

Article

Development of Renewable Energy Sources in the Context of Threats Resulting from Low-Altitude Emissions in Rural Areas in Poland: A Review

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Abstract: The process of transformation of the Polish economy, traditionally based on coal, into an economy that uses low-carbon technologies, faces a problem associated with the diversification of energy sources, especially in rural areas. The scale of the use of conventional energy carriers in households located in rural areas in Poland has a very negative impact on the natural environment. The aim of the paper is to indicate possibilities of reducing low-altitude emissions (with emitters not exceeding 40 m in height) in rural areas in Poland, through the development of renewable energy sources. This paper provides an overview of the specific character of rural areas in Poland and the development challenges faced in these areas in the investigated scope. In order to reduce greenhouse gas emissions and improve energy efficiency, it is necessary to dynamize pro-ecological activities in agriculture and in rural areas, including the development of agricultural biogas plants, wind and photovoltaic farms. The use of renewable energy sources can be an important factor in the development and sustainable growth of rural areas in Poland.

Keywords: air pollution; bioenergy; rural area; sustainable development

1. Introduction

Renewable energy is one of the basic elements of sustainable development, as well as in the scope of protection and improvement of air quality [1–5]. In this context, the prevention of low-altitude emissions (with emitters not exceeding 40 m in height) is in line with trends in modern environmental management and thereby with trends in the sustainable regional development of various spatial units in urban and rural areas [6–8]. This problem can be examined both from macro and micro perspectives. From the macro perspective, air pollution resulting from the use of fossil fuels poses a threat to the stability of the Earth's climate (greenhouse gases), while from the micro perspective, it affects human health on the local and regional scale (e.g., particulate air pollution PM_{2.5} and PM₁₀) [9–11]. These particulates, due to their dimensions, are easily carried over large distances along with movements of air masses, and affect residents of neighbouring areas. It has been found that particulate matter (0.1–1 µm) can cover a distance even up to several thousand kilometers [12]. Recent studies [13] have shown that considerable levels of PM₁₀ released over Silesia (southern Poland) can travel several hundreds of kilometres to northern Poland and Scandinavia. Air pollution from this region of Poland is a substantial external source of pollution in the Czech Republic [14].

Both high-altitude and low-altitude emissions have a large impact on air quality [15–20]. High-altitude emissions occur when the place of introduction of pollutants into the air is over 40 meters above ground level. Examples of sources of such emissions include industrial stacks in

power plants. In turn, the term “low-altitude emissions” refers to emissions of pollutants into the air through emitters with a height up to 40 m. Thus, the main sources responsible for low-altitude emissions are local boiler rooms, individual home furnaces and transport. Poland (alongside Bulgaria) belongs to the countries with the highest air pollution recorded in Europe. In particular, this is an area with a high content of PM10 particulate matter (above 50 $\mu\text{g}/\text{m}^3$) [21–23].

In the Polish society of recent years, energy and climate policy in the scope of emissions of pollutants into the air is more often confronted, both in public debates and scientific studies, with the problems of mining and challenges for the energy sector, than it is with the distributed generation in rural areas. A general opinion among Polish citizens is that the air in rural areas is clean and healthy. However, many publications in this field prove that the situation is quite opposite—the air in the countryside is often more polluted than in cities [24–27]. The problem of air pollution in rural areas in Poland results, to a large extent, from using conventional energy carriers to heat premises [28]. The effects of burning fossil fuels include the emission of harmful components into the atmosphere. These sources emit substances such as sulphur dioxide (SO_2), nitrogen dioxide and nitrogen oxides (NO_x), carbon oxides (CO_x) and particulate matter. Among the particulates, the most dangerous to health and life are fine particles with a diameter below 10 μm , which include PM2.5 and PM10 particulates [29]. Exposure to particulate matter (PM2.5) has been associated with increased cardiovascular outcomes [30]. Components of these particulates often also include other pollutants such as arsenic, cadmium, nickel, and some polycyclic aromatic hydrocarbons, such as benzo(a)pyrene, that are considered to be mutagenic, as well as substances which contribute to carcinogenesis [31]. They are among the most dangerous components that pollute the atmosphere [32]. As a result, the combustion of conventional energy carriers contributes to the degradation of the natural environment: destruction of forests, greenhouse effect, water pollution, etc. In addition, in rural areas in Poland, there is still a problem associated with the restoration and modernization of the rural electricity grid. The condition of the power infrastructure and the level of energy services in the countryside are relatively low.

Poland, as a result of the system and economic transformations that took place in the 20th century, has only relatively recently begun to carry out activities aimed at supporting the renewable energy sector and investing in it. However, it should be emphasized that a significant reduction in emissions of pollutants into the air took place in Poland in the 1990s, as a result of the economic transformation. At that time, the obsolete technologies that caused significant pollution of the environment were eliminated and changes were made in the energy sector to improve the efficiency of the use of fuels or to replace them with the fuels that caused lower emissions of pollutants. The technologies enabling co-combustion of biomass with coal in the existing power boilers have attracted the greatest interest from domestic energy and heat sectors [33]. Unfortunately, the changes in the scope of technologies and techniques in individual heating of buildings in rural areas only occurred to a small extent. Combustion processes in the municipal and residential sectors in rural areas in Poland are important and topical issues. Various types of stoves, often of low efficiency, without any de-dusting systems, are used for heating purposes, which contributes to pollution of the natural environment. A lack of appropriate standards and legal regulations in this scope also poses problems. The aim of the paper is to indicate possibilities of reducing low-altitude emissions in rural areas in Poland through the development of renewable energy sources (RES). The paper provides an overview of the specific character of rural areas in Poland and the development challenges faced in these areas in the investigated scope.

2. The Use and Substitution of Energy Carriers in Poland with a Particular Focus Put on Rural Areas

Renewable energy sources constitute an alternative to traditional, non-renewable energy carriers (fossil fuels). Their resources are replenished in natural processes, which in practice, allows for treating them as inexhaustible. In addition, the generation of energy from these sources is more environmentally friendly than from traditional (fossil fuel) sources (Table 1).

Table 1. Standard emission factors [34].

Fuel Type	Emission Factors (Mg CO ₂ ·MWh ⁻¹)
Anthracite	0.354
Bituminous coals	0.346
The remaining bituminous coal	0.341
Lignite	0.364
Natural gas	0.202
Wood*	0–0.403
Solar energy	0
Geothermal energy	0

* The lower value should be selected if the wood is harvested in a sustainable way, and higher if it is sourced unsustainably.

If an area is harvested for woodfuel below the annual growth rate, then woody biomass stocks are not depleted and harvesting is sustainable. However, if annual harvesting exceeds incremental growth, it is unsustainable, leading to a decline of woody biomass, forest degradation and net carbon emissions [35]. These issues in the scope of GHG (greenhouse gas) concern the entire supply chain and are associated with emissions at various stages (drying, storage, transport, etc.) [36].

The use of biomass for energy purposes is inseparably associated with thermochemical processes of organic fuel conversion. They take place in processes of combustion, pyrolysis, gasification and liquefaction or in biochemical transformations—in fermentation processes. The type of process used depends, inter alia, on the type and volume of biomass resources, the type of energy form required, and the users' requirements. Environmental protection requirements and economic conditions are also becoming increasingly important [37].

Biomass combustion processes are used in the production of electricity as well as mechanical and thermal energy. This is the simplest form of obtaining energy from biomass. A more effective way is conversion in cogeneration and trigeneration systems. In terms of efficiency, relatively higher efficiencies are obtained during co-firing of biomass and coal [38]. In Polish conditions, the most common solution for converting biomass into energy is direct co-firing. Co-firing of coal with biomass, as compared with the combustion of coal alone, also reduces gaseous pollutants: SO₂ and NO_x [33].

Biomass is characterized by the ease of thermal decomposition and a high efficiency of degassing. During the pyrolysis process, biomass is thermally converted in anaerobic conditions. The properties of products formed in the biomass pyrolysis process depend on the time of subjecting the feedstock to a high temperature, the value of this temperature, the presence of water, oxygen and gases, as well as the parameters of the feedstock subjected to the pyrolysis [39]. Pyrolysis can be fast or slow. In the fast pyrolysis process, biomass is decomposed under the influence of an elevated temperature (approximately 450–500 °C) [40,41]. Almost any type of biomass can be subjected to a fast pyrolysis process. Pyrolysis can be an independent process, but is also a part of the process of gasification of solid fuels.

The process of biomass gasification for energy purposes is relatively well recognized, while technological systems are continuously improved. Studies concerning the systems for the production of the most promising and environmentally friendly energy carrier (hydrogen) are being conducted. The thermochemical processes used to obtain hydrogen are based on the decomposition of biomass with the use of heat [42,43].

Methods of obtaining energy from biomass have been known for a long time, but are still being developed, modified and improved. The above methods of converting biomass into usable energy provide a general description. In Poland, the greatest hopes related to the use of renewable energy are associated with biomass. In the literature, there are many detailed studies in this scope, which

describe, for example, high-temperature gasification in a flow reactor [44], integrated technologies for the production of fuels and energy from biomass, agricultural waste and other waste [45], as well as technical and economic aspects of biomass co-firing processes, including thermo-ecological analysis of the costs of energy cogeneration and polygeneration systems [46,47].

In the case of wind, solar and geothermal energy, we are also dealing with energy conversion processes. With regard to the operation of water and wind turbines, we are dealing with the conversion of mechanical energy into electricity. Heliothermal and helioelectric methods are used to convert solar radiation into heat and electricity, respectively [48,49]. The technology of utilization of energy from geothermal sources is based on heat (in the form of hot water and steam) and is used mainly for the production of heat for heating purposes and electricity [50].

The energy sector in Poland is undergoing profound transformations related to the transition from the conventional power industry (based on non-renewable resources—hard coal and lignite) towards new technologies and renewable energy. However, this transition is not very dynamic, due to the existence of large deposits of minerals, which significantly contribute to ensuring the energy security of the country. [51].

Wind energy is one of the pillars of renewable energy in Poland. Poland is one of the countries with wind resources conducive to the development of the power industry, comparable to Germany (the leader in wind energy in the EU). However, the enthusiasm and progress for wind energy development in Poland (the period of 2005–2016) was impeded as a result of changes in legal regulations (increased restrictions for on-land wind farms in terms of distance from buildings and protected areas). It is not possible to build wind turbines in Poland closer than 10 times the height of the entire turbine. In practice, this means that wind turbines should be located approximately 1.5–2 km from buildings. This change stopped not only the development of large-scale wind energy industry, but also of small wind farms. According to economic analyses, government support for producers of this type of green energy is currently very important in the wind energy sector [52,53].

The potential for development lies also in other renewable energy sources. Solar energy, especially photovoltaics, can be an important factor in the development of many regions and communities in Poland. The annual density of solar radiation in Poland on a horizontal plane ranges from 950 to 1250 kWh/m², while the average sunshine duration is 1600 hours a year. Due to the geographic location, the possibility of using the solar energy stream is limited in Poland. In the examined area, the distribution of solar radiation in the annual cycle is uneven. About 80% of the total annual amount of sunshine occurs in six months of the spring–summer season (from early April to late September) [54]. Nevertheless, in recent years the share of photovoltaic installations in the national RES balance in Poland has been increasing. Further development of this part of the renewable energy sector is associated, *inter alia*, with a reduction in the costs of installations and with new technical solutions [55,56].

The literature often indicates a significant, unused potential associated with geothermal waters in Poland [57]. Geological resources (static resources) of geothermal energy are estimated at 1.58×10^{22} J, while static recoverable reserves, at 3.18×10^{21} J [58]. As of 31 December 2018, thermal waters were used in 6 geothermal district heating plants (geoDHs), 10 health resorts, as well as 15 bathing resorts and recreation centers. District heating is a strategic and still promising area of utilization of geothermal energy in Poland. This is a key element of sustainable development, ensuring rational, economic, ecological and social effects in the area of heat energy production [59]. Sales of heat in 2017 by geothermal heating plants in Poland reached the level of approximately 868 TJ/year. In 2018 the installed geothermal capacity of six geoDHs was 74.6 MW and geothermal heat production was 250.4 GWh, while total production amounted to 289.5 GWh [60,61]. Further development in this area, *i.e.*, an increase in the level of use of geothermal resources, may contribute to the development of a low-emission heating sector in Poland. The short term forecasting for the installed capacity of geothermal electricity in Poland to 2020 is 1 MWe [62].

The development of the renewable energy sector depends on many factors, including economic, social, environmental and legal ones [63]. From the economic point of view, it is important to optimize the share of individual renewable energy technologies in the context of the potential, available resources and the purpose of quantitative development of renewable energy sources (in Poland's conditions, the obligations resulting, *inter alia*, from the climate and energy policy of the European Union are important factors). Economic conditions include, among other things, the problems of production costs and funding of investment projects, the development of the institutional sphere (auctions and commodity exchanges), the level of compensatory charges (e.g., system of green certificates), etc. For many decades, the Polish economy has been based on the use of coal, which results from the available resources of both hard coal and lignite. In the current macroeconomic conditions, the development of the use of renewable energy in Poland must therefore be supported by various financial mechanisms and incentive systems.

The social and environmental determinants for the development of the renewable energy sector in Poland are, in turn, associated with the need to take into account the interests of future generations when taking the actions. In this context, the development of renewed sources is one of the guarantees of energy security. The social aspect is closely related to improvement in the quality of life of residents of Poland. As to legal factors, the regulations in Poland are determined by the regulations of the European Union—primarily by Directive of the European Parliament and Council 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC [64]. As a result of those changes, Poland has sped up the development of the renewable energy sector (Figure 1).

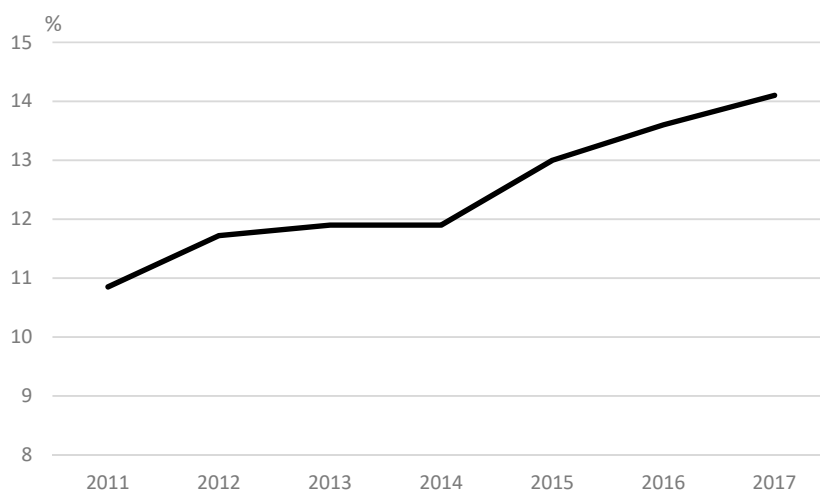


Figure 1. Share of energy from renewable sources in total primary energy in 2011–2017 [65–68].

In 2011–2017, the share of electricity generated from RES in the total production of energy increased from 10.85% to 14.1%. In this period (2011–2017), there took place also an increase in the share of electricity generated from RES in the final consumption of electricity in Poland. In terms of sources of renewable energy carriers, biomass constitutes the basis. The share of individual renewable energy carriers in the generation of energy from renewable sources is presented in Table 2.

In domestic generation (and use) of energy from renewable sources, solid biofuels have a dominating position. Their share in the generation of energy from renewable sources in 2017 accounted for 67.87% of the energy obtained from RES. However, it is worth noting that this share has been systematically decreasing in the period of 2011–2017. An increase, in this regard, took place in the wind power sector and in the production of liquid biofuels (both these carriers obtained over 10-percent share in the structure of generation of energy from renewable sources in Poland in 2017). It is also worth noting that Poland was among European leaders in the production of methyl esters in the analyzed period.

Table 2. The share of renewable energy commodities in the total of renewable energy obtained in the years 2011–2017 [67,68].

Specification	2011	2012	2013	2014	2015	2016	2017
	[%]						
Solid biofuels	84.89	82.07	79.88	76.14	72.24	70.65	67.87
Solar energy	0.17	0.17	0.29	0.43	0.56	0.69	0.75
Water energy	2.68	2.06	2.45	2.31	1.77	2.03	2.40
Wind energy	3.68	4.79	6.03	8.13	10.51	11.92	14.01
Biogas	1.83	1.97	2.12	2.56	2.58	2.88	3.07
Liquid biofuels	5.76	7.96	8.18	9.18	9.10	10.15	10.03
Geothermal energy	0.17	0.19	0.22	0.25	0.24	0.24	0.25
Municipal waste	0.43	0.38	0.39	0.45	0.45	0.85	1.01

In the last decade, a significant increase in the installed RES capacity was recorded in Poland (Table 3). The tabular data concerning individual types of RES plants include the plants that obtained:

- a license for electricity production;
- entry into the regulated activity register kept by the President of the Energy Regulatory Office (register of producers generating energy in small plants);
- entry into the regulated activity register kept by the President of the Agricultural Market Agency (register of agricultural biogas producers), and
- micro-plants applying for issuance of certificates of origin.

Table 3. Installed capacity of RES plants in Poland in 2005–2018 (MW) [69].

Specification	2005	2006	2007	2008	2009	2010	2011
Biogas power plants	31.972	36.76	45.699	54.615	70.888	82.884	103.487
Biomass power plants	189.79	238.79	255.39	231.99	252.49	356.19	409.68
Power plants that produce electricity from solar radiation	-	-	-	-	0.001	0.03	1.125
Wind farms	83.28	152.56	287.909	451.09	724.657	1 180.272	1 616.361
Hydroelectric power stations	852.495	934.031	934.779	940.576	945.21	937.044	951.39
Total	1157.537	1362.141	1523.777	1678.271	1993.246	2556.423	3082.043
Specification	2012	2013	2014	2015	2016	2017	2018
Biogas power plants	131.247	162.241	188.549	212.497	233.967	235.373	237.618
Biomass power plants	820.7	986.873	1008.25	1122.67	1281.07	1362.030	1362.870
Power plants that produce electricity from solar radiation	1.29	1.901	21.004	71.031	99.098	103.896	146.995
Wind farms	2496.748	3389.541	3833.83	4582.04	5807.42	5848.671	5,864.443
Hydroelectric power stations	966.103	970.128	977.007	981.799	993.995	988.377	981.504
Total	4416.088	5510.684	6028.64	6970.03	8415.54	8538.347	8593.430

At the end of 2018, the installed RES capacity in Poland was 8593 MW. In the structure of the installed RES capacity in Poland, there predominates the use of wind power. In the analyzed years in Poland, there was a significant increase in the production of the electricity from RES, wind farms and co-combustion of biomass with coal.

The development of the renewable energy sector in rural areas in Poland is interesting from the point of view of the subject and aim of the study. According to statistical data, the main energy carriers in households in rural areas in Poland include fuel gas (natural gas) and non-renewable solid fuels (hard coal) (Table 4).

Table 4. Average annual consumption of energy carriers per capita in households in rural areas in Poland in 2009, 2012 and 2015 [70].

Specification	Unit	2009	2012	2015
Electricity*	kWh/person	1838.4	2750.0	1924.2
	GJ/person	6.6	9.9	6.9
Natural gas	kWh/person	5278.5	3684.1	3792.2
	GJ/person	18.8	13.1	13.7
Liquefield gas	kg/person	431.0	169.7	48.8
	GJ/person	20.4	8.0	2.3
Coal	kg/person	925.4	909.1	861.7
	GJ/person	24.1	23.6	22.4
Firewood	m ³ /person	2.2	2.3	2.3
	GJ/person	15.6	15.8	16.2

*Values of the energy carriers' consumption are given per a household that actually consumes a given carrier.

Households in rural areas in Poland, despite the fact that they are located in regions with a high potential of production of biomass for energy purposes and favourable conditions for the development of other renewable energy resources, use them only to a small extent (Table 5).

Table 5. The share of the households in rural areas in Poland which use selected energy carriers to heat premises [70].

Specification	2009	2012	2015
		[%]	
Electricity	4.7	3.2	2.9
Heat network	3.4	4.0	3.3
Natural gas	6.0	5.7	5.7
Liquefied gas (propane-butane)	0.7	0.3	0.4
Fuel oil	0.7	0.9	0.5
Coal	76.3	76.4	77.7
Lignite	1.9	2.7	1.7
Coke	1.0	1.1	1.3
Firewood	83.3	80.0	82.2
Other type of biomass	10.3	6.8	5.4
Solar energy	0.06	0.09	0.45
Heat pump	0.00	0.00	0.09

As it appears from the data presented in Table 5, the level of the use of renewable energy sources in rural areas in Poland, especially heat pumps and solar energy, is low. In 2015, less than 0.1% of households in rural areas in Poland used heat pumps to heat premises and less than 0.5% of them used solar energy for this purpose. Firewood and hard coal were the main energy carriers in the investigated scope. This results from a relatively difficult financial situation of many families living in rural areas in Poland and a low ecological awareness [71].

3. Possibilities to Reduce Emissions of Air Pollutants through the Development of Renewable Energy Sources in Rural Areas in Poland

The reduction of air pollutants emissions through the development of renewable energy sources in rural areas in Poland requires changes in the scope of technology and production methods in agriculture (Table 6).

Table 6. Share of agriculture in major greenhouse gases emission in Poland in 2014 [72,73].

Specification	CO ₂		NO ₂		CH ₄	
	(Thousand Tons)	(%)	(Thousand Tons)	(%)	(Thousand Tons)	(%)
Total*	277,703.8	100	1654.62	100	66,48	100
Agriculture	905.41	0.33	557.1	33.67	52.27	78.63
Intestinal fermentation	-	-	491.78	29.72	-	-
Excrement management	-	-	64.26	3.88	7.06	10.62
Agricultural soils	-	-	-	-	45.17	67.95
Burning of plant residues	-	-	1.06	0.06	0.04	0.06
Liming	467.55	0.17	-	-	-	-
Use of urea	437.86	0.16	-	-	-	-

* Net emissions, i.e., taking into account emissions and removals from the sector "Land use, land use changes and forestry".

Polish agriculture is facing many difficult challenges, including reduction of ammonia and greenhouse gas emissions from livestock production and emission of nitrous oxides and suboxides from manure and mineral fertilizers. Reducing emissions of among others, gas emissions from agriculture requires the introduction of innovative techniques and tools to increase the efficiency of agricultural production and waste from livestock and crop residues. The condition for the development of low-carbon economy in agriculture is smart growth based on knowledge and innovation [74–76]. This necessarily requires, among others, the use of innovative means of agricultural production with relatively low environmental pressures (including bio-fertilizers and bio-pesticides), the implementation of the principles of precision farming, the development of low-carbon energy sources on farms (e.g., biogas plants), the use in crop rotation of the ones with a positive rate of reproduction of soil organic matter, adding to the feed preparations binding nitrogen compounds. It is worth emphasizing that a development in production of biostimulators, i.e., fertilizers containing chemical compounds that increase the efficiency of physiological processes in plants (e.g., photosynthesis) and improve the resistance to stress factors, has been observed in recent years in the Polish fertilizer market.

Changes in the technologies and methods of agricultural production should also take into account the increase in demand for biomass, which may partially replace classic fuels used in rural areas in Poland. The most popular perennial plants for energy purposes in Poland include, first of all, a shrub willow as well as topinambour, miscanthus, Virginia mallow and Rosa multiflora [77]. Other plant species potentially useful for energy purposes are distinguished in the literature of the subject, e.g.,

Silphium perfoliatum [78] and *Helianthus salicifolius* [79]. Biomass can also be used for production of liquid biofuels or biocomponents [80–82]. In Poland, the liquid biofuels constituting self-contained fuel (B-100 and E-100) are used on a small scale. In turn, the biocomponents added to motor gasoline (bioethanol) and diesel oil (fatty acid methyl esters) are of fundamental importance [83]. Biocomponents in Poland are produced from agricultural feedstock and by-products from agriculture and food industry. The feedstock most commonly used in Poland for the production of bioethanol is maize grain, while rapeseed oil is used in greatest amounts for the production of biodiesel [84,85]. According to the priorities set by the European Union, the production of third- and fourth-generation biofuels will develop in Poland. Third-generation biofuels can be obtained using methods similar to those used in the case of second-generation fuels, but from feedstock modified at the stage of cultivation (biomass). This group of biofuels includes, inter alia, those obtained in the algae cultivation process. Algae are characterized by a rapid growth and can be the source of several types of renewable biofuels, e.g., biodiesel, biohydrogen and biomethane [86,87].

The use of fast-growing plants for energy purposes can bring significant environmental benefits. However, the technological and economic conditions of cultivation, including primarily the genetic potential of planting stock, as well as the appropriate agricultural and economic conditions are also important here. The amount of the subsidies for energy crops, which determines the interest of farmers in this type of production, is important from an economic point of view. In terms of the potential, biomass is the most important renewable energy resource in Poland. A potentially effective way of using biomass for heat and electricity in Poland is to process it in agricultural biogas plants [88]. In Poland, the authority that keeps the register of entrepreneurs conducting business activity in the field of agricultural biogas production is the President of the Agricultural Market Agency (ARR). The data on the operations of agricultural biogas producers collected by the ARR have shown that the number of entities entered into the register of agricultural biogas producers as of 31 December 2017 was 84 (number of plants: 94). A slow and systematic increase, both in the number of entities producing the agricultural biogas and in the number of plants, has been observed since 2011. In the period of 2011–2017, the amount of agricultural biogas produced increased by 255.1 million m³, while the amount of electricity generated from agricultural biogas in this period increased by 534.8 GWh [89].

At present, the main types of feedstock for biogas production in Poland are as follows: liquid manure, fruit and vegetable residues, distillers' grains with solubles and maize silage. As emphasized in the literature of the subject, the current state of development of this market corresponds to potential opportunities only to a minor extent. The theoretical potential, which assumes a maximum level of technical parameters, has been estimated in Poland at 4.2 billion m³ of biogas per year. The estimated theoretical potential of biogas production reflects only the production capacities that result from the production of animal manure [90]. The agricultural production space can also be used as a location for solar panels or wind turbines. This use is largely dependent on the financial conditions—now and in the future. The development of bioenergy in Poland in the scope of energy production from biomass requires joint and coordinated actions of farmers, representatives of local government authorities, business entities, etc. A long-term policy combining the interests of farmers, power companies and consumers is also important.

Biomass is not the only interesting alternative to fossil fuels in Poland in the context of changes in agriculture and in rural areas. Until 2016, wind energy was the fastest growing form of use of renewable energy sources in Poland. A change in legal regulations (location restrictions and lack of support system) stopped new investments. This is very important, especially in the context of the problems analyzed in this study. Small wind farms operated in agricultural holdings would be a large support for the plans to reduce emissions of CO₂ and to conserve fossil fuels in Poland. Disadvantages of wind farms include primarily high capital expenditure and noise emissions. The location of wind farms in rural areas often leads to conflicts in rural communities.

Due to variable wind conditions, small wind farms may be combined with other sources, e.g., photovoltaic panels. Distributed and prosumer energy models, where special importance is attached to

the development of photovoltaics, are considered to be the future of the development of RES. In Poland, there are good natural and spatial conditions for the use solar energy. In addition, the development of photovoltaic farms in rural areas is generally supported by the neutral impact of such investment projects on the environment. In contrast to wind farms and agricultural biogas plants, photovoltaic farms in rural areas are more socially acceptable [91–94].

4. Summary

A very large technical and economic potential of renewable energy sources in rural areas in Poland is only used to a small extent. This applies to the use of solar and geothermal energy, as well as to the energy use of solid and liquid biomass from agricultural production and the agri-food industry, processed in agricultural biogas plants. Highly efficient energy production technologies based on renewable sources may ensure a reduction of external environmental and social costs.

The pace of development of the renewable energy sector is today one of the primary problems in the context of sustainable development of rural areas in Poland. The low level of use of renewable sources for energy purposes in rural areas in Poland results in exceeding the standards of pollution, due to combustion of solid fuels in household furnaces and boilers. Particulate and gas pollutants have a negative impact on the environment and intensify climate changes. Obsolete and inefficient heating equipment, low quality of coal, burning of waste in stoves, as well as inadequate technical conditions of boiler installations are challenges in the investigated problem area, which concern energy, environmental and agricultural policies.

A relatively large program entitled “Czyste powietrze” (Clean air) is currently being implemented in Poland. The program was launched on 19 September 2018 and is to be enacted up until the end of June 2029. Subsidies for solar collectors and photovoltaics under the “Czyste powietrze” program can only be obtained in the form of a preferential loan. In July 2019, the implementation of the program entitled “Agroenergia” (Agro-energy) was started. Only individual farmers with the total area of agricultural land not exceeding 300 ha can benefit from the “Agroenergia” program. A relatively short period of implementation of the above mentioned projects makes it impossible to describe their effects (purchase and fitting of small and micro pro-ecological installations for production of heat and electricity). Similarly, the change in the support system from feed-in tariffs to the auction system does not guarantee the certainty in energy trading. More laws and programs are needed, because the national legislation still provides too few incentives for producers of energy from RES, including those in rural areas. The authors of this paper have in mind, inter alia, tax allowances for purchase of materials, equipment and services associated with RES installations, establishment of guaranteed price mechanisms (preferential energy prices for renewable sources in a long-term perspective, e.g., 10 years). The level of prices must be oriented towards the support for the development of energy technologies. It is also possible to use degressive rates (depending on the type of installation—heat pumps, solar collectors, etc.).

Development of local energy sources in Poland requires changes in law, a development of the support system, as well as changes in the awareness of farmers and other residents of rural areas. The current mechanisms and support systems appear to be insufficient. There is a need not only for financial mechanisms and direct investments funded (co-financed) from public resources, but also for grass-roots initiatives taken by investors with a support from non-governmental institutions. In this context it is possible to introduce, for example, an investment allowance for purchase and installation of equipment enabling the use of renewable energy sources in rural areas. Speeding up the development of renewable energy sector in rural areas in Poland also requires extensive ecological education concerning the protection of air as well as implementation of plans and programs for protecting it. The agricultural holdings and households in rural areas, which are implementing innovative solutions in the scope of environmental protection, should be supported through additional subsidies or tax exemptions. Appropriate policy in this scope will eliminate the technical and economic barriers, as well as barriers associated with location and infrastructure. Growing demand for electricity and the

fact that the transmission infrastructure in rural areas requires modernization cause that it is necessary for Poland to undertake projects that require huge capital expenditures. This also requires changes in the management and transfer of knowledge on counteracting low-altitude emissions at the central and local government level. A special role may be played by energy cooperatives based on local communities which produce energy using renewable energy sources and use it for their own needs. This can bring measurable health, social and environmental benefits leading to an improvement in the quality of life of residents of rural areas in Poland.

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