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TECHNOLOGICAL ECO-INNOVATIONS RELATED TO RES – OPPORTUNITIES AND BARRIERS

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Abstract

Functioning of modern agriculture and farms is dominated by increasing demand for energy. Meeting this demand is, however, a strategic problem which affects energy, food and environmental safety as well as operating costs of commercial farms and rural households. This paper discusses the problems of implementation of eco-innovation on the example of renewable energy sources in the Polish farm sector. The paper analyses energy intensity and structure of energy consumption in the Polish agricultural sector. It discusses the structure of energy consumption, taking into account rural areas, in Poland and Europe as well as analyzes energy costs in various types of agricultural production. Moreover, the paper assesses the potential of renewable energy sources in the Polish agriculture and presents barriers connected to their use.

Keywords: farms, energy intensity and energy consumption structure in the rural sector, renewable energy sources, RES.

JEL codes: O13, Q20, Q40, Q55.

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Introduction

The agricultural and food sector in Poland, just like in other 'new' EU Member States, is characterized by significantly lower competitive potential, compared to 15 countries of the 'old' EU, which was proved on the basis of the analysis of the factors influencing the competitiveness of the domestic agriculture by Nosecka and Pawlak (2014). One of efficient methods for increasing the competitive potential of the Polish agriculture is development of conditions for wider implementation of innovation, with particular focus on eco-innovation connected to renewable energy sources (RES) that not only can contribute to improvement of economics of the sector but also are perfectly compatible with the energy policy of the European Union, concentrating mainly on transforming energy production based on fossil fuels into new user-friendly generation of renewable energy[1].

Increasingly bigger demand for energy, generated by contemporary commercial farms and the need for its constant supply conditioning their operation, constitutes an important factor encouraging farmers to invest in RES[2]. The issue is presented in programme of the Ministry of Agriculture and Rural Development (MRiRW, 2015) in the part "Initiating and supporting efficient processes for the benefit of sustainable development or rural areas" planned for implementation in 2015-2019. The programme specifies numerous interlinked problem areas contributing to sustainable development of agriculture and rural areas. Renewable energy generation, defined by means of three targets (MRiRW, 2015), is one of such areas:

- Target: 03.01. Supporting the economic development of rural areas by creating efficient technical and social infrastructure.
- Target 03.05. Development of the biofuel resources and technologies of their processing, innovative forms of energy acquisition.
- Target 03.06. Development of resources and technologies using other forms of renewable energy sources (RES) on rural areas.

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[1] Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources was adopted on 23 April 2009, which imposed on particular Member States specific national targets regarding consumption of energy from RES in the final gross energy consumption in 2020 – for Poland it is at the level of 15%. Increasing the use of RES as an important component of the cohesion policy in 2014-2020 constitutes a significant factor contributing to the realization of one of the major goals of the 'Europe 2020' strategy, i.e. sustainable growth meaning, for instance, support for environment-friendly economy.

[2] The voltage instability in the network (particularly in peripheral networks) and power outages hinder and sometimes even prevent the use of modern technologies in rural areas and generate additional costs for the farmers. Most milk producers or fruit growers must be equipped with power generator units used in case of power cuts.

Realization of these targets becomes particularly important in the context of identifying the agricultural sector not only with food production, but also with more broadly understood business activity, frequently referred to as bioeconomy[3]. This includes power industry, which just as the entire bioeconomy should be developed relying on the concept of sustainable development – including the promotion of RES (Prandecki, 2014)

Thus, it can be assumed that energy and ecological security of energy supply to rural areas, while maintaining balance between conventional and renewable energy generation accompanied by constant lowering of costs resulting from energy consumption for the needs of agricultural production, constitute priority goals of agricultural policy which should be implemented in view of the necessity of improvement of cost competitiveness of the Polish agricultural sector.

The article aims to identify the structure of energy consumption on the Polish farms and to assess the possibilities of using by the agricultural sectors technological eco-innovations related to renewable energy and to diagnose barriers hindering (inhibiting) the development of local renewable energy on domestic farms.

Energy intensity and the structure of energy consumption in the Polish agricultural sector

The share of the agricultural sector in balance of the consumption of final energy amounts at present to about 5.31%, while in the whole EU the average share of agriculture in the consumption is more than two times lower and amounts to about 2.2% (see Fig. 1 and Tab. 1).

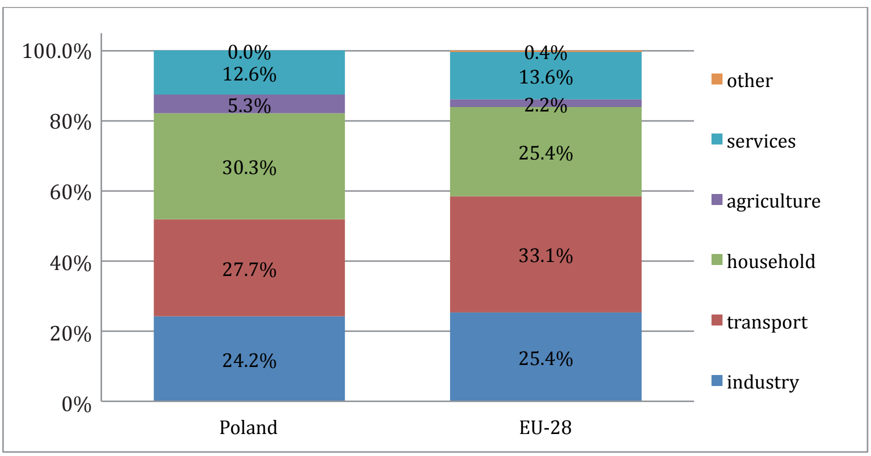

Fig. 1. The structure of the final energy consumption in Poland and in the EU-28 in 2015 in particular sectors (energy consumption in agriculture does not include Germany).

Source: Wysokiński, Trębska and Gromada (2017, p. 240).

[3] The concept has to be understood as production of renewable biological resources and their transformation (including waste generated in the waste processing) into products of added value such as food, fodder, bio-products and bio-energy (Komisja Europejska, 2012).

Table 1

The share of agriculture in the total consumption of final energy in the years 2005-2015

Country	Final energy consumption in agriculture			Total final energy consumption			Share of agriculture in final energy consumption		
	Mtoe						%		
	1995	2005	2015	1995	2005	2015	1995	2005	2015
EU (28 countries)	31 086	27 633	23 441	1 082 834	1 192 280	1 083 957	2.9	2.3	2.2
Euro zone (19 countries)	20 023	18 996	16 097	741 149	845 201	765 149	2.7	2.2	2.1
Austria/*AT*	539	543	550	21 368	27 837	27 370	2.5	2.0	2.0
Belgium/*BE*	1 102	814	722	34 345	36 580	35 780	3.2	2.2	2.0
Bulgaria/*BG*	384	304	186	11 421	10 186	9 508	3.4	3.0	2.0
Croatia/*HR*	199	212	203	5 283	7 237	6 587	3.8	2.9	3.1
Cyprus/*CY*	6	38	42	1 425	1 833	1 660	0.4	2.1	2.5
The Czech Republic/*CZ*	1 232	547	607	26 321	26 330	24 187	4.7	2.1	2.5
Denmark/*DK*	746	684	634	14 818	15 499	13 946	5.0	4.4	4.5
Estonia/*EE*	84	104	132	2 562	2 878	2 765	3.3	3.6	4.8
Finland/*FI*	757	715	689	21 974	25 185	24 181	3.4	2.8	2.8
France/*FR*	3 630	4 269	4 130	143 483	160 765	144 123	2.5	2.7	2.9
Greece/*GR*	1 011	1 152	258	15 806	20 958	16 502	6.4	5.5	1.6
Spain/*ES*	2 204	3 110	2 262	64 032	97 766	80 461	3.4	3.2	2.8
Netherlands/*NL*	4 209	3 877	3 578	50 985	54 179	48 505	8.3	7.2	7.4
Ireland/*IE*	340	336	221	7 988	12 597	11 214	4.3	2.7	2.0
Lithuania/*LT*	240	104	98	4 595	4 671	4 869	4.4	2.2	2.0
Luxemburg/*LU*	11	23	24	3 114	4 475	3 988	0.4	0.5	0.6
Latvia/*LV*	124	126	154	3 846	4 018	3 788	3.2	3.1	4.1
Malta/*MT*	X	X	5	455	382	572	X	X	0.9
Germany/*DE*	X	X	X	221 619	218 456	212 124	X	X	X
Poland/*PL*	4 764	4 429	3 306	62 940	58 471	62 251	7.6	7.6	5.3
Portugal/*PT*	488	522	345	13 852	19 009	16 038	3.5	2.7	2.2
Romania/*RU*	1 004	215	459	26 968	24 714	21 893	3.7	0.9	2.1
Slovakia/*SK*	302	165	150	11 034	11 561	10 077	2.7	1.4	1.5
Slovenia/*SI*	X	75	75	4 089	4 897	4 689	X	1.5	1.6
Sweden/*SE*	779	750	350	35 050	33 659	31 759	2.2	2.2	1.1
Hungary/*HU*	663	560	576	16 230	18 229	17 309	4.1	3.1	3.3
United Kingdom/*UK*	1 272	938	1 024	142 654	152 755	131 370	0.9	0.6	0.8
Italy/*IT*	3 022	3 009	2 664	114 578	137 153	116 444	2.6	2.2	2.3

X – data not available

Source: Eurostat as in: Wysokiński et al. (2017, p. 241).

The analysis of the consumption of energy in the agricultural sector in the period of 20 years from 1995 to 2015 in percentages, both in the EU-28 and in Poland indicates a decreasing trend. Although in Poland in 2005-2015 there was a significant fall by 2.3 pp[4] relative to other European countries, the present index of final energy consumption at the level of 5.31% ranks Polish agriculture second among the EU Member States in respect of final energy consumption (only the Netherlands have a higher position with the index of 7.4%, yet the total final energy consumption in Mtoe in the Netherlands dropped in the discussed period, while in Poland in grew[5]) – see Table 1.

High energy consumption index is typical of Polish commercial farms producing food for the market. Average annual energy bills for such farms usually exceed PLN 10 thousand, although there are also farms where annual energy bills total to PLN 25-55 thousand. These fees constitute 15-30% of the costs of farms which means that 70-85% of the costs borne on commercial farms for energy are costs of the energy used for needs of agricultural production. Social farms producing only for their own needs are comparable with urban households in respect to energy consumption (Curkowski, 2016).

The share of energy costs in the total costs of agricultural production vary depending on the range and volume of production. The total average energy intensity of production for farms participating in the Polish Farm Accountancy Data Network (FADN) in 2013 totalled 9.7% and was almost two times higher than the EU average. Energy intensity of final production of the Polish agriculture, calculated in the same year on the basis of data of the Statistics Poland (GUS) totalled to 11.8% and was 2.1 pp higher. In 2004-2014 the value of the discussed index in the Polish agriculture ranged from 14.6% in 2005 to 10.4% in 2014. The average energy intensity in the period of eleven years totalled to 12.2% (Maciulewski and Pawlak, 2016).

In turn, the comparison of energy intensity of production measured by the percentage energy cost to the total production value showed that gardening and orchard farms generate the highest energy consumption, whereas farms breeding granivores – the lowest (more than 3 times lower) – Figue 2.

[4] The improvement of indexes of energy intensity in agriculture was strongly influenced by the introduction of energy efficient technologies of agricultural production.

[5] The level of the energy consumption indicator by agriculture in the Netherlands is caused by a relatively large share in the agricultural production of the gardening sector, which is characterized by highly energy-intensive production.

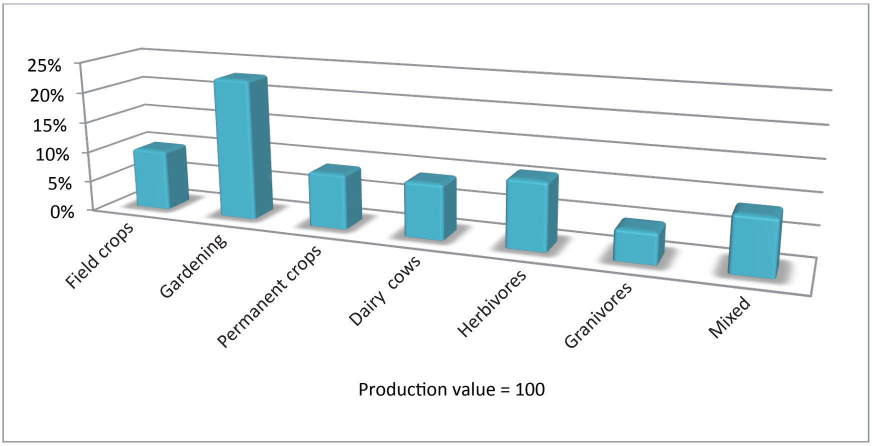

Fig. 2. The percentage share of the costs of energy in different types of agricultural production in reference to value of total production.
Source: Floriańczyk (2013).

The level of energy costs is significantly influenced by the price of energy raw materials, in particular crude oil and natural gas as well as the structure of their consumption. According to research conducted by the Department of Economic and Energy Analysis of the Institute of Technology and Life Sciences in Falenty, the total costs of twelve analysed energy carriers consumed by the Polish agriculture, compared to the situation in 2004, in 2014 increased by 50.9%, including the most in the case of hard coal – by 104.8%, lignite – by 95.7%, diesel oil – by 66.2%, LPG – by 29.8%, methane-rich natural gas – by 265.1%, nitrogen-rich natural gas – 6.1%, electric energy – by 76.7%, heat – by 50.9%. At the same time, the costs of consumed cokes lowered by 79.8%, light heating oil – by 65.4%, heavy heating oil – by 67.5%, petrol – by 71.1%. In the group of solid fuels, analysed jointly, the costs increased by 82.3%, liquid fuels by 46.8% and gas fuels by 50.8% (Pawlak, 2016).

It should be also emphasised that according to the data of the Statistics Poland (GUS), high emission coal, whose direct consumption constitutes more than 40% of the total energy consumption, is still the most frequently used energy carrier in the Polish agriculture. The share of gas fuels is lower than 3%, whereas the consumption of the most desirable in the modern agricultural production electric energy does not exceed 4% and is significantly lower than electric energy consumption in the agriculture of the EU-15 countries (the so-called CEEC). Nonetheless, it should be noted that despite relatively stable Poland-wide electricity consumption since 2010, areas with a large share of agriculture have been characterized by a sustained upward trend for several years (see Fig. 3). This trend indicates improvement of modernity of the Polish farms and substitution of electricity with other, less useful energy carriers, often generating the so-called low emission, which has a negative impact on the quality of life of rural residents.

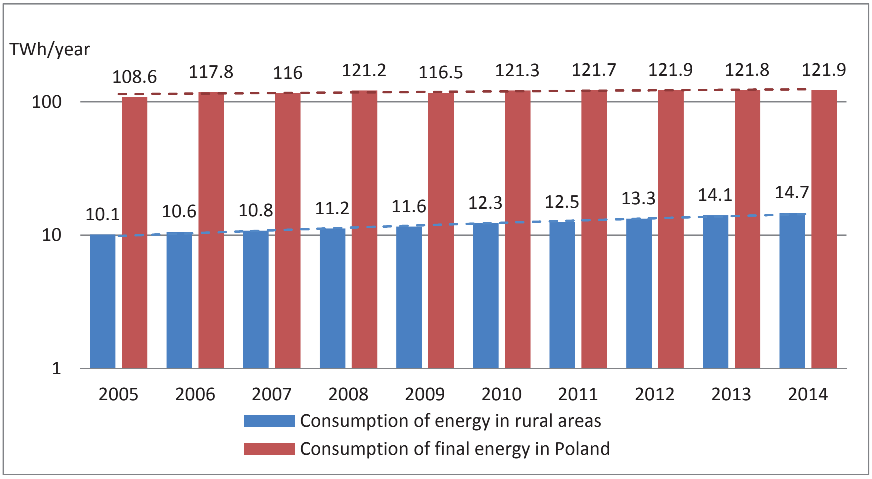

Fig. 3. Consumption of electric energy by consumers in Poland in total and in the rural areas.
Source: Wiśniewski (2016b, p. 62)

Wiśniewski, the President of the Institute for Renewable Energy, fears that, on the one hand, this positive modernisation of the Polish agricultural sector manifested by the increasing demand for electric energy may, on the other hand, result in infrastructural development barriers for the Polish commercial farms, because of long-term neglect in the area of electrical energy supply applying in particular to peripheral networks (Wiśniewski, 2016b). It has to be noticed that higher consumption of electric energy in the general structure of energy carriers, considering the current level of its prices, will unfortunately not improve the cost competitiveness of the sector. Similar doubts are shared by Karaczun – an expert of the Polish Climate Coalition, who observes that high consumption of electric energy by the agricultural sector results in its significant share in the costs of production. Farmers, depending on the profile of specialisation, spend from 60% to 90% of the total electricity consumption on production[6] (Karaczun, 2017). It is obvious that the costs of energy borne by farmers are translated onto the entire economy: they are directly reflected in relatively high prices of agricultural products, which in turn transfers to the consumer market. This difficult economic situation of agricultural producers caused by high energy costs is further deteriorated by the fact that in general they cannot use the G-type cheaper tariffs for electric

[6] For comparison – one urban household on average uses approx. 1500 kWh and an agricultural household may use more than 22 thousand kWh. For instance, a household of a farmer who breeds 40 milk cows – according to the calculations of OZERISE – uses almost 6000 kWh, out of which only 40% is used for the house, and the rest for milk production, including milking units and coolers. Approximately 7 thousand kWh is used by a farm breeding pigs of the size of 150 LU. Crop growing farms are most energy intensive since grain has to be dried. 150-ha farm needs more than 20 000 kWh, while a 30-ha fruit growing farms, because of the use of coolers, use up to 22 000 kWh.

energy available for households, but they have to use the more expensive tariff C meant for small-sized entrepreneurs who pay the highest rates for electric energy and its supply (see Fig. 4).

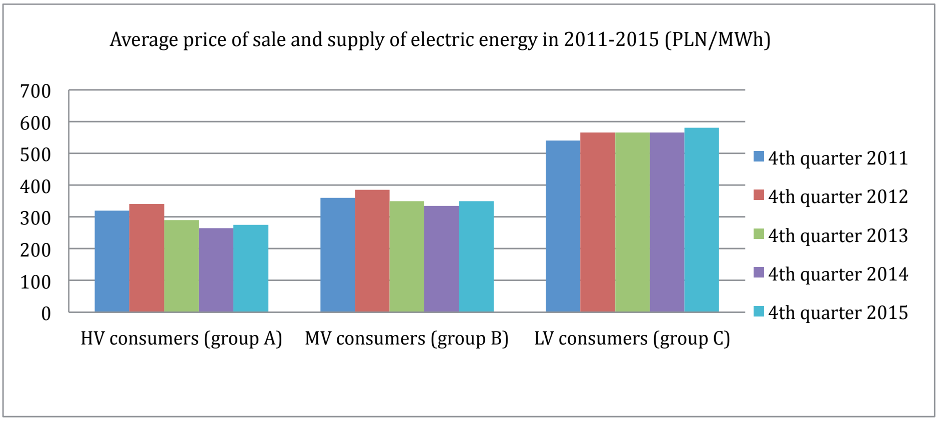

Fig. 4. Various tariffs for energy for large companies (group A) and small enterprises (group C).
Source: Wiśniewski (2016b, p. 66).

The data of the Polish Energy Regulatory Office (URE) show that farmers and small enterprises (tariff C) pay for energy twice as much as medium-sized and large companies (tariff B) or energy-intensive very large-scale industry (tariff A), which in view of the structure of tariffs and its strong negotiating position, benefits from discounts in the excise tax and fees for promotion of RES (group A). This is particularly unfair for small multi-functional farms, since the share of the energy costs in agricultural production is twice as high as the costs of energy in industrial production[7] and, undoubtedly, it undermines their competitiveness on the European and international markets.

Karaczun forecasts that the Act of 18 January 2018 on the capacity market[8] (Journal of Laws 2018, item 9) will further decrease the profitability of the Polish agriculture and deteriorate the quality of life in the rural areas. Neither will it solve the basic energy problems of rural areas, manifested by poor quality of energy supply services, because the means collected by the mechanism created by the Act will

[7] It should be noted that the Figure presents net prices, which means that farmers using 'C' tariffs and not paying VAT, pay relatively more for gross energy than small companies – Urząd Regulacji Energetyki: Raport Roczny Prezesa URE – 2015. Warszawa 2016.

[8] The capacity market is a special mechanism aiming to prevent the lack of generating capacity. It is connected with additional fees for electric energy encouraging the owners of conventional power plants to keep their power units in 'readiness' and some investors to construct new units. On the power market, such power units would receive money for 'readiness' as specific amount in PLN for each MW of the installed power and installations ready for operation. The unavoidable increase in the distribution fees, connected with investment in transmission and distribution networks worth billions, will not only increase the price of energy supply but it will also dangerously intensify the differentiation of the energy costs in the country and discriminate peripheral areas, including agriculture, to the benefit of industrial and urban areas.

be used for maintaining the available (reserve) disposable power and not for modernization and improvement of distribution networks, particularly the peripheral rural areas. Introduction of the so-called power fee will certainly result in further increase in the prices of electric energy and will strengthen the negative impact on the competitiveness of the Polish agriculture (Karaczun, 2017).

It has to be added that according to the latest analyses of electricity prices and the factors influencing the current trends in all market segments, the economists from Credit Agricole forecast that the wholesale prices of energy will increase significantly over a year. The average price of a contract for energy supply on the following day (BASE) on the TGE Polish Power Exchange in September 2018 amounted to 276.24 PLN/MWh (increase by 60.2% year-to year). Whereas the price of a contract for energy supply on the following year (BASE_Y-19) amounted to 285.53 PLN/MWh (71.7% more than in the previous year). There are two causes for the increase in energy prices:

- Increase in the coal prices of (in September 2018 the price of ARA coal totalled USD 100.69 per tonne, i.e. 11% more than in the previous year);
- Increase (two times in one year) in the CO2 emission rights, which approximate to EUR 24 per tonne.

Polish energy production industry – in 80% based on coal – is particularly sensitive to these two factors and hence there is a threat of doubling the prices of energy. Considering the techniques of the purchase of energy most often used in Poland by companies, Polish enterprises will be affected by the growth of prices of electric energy at the beginning of 2019 and according to the estimates it will most probably range from 50% to 70% year-to-year – this is the forecast of the CreditAgricole economists. If these increases are fully transferred to consumers (industry and agriculture) they will exert a negative impact on the competitiveness of the Polish economy (Sofuł, 2018).

Potential of RES in the Polish agriculture

The potential in the area of renewable energy use in the European agriculture is considerable, although still not fully tapped. The report on Impacts of renewable energy on European farmers prepared for the Directorate-General Agriculture and Rural Development, on the one hand, shows that the European agriculture is the only sector of economy generating much more energy from RES than it uses and that the farmers make the biggest contribution into the implementation of the EU targets related to RES. But, on the other, the scenarios of the Report indicate the need for increase in RES energy generation by 5 times, from 11.8 million toe (tonne of oil equivalent) in 2008 to 36-63 million toe in 2020. The growth is to largely apply to production of electric energy from RES (more than 80% of the total of energy generated in the rural areas, until the end of 2012 mainly by wind power plants), whereas the growth in production of heat from RES, in view of better efficiency of its use and substitution by electric energy, will remain small (*Impacts of Renewable Energy on European Farmers*, 2011). In the Polish agricultural sector, despite the fact that the significance of agriculture and rural areas in the Polish economy is higher than in the other EU countries, and the potential of renewable sources at the disposal of local farmers is also greater, the use of energy from RES is far from the possibilities existing in this area. This results primarily from lack of complete information concerning effective use of energy, lack of a professional offer and unawareness of the principles of selection, use and profitability of particular RES technologies. According to the Institute for Renewable Energy, this adverse situation may be improved only by changing the thinking about industrial power engineering, consisting in taking into account the potential and valorisation of agricultural land as regards the use of RES, appreciation of farmers as active customers – prosumers[9], on the energy market and granting farmers the rights to produce energy from RES as well as freely use it in the form guaranteed tariffs – a solution tested in the agriculture of other countries.

The principle legal acts regulating the duties related to energy generation from renewable sources in Poland include:
1) the Act of 20 February 2015 on renewable energy sources (consolidated text, Journal of Laws, 2018, item 1269),
2) the Act 25 August 2006 on biocomponents and liquid biofuels (consolidated text, Journal of Laws, 2018, item 1344),
3) the Act of 10 April 1997 – the Energy Law (consolidated text, Journal of Laws, 2018, item 755).

The Minister of Energy, Krzysztof Tchórzewski, stresses that the above legal regulations after the recent amendments have 'maturated' and should well prepare the Polish economy and the society for the challenges of the new era, when power engineering will be largely based on dispersed and local generation using, e.g. stable and tested renewable sources. He stresses that the amended legal regulations form a new quality which will facilitate effective management of the resources of fossil fuels, with the use of alternative energy sources (Tchórzewski, 2016).

The most important and stable types of RES in Poland include: biomass, agricultural biogas, hydropower and also in the coming years – local dispersed power engineering, based on the prosumer model and the system of energy clusters.

At present the installed electric power of all installations of renewable energy resources in Poland totals 8 241.479 MW, and the national share of particular carriers of renewable energy in acquisition of energy from renewable resources in recent years in Poland is presented in Figure 5.

[9] Prosumer is an end user purchasing electric energy on the basis of a comprehensive contract, generating electric energy only from renewable sources in micro-installations for his own needs, unrelated with the business activity regulated on the basis of the Act of 2 July 2004 on free business activity (Journal of Laws of 2015, item 584 as amended). If at a specific moment in time, the prosumer generates more energy than it is able to use, the surplus can be transferred to the network and collected at some other moment, yet not later than 365 days from the date of transfer. Prosumer's bills are balanced on the basis of discounts at the ratio of1 to 0.7, and in case of smaller installations of 10kW power at the ratio of 1 to 0.8. Such settlement rules, not requiring the registration of non-agricultural business activity, should simplify the entire procedure and will be binding for 15 years (see Jurgiel, 2016).

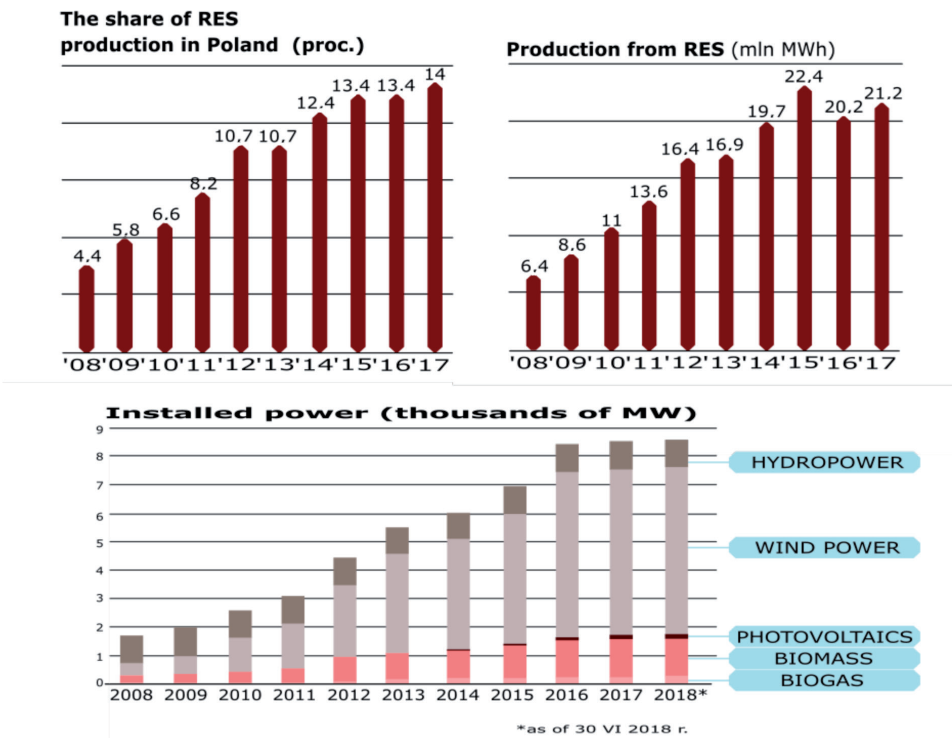

Fig. 5. The national share of particular renewable energy carriers in energy acquisition from renewable sources in Poland in 2008-2018.

Source: Baca-Pogorzelska (2018).

The national agricultural sector can play a significant role in acquisition of energy from RES, and in particular solar and wind energy, simultaneously popularising the processes of micro-generation[10] (Żabińska, 2017). In Polish climactic conditions, with annual solar radiation levels at 1000 kWh/m^2 (3600 TJ/km^2), from 1 km^2 intended for RES energy generation, it is possible to obtain, respectively, 1440 TJ from thermal solar energy (solar collectors of 40% efficiency), 360 TJ from photovoltaic solar energy (of 10% efficiency), up to 70 TJ from wind energy (assuming a high density of wind turbines – 8MW/km^2) and up to 15TJ from biomass provided the most energy efficient plants are used – see Table 2 (Wiśniewski, 2016b).

[10] Micro-generation – is a technological process of generating two useful forms of energy (heat and electric energy) within one integrated unit and for a small-scale, with the use of low-emission or RES-based technologies.

Table 2

The possibility of energy generation (energy density) from RES per one hectare of agricultural land

	Tj/km^2	GJ/ha	MWh/ha	Assumptions
Solar radiation	3 600	36 000	10 000	*Per horizontal surface*
Heat from solar collectors	1 440	14 400	4 400	*35% efficiency*
Electric energy from photovoltaic systems	360	3 600	1 000	*10% efficiency*
Electric energy from wind farms	70	700	194	*6 MWh/km^2 CF=2400 h*
Biomass	19	190	53	*1000 tonne of dry mass/km^2, Wo=19 GJ/t*
Bioethanol	6	55	15	*0.25 l/kg biomass, Wo=22 MJ/litre*

Source: Wiśniewski (2016, p. 68).

The average indexes presented in Table 2 after the Institute for Renewable Energy (IEO) can be converted into productivity per hectare. If the total of 1 ha of land on a farm is intended fully for the purpose of installation of photovoltaic systems (limiting the costs of energy purchase from the network to approx. 50 gr/KWh), the contractual productivity per hectare in the case of electric energy production by the farmer for own needs would total to PLN 500 thousand per ha. Analogically calculated revenue in the case of energetic biomass cultivation (indirect use of solar energy) and its sale to the nearest power plant (at the price of up to PLN 25 per GJ) amounts at less than PLN 5 thousand per ha, i.e. 100 times less than in the case of photovoltaic systems. For comparison, the average land productivity on the Polish farms in 2010, according to the Statistics Poland (GUS) (the so-called standard output – SO) amounted to PLN 6 thousand per ha, which points to unprofitability if biomass production. From the point of view of the farmer, the use of solar energy, but also wind energy, which has higher productivity per land unit than e.g. biomass, generates more benefits and facilitates multifunctional use of agricultural space for the purpose of food production and energy generation[11].

Barriers to RES use in the Polish agriculture

The national agricultural sector, although privileged as the owner of resources which can be used in renewable power industry, faces numerous barriers and despite numerous statements of the Polish government and well prepared strategies, such as: *Kierunki rozwoju biogazowni rolniczych w Polsce w latach 2010-2020* (Ministerstwo Gospodarki, 2010), lack of stability and conditions which could satisfy investors and encourage them to develop micro-sources of renewable energy

[11] Agricultural land in Poland covers 18 million ha, out of which 4-5 million ha is sufficient for food production, hence a significant part of the area can be used for energy production purposes.

in rural areas is widely felt. The primary barriers in the development of RES in the Polish agriculture consisted in marginal treatment of the issue in the *National action plan for renewable energy sources or in the strategic document Energy policy of Poland*. The national agricultural sector in these documents is perceived, at most, as a payer, i.e. electric energy consumer, or possibly as a supplier of biomass for not very innovative and declining renewable energy technologies, such as co-incineration of biomass in coal-fired power plants. Such approach does not contribute to the development of innovative technologies regarding RES in rural areas, and failure to tap the energy potential of the national agricultural sector makes this branch dependent on professional power industry and implies related consequences such as increase in the energy price, which translates into production costs and, finally, to costs (the so-called food basket) of all households in Poland (Wiśniewski, 2016a). Secondary barriers in respect to the development of RES are multi-faceted: legal and administrative, economic and financial, technological and technical, and environmental and information-related. The national legislation in the area of micro RES facilities for years has been characterised by high volatility, which consolidated the lack of trust and sense of security of investors. It suffices to recall the Act of 20 May 2016 on investments in wind farms (commonly referred to as 'distance' Act – Journal of Laws, 2016, item 961), which not only stopped the development of wind power engineering, but also caused confusion in the area of taxation of wind farms[12].

Comprehensive identification of RES development barriers was the main topic of the 2nd conference on *Micro-sources of renewable energy as the basis of civic energetics and the prospects of their development in Poland and the EU* organized on 7 July 2017 by The European Fund for the Development of Polish Villages Foundation in the Centre for International Cooperation in Grodno near Międzyzdroje. It needs to be stressed that during the meeting the analysis of development barriers was conducted in a wide context – from legal limitations and regulatory changes and evolution of the Polish energy policy in respect to RES, through perception of development barriers from the perspective of municipalities and rural residents, to the diagnosis of barriers conducted by experts of the RES market. Księżopolski and Pronińska (2017), prepared a report from the above-mentioned conference, indicate that in view of the legal limitations, the key barrier in the development of micro-

[12] In 2017 some municipalities (*gminas*) decided to increase tax on the owners of wind farms – despite unclear interpretations and formal assurances of the authors of the Act who claimed that the tax will not be increased. The Ministry of Finance issued an opinion justifying the increase of the tax after the introduction of the Act. Such interpretation meant that the owners of wind turbines, already in a difficult financial situation because of a dramatic decrease in the prices of green certificates, had to additionally incur costs of operation and in result it strained the trust of investors, despite the actions undertaken by the Ministry of Energy to reestablish the legal status from the period prior to the introduction of the Act on investments in wind farms. It should be noted that on 22 October 2018 the Supreme Administrative Court on the basis of the decision (case file II FSK 2983/17) put a stop to the uncertainty lasting for local governments and owners of the wind farms since 2016 and clearly decided that the regulations changed in 2017 oblige local municipalities, which charges higher tax (depending on estimates it was PLN 466 million at the national scale) to return it to the owners of wind farms. This applied to 897 municipalities where there were wind farms or individual wind turbines at the end of 2016, a total of 1193 facilities with 5.8 GW of total power.

sources in rural areas is the postponement of the date of full transposition of the Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources (Official Journal EU L.140/160). Further barriers include numerous, almost revolutionary changes in the system of support for RES, which resulted in the situation when the Polish RES market is perceived as instable and to a large extent unpredictable. This applies to changes both in the basic model of support for installations up to 1 MW and above 1 MW – replacing green certificates by an auction system; as well as its consequences for prosumer energetics and micro-installations (the battle between the concept of guaranteed FIT (fed-in tariffs)[13] and NM[14] (net metering tariffs)), and a separate regulation focused only on one segment of RES – wind farms, which according to the opinion of the International Energy Agency (IEA, 2016) "makes Poland a less attractive place to invest in wind power and will damage the profitably of existing investments." (IEA, 2016, p. 11 after Księżopolski and Pronińska, 2017 p. 20).

To sum up, the transposition of the RES Directive to the national legal system was reluctant and selective, and principal changes were introduced only by the amended Act on RES of 22 June 2016 on amendment of the Act on renewable energy resources and several other acts (Journal of Laws, 2016, item 925)[15]. Indeed, the amendment introduced satisfactory legal solutions for the sector of renewable energy, in particular the so-called technological baskets for RES auctions, the net metering mechanism for micro-installations, and created input conditions for developing energy clusters[16]. From the perspective of prosumers, the most signifi-

[13] The main advantage of the guaranteed tariffs lies in ensuring investment security, since the FIT mechanism is based on long-term guarantee of stable prices for the production of electric energy from RES, with simultaneous introduction of the obligation of its purchase by the network operator.

[14] The NM mechanism enables final energy consumers to develop production of electric energy (in RES micro-installations) in order to satisfy their own energy needs and simultaneously guarantee for offset exchange with the market energy provider, thanks to the installation at the place of consumption and production of the so-called smart meters that register this two-directional energy flow and balance the energy introduced into the network with the energy collected. The mechanism consists in settling the prosumers (simultaneous consumers and producers of energy from RES) at the end of the settling period on the basis of the use of net electric energy (the difference between the energy produced and collected from the network). The energy produced in such installations is entered into the energy network and sold on the market for retail prices, and if the production is higher than consumption, prosumers get the surplus in the bill. If the surplus is maintained at the end of the year, then, depending on the policy of the energy company (the obliged seller), with whom the contract was signed, the prosumer may (1) receive payment, (2) transfer the surplus to the subsequent calendar years as a compensation for the potential negative balance; (3) transfer the surplus to the energy company free of charge.

[15] Previously there were attempts to introduce some of the regulations of the RES Directive in the form of the so-called small energy three-pack that is amendment of the Energy Law and some regulations concerning the electric energy and gas market of 26 July 2013 and introduced on 11 September 2013 (Journal of Laws 2013, item 984).

[16] The introduction in the Act on renewable energy sources of the institution of energy clusters is an innovative solution. The clusters are expected to function on the basis of civil law agreements between various entities – natural and legal persons, scientific and research institutes as well as local government units. Their tasks include "… generation, balancing the demand, distribution and trade of energy from renewable energy sources or other sources and fuels within the distribution network of the rated voltage below 110 kV on the area of the operation of the cluster, not bigger than one county (…) or 5 municipalities".

cant change applied to the system of remuneration for electric energy generated in micro-installations – the resignation from direct tariffs (FIT) and introduction of the discount mechanism. From the perspective of the producers of agricultural biogas, the introduction of certificates of origin were a novelty. In case of all micro-installations, reduction of duties connected with the provision of information by producers and abolition of former proceedings related to infringement of such duties were particularly important.

It should be emphasised, however, that long-term perception of the Polish regulatory environment as largely unstable contributes to the generation of further economic and financial barriers, since it did leave its impact on decisions made by financial institutions as regards subsidies or beneficial credits playing the principle role in the development of this capital-intensive branch of energy industry. The decision of the European Bank for Reconstruction and Development (EBRD) on the reduction of financing for the Polish sector of renewable energy (especially wind power industry) made in 2016 constitutes a key example (Księżopolski and Pronińska, 2017). Technical and technological barriers occur primarily at the macro level and are connected with problem of long-term neglect in the sphere of transmission and distribution infrastructure, in particular bearing in mind that the costs of the expansion of networks are high and it is difficult to imagine that they could be transferred to RES investors. It should be noted that the past investments in the national power system (KSE) concentrated on the development of 110 kV rated voltage and next on the development of 15kV and 20 kV municipal MV networks. Significant neglect in the development of LV 230/400 V networks, which often mean negative decisions concerning RES connection[17] to the grid, is a consequence of such policy (Księżopolski i Pronińska, 2017). On the micro scale, technical and technological barriers were largely mitigated by the introduction of the OZERISE project, whose primary aim was to facilitate practical support in the choice of micro-scale renewable energy sources on farms and in energy groups/cooperatives (ozerise.pl)[18].

The problems with location and integrally related environmental problems constitute another significant issue which cannot be omitted while identifying RES developmental barriers. In the case of the most RESs location plays an important role in developing their efficiency (the coefficients of used power to installed power), yet in accordance with the current legal regulations some RES installations are confronted with exceptionally rigorous standards related to the environment and

[17] For the total number of 133 cases of refusal in 2016, as many as 114 concerned connecting RES to the electric energy grid, i.e. wind farms (49 refusals for the total power of 462,685 MW), photovoltaic energy generators (62 refusals for the total power of 1060,667 MW), and biogas plants (three of the total power of 2,627 MW). In 2016 the refusals covered the total power of 1525,979 MW and were usually substantiated by overload of the grid and short circuit threat in low voltage networks – Raport Krajowy Prezesa URE 2016, lipiec 2016; Sprawozdanie z działalności Prezesa URE w 2016 roku Warszawa, kwiecień 2017.

[18] The OZERISE project concerning “Renewable Energy Sources on farms” is realized under the honorary patronage of the Minister of Agriculture and Rural Development, co-financed from the resources of the financial instrument LIFE+ and NFOŚiGW. The project is coordinated by the Institute for Renewable Energy and the Association of the Employers of the Forum for Renewable Energy, NMG and ApiMicon are project partners.

distance[19]. The procedure of obtaining various kinds of permits (also depending on RES technology) may take up from one to several years. The most important documents and decisions at the stage of investment and construction, which precondition successful completion of the project include: environmental impact assessment (EIA), decision on the development conditions and spatial planning (sometimes it may be necessary to change in the spatial development plan of municipalities, if particular areas on which the investment is to be erected is included in the spatial development plan which does not provide for construction of such installations), building permit issued on the basis of a construction design and an application to the district (*starosta*) or province (*wojewoda*) governor. Finally, it should be noted that the attitude of the local authorities may intensify RES development by creating a favourable climate for investment, and at the stage of investment execution, also by ensuring channels of communication and cooperation between investors and residents. And the other way round, unfavourable attitude of local authorities may significantly hinder investment activity and constitute a key conflict generating factor, also at the investors-residents level. Municipalities may also offer financial support for construction of micro-installations, which may play a significant role in the development of RES in rural areas (Księżopolski and Pronińska, 2017).

Conclusions

The actions concerning the development of dispersed and prosumer power industry are a significant element of sustainable development of rural areas. They contribute to strengthening energy security by creating decentralised networks and sources of energy, they improve the economic situation of agricultural producers by lowering the costs of energy and thus they contribute to the improvement of competitiveness of the agricultural sector. The impact of RES on the improvement of the quality of life of the rural residents is also significant in view of the two aspects: economic (an opportunity to trigger economic activity by creating new jobs) and ecological (lowering the so-called low emission in non-urbanized areas). The significance of these issues for the development of the Polish agricultural and food sector should enforce development of practical solutions aimed at reducing the costs of energy for farms and increasing the efficiency of its use by applying smart energy networks, with particular emphasis on those elements of micro-networks which allow for the use of generated energy for own needs of farms. This constitutes a challenge for the Ministry of Energy and the Ministry of Agriculture and Rural Development, since broad investment and institutional opening both to Polish prosumers as well as renewal energy industry are irrevocable.

[19] While choosing the location each investor is obliged to take into account the following factors: environmental (such as natural and leisure qualities of the area, proximity of national or landscape parks); spatial (shape and size of the area, distance, etc.); economic (the cost of investment at a given location); political (including the policy of local authorities, programmes of infrastructure development, promotion of the region); social (the attitude of the local population to the investment); legal and administrative (especially spatial planning); technological (the level of development of transmission and sometimes transport networks).

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EKOINNOWACJE TECHNOLOGICZNE ZWIĄZANE Z OZE – MOŻLIWOŚCI I BARIERY

Abstrakt

Współczesne rolnictwo oraz gospodarstwa rolne charakteryzuje coraz większe zapotrzebowanie na energię. Jego pokrycie stanowi problem strategiczny wpływający na bezpieczeństwo energetyczne, żywnościowe, środowiskowe oraz bezpieczeństwo i koszty funkcjonowania rolnych gospodarstw towarowych i domowych gospodarstw wiejskich. Niniejszy artykuł przedstawia problematykę związaną z wdrażaniem ekoinnowacji na przykładzie odnawialnych źródeł energii w krajowym sektorze gospodarstw rolnych. Analizie poddano energochłonność i strukturę zużycia energii w polskim sektorze rolnym. Omówiono strukturę zużycia energii z uwzględnieniem obszarów wiejskich, Polski ogółem oraz Europy, a także przeprowadzono analizę kosztów energii w różnych rodzajach produkcji rolnej. Dokonano również oceny potencjału odnawialnych źródeł energii w polskim rolnictwie, a także przedstawiono bariery w zakresie ich wykorzystania.

Słowa kluczowe: gospodarstwa rolne, energochłonność i struktura zużycia energii w sektorze rolnym, odnawialne źródła energii, OZE.

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