Proceedings of the 2016 International Conference "ECONOMIC SCIENCE FOR RURAL DEVELOPMENT" No 41
Jelgava, LLU ESAF, 21-22 April 2016, pp. 219-228

BIO-ECONOMY SECTOR IN POLAND AND ITS IMPORTANCE IN THE ECONOMY

Wicki Ludwik[1], DSc.; **Aleksandra Wicka**[1] PhD

[1]Faculty of Economics, Warsaw University of Life Sciences–SGGW

Abstract. The aim of the study is to identify the importance of bio-economy in Poland, both in the traditional and the innovative sectors. The analysis covered the years 2000-2014. In this study were used statistical data from the Central Statistical Office and data from Agricultural Market Agency. The importance of the discussed sector was evaluated mainly based on its share in the entire economy. It was found that bio-economy sector generates 6.5% of gross value added, nearly 20% of employment and 15% of the Polish export. Energy production from biomass is almost 10% of overall production of energy. Modern, innovation-based sectors of bio-economy are still not developed and the related technologies are in the phase of laboratory tests. The structure of bio-economy in Poland is dominated by traditional sectors: agriculture and agri-food industry. Energy production from biomass is carried out using not very innovative technologies. A precondition for development and dissemination of new technologies is the support of public funds.

Key words: bio-economy, bio-energy, agriculture, food processing, forestry.

JEL code: Q16, Q23, Q42

Introduction

Bio-economy is a part of the national economy, which uses biomass – renewable biological material from agriculture, forestry and seas. It is a broad term, which (as defined by the Organisation for Economic Cooperation and Development (OECD)) encompasses any activity associated with use of biotechnology, bio-processes and bio-based products, aimed at production of goods and services. The emergence of the concept of bio-economy was linked with a noticeable continuing deterioration of the natural environment and the related decreasing availability of natural resources. This requires a change in public attitudes to the issue of production, consumption, storage and recycling of biological resources. As pointed out by Christian Patermann, it is a new concept, which is still difficult to understand for a wider audience (EC, 2012).

Development of bio-economy is a topic increasingly discussed in the sphere of policy-making and economics. Both in the European Union (European Commission, 2012) and in the United States of America (The White House, 2012), bio-economy is mentioned as an important area of development. However, a relatively new concept of bio-economy is still not precisely defined. There are two groups of definitions (Maciejczak, 2015). From a broad perspective, bio-economy is a system combining natural resources, technologies, markets, people and policies. This includes both industry based on the old, well-known technologies and the new sectors, which use innovative technologies and, at the same time, are linked by symbiotic relationship, where one sector uses the products, which are by-products of another sector. In a narrow meaning, bio-economy is the use of biotechnology in the industry, environmental protection and in challenges posed by climate change. Most definitions associate bio-economy with sectors, which use raw materials and biological processes: from food production, through production of chemicals and pharmaceuticals, up to production of energy (Maciejczak and Hofreiter, 2013). The importance of broadly defined bio-economy in the EU is very high. In this sector around 22 million people are working, and its market size is approximately EUR 1.5 trillion (Patermann, 2008).

The growing interest of the scientists, governments and societies in bio-economy is a result of new challenges in the modern world. Growing population and demand for food, scarcity of energy resources as well as climate change and environmental pollution are just a few of them. It is postulated to act globally and to develop new, innovative processes, products and services (Tapscott and Williams, 2011;

[2]Corresponding author. Tel.: +48225934003; fax: + 48225934230. E-mail address: ludwik_wicki@sggw.pl.

Bukowski, Szpor and Sniegocki, 2012). Eco-innovation proposed by bio-economy allows us to minimise the negative phenomena (Chylek and Rzepecka, 2011). Significant limitations in development are often a result of poor relations between the bio-economy research and business.

In Poland, traditional bio-economy sector is well developed and produces about 8% of domestic value added (Wicki and Grontkowska, 2015) but modern and innovative areas of bio-economy are still in the early stages of development. Only energy from biomass is produced on an industrial scale but just as in the entire European Union, biomass is mainly used for heat energy production for home heating (SeeNews, 2015).

Likewise, the world production of bio-based products with high value added is low. Polymer production from biomass is just a fraction of world production. For example, production of bio-polypropylene is only 0.02% of its global production (TechNavio, 2015b). In 2014, value of the global market for bio-refining was USD 425 billion (TechNavio, 2015), including green chemicals market totalling about USD 55 billion. The most significant was production of bio-alcohols and bio-polymers (TechNavio, 2014).

In line with the EU strategy for the development of bio-economy, it is a strategic, integrating, cross-sectoral form of activity, which is consistent with interdisciplinary approach to the principles of planning and funding for research. Bio-economy also covers the issues of energy obtained from renewable sources and manufacturing processes of industries such as textile and paper industries as well as, partially, chemical, cosmetic and pharmaceutical industries. These integrating features of bio-economy will be crucial for the future of the EU as a centre of business and technology (European Commission, 2012). These issues are similarly defined in the United States White Paper on Bioeconomy (The White House, 2012). The use of plant, animal and micro-organism resources, with the support offered by biotechnology, genetics, chemistry and economics, may bring the expected results to the consumers and the EU economy but also to other regions of the world but so far the importance of this sector in the economies of various countries is small.

In Poland, the most important directions of research in the field of bio-economy are as follows (Kolesinska, 2015):

- developing processes for obtaining energy and chemicals with high value added from biomass derived from waste and vegetation using industrial biotechnology methods;
- obtaining new biomaterials and polymer composites of controllable biodegradability based on cellulose nanofibers and bio-nano-cellulose;
- developing technologies for obtaining new biocatalysts and biocatalyst mimetics for the production of fuel and organic chemical compounds of substantial industrial significance (platform molecules) from biomass;
- developing biotechnological processes for producing functional foods useful in preventing and treating diet-related diseases;
- developing new ways of integrating fermentation and bioconversion processes with product separation, purification and batching;
- developing biorefinery processes based on waste and renewable resources.

In short-term perspective, R&D activity in Poland in the area of bio-economy shall be mainly focused on 1) strengthening innovativeness and increasing competitiveness of food industry; 2) developing technologies for conversion of second generation biomass (residues from food industry, household and municipal wastes) into biofuels and raw industrial materials (Bielecki, 2014).

Latvia is among the countries, which, like Poland, put an emphasis on knowledge-intensive bio-economy, biomedicine and biotechnology,

[2]Corresponding author. Tel.: +48225934003; fax: + 48225934230. E-mail address: ludwik_wicki@sggw.pl.

within the intelligent specialisations (OREANDA-NEWS, 2015). Development of bio-economy may also give an impulse for development of local links between cities and their surrounding rural regions (Bulderberga, 2015) and for reducing greenhouse gas emissions, e.g. by producing energy from manure and waste (Popluga, Naglis-Liepa, Kaspars and Lenerts, 2015). So not only an economic evaluation of biogas production is important but also its assessment from the ecological perspective (Morken, Fjorttoft and Briseid, 2015). Production of bio-energy is currently unprofitable without public support related to environmental objectives pursued in the production of bio-energy.

Total growth in demand for food is anticipated on a global scale. Over 58% of the agricultural crop production is intended for food, 37% for animal feed and 5% for bio-fuels. Increasing production of biofuels is an activity in competition with food production. It is recommended that energy is produced from second- and third-generation raw materials such as waste and non-food products, bacteriophages, microalgae, and, finally, fourth-generation raw materials, i.e. genetically modified plants.

Production of energy from biomass is currently the only sphere of innovative bio-economy, which has developed on an industrial scale. It is also characterised by the lowest value added. This concerns the use of solid biomass and production of bio-ethanol, bio-diesel and biogas. Production of first-generation biofuels from products, which can be processed into food, and special agricultural production competing with food production is less and less supported. It is emphasized the need for production of biofuels from waste, by-products and special production, like algae that is second- and third-generation raw materials. The technological progress of production of bio-diesel from algae is significant and there are already industrial technologies available (Yu et al., 2009; Schenk et al., 2008). As of energy production from solid biomass, still a big limitation is the organisation and costs of transportation and storage (Rentizelas, Tolis and Tatsiopoulos, 2009). Large power plants require oil to be transported over long distances (Gostomczyk, 2012), while with the transport over a distance of more than 50 km, production of biomass from willow (Salix spp.) is unprofitable (Krzyzaniak, Stolarski, Szczukowski and Tworkowski, 2013). Eco-friendly production of energy from both the municipal and the industrial biological waste becomes more and more important (Parker, Fan and Ogden, 2010).

As indicated above, in addition to agriculture, food processing and forestry, bio-economy sectors, in which the production on an industrial scale is carried out, include primarily bio-energy sector.

Bio-economy has two pillars. The traditional one encompassing forestry, agriculture and food processing, and the modern one, associated with production of bio-energy and bio-materials, for example. The data concerning the entire sector based on biomass are not available. Therefore, for the purpose of this study, the importance of bio-economy in the national economy was defined as the sum of the sectors of economy, for which statistical records exist. Production of energy from biomass was described separately, pointing to its importance in the energy sector and the prospects for its development.

Goal and methods

The aim of the study is to determine the importance of bio-economy and its structure in Poland. The research tasks are as follows: 1) to determine volume of the bio-economy sector in Poland; 2) to determine the share of bio-economy in the overall economy; 3) to determine the importance of new sectors of bio-economy and the dynamics of their development.

The analysis covered the years 2000-2014. In this paper were used statistical data provided by the Central Statistical Office (GUS) and data provided by the Agricultural Market Agency, which supervises the biogas market. In terms of

[2]Corresponding author. Tel.: +48225934003; fax: + 48225934230. E-mail address: ludwik_wicki@sggw.pl.

the values, data are presented in nominal values, and the importance of the sector was assessed on the basis of its share in the economy.

In the assessment of bio-economy in the Polish economy, the following criteria were taken into account: share in global production, share in gross value added in the economy, share in fixed assets in the economy, share in employment and share in foreign trade. With regard to bio-energy market, in article is presented information about the volume of bio-energy production by source, the dynamics of growth of bio-energy production and its share in the energy supply in Poland.

Research results

In Poland, agriculture still plays an important role in the national economy, although year after year its importance decreases. It is a major branch of bio-economy, which provides raw materials of biological origin for further processing. Another important sector is agri-food processing industry and the following one is forestry. Table 1 shows the volume and share of the bio-economy sector in Poland. Global production volume, gross value added, gross fixed assets used in the sector as well as foreign trade turnover have increased in both nominal and real terms. In the analysed period, real increase in the global production volume and gross value added in agriculture was more than 25% and more than 60% in agri-food processing industry. In the same period, the gross value added in the Polish economy increased by 65%, so the relative share of bio-economy decreased.

Global production volume in bio-economy in 2014 amounted to more than PLN 340 billion (approx. USD 92 billion) that is 10% of global production volume in the Polish economy. Even greater was the importance of the sector for the employment, near 20%. This is so mainly due to fragmented agriculture, which employs more than 80% of the workers in the bio-economy sector. Another important area is foreign trade. Export generated by the sector was as much as 9.5% of the total Polish export. There was observed a positive balance of trade in products of the sector, which in 2014 amounted to about USD 12 billion. Polish foreign trade recorded a negative balance: USD -3.6 billion.

In 2014, the share of bio-economy sector in creating the gross value added was 6.2%. Its importance decreased steadily from 2000 to 2014 on an annual average of 2.3%. Its importance in fixed assets and employment was decreasing at similar pace. Only for foreign trade there was recorded a growing trend. On an annual average export grew by 1.7% and import by 2.1%.

Figure 1 shows changes in the bio-economy structure in the years 2000-2014. The structure of the bio-economy has become more modern. In 2000, the share of agriculture in generating gross value added was 57% and in 2014 as little as 41%. The role of food processing increased during this period from 39% to 53%. Forestry share remained at a similar level. Structure of the employment in bio-economy was quite different. As many as 83% of the employees worked in agriculture. Work efficiency in agriculture amounted to only 18% of the average productivity in the economy and in the processing sector and forestry it was close to the average. Law work efficiency will remain as long as there is no closer relationship between the agricultural enterprises and the market (Golebiewska, 2011). A limitation for rapid changes in agriculture is also low production profitability (Wicka et al., 2013).

[2]Corresponding author. Tel.: +48225934003; fax: + 48225934230. E-mail address: ludwik_wicki@sggw.pl.

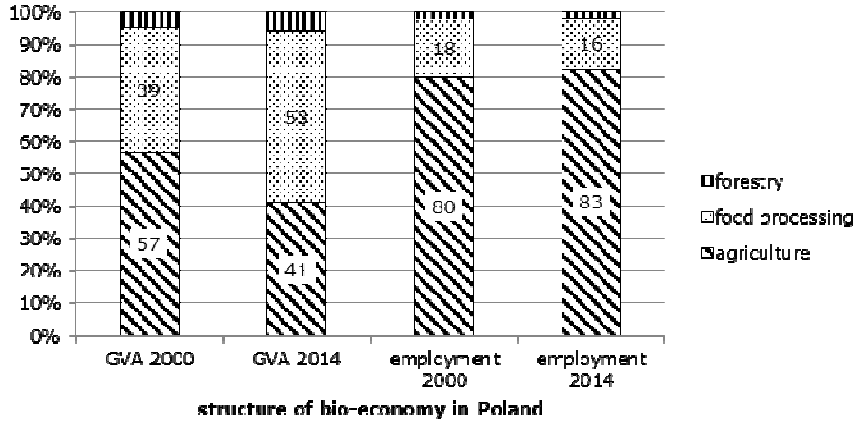
Table 1

The size and the share of bio-economy sector in Polish economy in the years 2000-2014

Year	Size of bio-economy sector in Poland						Share of bio-economy sector in national economy in Poland					
	gross production	GVA	fixed assets	export	import	no. of employees	gross production	GVA	fixed assets	export	import	no of employees
	in PLN billions (nominal value)					in milion	in percent					
2000	179	57.5	155	16.5	15.6	4.8	12.3	8.7	13.4	12.0	7.3	31.7
2001	184	59.6	158	17.1	15.8	4.8	12.0	8.6	13.0	11.6	7.6	32.5
2002	184	55.8	164	18.8	16.6	2.6	11.7	7.8	10.2	11.2	7.4	20.5
2003	193	56.9	168	24.7	18.0	2.6	11.7	7.7	10.0	13.2	6.8	20.5
2004	221	68.4	172	29.0	20.0	2.6	11.9	8.4	9.8	10.6	6.1	20.4
2005	218	68.3	178	37.3	25.6	2.6	11.2	7.9	9.7	12.9	7.8	20.0
2006	234	72.5	184	42.7	29.2	2.6	10.9	7.8	9.6	12.4	7.4	19.6
2007	274	79.3	192	48.2	35.3	2.6	11.4	7.7	9.3	12.5	7.7	18.9
2008	274	74.6	199	49.8	40.6	2.6	10.4	6.7	8.9	12.3	8.2	18.4
2009	282	80.8	207	58.8	44.0	2.6	10.5	6.8	8.7	13.9	9.5	18.6
2010	282	86.0	213	64.0	48.1	2.8	9.9	6.9	8.5	13.3	9.0	20.0
2011	326	97.5	231	73.4	56.9	2.8	10.4	7.3	8.6	13.1	9.1	19.8
2012	332	90.7	233	86.8	61.9	2.8	10.1	6.3	8.1	14.4	9.5	19.9
2013	344	95.1	243	98.5	64.6	2.8	10.3	6.5	7.9	15.2	9.8	19.7
2014	343	94.9	254	105.9	69.0	2.8	10.0	6.2	7.8	15.3	9.8	19.4
Annual avg. change (%)	-	-	-	-	-	-	-1.5	-2.3	-3.8	1.7	2.1	-3.4

In 2015 the exchange rate was: 1 USD =3,75 PLN

Source: authors' calculation based on statistical data of the Central Statistical Office of Poland



Source: authors' calculation based on statistical data of the Central Statistical Office of Poland

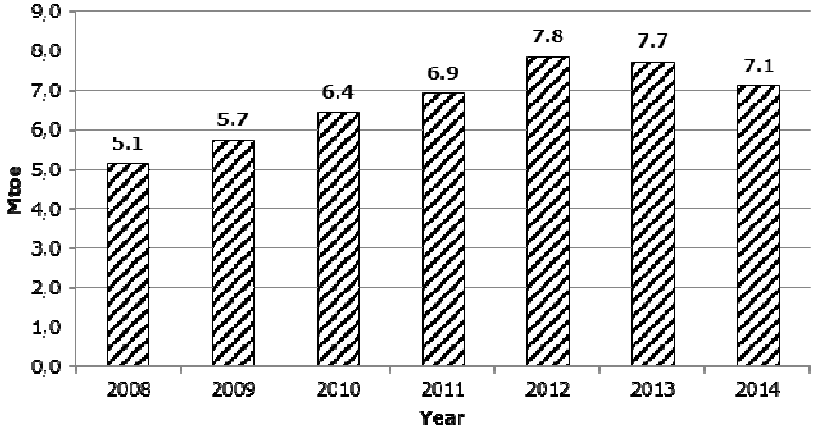
Fig. 1. **Internal structure of bio-economy in Poland in 2000 and 2014**

[2]Corresponding author. Tel.: +48225934003; fax: + 48225934230. E-mail address: ludwik_wicki@sggw.pl.

The visible importance of bio-economy in the Polish economy and its internal structure show that it is still a significant part of the economy. The volume of this sector will increase in real terms, mainly due to the increasing role of industrial processing. The most important area of processing is production of food, followed by production of energy. Bio-economy share in the national economy will be decreasing to around 4% of GDP.

In Poland, there are no available statistics to determine separately the importance of biofuels, biochemicals, bio-pharmaceuticals and bio-based construction materials. Production of liquid biofuels is classified to the agri-food processing industry. However, one can determine the growth of volume of production of biofuels, which are produced on an industrial scale. In other areas, the production has not even gone out beyond the laboratory stage.

Production of energy from biomass in Poland is based on four groups of raw materials. These include: solid biomass, bio-ethanol, bio-diesel and biogas. Data for the entire Poland are available from 2008. In the years 2008-2014, energy production based on the raw materials of biological origin increased (Figure 2). In 2008, it was 5.1 Mtoe (toe – tonne of oil equivalent) and in 2014 as much as 7.7 Mtoe. The largest share in the structure of the generated energy was the energy produced from solid biomass, in 2008 there was 92% and in 2014 - 87%. This was primarily biomass produced from wood achieved in forestry and from straw. Share of energy from bio-diesel and bio-ethanol increased rapidly but it still did not exceed 10% (Table 2). The share of biomass raw materials in the production of electricity from renewable energy sources increased significantly, from 28% in 2004 to 50% in 2014. The overall share of energy produced from biomass is approximately 84% of renewable energy in Poland.



Source: authors' calculation based on statistical data of the Central Statistical Office of Poland (GUS 2015)

Fig. 2. Volume of energy production form bio-renewable sources in the period 2008-2014 in Poland

[2]Corresponding author. Tel.: +48225934003; fax: + 48225934230. E-mail address: ludwik_wicki@sggw.pl.

Table 2

Structure of energy production from bio-renewable sources in Poland in the period 2008-2014 (in percent)

Year	Share of energy produced from bio-sources (in percent)			
	solid biomas	**biodiesel**	**bio-ethanol**	**biogas**
2008	92.4	4.6	1.1	1.9
2009	90.8	5.9	1.6	1.7
2010	91.1	5.4	1.7	1.8
2011	91.8	4.8	1.4	2.0
2012	89.2	7.1	1.6	2.1
2013	88.6	7.5	1.6	2.4
2014	86.7	9.2	1.3	2.9

Source: authors' calculation based on statistical data of the Central Statistical Office of Poland (GUS 2013, GUS 2014, GUS 2015)

It is important that production of bio-energy does not compete with production of food and there are used the second-generation biofuels. In Poland, the share of energy produced from agricultural raw materials is still large. This concerns, in particular, production of bio-diesel and bio-ethanol and, partially, also production of biogas. Production of bio-diesel in Poland increased from 263 thousand tonnes in 2008 to 740 thousand tonnes in 2014. Given that the yield of rapeseed oil is 40%, whereas 1.63 million tons of rapeseed are required for production of bio-diesel. With the average yield of about 2.85 tonnes per 1 ha in Poland, about 570 000 ha of land is needed to produce the sufficient amount of bio-diesel.

Productivity of bio-ethanol from cereal raw materials is about 340 litres per 1 tonne (Kaszkowiak and Kaszkowiak, 2013). In order to produce bio-ethanol consumed in Poland for energy purposes (91 thousand tonnes in 2014) are required 335 thousand tonnes of cereal grains. With the average yields of cereals amounting to 3.6 tonnes per 1 ha in Poland, the area of cereal production for bio-ethanol is 93 thousand ha. The area for production of bio-diesel and bio-ethanol should cover 660 thousand ha of the arable land. It is 6% of the arable land in Poland. This production competes with food production. It is also pointed out that it is inefficient in terms of energy-saving (Dobek, 2007; Dobek et al., 2010). The energy produced from such biofuels covers only energy consumption for its production. A surplus of energy could be gained only by burning, in addition, the straw from rape and cereals.

In 2014, production of agricultural biogas in Poland was carried out in 58 agricultural biogas plants and amounted to 174 million cubic meters of biogas (ARR, 2015), i.e. 38.9 thousand toe. Agricultural biogas represented around 30% of the biogas production in Poland. Another part of production of biogas in landfills and waste water treatments, together totalling to 140 thousand toe. Share of biogas in production of energy from renewable sources is about 2.9%, and in total energy production – only 0.09%.

Production of biogas in agricultural biogas plants is based on the use of waste and specially produced vegetable raw materials (e.g. silage maize). In 2014, 2.1 million tonnes of raw materials were used in agricultural biogas plants. The raw materials included: manure (about 30%), waste from food industry (40%) and silage maize (30%). The overall area of production of silage maize to be used as an input to biogas plants is 7000 ha that gives an average of 120 ha per 1 biogas plant. The biogas plants processed manure from about 28 thousand large units of animals. This is the amount of manure

[2]Corresponding author. Tel.: +48225934003; fax: + 48225934230. E-mail address: ludwik_wicki@sggw.pl.

that can be produced by 170 thousand pigs for fattening (1.8% of the pig population in Poland). Both the area for production of raw materials and the share of the manure processed show that importance of agricultural biogas production in Poland is small. Considering the current prices of energy and green certificates in Poland it is not a profitable production, with zero profitability (Ciurzynski, 2014) and the prospects of price changes are not satisfactory (Biomasa Magazine, 2016).

Conclusions

Bio-economy sector in Poland has a traditional structure and is still quite important in the overall economy. Its share in generating gross value added is about 6.5%, in employment as much as 19% and in foreign trade: 15% in export and 10% in import. The importance of the sector in the years 2000-2014 decreased by about 2% on an annual average. Global annual production volume of the sector is about USD 90 billion. The structure of bio-economy is dominated by traditional sectors: agriculture, food processing industry and forestry. The importance of agriculture decreases and in 2014 it fell to a 41% share in the sector. The importance of food processing increased – from 39 to 53% GVA of the sector.

Production in the innovative areas of bio-economy is still small and relates primarily to production of energy from biomass. There is currently no plant for processing biomass into products with higher value added. These technologies are still in the experimental stage.

Production of energy from biomass in Poland increases. In 2014, energy from biomass was 9.9% of total energy production. Its primary source was the solid biomass, mainly from forestry, which represents as much as 87% of the total volume. Production of bio-ethanol and bio-diesel (9.2% and 1.3%) and production of biogas (2.9%) are of less importance. In Poland, agricultural raw materials for production of biofuels are produced in about 6% of the arable land. The main direction of development of bio-energy production should be production from waste, including waste from agriculture.

Production of agricultural biogas in Poland is small. Only 0.9% of energy is produced from biomass. Development of this production is not profitable without public support, which should be compensated by the environmental effects, including reduction of GHG emissions. In Poland, biogas plants process only 2% of manure.

Development of bio-economy in Poland should be based on production of bio-energy from second- and third-generation biomass and production of products with high value added, e.g. bio-polymers. Innovative areas of bio-economy in Poland are still in the initial stage of development. Production on an industrial scale does not exist. A major limitation may be low competitiveness of these technologies in terms of cost.

Bibliography

1. ARR. (2015). *Sprawozdanie z dzialalnosci Agencji Rynku Rolnego w 2014 r. (The report on the activities of Agricultural Market Agency in 2014.)* Warszawa: Agencja Rynku Rolnego.
2. Bielecki, S. (2014). Bioeconomy in Poland - Open Opportunities. *3rd Bioeconomy Stakeholder Conference,* Turin October 8-9, 2014. Turin.
3. Biomasa Magazine. (2016). Bedzie rezerwa zielonych certyfikatow dla biogazowni (There Will Be the Reserve of Green Certificates for Biogas). *Magazyn Biomasa (Biomasa Magazine).* Retrieved: http://magazynbiomasa.pl/bedzie-rezerwa-zielonych-certyfikatow-dla-biogazowni/. Access: 1.20.2016.
4. Bukowski, M., Szpor, A., Sniegocki, A. (2012). Drzemiacy tygrys, spetany orzel. *Dylematy polskiej debaty o polityce innowacyjnej (Napping Tiger, Eagle Hindered. Dilemmas of Polish Debate on Innovation Policy).* Warszawa: Instytut Badan Strukturalnych (Institute for Structural Research).
5. Bulderberga, Z. (2015). Forecasted Outcomes of Latvian Regional Policy's Implementation in Municipalities. In: In Proceedings of the 25th NJF Congress. *Nordic View To Sustainable Rural Development*. Riga: NJF Latvia, pp. 472-480.
6. Chylek, E., Rzepecka, M. (2011). Biogospodarka – konkurencyjnosc i zrownowazone wykorzystanie zasobow (Bio-economy - Competitiveness and the Sustainable Use of Resources). *Polish Journal of Agronomy*(7), pp. 7-13.

[2]Corresponding author. Tel.: +48225934003; fax: + 48225934230. E-mail address: ludwik_wicki@sggw.pl.

7. Ciurzynski, L. (2014, 10 9). Ile mozna zarobic na biogazie, czyli oplacalnosc biogazowni (How Much You Can Earn on Biogas, or the Profitability of Biogas Plants). *Magazyn Biomasa (Biomasa Magazine).* Retrieved: http://magazynbiomasa.pl/ile-mozna-zarobic-na-biogazie-czyli-oplacalnosc-biogazowi/. Access: 3.01.2016.
8. Dobek, T. (2007). Ocena efektywnosci ekonomicznej i energetycznej produkcji pszenicy ozimej i rzepaku ozimego wykorzystanych do produkcji biopaliw (Evaluation of Economic Effectiveness and Power Consumption for Farming of Winter Rapeseed and Winter Wheat Utilized for Biofuel Production). *Inzynieria rolnicza (Agricultural Engineering),* (6 (94)), pp. 41-48.
9. Dobek, T., Dobek, M., Sarec, O., (2010). Ocena efektywnosci ekonomicznej i energetycznej produkcji pszenicy ozimej i rzepaku ozimego wykorzystanych do produkcji biopaliw (Assessment of Economic and Energy Efficiency for the Production of Winter Wheat and Winter Rape Used to Manufacture Biofuels). *Inzynieria rolnicza (Agricultural Engineering)*, (1(119)), pp. 161-168.
10. European Commission. (2012, 2 7). *Why the Bioeconomy Matters. European Commission workshop outlines the Bioeconomy's impact in our lives*. Retrieved: http://ec.europa.eu/research/bioeconomy/pdf/120207_european_commission-bioeconomy-workshop_en.pdf. Access: 4.01.2016.
11. European Commission. (2012, 2 13). *Innowacje w sluzbie zrownowaznego wzrostu: biogospodarka dla Europy (Innovating for Sustainable Grow: A Bioeconomy for Europe).* (COM2012(60)). Brussel: European Commission.
12. Golebiewska, B. (2011). Significance of Connections with the Environment of Agricultural Farms in Poland for their Production and Economic Situation. *Economic Science for Rural Development - Production and Taxes*, (24), pp. 40-49.
13. Golebiewski, J. (2013). Value Chains Within Bioeconomy. *International Scientific Electronic Journal "Earth Bioresources and Life Quality"*, (4), pp. 1-15. Retrieved: http://gchera-ejournal.nubip.edu.ua/index.php/ebql/issue/current. Access: 16.01.2016.
14. Golebiewski, J. (2014). Biogospodarka jako inteligentna specjalizacja regionow w Polsce (Bioeconomy as a Smart Specialization of Regions in Poland). *Przedsiebiorczosc i Zarzadzanie (Entrepreneurship and Management),* Vol. 15, z. 8, part 1, pp. 55-69. Retrieved: http://piz.san.edu.pl/docs/e-XV-8-1.pdf. Access: 18.01.2016.
15. Golebiewski, J. (2015). Zrownowazona biogospodarka – potencjal i czynniki rozwoju (Sustainable Bio-economy - the Potential and Development Factors). In: (Czyzewski, A., Klepacki, B. eds.) *Problemy rozwoju rolnictwa i gospodarki zywnosciowej w pierwszej dekadzie czlonkostwa Polski w Unii Europejskiej: IX Kongres Ekonomistow Polskich (Problems of Development of Agriculture and Food Economy in the First Decade of Polish Membership in the European Union: IX Congress of Polish Economists)*. Warsaw: Polskie Towarzystwo Ekonomiczne, pp. 344-362.
16. Gostomczyk, W. (2012). Organizacja systemu logistycznego w produkcji i wykorzystaniu biomasy energetycznej (The Organization of the Logistic System in the Production and Use of Biomass Energy). *Logistyka (Logistics),* (4), pp. 939-946.
17. GUS. (2014). *Energia ze zrodel odnawialnych w 2013 r. (Energy from Renewable Sources in 2013).* Warsaw, Polska: Glowny Urzad Statystyczny (Central Statistical Office of Poland), p. 69.
18. GUS. (2015). *Energia ze zrodel odnawialnych w 2014 r. (Energy from Renewable Sources in 2014)*. Warszawa, Polska: Glowny Urzad Statystyczny (Central Statistical Office of Poland), p.68.
19. Kaszkowiak, E. i Kaszkowiak, J. (2013). *Plon i wydajnosc bioetanolu z kukurydzy w warunkach gleb lekkich (The Yield and Efficiency of Bio-ethanol From Corn in the Conditions of Light Soils).* Inz. i Ap. Chem. (Chemical Engineering And Equipment), 52(2), pp. 56-57.
20. Kolesińska, B. (2015, 5 7). *University for the Bio-Economy. Retrieved*: The Warsaw Voice online: http://www.warsawvoice.pl/WVpage/pages/articlePrint.php/28053/article. Access: 4.01.2016.
21. Krzyzaniak, M., Stolarski, M., Szczukowski, S., Tworkowski, J. (2013). Ekonomiczne aspekty produkcji biomasy wierzby w jednorocznym i trzyletnim cyklu zbioru (Economic Aspects of Willow Biomass Production in Annual and Triennial Harvest Cycle). *Rocz. Ekon. Rol. i Rozw. Obsz. Wiejskich (Annals of Agricultural Economics and Rural Development)*, 100(1), pp. 211-119.
22. Maciejczak, M. (2015). How To Analyze Bioeconomy? Roczniki Naukowe, *Stowarzyszenie Ekonomistow Rolnictwa i Agrobiznesu (Annales of Polish Association of Agricultural and Agribusiness Economists),* vol. XVI(6), pp. 165-171.
23. Maciejczak, M., Hofreiter, K. (2013). How To Define Bioeconomy? Roczniki Naukowe Stowarzyszenia Ekonomistow Rolnictwa i Agrobiznesu (Annales of Polish Association of Agricultural and Agribusiness Economists), vol. XV(4), pp. 243-248.
24. Morken, J., Fjorttoft, C., Briseid, T. (2015). *Agricultural Biogas Plants - Energy Balance*. In Proceedings of the 25th NJF Congress. Nordic View To Sustainable Rural Development. Riga: NJF Latvia, pp.370-374.
25. OREANDA-NEWS. (2015, 5 29). Latvia to Become European Centre for Innovation and Research for One Week. *Международные экономические новости (International Economic News).*
26. Parker, N., Fan, Y., Ogden, J. (2010). *From Waste to Hydrogen: An Optimal Design of Energy Production and Distribution Network*. Transportation Research Part E, Logistics and Transportation Review, 46(4), pp. 534-545.
27. Patermann, C. (2008, 10 1). *The Knowledge-Based Bio-Economy - from Concept to Practice: Experiences in Germany - Particularly in North-Rhine Westphalia - and Europe*. Retrieved: Webpage of Kassel University - Ost-West-Wissenschaftszentrum, documents from V International Symposium "EU-Russia": http://www.owwz.de/fileadmin/Biotechnologie/BioVeranst/Pushchino_2008/Patermann.pdf. Access: 14.01.2016.
28. Popluga, D., Naglis-Liepa, K, Lenerts, A. (2015). Latvia's Progress Towards Agricultural GHG Mitigation. In Proceedings of the 25th NJF Congress. *Nordic View To Sustainable Rural Development*. Riga: NJF Latvia, pp. 265-269.
29. Rentizelas, A., Tolis, A., Tatsiopoulos, I. (2009). Logistics Issues of Biomass: the Storage Problem and the Multi-biomass Supply Chain. *Renewable and Sustainable Energy Reviews*(13), pp. 887-894.

[2]Corresponding author. Tel.: +48225934003; fax: + 48225934230. E-mail address: ludwik_wicki@sggw.pl.

30. Schenk, P., Thomas-Hall, S., Stephens, E., Marx, U., Mussgnug, J., Posten, C., Hankamer, B. (2008). Second Generation Biofuels: High-efficiency Microalgae for Biodiesel Production. *Bioenergy Research*, 1(1), pp. 20-43.
31. SeeNews. (2015, 10 22). AEBIOM Sees Bioenergy Growing by 33 Mtoe by 2020. *SeeNews Renewables*.
32. Tapscott, D., Williams, A. (2011). Makrowikinomia. *Reset swiata i biznesu (Macrowikinomics: Rebooting Business and the World)*. Warszawa: Studio Emka, p. 432.
33. TechNavio. (2014). *Global Green Chemicals Market 2014-2018*. Infiniti Research Limited, p. 71.
34. TechNavio. (2015). *Global Biorefinery Market 2015-2019*. Infiniti Research Limited, p. 117.
35. TechNavio. (2015b). *Global Bio-Polypropylene Market 2015-2019*. Infiniti Research Limited, p. 70.
36. The White House. (2012). *National Bioeconomy Blueprint. Washington DC*: The White House.
37. Wicka, A., Golebiewska, B., Golebiewski, J., Jedrzejczyk, I., Kobus, P., Wicki, L., Wojciechowska-Lipka, E. (2013). Czynniki i mozliwosci ograniczania ryzyka w produkcji roslinnej poprzez ubezpieczenia (Factors and Possibilities of Reducing the Risk of Crop Production Using Insurance). Warszawa: Wydawnictwo SGGW, p. 271.
38. Wicki, L., Grontkowska, A. (2015). *Zmiany znaczenia agrobiznesu w gospodarce i w jego wewnetrznej strukturze (Changes of the Importance of Agribusiness in the Economy and in Its Internal Structure).* Rocz. Nauk Ekonomii Rolnictwa i Rozwoju Obszarow Wiejskich (Annals of Agricultural Economics and Rural Development), 102(3), pp. 20-32.
39. Yu, G., Zhang, Y., Schideman, L., Funk, T., Wang, Z. (2009, October 11-14). Bio-crude Oil Production From Microalgae Through Hydrothermal Process. Bioenergy Engineering(11-14).

[2]Corresponding author. Tel.: +48225934003; fax: + 48225934230. E-mail address: ludwik_wicki@sggw.pl.