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The Wood Pellet Sector: Barriers to Growth and Opinions of Manufacturers in Poland

Abstract. Biomass is a major source of renewable energy in the EU and Poland, stimulating the growth of the wood pellet sector. Wood pellet demand is stimulated by a complex interaction of market forces and policies including EU climate, energy, and environmental regulations, Poland's program to improve air quality, and subsidies for the replacement of inefficient stoves used by households. This article focuses on the growth of the wood pellet industry, imports and exports in Poland, and wood pellet quality and use by households. The main issues faced by the EU wood pellet sector between 2013 and 2016 are further considered in the context of opinions of Polish wood pellet manufacturers. Industry opinions were collected in response to an open-ended question that probed for the main issues faced by wood pellet producers during the survey implemented by the authors in 2019. Respondents identified difficulties in obtaining raw material for pellet production and poor pellet quality as major problems. Although the majority did not feel concerned about competition from imported wood pellets, a small number of respondents viewed such competition as a problem reflecting the reversal of decreasing imports in 2017. Overall, the domestic wood pellet industry can be expected to grow because of increasing pressure to expand the use of renewable energy and will be driven by the household sector switching to more efficient, wood burning stoves. Additionally, the expanding area of private Polish forests may become a source of much-needed raw material for wood pellet manufacturing.

Key words: Renewable energy, wood pellet stoves, raw material, imports, quality, rural household

JEL Classification: Q42, Q56, Q57

Introduction

The European Union (EU) energy strategy for the period 2021-2030 foresees that the share of renewable energy in utilized gross energy will reach 32% as compared to the 20% share planned for 2020 (European Commission 2018). In Poland, the Energy Ministry plans to reach a 21% share of renewable energy in gross final energy use by 2030. By 2022, the share will reach 15%, then 17% in 2025, and about 19% in 2027 (Gramwzielone.pl, 2019).

One of the primary renewable energy sources is solid biomass that includes organic, non-fossil feedstock of biological origin, which can be utilized as fuel to generate heat or electrical energy. Among solid biomass types, fuel wood is available in various forms such as tree trunks, chips, briquettes, pellets, and forestry waste including branches, brush, shrubs, wood obtained from thinning, stumps, and byproducts from the wood processing (sawdust, shavings) and cellulose industries (GUS 2017a). Since 2018, in accordance with the legislation on renewable energy, biomass is defined as “parts of products, subjected to

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biodegradation waste or byproducts of biological origin from agriculture, including plant and animal substances, forestry or related industries, such as fishery and aquaculture, processed biomass, especially in the form of briquettes, pellets, peat, biocoal ..." (article 2, item 3).

Wood pellet popularity was initially associated with the oil crisis of the 1970s (enplus-pellets.eu, 2019). More recently, the development of wood pellet sector has been shaped by markets and policies (Goh et al. 2013). The numerous renewable energy types, global climate change issue and related policies, local environmental impact of fossil fuel use, and public health concerns that vary by country and region illustrate the complexity of conditions affecting the wood pellet sector. Within the European Union (EU), solid biomass including wood pellets has been recognized as the source of renewable energy creating pre-conditions for the sector's growth. The demand for wood pellets led to wood pellet imports (primarily from Canada and the United States), and the volume of wood pellet imported from non-EU countries to EU was comparable to biodiesel and bioethanol in 2010 (Goh et al. 2013). The projected growth of wood pellet use in the EU offers opportunities for the sector expansion in each member-country, including Poland that has suitable resources.

Wood biomass accounts for one-half of the renewable energy in Europe. In some countries, notably Finland, wood biomass accounts for 80% of demand for renewable energy making this source a primary renewable energy feedstock. In Poland, biomass was responsible for generating 91% of energy from renewable sources in 2006 (Werner-Juszczuk, Stempniuk 2010), but its share dropped to about 80% as other renewable energy sources have become more common in recent years. The total forest resources in the EU-28 amount to about 26.5 billion cubic meters in 2015. Germany, Sweden, and France owned the largest shares, which are 13.8%, 11.3%, and 10.8%, respectively. In 2015, Germany also owned the largest inventory of available wood in accessible forests, about 3.5 billion cubic meters, while Finland, Poland, France, and Sweden reported inventories between 2 billion and 2.3 billion cubic meters (AEBIOM 2017).

Material and methods

The objective of this study is the examination of the wood pellet sector as a renewable energy source for households, including those located in rural areas. The focus on households distinguishes the focus of this study from the production and use of wood pellet destined for commercial furnaces, which require pellets of distinct characteristics. Specifically, this study reviews the growth of the wood pellet sector and describes the sources of raw material, pellet quality, and quality standardization in Poland. The competition from imported wood pellets is considered, in order to illustrate the growth of domestic demand. Finally, this study examines the opinions of Polish wood pellet manufacturers regarding the key issues of raw material sourcing, pellet quality, and perceptions of competition from foreign wood pellet exporters. Opportunities offered by the EU climate policy, domestic air quality policy, and the EU-funded support program to replace old, inefficient stoves in homes by more efficient less-polluting furnaces contribute to the wood pellet sector expansion and could make Poland a major producer, user and exporter of pellets in the EU.

The study uses the descriptive methods using secondary, publicly available data from AEBIOM and GUS. Polish and international literature pertaining to the subject is cited to illustrate the observed tendencies and developments in wood pellet energy use.

The study also involved the preparation and implementation of a mail survey among the pellet manufacturers in Poland in 2019. The survey was necessary because there is a huge void in information regarding the industry, especially about the challenges faced by the emerging domestic pellet manufacturers. The preparations for the survey required the development of a comprehensive mailing list, since the list of wood pellet manufacturers is not readily available. The collection of company contact information involved online and telephone research.

Results and discussion

Wood pellet sector growth

Global wood pellet production shows continuous growth and reached 36.1 million tons in 2016, an 11% increase over the 2015 level. The 28 EU member-countries (the EU-28) account for 39% of the world's production of wood pellets or 16.6 million tons (AEBIOM 2017). Germany remains the leader in wood pellet production, manufacturing 1.9 million tons in 2016.

Table 1. Production, import, and export volume of wood pellets and other components in Poland in the period 2012-2017, in tons

Activity/Change	2012	2013	2014	2015	2016	2017
Production	1,107,991	1,186,978	1,394,313	1,463,828	1,448,302	1,600,000
Year-to-year change in production, %	-	9.9	17.5	5.0	-1.1	10.5
Import	324,453	112,153	67,628	78,629	83,766	106,103
Year-to-year change in production, %	-	-65.4	-17.8	5.0	-1.1	10.5
Export	226,494	305,782	311,112	365,922	440,265	575,390
Year-to-year change in production, %	-	35.0	1.7	17.6	20.3	36.0

Source: Authors' own study based on <http://www.fao.org/faostat/en/#data>.

Initially in Poland, a sizable portion of pellet output was manufactured from agricultural waste, mostly straw. Agri-pellets were used mostly as a feedstock in local power plants and Poland was the main producer. Between 2011 and 2016, Poland increased wood pellet production by 33% (Klepak 2018), restructuring the sector from manufacturing agri-pellets to wood pellets (AEBIOM 2017). Currently, both the production and export volume indicate the potential of the wood pellet market in Poland (Table 1).

The growth of wood pellet production was uneven between 2012 and 2017. In 2015 and 2016, the growth initially slowed and reversed itself (table 1). The year-to-year growth rate shows that the slowdown period was sandwiched between two periods of accelerated growth, namely between 2012 and 2014 and after 2016. The expanding production reduced the need for imported wood pellets. Between 2012 and 2017, the volume imported decreased by 67.3%. Imports registered a moderate increase in 2015 and 2017. However, the increase in the most recent year for which data are presented, 2017, suggests a possible increase in demand reflecting the competitiveness of imported wood pellets. Finally,

growing domestic production enabled Polish wood pellet manufacturers to steadily increase exports (Table 1). The growth of volume exported kept increasing even in years of reduced production, suggesting that wood pellet manufacturers adapted to the changing domestic demand by taking advantage of foreign markets. The likely destinations of Polish wood pellets was neighboring EU countries, including Scandinavia.

The growth of the wood pellet market in Poland has been supported by, among other reasons, the climate policy adopted by the EU. The policy emphasizes the increased use of renewable sources in energy generation to improve air quality. However, the changing regulations in Poland and the altered system “green certificates” had a big influence on the renewable energy market (Klepacka, Pawlik 2018). In 2016, the EU-28 used 21.7 million tons of wood pellets (AEBIOM 2017). The demand for a clean and price-stable fuel in the form of wood pellets proved to be a beneficial solution for individual households. In 2015, biomass accounted for 15% (14.6% in 2014) of used energy per capita in households, while its share in Poland was 13.4% (slightly more than 13.3% in 2014) (GUS 2017b, GUS 2016b). It appears that among the causes driving the increased demand for wood pellets is price. Currently, wood pellet prices are comparable to coal, the main fuel used in rural households, but stoves burning wood pellets are about twice as efficient as coal stoves. However, wood burning stove prices were viewed as “too expensive” among the United Kingdom households adopting more environmentally friendly heating technologies (Caird et al. 2008).

There were 650 wood pellet manufacturing plants in EU-27 in 2009 (Sikkema et al. 2011). It is likely that a single manufacturer owned more than a single plant since AEBIOM (2017) reports 632 wood pellet manufacturers in the EU-28 in 2016 (19 more than in 2015), including 52 firms in Poland (two more than 2015). In the same year, in the EU-28 countries the production capacity amounted to 20,509,965 tons, less than the 21,634,175 tons in 2015, while the production capacity increased by 50,000 tons to 1,100,000 tons in Poland. Other sources indicated the number of wood pellet manufacturers at 900 in 45 countries (enplus-pellets.eu, 2019) when referring to the use of specific wood pellet quality certification programs. The world demand for wood pellets stimulated production and exports not only in North America, but also in Russia, Africa, South America and Asia (Verhoes et al. 2012).

Demand and supply developments in the wood pellet sector in Poland and the EU-28 in recent years

With the growth of the wood pellet market in Europe, national associations of wood pellet manufacturers have monitored the main barriers to industry expansion since 2013. Among the named constraints noted by separate associations are the volume demanded, price competition, raw material prices, and pellet inventory management. However, between 2013 and 2016, the relative importance of the listed factors varied. In 2013, the volume demanded was of little concern, but it has grown in importance in 2014 and 2015, confirming unfavorable market conditions for European manufacturers. In 2016, despite the increased demand for wood pellets in the heat-generating market, the problem was not completely solved.

Changes in the wood pellet market do not fully account for the recent growth. At a household level, it is critical to invest in a wood pellet-burning stove to assure continuous heat generation with little direct monitoring due to an automatic pellet feeding system.

Information about the sales volume of heating equipment using wood pellets is difficult, but some trends can be discerned. Figures reported by AEBIOM (2017) for the years 2014-2015 and the beginning of 2016 show a lack of growth in stove sales in the majority of European countries, mainly due to mild winters and low heating oil prices. In contrast, the purchase of a stove for pellets was viewed as an investment with a reasonably short period of return. Very low heating oil prices also impacted the wood pellet sector in the majority of national markets. Indeed, in those markets, the 2016/2017 heating season did not register sales improvement, but there was a noticeable increase in the number of potential customers interested in investing in wood pellet stoves. Besides Germany, Austria, and France, which did not show sales growth, Italy and especially Poland saw an increase in stove purchases. In Poland, wood pellet stove sales increased by 150% in 2016 as compared to 2014. The sales growth seems to confirm the boom in the country's wood pellet production as well as domestic use.

One of the drivers of wood pellet stove use by households and its effect on the wood pellet market is the area heated in an apartment or a house and the desire to save on energy costs. The average apartment covered 73.6 square meters in Poland as of December 31, 2015, and was 0.2 square meters larger than a year earlier. Rural residences were on average 28.3 square meters larger than the average urban apartment (the average rural residence covered 92.7 square meters vs. 64.4 square meters in a city) (GUS 2016a), which creates opportunities for growth in the local wood pellet market. Additionally, since the size of apartments and residences varies across regions, regional wood pellet sales could grow at different rates. The largest differences in the square area between rural and urban residences have been observed in Śląskie and Opolskie Voivodships (35 square meters and 33 square meters, respectively), while the smallest differences are in Warmińsko-Mazurskie Voivodship (about 20 square meters).

A strong motivating force encouraging the use of renewable energy in the form of wood pellets is the EU program supporting the replacement of heating stoves operated by households. The program may play a key role in increasing the use of wood pellets in the long run. In recent years, the program varied across regions and one could apply for a subsidy from the Voivodship Fund of Environment Protection and Water Resources Management (Pol.: Wojewódzki Fundusz Ochrony Środowiska i Gospodarki Wodnej) in the region of permanent residency (Ecocomfort.pl 2019). An additional program stimulating the sales of wood pellet-burning stoves is the "Clean Air" Program (Program „Czyste powietrze") that is currently being implemented and covers the period 2018-2029.

The market for medium size wood pellets has been growing more steadily than the residential wood pellet stove market (AEBIOM 2017). Between 2015 and 2016 the total number of installed wood pellet-burning systems grew 10-20% in the majority of countries in Europe. A particularly high growth rate was recorded in Poland. The success of wood pellet utilization in that part of Europe might surprise because in Poland the support for renewable energy was less than several other EU countries (Eurobarometer 2014). However, the observed wood pellet use growth is not purely a result of policy, but of recognizing the convenience and cleanliness of wood pellet fuel as compared to coal, which still dominates the heating fuel market in some parts of Europe. In 2015, 78% of rural households in Poland burned coal (GUS 2017c). The average rural household burned 2910 kg per year. A number of those households could benefit from currently implemented programs subsidizing the replacement of old furnaces with modern stoves, including those using wood pellets as feedstock to heat space and water. Ultimately, heat-generating

potential and moisture determine the suitability of wood pellets (Werner-Juszczuk, Stempniuk 2010) and reliable quality is necessary to assure their use by households to replace coal.

The raw material price was the main issue in 2013. The relevant importance of the issue diminished in the two subsequent years. It regained importance in 2016 because some countries, including Poland, witnessed a sudden price increase due to rapid changes in the domestic market. AEBIOM added constrained wood pellet inventory management as an issue in 2017, although it was not considered the primary problem for pellet manufacturers in 2016. It is worth mentioning that despite the raw material price increase faced by wood pellet producers, the agri-pellet market has stagnated and accounts for 10% of the European pellet production (AEBIOM 2017).

The heat-generating potential of wood pellets is higher than other forms of wood biomass. The quality of wood pellets depends on the quality of biomass used in their production, especially on chemical, mechanical, and physical properties of biomass (Rhén et al. 2005). However, the management of the manufacturing process also influences wood pellet quality (Lehtikangas 2001). As international trade, including within the EU, increases, an applicable international standard for solid biomass fuels is desirable (Garcia-Maraver et al. 2011). Several countries have developed national standards, which not only differ in details but are mandatory in some countries (for example, Austria and Sweden), while limited to providing guidelines in others (for example, France and Italy). The European Commission mandated the European Committee on Standardization (CEN) to develop standards for solid biofuels. It appears that the currently most widely used wood pellet certification program is ENplus® developed in Germany in 2011 (enplus-pellets.eu 2019). Numerous Polish wood pellet manufacturers have adopted the German wood pellet since the implementation of the certification, and the number of countries and pellet manufacturers awarded the ENplus® standard has grown rapidly. In 2017, 42 countries produced 9.2 million tons of certified wood pellets (AEBIOM 2017). Further growth of wood pellet sales is expected as more manufacturers adopt ENplus®, including those in Bulgaria, Belarus, Croatia, Poland, and Russia. The presence of imported wood pellets from outside Europe led to the obligatory compliance with phytosanitary regulations that require heat or alternative treatment of imported wood chips (European Commission 2000). Although such requirements may increase the cost of imported wood chips, they are necessary to protect the European wood and forest resources.

Price competition with imported wood pellets was important in 2015. The competition intensified in 2016 according to some sources, although the issue did not dominate the wood pellet market (AEBIOM 2017). It is important to note that the share of the industrial trade in wood pellets intended for co-firing in coal-fired power stations is about 10 million tons annually (Verhoest et al. 2012), but statistics may provide limited information about the composition of internationally traded wood pellets, i.e., the distinction between pellets for household vs. commercial use.

Barriers to the expansion of the wood pellet sector in opinions of Polish companies – survey results

A survey of 67 wood pellet manufacturers in Poland was implemented in January 2019. Preparations for the survey involved several stages. An initial search of the existing databases helped identify firms producing and selling wood pellets. Next, the drafted list

was corrected by verifying the information on the websites of individual firms. Finally, the list was compared to the list of the association of wood pellet manufacturers.

The survey implementation involved mailing a cover letter and a copy of the questionnaire. The participation of firms was strictly voluntary and the survey organizers recognized that their request to complete and return the questionnaire required a time commitment on the part of respondents. Not surprisingly, the return rate following the single mailing of the questionnaires was 16%. Among the respondents who participated in the survey, according to their location in a given voivodship, are: 3 in Świętokrzyskie, 2 in Pomorskie, and one each in Dolnośląskie, Kujawsko-Pomorskie, Łódzkie, Opolskie, Podlaskie, and Mazowieckie.

The questions referred to major issues: barriers to growth in wood pellet production and the degree of market competition. One question focused on sources of company financing with support from EU funds. Another probed for opinions and was an open-ended question encouraging the respondent to name the most important problems facing the wood pellet producing sector in the country.

Among 11 firms participating in the initial stage of the survey, only one company indicated using the EU-funded loan of 755,000 PLN for the expansion and modernization of production. The interest-free loan was obtained from the regional fund in one of the voivodships. The lack of participation in the interest-free loan program could be a result of lack of information about such opportunities or financial self-sufficiency of wood pellet manufacturers in the domestic and export markets. Anecdotal information also suggests that some firm owners are discouraged by the extensive paperwork involved and the amount of supporting information they need to provide.

When asked about the problem of imported wood pellets, respondents answered on a ten-step scale ranging from 1 = "I am not concerned" to 10 = "I am very concerned". The majority of respondents, 80%, selected a response option not higher than 5, the middle step on the scale. Specifically, 20% indicated no concerns (Step 1), 30% choose Step 3, 10% indicated Step 4, and 20% selected Step 5. Among respondents indicating some level of concern, 10% choose Step 6 and 10% Step 8. None of the respondents indicated that imported wood pellets were of great concern. The distribution of responses across the ten-step scale confirm the observed steady decline of the volume of imported wood pellets that in 2017 amounted to less than a third of the volume reported in 2012 (Table 1).

The open-ended question to name the most important problem faced by the sector allowed a grouping of responses, and three issues were named particularly often. They were the lack of raw material sources, poor quality pellets, and, surprisingly, import competition.

One-half of respondents indicated having problems with sources of raw material for wood pellet production. In major wood pellet-producing countries outside Europe, two-thirds of wood fiber used by the wood pellet manufacturers is supplied by sawmills; for example in the United States (Spelter, Toth 2009). Another substantial source is furniture factories and pulpwood. The wood fiber supply sources determine the location of wood pellet plants. In Poland, wood pellet plants also utilize local supplies since the transportation costs of raw material could be substantial. However, the problem as indicated by the surveyed pellet manufacturers threatens the growth of the sector. One possible reason is the ownership structure of forest resources in Poland. Only 20% of forests are privately owned. The proportion of private forests share increased substantially due to subsidies for reforestation of low-quality agricultural land. Farms already having some forested land and operating low quality land have been characterized by a low level of cost

effectiveness (Klepacka et al. 2017) and some expanded their forested area. Privately-owned forests may become suppliers of raw material but not until the plantings reach suitable size and market prices encourage selective harvesting. Otherwise, Polish wood pellet producers may have to deal with the imported sawdust, which tends to be less expensive in North America than in Europe (Sjølie, Solberg 2011).

Another one-third of respondents pointed towards the poor quality wood pellets that are present in the market. Poor quality pellets result from the raw material used for its production (conifers, deciduous trees, mixed wood). They could also result from high moisture content and be linked to the wood energy value. It is very important to protect already manufactured pellets from humidity, which causes pellets to lose durability and disintegrate. Although the wood pellet size is uniformly defined, moisture content is not included in some national standards (Garcia-Maraver et al. 2011). Other important factors are the content of dust in pellets, their energy value, and uniform size and shape (Kołacz 2002). These attributes are responsible for making wood pellets an environmentally friendly, easy to transport fuel. The residential wood pellet market may involve highly variable storage conditions and frequent handling, which could also lower pellet quality (Whittaker, Shield 2017). Since wood pellet is a relatively novel type of solid fuel, distributors may lack information and skills to properly handle wood pellets. Finally, 15% of respondents named competition from imported wood pellets as very important. The low share of such comments reflects the previously mentioned rapid decline of volume imported in the last few years, but may reflect the potential reversal of the tendency in 2017 (Table 1).

Conclusions and recommendations

Solid biomass accounts for the major share of renewable energy use in the EU and Poland. A relatively novel product in the category of solid biomass is wood pellet. Wood pellet is subject to international trade within the EU and between EU and non-EU countries, with the latter representing mostly importers. The EU countries including Poland have sizable forest resources allowing the production of a large volume of wood pellets. The increased demand for wood pellet results from the EU climate and energy policy and in Poland, additionally, from the desire to improve air quality and the recent government program aimed at replacing inefficient stoves in households. This program is particularly applicable to rural households because of their heavy dependence on coal and because the home heated area is larger than in urban areas.

The growth of Poland's wood pellet sector between 2012 and 2017 was impressive. The production expansion led to a substantial decrease in the imported volume of wood pellets. Moreover, the fast growth of production capacity led domestic wood pellet manufacturers to expand exports. Many Polish wood pellet producers also adopted some of the most popular quality certification schemes to gain access to some markets or to maintain their competitiveness.

A survey of the Polish wood pellet manufacturers revealed that three issues were viewed as the possible constraints to the sectors' growth. Access to raw material was one of those issues, and the proximity of the supply source which could lower the raw material cost (including transportation), since raw material is lighter than the finished pellets. The expanding area of privately owned forests in Poland could ease the raw material constraint

over time as the reforested areas reach harvesting age. Another constraint was the presence of poor wood pellet quality on the market that likely negatively affects the perception of its energy value given prices of pellet vis-a-vis competing coal. Perhaps, tracking the source of poor quality wood pellet could eliminate such suppliers. Additionally, distributor practices such as storage and handling of wood pellet may be reviewed and training workshops in proper handling could eliminate the deterioration of post-production quality.

Although the majority of the surveyed pellet producers did not consider the imported pellet as a source of competition, a few manufacturers chose to differ in this regard. A future study may examine the problem and verify if the imported wood pellet affects the market aiming at household use of pellets or the wood pellets used in co-firing in commercial power plants. Also, the very limited use of EU funds offered as interest-free loans to invest in wood pellet production was unexpected, especially given the subsidy to households for the inefficient stove replacement, and both issues may be investigated in the follow-up study to further discern motives driving wood pellet producer decisions and household decisions to invest in wood pellet stoves.

Literature

- Caird, S., Roy, R., Herring, H. (2008). Improving the energy performance of UK households: results from surveys of consumer adoption and use of low- and zero-carbon technologies. *Energy Efficiency* 1(2), 149-166.
- Dziennik Urzędowy. (2018). Act of February 20, 2015 on renewable energy, Dz. U. of 2018, item 2389 and 2245, of 2019, item 42, 60, 730.
- Ecocomfort. (2018). <https://www.ecocomfort.pl/strefa-specjalistyczna/artykul/6-krokow-do-uzyskania-nawet-20-000-zl-dofinansowania-do-wymiany-pieca/>. Accessed 8 May 2019.
- Enplus-pellet.eu. (2019). <https://enplus-pellets.eu/en-in/about-us-en-in.html>. Accessed 6 June 2019.
- Eurobarometer. (2014). Climate Change, Special Eurobarometer 409. Brussels, Belgium: European Commission. Available online: http://ec.europa.eu/public_opinion/archives/ebs/ebs_409_en.pdf. Accessed June 2018.
- European Biomass Association (AEBIOM). (2017). Statistical Report (full report). European Bioenergy Outlook 2017.
- European Commission. (2000). EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. European Commission, Brussels.
- European Commission. (2018). Europe leads the global clean energy transition: Commission welcomes ambitious agreement on further renewable energy development in the EU. http://europa.eu/rapid/press-release_STATEMENT-18-4155_en.htm. Accessed 30 August 2018.
- FAO. (2019). <http://www.fao.org/faostat/en/#data>. Accessed May 8, 2019.
- Garcia-Maraver, A., Popov, V., Zamorano, M. (2011). A review of European standards for pellet quality. *Renewable Energy*, 36 3537-3540.
- GUS. (2017a). Energia ze źródeł odnawialnych w 2016 r. (Energy from renewable sources in 2016). Warszawa.
- GUS. (2017b). Energia (Energy). Warszawa.
- GUS.(2017c). Sustainable Development Indicators. http://wskaznikizrp.stat.gov.pl/prezentacja.jsf?symbol_wsk=005003002001&poziom=kraj&jezyk=en. Accessed 18 May 2017.
- GUS. (2016a). Gospodarka mieszkaniowa w 2015 r. Informacje i opracowania statystyczne. Warszawa.
- GUS. (2016b). Energia (Energy). Warszawa.
- Goh, C.S., Junginger, M., Cocchi, M., Marchal, D., Thrän, D., Hennig, C., Heinimö, J., Nikolaisen, L., Schouwenberg, P-P., Bradley, D., Hess, R., Jacobson, J., Ovard, L., Deutmeyer, M. (2013). Wood pellet market and trade: a global perspective. *Biofuels, Bioproducts & Biorefining – Biofpr*, 7, 24-42.
- Gramwzielone.pl. (2019). <https://www.gramwzielone.pl/trendy/34065/ministerstwo-energii-okreslilo-cel-oze-narok-2030-ambitny>. Accessed May 8, 2019.
- Klepacka, A.M., Florkowski, W.J., Revoredo-Giha, C. (2017). Farmers and their groves: will cost inefficiency lead to land use change? *Land Use Policy*, (61), 329-338.
- Klepacka A.M. (2018). Potencjał użytkowy pelletu z biomasy drzewnej: energia odnawialna jako element zrównoważonego rozwoju (The potential utilization of pellet made from wood biomass: renewable energy

- as a sustainable development element). *Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu*, 20(6), 124-132.
- Klepacka A.M., Pawlik K. (2018). Return on investment in PV power plants under changing support regimes (schemes). *Problems of Agricultural Economics*, 356(3), 168–191.
- Kołacz I. (2002). Wykorzystanie granulatu z odpadów drzewnych do produkcji energii (The use of pellets from wood waste for energy production). *Czysta Energia* (3), 8-9.
- Lehtikangas, P. (2001). Quality properties of pelletised sawdust, logging residues and bark. *Biomass and Bioenergy*, 20, 351-360.
- Rhén, C., Gref, R., Sjöström, M., Wästerlund, I. (2005). Effects of raw material moisture content, densification pressure and temperature on some properties of Norway spruce pellets. *Fuel Processing Technology*, 87, 11-6.
- Sikkema, R., Steiner, M., Junginger, M., Hiegl, W., Hansen, M.T., Faaij, A. (2011). The European wood pellet markets: current status and prospects for 2020. *Biofuels, Bioproducts & Biorefining – Biofpr*, 5, 250-278.
- Sjølie, H.K., Solberg, B. (2011). Greenhouse gas emission impacts of use of Norwegian wood pellets: a sensitivity analysis. *Environmental Science & Policy*, 14, 1028-1040.
- Spelter, H., Toth, D. (2009). North America's wood pellet sector. Research Paper FPL-RP-656. Madison, Wisconsin, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.
- Verhoest, C., Ryckmans, Y. (2012). Industrial wood pellet report. In: Laborelec (Ed.) Laborelec&Pellcert. Accessed from: http://www.enplus-pellets.eu/wp-content/uploads/2012/04/Industrial-pellets-report_PellCert_2012_secured.pdf.
- Werner-Juszczuk, A., Stempniak, A. (2010). Analiza techniczno-ekonomiczna wykorzystania biomasy stałej jako paliwa (Technical and economic analysis of the use of solid biomass as fuel). *Civil and Environmental Engineering*, 1, 91-96.
- Whittaker, C., Shield, I. (2017). Factors affecting wood, energy grass and straw pellet durability – A review, *Renewable and Sustainable Energy Reviews*, 71, 1-11.

For citation:

Klepacka A.M., Florkowski W.J. (2019). The Wood Pellet Sector, Barriers to Growth, and Opinions of Manufacturers in Poland. *Problems of World Agriculture*, 19(4), 9-18;
DOI: 10.22630/PRS.2019.19.4.52