive technology was at the level of 5.5 $t \cdot ha^{-1}$, while in the extensive technology at the level of 3.5 $t \cdot ha^{-1}$, for rye, respectively: 6 $t \cdot ha^{-1}$ and 3 $t \cdot ha^{-1}$, while corn: 11 $t \cdot ha^{-1}$ and 6 $t \cdot ha^{-1}$.

The straw crop amount was evaluated on the basis of ratios regarding the straw harvest to grain harvest, presented in literature [Harasim 1994].

Data needed for calculations were taken from market reports (Rynek rolny... 2005-2009) and from the distributors of production means.

The exploitation costs of tractors and machines were calculated according to the IBMER methodology and ratios presented in the literature [Muzalewski 1999, Lorencowicz 2008].

The economical analyses regarded a small farm, in which the yearly exploitation of machines is low, because of its area and production conditions. Because of that, according to IBMER suggestions [Muzalewski 1999], it was estimated that the normative exploitation of machines in a 20-year period is used only in 50%, which is equal to the exploitation of a tractor for about 300 hours a year.

Because of the above assumptions, the calculations of work effectiveness and exploitation costs included machines and tools working with a tractor of 35 kW power. In case of a harvest with the use of a harvester, it was assumed that the farm will use external services. The service cost was taken from market data at the level of 270 PLN×h^{-1} (Bizon Rekord harvester) [Rynek rolny... 2009].

In case of grains, because of their energetic purposes, it was assumed, that the straw will be grinded and ploughed. Because of the fact, that the ploughed straw brings some nutrition elements to soil, like nitrogen, phosphorus and potassium, the production costs were decreased by the value of ploughed straw. In order to calculate the value of ploughed straw, the value of 1 kg of pure element in the fertilizers was calculated in the analysed technologies. By multiplying the individual cost of elements by the content of elements in ploughed straw [Internet2] the value of ploughed straw was calculated. It was decreased by the value of nitrogen fertilizer, which, according to agricultural science (disturbances in carbon and nitrogen), should be used before ploughing of straw [Artyszak 2007].

The efficiency of machines and tools was calculated on the basis of methodology and ratios presented in the literature [Krok, Piotrowski 1985, Lorencowicz 2008].

In case of combustion of grain purchased on the market, the calculations were made for three price levels: minimum and maximum price noted by IERiGŻ for the period of May 2004 – May 2009, and the current price level (May 2009) [Rynek rolny... 2005- 2009]. For oat, the minimum price was estimated at a level of 370.2 PLN $\cdot$ t^{-1}, maximum at the level of 702.9 PLN $\cdot$ t^{-1} and the current price of 495.7 PLN $\cdot$ t^{-1}, for rye, respectively: 346.7 PLN $\cdot$ t^{-1}, 694.1 PLN $\cdot$ t^{-1}, 475.2 PLN $\cdot$ t^{-1}, for corn: 269.9 PLN $\cdot$ t^{-1}, 659.3 PLN $\cdot$ t^{-1}, 537.6 PLN $\cdot$ t^{-1}.

The following energetic values of grain were assumed: oat-18.5 GJ $\cdot$ t^{1}, rye-17.5 GJ $\cdot$ t^{1}, corn-17.2 GJ $\cdot$ t^{1} [Internet1].

The calculated heating costs also included the cost of furnace amortization. In the variant of combusting grain and „eco pea coal", the boiler Ling Duo 25, of gross price 9918 PLN (Internet5) was taken into consideration, while in the variant of combusting coal, the boiler Maximus SAS NWT (gross price of 3780 PLN) (Internet6).

The coal price was assumed at the level of 675.68 PLN $\cdot$ t^{-1} on the basis of IERiGŻ [Rynek rolny… 2009]. While the price of the „eco pea coal" was assumed at a level of 660 PLN/t , the average of the market offer [Internet7, Internet8].

For the evaluation of building heating variant, the gains/losses from heating with the grain energy were calculated in comparison to the costs of heating using coal. They were calculated by taking off the costs of straw heating from the costs of coal heating.

CONCLUSIONS

The calculated yearly cost of building heating with the energy coming from coal combustion, including the amortization cost of furnace is 2078.13 PLN, while in the case of „eco pea coal" combustion it is 2343.53 PLN $\cdot$ $year^{-1}$. The difference between heating costs is mainly caused by a significant difference between the prices of furnaces. However, in case of purchasing „eco pea coal" at lower prices (e.g. loose), the heating costs may be comparable. However, as one can observe from the market offers [Internet8], the prices of „eco pea coal" can be much higher, which, of course, significantly increases the heating costs.

The costs of energy acquisition from grain combustion are presented in Table 1.

Table 1. The costs of grain plantation and financial results of energy acquisition from grain

Extensive technology of plantation			
	oat	rye	corn
The plantation cost, minus the subsidies and value of ploughed straw [PLN · ha-1]	1479.15	1354.80	2214.80
Energy acquisition cost [PLN · GJ-1]	22.84	25.81	30.18
Cost of building heating by grain combustion [PLN · year-1]	2109.36	2304.47	2592.61
Gain/Loss when compared to coal combustion [PLN]	-31.22	-226.34	-514.47
Intensive technology of plantation			
	oat	rye	corn
The plantation cost, minus the subsidies and value of ploughed straw [PLN · ha-1]	1511.33	1467.73	2453.69
Energy acquisition cost[PLN/GJ]	18.50	17.50	21.69
Cost of building heating by grain combustion [PLN · year-1]	1583.14	1525.52	2033.34
Gain/Loss when compared to coal combustion [PLN]	494.99	552.61	44.79

Grain combustion in order to heat a building is cost-effective only in case of large grain harvest (intensive technology). In this variant, rye and oat grains are the best.

Table 2. The costs of building heating with grain purchased on the market

Low grain purchase prices			
	oat	rye	corn
Cost of building heating by grain combustion [PLN×year-1]	1922.78	1909.74	1638.36
Gain/Loss when compared to coal combustion [PLN]	155.35	168.39	437.77
High grain purchase prices			
	oat	rye	corn
Cost of building heating by grain combustion [PLN×year-1]	3107.08	3217.12	3129.26
Gain/Loss when compared to coal combustion [PLN]	-1028.95	-1138.98	-1051.13
Current grain purchase prices			
Cost of building heating by grain combustion [PLN×year-1]	2369.52	2392.95	2663.31
Gain/Loss when compared to coal combustion [PLN]	-291.39	-314.82	-585.18

Building heating through the combustion of purchased grain is cost-effective only in case of low market prices of grain. High grain prices generate large financial losses in building heating. Purchase of grain for energetic purposes at current prices is also uneconomic.

The presented calculation results concern complex production technologies, conditions and assumed prices of production means, grain and coal. In other production or market conditions, the results may differ from the above-mentioned.

Summary: On the basis of the performed analyses for the assumed production and market conditions, one can say that grain combustion in comparison to coal combustion may be cost-effective. The condition for this is low individual cost of energy acquisition from grain, which, as these analyses have shown, is possible by the intensive technology of production or by purchasing grain at low market prices.

The most attractive energy source, from the analysed plants, is grain of oat and rye.

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KOSZTY OGRZEWANIA BUDYNKU MIESZKALNEGO ENERGIĄ POCHODZĄCĄ ZE SPALANIA ZIARNA

Streszczenie. Dokonano analiz opłacalności ogrzewania budynku mieszkalnego energią pochodzącą ze spalania ziarna zbóż w odniesieniu do energii z węgla kamiennego. Wykazano, że spalanie ziarna jest opłacalne w wariancie uprawy zbóż w technologii produkcji intensywnej lub zakupu ziarna na rynku w sytuacji niskich cen rynkowych. Natomiast nieopłacalne jest spalanie ziarna pozyskanego w technologii produkcji ekstensywnej lub zakupionego po wysokich cenach rynkowych jak również bieżących cenach rynkowych.

Słowa kluczowe: spalanie ziarna, koszty ogrzewania, odnawialne źródła energii