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PRODUCTION AND USE OF BIOENERGY IN POLAND IN THE CONTEXT OF THE DEVELOPMENT OF BIOECONOMY

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Growing demand for energy, along with the depletion of traditional fossil fuels and the development of civilization, raises interest in the use of bioenergy in all sectors of the economy, including electricity, transport, heating, cooling, and industry. In developed countries bioenergy is an alternative to traditional non-renewable energy from fossil fuels, as its resources renew in natural processes, making it practically inexhaustible. Due to the reduction of greenhouse gas emissions, bioenergy is also more environmentally friendly than fossil energy. Thus bioenergy sector is a key segment of bio-economy and determines its competitiveness and development. Increase in bioenergy production, resulting from both market and energy policies, leads to greater interdependence between energy and agricultural markets, affects food and feed prices and change in land use.
The aim of this study was to identify changes in the bioenergy market in Poland in 2010-2015, present the role of bioenergy sector production in the structure of bio-economy, the changes in production and directions of biomass-based energy use and determine the importance of the major bioenergy markets in the structure of the energy market in Poland. The study was based on the aggregated statistical data on the acquisition and consumption of bioenergy in Poland, including energy from municipal waste, solid biofuels, biogas and liquid biofuels.
Findings prove that bioenergy is the most important renewable energy source in Poland. It is also a diversified source of energy, as it can be converted into solid, liquid and gaseous fuels. Although solid biofuels and liquid biofuels dominate in Poland, the share of biogas and energy produced from municipal waste is small. Concluding, bioenergy in Poland changes its character from traditional and local energy source into modern, international commodity.

Keywords: bioeconomy, bioenergy, Poland

INTRODUCTION

The term ‘bio-economy’ refers to a set of sectors within the national economy, which produce and process renewable resources. In the report titled ‘The Knowledge Based Bio-Economy (KBBE) in Europe: Achievements and Challenges’ the term ‘bio-economy’ was defined as follows: ‘the bio-economy is the sustainable production and conversion of biomass, for a range of food, health, fibre and industrial products and energy. Renewable biomass encompasses any biological material to be used as raw material’ (European Commission, 2010). In the sectoral approach, the bio-economy encompasses many areas of economic activity that are involved in the production and distribution of articles containing components of biological origin (European Commission, 2012; Adamowicz, 2014). The most important segments of bio-economy include primary production sectors such as agriculture, forestry and fishery, which produce biomass using natural resources (soil, air and water). The biomass can be next used as a primary raw material for other areas of bio-economy e.g. food production, chemical industry, pharmaceutical industry, production of cosmetics and textiles, as well as energy production (Chyłek, 2012).

In 2012, the European Commission adopted the ‘Sustainable growth: a bio-economy for Europe’ strategy, which seeks to create conditions for the development of an innovative, resource-efficient and competitive economy. In this economy it will be possible to reconcile food security with the use of renewable resources for industrial and environmental purposes (European Commission, 2012). The bio-economy development strategy also aims to increase the use of biomass raw materials, which will be used not only for traditional food applications, but more and more frequently also for modern, innovative, high value added products such as chemicals, pharmaceuticals, energy and fuels (Gołębiewski, Pająk, 2016).

Bioenergy sector, including the use of biomass for food, feed, materials and chemicals, is a key segment of bio-economy (European Commission, 2012a) and determines its competitiveness and development (Schmid et al, 2012). Bioenergy is mainly obtained from organic matter, called biomass, i.e. all materials of biological origin not embedded in

geological formations (fossilised). Biomass can be used in its original form as fuel, or be converted into different kinds of solid, gaseous or liquid biofuels. These fuels can be used by the society and in all sectors of the economy, including production of electricity, transport, heating and cooling, as well as industrial processes (World Energy Council, 2016). Biomass is supplied by three sections – forestry, agriculture and waste. Although globally some of the waste is mixed with materials of fossil origin, like fossil-based plastics, most waste consists of a large share of biogenic material such as paper, wood, biogenic textiles, rubber, bio plastics, etc., and there are also large streams of waste and residues from agriculture, forestry, fishing, food chains, and all connected industries. In most countries, the first step in developing a modern bioenergy sector is to better utilise wastes and residues as sources of bioenergy (Gołębiewska, 2017).

Increasing interest in the use of bioenergy in all sectors of the economy results from growing demand for energy generated by the developing and developed societies and the depletion of traditional fossil fuels (World Energy Council, 2016). Although the increase in bioenergy production results from market conditions it needs to be supported by energy policies (Scarlat, 2015). The development of the EU energy policy started with the Green Paper 'A European Strategy for Sustainable, Competitive and Secure Energy' (European Commission, 2006) following the request of the European Council to develop a long-term and coherent energy policy. The European Council adopted energy and climate change objectives for 2020: to reduce GHG emissions, to increase the share of renewable energy, and to make an improvement in energy efficiency compared to the baseline projection. The Renewable Energy Directive 2009/28/EC (RED) on the promotion of renewable energy sources translated the energy targets for 2020 into legally-binding frameworks and tasks: the 20% share of renewable energy in final energy consumption and 10% renewable energy use in the transport sector (EU, 2009). Next the Fuel Quality Directive 2009/30/EC (FQD) set a target of a 6% GHG reduction for the fuels used in transport in 2020 (EU, 2009b). And so, bioenergy is expected to provide almost 60% of the renewable energy in 2020 (EU, 2009a).

Furthermore the communication 'A policy framework for climate and energy in the period from 2020 to 2030' put forward an integrated policy framework for the period beyond 2020 and up to 2030 to drive progress towards a low-carbon economy (European Commission, 2014). It aims to build a competitive energy system that increases the security of energy supply, reduces energy dependence and creates new opportunities for growth and jobs. Targets proposed for 2030 include 40% reduction of GHG emissions compared to 1990 levels and at least 27% share of renewable energy in the final energy consumption.

The key constraint to the expansion of bioenergy production is the limited amount of land available to meet the needs for fuel, feed, and food in coming decades. Large-scale bioenergy production raises concerns about food versus fuel trade, demand for natural resources such as water, and its potential impacts on environmental quality. Policies to support bioenergy production have distributional implications for consumers and producers, farm and nonfarm sectors (Khanna et al., 2010). Moreover, the potential to gain significant independence from foreign oil for most countries, by relying simply on corn as feedstock for bioenergy is limited. This has increased interest in second-generation lignocellulosic feedstock that can increase the energy productivity of the land resource (Wicki, 2017).

The increasing production of biomass feedstock and conversion to energy has important direct and indirect economic consequences which influence the environmental and socio-economic performance of bioenergy systems and policies. In the past, agricultural markets and energy markets were not closely correlated. Higher energy prices and the use of conventional agricultural crops and wood pellets for bioenergy increased the correlation between energy markets and conventional markets for agricultural commodities and forestry production (Du, McPhail 2012; Baffes, Dennis 2013).

In Poland, the assumptions for the development of renewable energy have been laid down in the 'Strategy for the development of renewable energy' (Ministry of Environment, 2000), 'Program for power engineering' (Ministry of Economy, 2006) and 'Poland's energy policy until 2030' (Ministry of Economy, 2009). In 2010, the Council of Ministers accepted the 'National Action Plan on Renewable Energy' (Minister of Economy, 2010), which sets the increase in the use of renewable energy to 15.5% in 2020 as the strategic aim of the state policy in Poland. According to the documents promoting the use of energy from renewable sources, it is also essential to increase the diversification of energy supplies and to create conditions for the development of distributed energy based on local sources, which in 2007-2015 was also supported by EU funding under operational programmes 2007-2013 (Rakowska, 2016).

Taking into consideration the above, the aim of this study was to identify changes in the bioenergy market in Poland in 2011-2015, present the role of bioenergy sector production in the structure of bio-economy, evaluate changes in production and directions of biomass-based energy use and determine the importance of the major bioenergy markets in the structure of the energy market in Poland.

RESEARCH METHODS

The study was based on the aggregated statistical data on the acquisition and consumption of renewable energy, including bioenergy published in reports of the Central Statistical Office of Poland for 2011-2015. The statistics are expressed in units of energy, i.e. TJ - Terajuoules and Mtoe - million tonnes of equivalent oil. The data were also used for EU-28 according to the energy balance sheets drawn up and made available by the EUROSTAT.

The paper presents the stand point that the supply of bioenergy includes domestic production, plus imports, less exports and is corrected with inventory balances. The domestic use of bioenergy includes the end use of bioenergy, directly by the end users, the use of bioenergy as feedstock for production and the use of bioenergy by the energy sector itself.

The end (final) consumption consists of the use of bioenergy in production (industrial production), construction, transport, and by other users, including trade and services, households, agriculture and forestry.

RESEARCH RESULTS

World bioenergy use in 2010 equalled 1277 Mtoe, which is about 10% of the total global primary energy use (IEA, 2012). About 60% concerned the traditional use of biomass for cooking and heating. Traditional use of bioenergy is the combustion of solid fuels such as firewood, charcoal and agricultural residues for cooking, heating and lighting. The remaining 40% was used in modern bioenergy systems. Modern bioenergy involves the use of biomass in producing higher value energy carriers, such as electricity, liquid and gaseous fuels, or heat and power in modern installations.

The industry and power sectors use more than half biomass in modern energy systems. Non- traditional biomass is expected to go up from 526 Mtoe in 2010 to nearly 1200 Mtoe by 2035, growing at a rate of 3.3% per year (IEA, 2012). Both biofuels and power doubled their share in the world energy consumption and by 2035 are expected to reach 210 Mtoe and 420 Mtoe, respectively. Traditionally biomass for heat, power and industrial applications has been locally sourced, but trade becomes more and more important (IEA, 2012).

On April 23, 2009 the European Parliament and the European Council adopted Directive 2009/28/EC on the promotion of the use of energy from renewable sources, that set a number of tasks for the EU Member States, in particular: the common framework for the promotion of energy from renewable sources, mandatory national general targets defining total share of renewable energy in gross final energy use and the share of renewable energy in transport (EU, 2009). It assumed that the share of renewable energy in total primary energy will increase in all EU-28 countries (Figure 1).

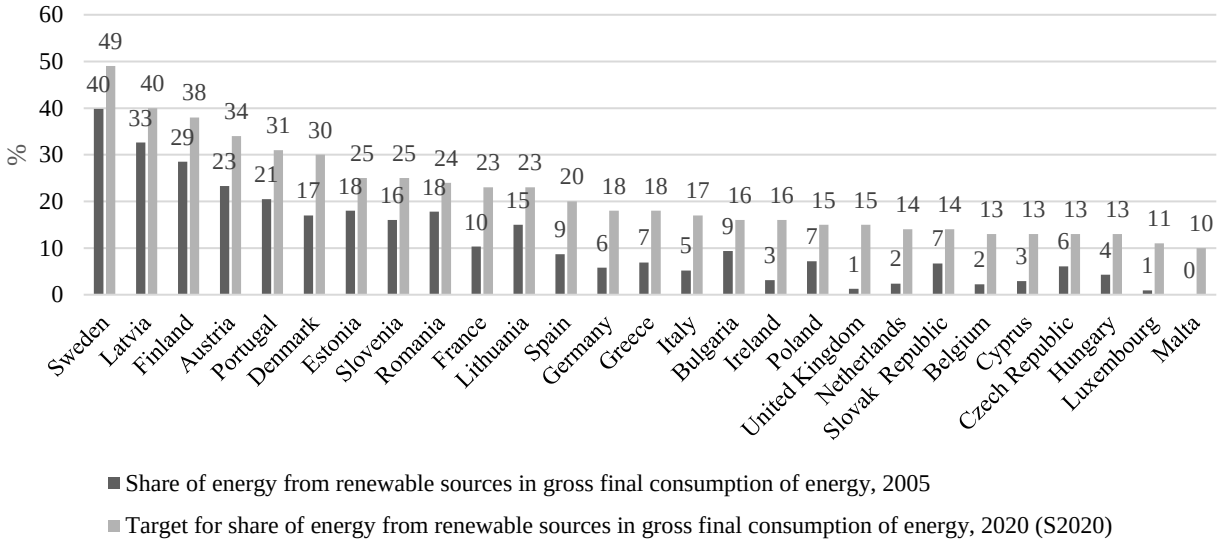

Figure 1. National overall targets for the share of energy from renewable sources in gross final consumption of energy in 2020
Source: EU, 2009. Directive 2009/28/EC of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC.

The highest level of these indices was established for Sweden and Latvia (over 40%, and a little less for Finland, Portugal, Austria and Denmark - up to 30%. These are country-specific targets and constitute reference points for their renewable energy development policies.

Table 1. Primary energy acquisition (including renewable energy sources) in selected EU countries

Specification	Primary energy acquisition								The share of energy from renewable sources in the total primary energy (%)			
	total (Mtoe)				from the renewable energy sources (Mtoe)							
	2011	2012	2013	2014	2011	2012	2013	2014	2011	2012	2013	2014
UE-28	802.2	795.3	790.5	770.7	164.3	180.6	192.8	195.8	20.5	22.7	24.4	25.4
Austria	11.4	12.4	12.1	12.1	8.3	9.4	9.4	9.4	72.8	75.2	77.6	77.6
Czechs	32	32	29.9	29.1	3	3.2	3.6	3.7	9.5	10.2	12.2	12.6
Finland	17.1	17.1	18	18.1	9.2	10	9.9	10.1	53.8	58.2	55.2	55.8
France	134.4	132.8	134.5	135.9	17.5	20.3	22.6	21	13	15.3	16.8	15.5
Netherlands	64.4	64.7	69.3	58.4	3.2	3.9	4.4	4.6	5	6.1	6.3	7.8
Lithuania	1.3	1.3	1.4	1.5	1.2	1.2	1.3	1.4	90.1	90.8	91.1	91.3
Germany	122.7	122.7	120.6	119.9	29.5	32.1	33.7	36	24	26.1	27.9	30
Poland	68.8	72.6	71.8	68.2	7.5	8.5	8.6	8.1	10.9	11.7	11.9	11.9
Slovakia	6.2	6.2	6.4	6.3	1.4	1.4	1.5	1.4	22.5	23	22.9	22.8
Italy	32	35	36.9	36.8	18.2	21.1	23.5	23.6	56.9	60.2	63.7	64.2

Source: authors' elaboration based on GUS 2015.

In June 2016 the European Parliament adopted a resolution on reporting on the progress in renewable energy sector (European Parliament, 2016). The Parliament also called on the Commission to present a more ambitious climate and

energy package to be carried out by 2030, setting a higher EU target for renewable energy of at least 30%. The new EU target should be implemented by setting and achieving individual national targets. It was emphasized that the targets set for 2020 should be considered as the minimum during the revision of the Renewable Energy Directive. In its resolution of September 13, 2016 titled 'Towards a New Energy Market Structure' the European Parliament called for the development of a common definition of 'prosumers' at the EU level and for 'incorporating a new chapter on prosumers into the revised Renewable Energy Directive in order to eliminate major barriers and to stimulate investments in own production and own consumption of energy from renewable sources' (European Parliament, 2016a). To develop the EU renewable energy package, which was presented at the end of 2016, the European Commission carried out research and analysis on how to ensure sustainable supply, combined with the optimal use of biomass for energy after 2020 (PwC, 2017). Table 1 shows changes in the production of renewable energy in selected EU countries in 2011-2014, compared to the production of primary energy.

Production of renewable energy in UE-28 increased from 164 Mtoe in 2011 to more than 195 Mtoe in 2014. It occurred while the production of total primary energy decreased slightly from 802 Mtoe in 2011 to 770 Mtoe in 2014. The share of the energy from renewable sources in the total primary energy increased in all the analysed countries (Table 1), although the dynamics of changes were different. The biggest share of energy from renewable sources in the total primary energy was observed in 2014 in Lithuania, Austria, Italy and Finland, which already at that time achieved the aims for 2020.

Table 2 shows the share of bioenergy in renewable energy in selected EU countries. The data prove that in 2011-2014 the share of bioenergy in the structure of renewable energy decreased from 67 down to 63%, meaning that bioenergy made less than 2/3 of the market of renewable bioenergy. Solid biofuels were the most important source of bioenergy. More than 43% of renewable energy was produced from wood biomass. Other sources of bioenergy, such as biogas and liquid biofuels account for about 7% of renewable energy production, while bioenergy from waste had the lowest share. The importance of bioenergy in renewable energy production varied considerably across the EU. The highest share of bioenergy in renewable energy production was achieved in 2014 by Lithuania and Poland, respectively 92.7 and 88.9%.

Table 2. The structure of bioenergy acquisition in selected EU countries (the share of bioenergy in renewable energy acquisition in %)

Years	EU-28	Austria	Czechs	Finland	France	Netherlands	Lithuania	Germany	Poland	Slovakia	Italy
Solid biofuels											
2011	49.3	52.8	68.6	83.4	49.4	35	84.6	36.1	85.2	56.5	26.2
2012	48.2	48.3	66.3	79.7	46	31.6	82.8	34.1	82.4	55.9	34.4
2013	45.9	49.9	63	81.4	46	27.5	80.8	32.4	80.2	52.4	31.7
2014	43.8	46.7	62.9	80.1	43.3	28.3	82.2	31.7	76.6	52.7	27.7
Biogas											
2011	6.4	2	8.2	0.6	2	8.9	1	17.6	1.8	3.3	6.1
2012	6.8	2.2	11.5	0.6	1.9	7.4	1	20	2	4.3	5.6
2013	7.2	2.1	15.7	0.9	1.9	7	1.2	20.4	2.1	3.7	7.7
2014	7.6	3.1	16.6	1	2.1	6.9	1.5	20.6	2.6	6.7	8.3
Liquid biofuels											
2011	6.4	3.2	7.3	2.4	11.7	13.6	7.1	10.9	5.8	12.2	3.4
2012	6.3	2.8	6.7	2.8	11.7	26.6	9	9.3	8	10.5	1.8
2013	6.6	2.4	6.3	3.7	10.7	33.9	9.2	9.4	8.2	10.1	2.3
2014	7.1	4.1	7.1	4	12.2	33.4	8.2	10	9.2	10.2	2.6
Renewable municipal waste											
2011	5	1.7	2.6	1.5	6.5	27.3	0	8.2	0.4	1.3	4.6
2012	4.7	1.5	2.6	1.9	6.2	21.8	0	8.1	0.4	1.3	3.8
2013	4.5	1.6	2.3	2.2	5.2	18.3	0.9	8.7	0.4	1.1	3.5
2014	4.6	1.9	2.3	2.4	5.6	17.4	0.8	8.4	0.5	0.8	3.6
Bioenergy total											
2011	67.1	59.7	86.7	87.9	69.6	84.8	92.7	72.8	93.2	73.3	40.3
2012	66.0	54.8	87.1	85,0	65.8	87.4	92.8	71.5	92.8	72,0	45.6
2013	64.2	56	87.3	88.2	63.8	86.7	92.1	70.9	90.9	67.3	45.2
2014	63.1	55.8	88.9	87.5	63.2	86	92.7	70.7	88.9	70.4	42.2

Source: authors' elaboration based on CSO 2015 and EUROSTAT.

Between 2011 and 2014 the share of biofuels in renewable energy decreased from 49.3% to 43.8% and municipal waste from 5% to 4.6%. On the other hand, growth was noted in case of biogas and liquid biofuels. As regards biogas, its use increased in the Czech Republic, Germany and Italy. National balances of renewable energy sources in Poland for 2011-2015 were elaborated based on the results of statistical surveys on the amount of energy produced and consumed in the given year. Figure 2 shows data on total primary energy generation in 2011-2015 in Poland, including energy from renewable sources.

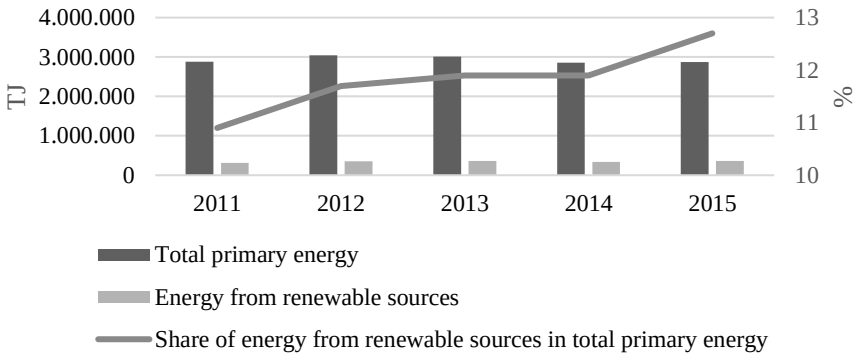

Figure 2. The acquisition of total primary energy, including renewable sources energy in TJ in Poland in 2011-2015
Source: authors' elaboration based on CSO 2015.

As shown in Figure 2, a relatively stable level of total primary energy production was accompanied by a systematic increase in the acquisition of energy from renewable sources (in 2015 by 16.0% higher than in 2011). The share of renewable energy in total primary energy increased from 10.9% in 2011 to 12.7% in 2015.

Table 3 presents detailed data on the balance of bioenergy in Poland in 2011-2015. According to the presented information, in 2015 the total consumption of bioenergy in Poland exceeded 326.8 TJ. Nearly 64% of the available bioenergy resources were used in by final consumers, including both industrial production and other segments of the economy such as transport, construction and households, trade and services, agriculture and forestry. Approximately 40% of bioenergy was used in the energy sector as a feedstock for production.

Table 3. Balance of bioenergy total in Poland in 2011-2015 (acquisition and use in TJ)

Specification	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Acquisition[1]	290987	329325	324542	300151	312860	na	na	na	na	na
Imports(+)	22598	8267	6988	39625	36430	na	na	na	na	na
Exports (-)	1438	1919	6029	17730	22087	na	na	na	na	na
Change of stock (+/-)	-91	-248	670	-65	-412	na	na	na	na	na
Total domestic use	312056	335425	326171	321981	326791	na	na	na	na	na
	in TJ					in % of domestic use				
Used as feedstock for production [2]	109926	142548	122465	131006	127932	35.2	45.7	39.2	42.0	41.0
Use by the energy sector itself[3]	162	160	122	39	0	0.1	0.1	0.0	0.0	0.0
End use (final)[4]	201968	192717	203585	190937	198860	64.7	61.8	65.2	61.2	63.7
	in TJ					in % of final use				
Production	41819	43708	54776	56446	59033	20.7	21.6	27.1	27.9	29.2
Construction	125	120	115	81	6	0.1	0.1	0.1	0.0	0.0
Transports	11090	1727	1061	648	5979	5.5	0.9	0.5	0.3	3.0
Other users	148934	147163	147633	133762	133842	73.7	72.9	73.1	66.2	66.3
of which:										
trade and services	9780	9113	9559	8674	8891	4.8	4.5	4.7	4.3	4.4
households	115000	116850	116850	105450	105450	56.9	57.9	57.9	52.2	52.2
agriculture and forestry	24154	21200	21223	19638	19501	12.0	10.5	10.5	9.7	9.7

[1]**Acquisition** means the amount of energy obtained from natural resources (only primary energy carriers). [2]**Use as feedstock for production** means the use of energy carriers which are the technological raw material for energy conversion into other energy carriers. [3]**Energy consumption by the energy sector** - energy consumption by auxiliary equipment used in the conversion process, such as: fuel feeders, pump and fan drives, etc. [4]**End (final) use** means the use of energy carriers by the users (industry, services, households) for their technological, production and living needs.
Source: authors' elaboration based on CSO 2015.

CONCLUSIONS AND DISCUSSION

Bioeconomy, which is perceived as a remedy limiting dependence on fossil fuels, is an important element of the economic development concept at the beginning of the 21st century. It addresses problems of the contemporary social and economic development in three dimensions: the local connected - among others - with rural development or employment growth, the national relating to food security and energy security and the global focusing on the reduction of greenhouse gas emissions. Bio-economy can contribute to the development of agricultural holdings and the economic growth of rural areas, provided that the regulatory systems for the production and processing of agricultural and forestry raw materials ensure the balance between economic and environmental objectives.

Renewable sources of energy play an important role in the global, European and Polish economy. The increase in bioenergy production is driven by declining manufacturing costs resulting from the use of modern technologies, rising fossil fuel prices and by policies supporting markets of renewable energy in the world and in EU as well.

The presented findings prove that bioenergy is the most important renewable energy source in Poland as in 2014 it amounted to nearly 89% of renewable energy production, which ranked Poland the second after Lithuania in this respect.

Biomass is also a source of diversified energy, as unlike other sources, it can be converted into solid, liquid and gaseous fuels. Solid biofuels and liquid biofuels dominate in Poland, while the share of biogas and energy produced from municipal waste is small. Concluding, bioenergy in Poland changes its character from traditional and local energy source into modern, international commodity.

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