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BIOMASS WASTES AS SOURCE OF ALTERNATIVE ENERGY

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Abstract: The paper is focused on use of renewable energy sources for energy production with special attention paid to the biomass wastes. Type and potential of wastes biomass, which can be used for production of electric and thermal energy, were generally characterized, use of the biomass as energy source in Poland was discussed, existing reserves were estimated and basic strategic-and-legal acts, which refer to the considered problem were presented. A type of possible activities to increase the amount of alternative energy produced in Poland, in the light of requirement to achieve a determined ecological-and-energy target resulting from international agreements and EU legislation, were indicated.

INTRODUCTION

Increase of using renewable energy sources (RES) is one of directions in Polish energy policy. This activity reflects world and European tendencies to protect natural environment, to save natural resources and to diversify sources of energy. Attention should be also paid to the soçial background of activity connected with extending labor market in renewable energy sector.

To reach the above-mentioned objective, besides a determined potential of RES, the real methods to use this potential, based on the proper organization of markets of "green" energy production and distribution, must exist. Legal and political mechanisms, which aid and stimulate considered sphere of activities play a very significant role.

Biomass plays a significant role in production of renewable energy in Poland. To popularize biomass as a source of energy, it is necessary to balance its amount and to assess real possibilities of its usage, with special attention paid to production areas, where the biggest reserves are. Legal regulations referring to RES, as regards their impact on the "green" energy market, should also be analyzed.

MAIN ASSUMPTIONS AND OBJECTIVES OF POWER-AND-ECOLOGICAL POLICY IN POLAND ASSOCIATED WITH RENEWABLE ENERGY SOURCES AND THEIR REALIZATION

Due to the strategy for renewable energy development in Poland [35], the use of renewable energy sources leads to significant ecological-and-power effects, among others it enables to reduce air pollution, to limit emission of greenhouse gases (and to implement

decisions of international protocol referring to climate changes [20]) or to reduce the amount of produced wastes. The mentioned strategy is in accordance with the power policy in Poland till 2025 [15] (consistent with principles of National Development Plan for 2007–2013 [45]), which determines a type of activities whose objective is to secure national energy balance, to increase the economy competitiveness and its energy effectiveness as well as to protect environment against negative effects of activity associated with production, transfer and distribution of energy and fuels. The Energy Law [39] describes principles for shaping the national power policy, conditions for supply and use of fuels and energy. Also Decree of Minister of Economy and Labor [16], which among others determines legal and financial mechanisms aiding investments associated with RES, is a document prepared to ensure development of power industry based on renewable sources. Acts on supporting thermo-modernization investments [40] and on financial support of investments [41], which among others determine the rules of promotion and support investments realized for the purpose of environmental protection, are also of significant importance for renewable energy sector.

There are the following quantitative targets as regards power-and-ecological policy in Poland, associated with popularization of application of renewable energy sources:

- reduction of greenhouse gases emission by 6% within 2008–2012 in relation to the base year 1988 [20],
- portion of RES in production of energy in the following amounts [15, 35]:
  - 7.5% in 2010,
  - 14% in 2020,
- portion of electric energy, produced from RES, in a total national consumption of electric energy is [16]:
  - 2.2% in 2005,
  - 2.6% in 2006,
  - 3.2% in 2007,
  - 4.0% in 2008,
  - 5.3% in 2009,
  - 7.5% within 2010–2014,
- portion of electric energy, produced by power plants from RES, in a total amount of energy sold to end consumers, is at the following levels [29]:
  - 3.1% in 2005,
  - 3.6% in 2006,
  - 5.1% in 2007,
  - 7.0% in 2008,
  - 8.7% in 2009
  - 10.4% within 2010–2014,
- 5.75% portion of bio-fuels on gasoline and diesel oil markets till the end of 2010 [3], what resulted in assuming targeted indices according to the caloric value of biocomponents in fuels used in transportation at the following levels [23]:
  - 0.5% in 2005,
  - 1.5% in 2006,
  - 2.3% in 2007,
  - targeted values for 2008–2010 have to be agreed on till 15th June 2007,

- 4% portion of electric energy produced from biomass in the scale of national energy consumption till 2010 [16],
- increase of weight ratio of burnt biomass, which does not come from forest production and wood processing in production units or in hybrid system according to decree [29], to the following levels:
  - 5% in 2008,
  - 10% in 2009,
  - 20% in 2010,
  - 30% in 2011,
  - 40% in 2012,
  - 50% in 2013,
  - 60% in 2014,

what enables to include the energy produced there, calculated according to the decree [29], to renewable energy.

Comparing the mentioned-above assumptions, with results obtained in 2005, it can be said that realization of set tasks proceeds in accordance with a plan that was previously determined [10]. Till 2004 emission of greenhouse gases dropped by 31.7% in comparison with 1988 (excluding absorption by biosphere), what proves that obligations within the climate convention were even exceeded (due to the climate policy regulation in Poland [19], it is predicted that considered emissions will be reduced by about 40% till 2020). As regards the market of bio-fuels or other renewable fuels, an index of biocomponents portion in fuels used in transportation, of approximate value of 0.48%, was reached in 2005, what meets the set target of 0.5%. At the same time it is assumed that systematic growth of considered parameter in the next years will enable meeting the obligations in this range. Also, when comparing a share of electric energy, produced from renewable sources, in a total amount of energy sold to end consumers in 2005 (3.46%) with a set target equal 3.1%, it can be said that assumptions were even exceeded.

Taking into consideration a total balance of renewable energy, which includes electric energy, thermal energy and production of liquid, solid and gaseous biofuels (biocomponents), it can be said that currently biomass (Tab. 1) is the main source of renewable energy. As it can be seen in Table 1, it was estimated that in 2005 a portion of energy obtained from biomass in a total renewable energy was about 91.5%, while the energy produced in all RES was about 5.43% in a primeval energy balance (5.55% according to [10]), what in a context of achieving the assumed level of 7.5% in 2010 and 14% in 2020 forces the necessity to look for any reserves in energy production process. On the Polish renewable energy market water energy plays a prevailing role (about 90% in 2005), however, it is assumed that till 2010 the share will have changed, so that in a total portion of electric energy produced from RES, which is planned to be 7.5%, about 4% will be from biomass, 2.3% will be from wind energy and 1.2% from water energy [16].

POTENTIAL OF BIOMASS AND ITS USE IN POWER INDUSTRY

Due to directive of the Minister of the Environment [29], biomass is a "solid or liquid substance of plant or animal origin, which is biodegradable, and which comes from products, wastes and residues of agricultural or forest production and also from technologies, which process these products as well as part of remaining wastes which are biodegradable".

Table 1. Production and use of energy from renewable sources in Poland within 1999–2005 according to energy production sources [1]

Year	Production of renewable energy					Total energy production	Total energy consumption	Share of renewable energy		Share of biomass energy		Share of energy obtained from biomass in total amount of energy produced from RES
	total	including						in total energy production	in total energy consumption	in total energy production	in total energy consumption	
		biomass	water	wind	geothermal							
	PJ							%				
1999	103.8*	101.8*	1.9*	0.01*	0.10*	3527.0	3916.8	2.94	2.65	2.89	2.60	98.1
	157.2	148.3	7.7	0.01	0.08			4.46	4.01	4.20	3.79	94.3
2000	159.1	150.2	7.6	0.02	0.13	3352	3770.2	4.75	4.22	4.48	3.98	94.4
2001	170.7	160.4	8.4	0.04	0.13	3360	3769.8	5.08	4.53	4.77	4.25	94.0
2002	173.3	163.3	8.2	0.21	0.25	3357	3734.0	5.16	4.64	4.87	4.37	94.2
2003	174.0	164.5	6.0	0.46	0.29	3344	3901.6	5.20	4.46	4.92	4.22	94.5
2004	180.7	170.1	7.5	0.50	0.33	3293	3839.5	5.49	4.70	5.16	4.43	94.1
2005	178.4	163.2	7.9	0.50	0.38	3284	3892.8	5.43	4.58	4.97	4.19	91.5

* – values determined by EC BREC [27]

Within the so-called clean biomass of zero carbon dioxide emission, the following can be distinguished [28]:

- plants and their parts;
- biomass wastes, e.g. from forestry, woodworking and wood processing, paper industry, manufacturing of wooden objects and constructions, used wood, bone-meal, fats, oils and animal suet, foodstuff wastes, sewage sediments, biogas;
- biomass fractions and materials of mixed composition, among others: biomass fractions of paper, cardboard, municipal and industrial wastes;
- fuels whose components and intermediate products were entirely produced from biomass.

The need of balancing the biomass as regards its availability for power purposes and distance from burning sources was emphasized in assumptions for power policy in Poland [15]. Quantitative estimations of energy produced from each renewable source (including biomass) are carried out, among others, by Central Statistical Office and EC Baltic Renewable Energy Centre (EC BREC). Due to the information provided by the first institution, a portion of energy from biomass in total energy production and consumption in Poland within 1999–2005 had a growth tendency till 2004, while in 2005 a small decrease of the analyzed parameter was noticed (Tab. 1).

There are large divergences in determination of technical potential of energy, which is possible to be obtained in Poland from RES (including biomass), while estimations

made by EC BREC were found to be most rational in strategy for development of renewable power industry [35]. Statistics made by institutions mentioned above referring to 1998 [6] and 2002 [25] are presented in Table 2. On the basis of their analysis, it can be seen that the potential of solar energy significantly decreased in that period of time, what was the main reason of decrease of total portion of RES in a total consumption of primeval energy (from about 62% in 1998 to about 46% in 2002). On the other hand, as regards biomass, it can be noticed that despite reduction of its resources by 140 PJ in 2002 in relation to 1998, its portion in total potential of energy produced from RES increased (from about 36% in 1998 to about 43% in 2002 – Table 2), with simultaneous, almost constant level of biomass potential in relation to total consumption of primeval energy (about 22% in 1998 and about 20% in 2002 – Table 2). Comparing technical potential of biomass estimated in 2002 (755 PJ – Table 2) with the amount of energy produced at its presence (about 163.3 PJ – Table 1), it can be noticed that its average use was about 21% (the same value was also presented in [44]). According to the data from EC BREC, when comparing biomass potential with amount of energy produced from biomass, even lower proportion is obtained. Comparing production of energy from biomass at the level from 1999 – 101.8 PJ (Tab. 1) with its potential determined in 1998, i.e. 895 PJ (Tab. 2), estimated consumption of biomass for power purposes in the amount of about is 11% obtained. Due to the above, it can be noticed that there are still large, unexploited reserves on the biomass market.

Table 2. Technical potential of RES and use of primeval energy in Poland [6, 19]

Source of energy	Poten-tial	Total consumption of primeval energy	Share of potential of a given RES in total consumption of primeval energy	Share of biomass potential in total RES potential	Poten-tial	Total consum-ption of primeval energy	Share of potential of a given RES in total consumption of primeval energy	Share of biomass potential in total RES potential
	1998 [6]				2002 [19]			
	PJ		%		PJ		%	
Biomass	895	4070	22	36	755	3768	20	43
Water energy	43		1		49		1	
Geo-thermal resources	200		5		220		6	
Wind energy	36		1		281		7	
Solar radiation	1340		33		445		12	
Total	2514		62		1750		46	

According to the strategy for development of renewable energy [35], it is predicted that use of solid biofuels (wood and straw) for power purposes will increase in the forthcoming years. According to the climate policy [19], apart from a type of biomass, which was mentioned above, the attention is also paid to a development of straw plantations for production of energy and production of liquid motor biofuels. On the other hand, increase of portion of biomass from biomass crop for production of energy as well as waste biomass and biomass which comes from sewage sediments, is emphasized in the information prepared by the Institute for Global Environment Problems and Climate Changes [10]. Broader use of biomass contained in municipal and industrial wastes (excluding plant and animal production) for energy production is one of power policy assumptions for Poland till 2025 [15].

POWER USE OF BIOMASS WASTES

Among biomass wastes, which can be used for power production, first of all we can distinguish waste wood, straw and other plant wastes, wastes from farm and food industry, wastes produced during animal breeding, organic municipal and industrial wastes.

Power use of basic types of wastes, which estimated share in a total energy produced from biomass, is presented in Table 3. Difficulties in getting suitable amount of biomass in a given area (dispersion of places of production), storage and transportation (biomass should be transported for a distance not longer than 50–80 km [33]) are the limitations in a rational use of biomass. Due to the above, the wastes are mainly used locally and produce the greatest economic and ecological benefits when they are used close to the places of their production, e.g. when they are used to heat the houses or in local heating systems.

Table 3. Power use of biomass in 2003 according to the Energy Market Agency and EC BREC [44]

Source of energy	Amount of produced energy PJ	Share of energy from a given source in its summary balance %
Firewood (280 thousand of heated buildings)	146.0	88.9
Wood wastes from industry in co-production systems	9.0	5.5
Wood wastes in heating systems (180 systems)	7.0	4.3
Straw (households and heating systems (0.1–7 MWt)	1.0	0.6
Biogas from sewage sediments (32 objects)	1.0	0.6
Landfill gas (25 objects)	0.3	0.2
Total biomass	164.3	100.0

Firewood and wood wastes

According to the European Union's assumptions [46], it is predicted that share of energy produced from wood in a total energy produced from RES should reach the level of 46% till 2010. Wood wastes, which are used in a power industry, first of all come directly from forests and industry involved in woodworking and wood processing, but they can also be obtained from orchards and other green areas.

According to reports from the Central Statistical Office, the area of forests in 2004 was about 8.97 mln ha, which equaled 29.9% of land in Poland [2]. According to plans published in a strategy for development of renewable energy [35], further increase of afforestation in Poland up till the level of about 33% in 2025 is assumed. Department for Agriculture and Environment Statistics estimates that the amount of firewood obtained in 2004 (coniferous and broadleaved firewood as well as small-size firewood) was about 3.4 mln m^3 [2]. In relation to statistics published directly by the General Management of National Forests [51], it can be found that the predicted amount of firewood and small-size wood to be obtained from national forests in 2005 was about 3.8 mln m^3 and about 3.9 mln m^3 in 2006, and its planned consumption equal about 2 mln m^3 (the data are consistent with the data published in [32], where the base of firewood from care cutting was estimated for about 2.2–2.8 mln m^3 and for 1 mln m^3 from clear cutting).

Higher estimated values refer to technical potential of wood, which can be used in power industry. According to a strategy for renewable energy development [35], it has been recorded that about 2–2.5 mln m^3/year of wood wastes remain in forests due to limited demand, what, when considering their real use at the level of about 2 mln m^3/year, enables to balance their potential use at the level of about 4–4.5 mln m^3. Even a higher value was presented in [11] where the author, referring to the General Management of Public Forests, talks about potential of wood, which is suitable for power production in the amount of 6.1 mln m^3/year (what corresponds to the energy of about 41.6 PJ) and in [8] where potential of forest biomass was determined to be 101 PJ.

There are also significant differences as regards a potential of wood from the industry. Assuming that power industry uses about 40% of total amount of waste biomass produced by wood industry, which is estimated to about 6.8 mln m^3, 2.7 mln m^3 of wastes, which can be used for energy production [11], is finally obtained. Estimation of volume of wastes, which are generated in wood industry, can also be made, assuming that even up to 60 m^3 of side products is produced [8, 33] (about 10 m^3 of bark, about 15 m^3 of branches and timber, about 20 m^3 of chunk wastes, about 15 m^3 of sawdust and cuttings) after processing of 100 m^3 of wood.

So, in the case of logging of about 15.6 mln m^3 of wood for production purposes in 2005 (summary volume of medium-size coniferous and broadleaved firewood (14.3 mln m^3) and small-size firewood (1.3 mln m^3) [2] for industrial processing), assuming that about 60% of initial volume are the wastes obtained during woodworking, the portion of wastes equals 9.4 mln m^3. Assuming further that about 40% of mentioned-above wastes are planned for production of energy, we obtain about 3.8 mln m^3 of wastes (according to [8] about 3.2 mln m^3 of wastes, used for production of energy in wood industry, were produced in 2001).

Besides the mentioned types of waste wood, also wastes from fruit farming of technical potential of about 57.6 PJ [8] and wastes from urban green areas should be taken into account in a total waste wood which can be used for energy production. Total potential of wood from forest industry and fruit farming is estimated at about 158.6 PJ [24], while in the case of waste wood and wood wastes from forestry, fruit farming, wood industry and urban green areas – about 270 PJ per year [54].

Real use of wood biomass for energy production is significantly smaller than its potential and can be estimated at the following level:

- about 50% of wood logged form forests (about 32% of wood of water content 20%, given in [8]),
- about 32% for wastes from fruit farming [8].

Only wastes from woodworking are used entirely.

Wood biomass can be burnt directly (mainly chips and briquette sawdust), co-incinerated with coal or used for production of liquid fuel (methanol). An estimation of a total number of installations, which were adapted for burning the wood in Poland in 2002 is given in Table 4.

Table 4. Structure of renewable energy production in Poland in 2002 [46]

Source of energy	Specification	Number of installations	Power	Production of electric energy	Production of thermal energy	Estimated total production of energy
			MW	GWh	PJ	PJ
Biomass[2]	Heat and power stations fired with wastes from cellulose-and-paper industry and furniture industry	5	600[1]	500[1]	5.0[1]	6.8
	Thermal power stations of high power fired with wood (> 500 kW)	180[1]	450.0[1]	–	6.75[1]	6.8
	Thermal power stations of high power fired with straw (> 500 kW)	65[1]	92.0[1]	–	0.92[1]	0.9
	Boilers of small and medium power fired with wood (< 500 kW)	110000[1]	5500[1]	–	59.4[1]	59.4
	Hearths of small power used for wood burning	175000	4375.0[1]	–	39.4[1]	39.4
	Boilers of small and medium power fired with straw (< 500 kW)	150[1]	23.0[1]	–	0.23[1]	0.2
	Municipal biogas stations	32	61.5	38.0[1]	0.45[1]	0.6
	Biogas stations fed with landfill gas	25	26.5[1]	22.3[1]	0.20[1]	0.3
	Total	285457	11128	560	112.3	114.4
Other RES		5711	659	2336	0.6	9.0
Total energy production from RES		291168	11787	2896	112.9	123.3

[1] – estimated data,
[2] – without liquid biofuels

Straw

Straw is a significant source of renewable energy. Surpluses of straw of all types of corn used in plantation and animal breeding (as feed, bed, manure) and canola, buckwheat, horse bean or sunflower straw, which are useless in agriculture, can be used in power industry. According to the EU prognoses, it is assumed that portion of energy produced from straw in a total energy produced from RES in Poland will equal 9% till 2010 [46].

The amount of straw produced per year which is not used for animal breeding and fertilization is estimated at the level of about 6–11.8 mln Mg (about 6 mln Mg according to [8], about 11.8 mln Mg (195 PJ) according to [11], 131.1 PJ according to [34] with reference to the Institute for Buildings, Mechanization and Electrification of Agriculture).

A significant increase of power obtained from RES, including straw burnt in thermal power stations and boilers (from about 20 MW in 1999 to about 115 MW in 2002) was observed in years 1999–2002, but during recent years such high increasing tendencies were not found [46].

Increase of interest in use of straw can, among others; result from the fact that since 1983 its production has been exceeding a demand in agriculture. Significant oscillations in straw harvest (e.g. in 2000 the amount of straw useful for power industry was about 3 mln Mg, and in 2001 it was 11.6 mln Mg [8]) are considered to be the difficulties in an increase of investments in power industry sector based on straw, what is connected with the necessity of making reserves for the years of lower harvest. Differences in the amount of straw, which is possible to be obtained for power purposes in each region of Poland, should also be emphasized (e.g. from the analyses conducted within 1999–2001 on a voivodeship scale it results that the biggest potential of straw was in Wielkopolskie and Kujawsko-Pomorskie Voivodeships, while the straw shortage was in Podlaskie and Malopolskie Voivodeships [8]). As there can be significant differences in amounts of straw in relation to significantly smaller areas (e.g. communes or districts), these estimations should be made on a micro scale. Cost-effectiveness of straw transportation only at relatively short distances (up to 30 km for round straw pallets and up to 100 km for cubical straw pallets [13]) is also the reason speaking for determination of straw potential for local production of energy.

In general, burning of straw is realized in boilers of small and medium power and installations of high power (Tab. 4) or, in the case of intermediate solution, in boilers of small power which complements coal fired boilers. Due to difficulties in balancing the straw resources and estimating its real use in power industry, power reserves referring to the considered raw material cannot be explicitly assessed. Comparing the cited potential of straw in the amount of about 131–195 mln PJ with its real use (e.g. at the level of 50 PJ in 2001 according to [9], in reference to Table 4 only in 2002 about 1.1 PJ, and 3 – 1 PJ in 2003 – Table 3), a very wide range of power use, from about 0.5–38%, is obtained.

Biomass wastes used for production of biogas

Biogas is produced in a result of anaerobic fermentation of cellulose, plant wastes, animal dung and sewages, which takes place mainly in sewage treatment plants, disposal sites and farms. Its power potential is estimated in the range from about 34 PJ (including about 15.2 PJ from agricultural biogas and about 11.5 PJ from landfill biogas [11]) to about 37.5 PJ [34]. The area of a potential power use of biogas is very wide and includes, among others, production of electric and thermal energy in combined units, delivery of landfill gas to the gas systems or use of biogas as a motor fuel. Ecological benefits, associated with a reduction of methane emission to atmosphere, reduction of waste disposal costs and decrease of contamination of soil, groundwater, surface tanks and rivers, result from construction of the installation for biogas production.

As it was already mentioned, biogas can be obtained from municipal wastes (so-called landfill gas). It is estimated that from 1 Mg of wastes, which are degradable, about

200–300 m^3 of gas which includes up to 65% of methane (on average about 45–55%) [21] can be produced. However, due to the fact that biodegradation process is dependent on a number of factors and it is limited in the case of some wastes, we assume that lower value of the range mentioned above [48] is more probable. Due to the lack of a precise separation of disposal sites, it is assumed that only 30–45% of total potential of biogas can be produced for practical use [8]. When assuming that there are about 100 bigger municipal disposal sites in Poland, which make the main part of biogas potential, the methane resources possible to be obtained were estimated at about 135–145 mln m^3 (what refers to about 5.2 PJ of energy per year [8]). This amount could significantly increase in the case of implementation of significant changes in waste disposal method at disposal sites, first of all by use of more effective geotechnical sealing which would stop migration of gases [8].

Practical use of landfill gas resources in Poland is very limited. Only 18 installations for landfill gas were operating in 2002 [48], while production of electric and thermal energy, obtained from biogas produced at disposal sites, was estimated at about 30 GWh and about 72 TJ respectively [8] (i.e. totally about 0.18 PJ), what, in comparison with its mentioned above potential (about 5.2 PJ), gives the power use at the level of about 3%. The above amounts were not significantly improved in 2004, when out of total number of 1049 operating disposal sites for wastes other than dangerous, installations for degassing were installed at 207 of them, and only at 32 installations biogas was used for production of electricity and thermal energy, at 168 disposal sites collected gas leaked out to the atmosphere, and gas from other installations was burnt without recovery of energy [37].

Animal dung (farmyard manure, liquid manure), wastes from plantations (leaves, potato haulms, straw, and tailings from sugar beets) or plantations of high methane production (e.g. mangolds or grass) can be other sources of biogas. It results from experimental tests that about 30 m^3 of biogas of caloric value of about 23 MJ/m^3 can be obtained from 1 m^3 of farmyard manure, while 1 m^3 of liquid manure can be the source of about 20 m^3 of biogas [8] (from 1 Mg of dry liquid manure about 347 m^3 of biogas, including 218 m^3 methane [17], can be obtained). Total potential of agricultural biogas in Poland, associated with animal breeding, was estimated in 2002 (neglecting small farms, where there are no technical-and-technological reasons for production of biogas) for about 3274 mln m^3 (128 PJ), while its technical potential was equal to about 674 mln m^3 (26.2 PJ) [17]. The first state-of-the-art agricultural biogas station using manure was started in 2005 in Poland in Pawlowek (Pomorskie Voivodeship).

Biogas can also be recovered at sewage treatment plants, but also in this case the range of operations aiming at biogas power use is small in Poland. In 2000 there were about 4000 sewage treatment plants in Poland (including 1844 biological sewage treatment plants [22]), while 260 new sewage treatment plants as well as modernization and expansion of about 900 already existing sewage treatment plants are planned till 2015 [14]. From 1994 only 20 biogas stations were installed at municipal sewage treatment plants in Poland [47]. In 1999 total electric power of these installations was about 14.5 MW, while thermal power was about 24.4 MW [8]. These biogas stations produced about 72.5 GWh of electric energy and more than 250 TJ of thermal energy [8, 47] (i.e. totally about 0.5 PJ). Due to economic reasons, it is assumed that biogas installations are profitable at those sewage treatment plants which receive more than 8–10 thousand m^3 of sewage per day [47]. At the same time it is assumed that from 1 m^3 of sediments (4–5% of dry

substance) 10–20 m^3 of biogas of about 60% methane content can be produced [48]. Due to high demand of sewage treatment plants for thermal and electric energy, use of biogas from fermentation of sewage sediments for own power needs or, after a purification, in gas installation, can significantly increase profitability of these municipal services. Present tendencies as regards the use of biogas from sewage sediments are directed onto new technologies of high efficiency and lower failure rate, including technologies based on production of combined electric and thermal energy.

Other possibilities of power use of biomass wastes from sewage treatment plants and from selected industrial and municipal wastes

According to the Polish power policy [15], apart from plant biomass also broader use of energy potential of industrial and municipal wastes for power purposes is planned. It must be emphasized that current use of mentioned wastes in such way is not realized on a large scale (according to the Polish plan for wastes management [37], recovery of energy from some wastes is a long-term objective).

Sewage sediments, among others, are accounted to wastes, which can be used in power industry. It is planned that till 2015 the amount of stabilized sediments, which will be produced in municipal sewage treatment plants, will equal 642.4 thousand Mg of dry substance, and 58% of it will be generated in 76 biggest agglomerations. Comparing the mentioned-above value with 397.2 thousand Mg of dry substance produced in 2001 [14] (in 2004 – 476 thousand Mg of dry substance [37]), it should be stated that increase by about 62% of sediments which need to be utilized will take place within a discussed period of time [14]. Apart from agricultural use, the sediments can also be used for power purposes, i.e. burnt directly (e.g. in fluidized-bed, stoker, rotary furnaces) or co-incinerated with conventional fuels (in stoker fired boilers, pulverized-fuel boilers, rotary boilers) in wastes incinerating plants, cement plants, power stations and heat and power stations. The analysis of use of sewage sediments from selected sewage treatment plants show that their amount for incineration in 2003 was at the level of about 4% (36% was used for reclamation of areas, 14% for production of composts and fertilizers, about 7% was used in agriculture, about 17% was sent to waste disposals, while the remaining 22% was used according to local needs and possibilities [14]). Much lower values in this range were obtained in 2004 where total share of all sewage sediments for thermal processing in their total amount was only 0.3%, while the rest was used for disposal (41.4%), for land reclamation (28.1%), in agriculture (17%), for cultivation of plants to be used for compost production (7.6%) and for temporary storage (5.6%) [37]. It is planned that till 2018 the mentioned-above structure of sewage sediments use will change, aiming among others at total elimination of sediments disposal, reduction of their agricultural and natural use (to about 10%) and use for reclamation (to about 10%), with simultaneous increase of their amount planned for composting (to about 25%) and, first of all, for processing by thermal methods (to about 55%) [37]. It is mainly associated with assumed reduction of biodegradable municipal wastes sent to disposal sites, whose level, according to the Council 1999/31/EC Directive [5], in relation to the mass of discussed wastes produced in 1995 (4.38 mln Mg [37]), should be at least as follows:

- 25% in 2010 (i.e. reduction by about 1.095 mln Mg),
- 50% in 2013 (i.e. reduction by about 2.19 mln Mg),
- 65% in 2020 (i.e. reduction by about 2.85 mln Mg).

This increasing tendency also results from the Union's obligations [4] which aim at elimination of agriculture sewage sediments, which have harmful impact on soil, plants, animals and people, by determination of permissible concentrations of heavy metals in soil and sediments, exceeding of which would cause that discussed use of sediments would be forbidden. Type of sewage sediments which can be under thermal processing was mentioned in the Decree of Minister of Economy [27], however, requirements associated with their quality as regards their use as substitute fuel e.g. in power boilers or cement kilns were not specified. Some arrangements, which enable to determine conditions of burning and co-incineration of wastes, and to verify possibilities of their power use, were included in a directive on emission standards [30].

Trials on co-incineration of sewage sediments in Poland are currently of testing character [36] (e.g. tests on co-incineration with coal in a pulverized-fuel boiler in Wybrzeże Heat and Power Station in Gdansk [50]). However, activities in this range, especially with use of pulverized-fuel boilers, are successfully conducted in other countries, e.g. in Germany. Such activities enable the following [18]:

- effective use of significant amount of discussed wastes (sediments are added to coal in the amount of about 5% by weight of dry sediment), while meeting the required emission standards;
- lower operational costs in relation to the installation of independent burning of wastes, even when outlays associated with equipment of existing power units are taken into account;
- use of ashes produced during burning of suitably selected proportions of coal and sediment as the building material.

In relation to the above, thermal processing of sewage sediments (i.e. mainly co-incineration) can be a method to use up that part of sediments which cannot be applied for agricultural purposes and it can lead to reduction of amount of sediments which are sent to disposal sites. When making decision about power use of wastes, ecological, economic, technological and sociological (social acceptance for the planned undertaking) conditions should also be taken into account.

Other biomass waste products, such as, e.g. wastes from cellulose-and-paper industry, which are used, among others, for production of fuel which is burnt in high-efficient power boilers, or wastes from gastronomy and meat-and-fat industry which are produced in the following amounts can also be considered for power use:

- fats – about 120 thousand Mg, vegetable oils – about 14.5 thousand Mg, after-refining fatty acids – about 25 thousand Mg, wastes of mineral oils – about 20.2 thousand Mg in 2003 [7];
- meat-and-bone meal – about 135.7 thousand Mg in 1999 [38], currently about 200 thousand Mg (together with the amount which is stored) [52].

Used fats and spent oils can be used, among others, for production of biogas (it is estimated that from 1 Mg of dry organic fat 700 m^3 of methane can be obtained [17]), they can be co-incinerated with coal e.g. in stoker furnaces or used for production of fuel for Diesel engines. Another potential power use of meat-and-bone meal is to burn them with used fats or to co-incinerate them in power boilers.

Within the years 2014–2018 an increase of power use of packaging wastes, including among others, paper (burnt in 2004 at not sufficient level of about 15.5 thousand), and recovery of energy from wastes which are not biodegradable, such as e.g. wastes

from used tyres co-incinerated in cement plants, power stations or heat and power stations, which meet environmental requirements in this range, is planned [37].

MAIN DIRECTIONS IN LEGISLATIVE CHANGES AIMING AT INCREASE OF RENEWABLE ENERGY PRODUCTION

Changes of legislative character which would allow to classify as renewable energy produced from biodegradable biomass wastes, other than mentioned in §16 of the directive [26], can be included to the main activities aiming at increase of energy recovery from RES, apart from more effective use of RES.

It should be emphasized that Polish legislation as regards management of wastes which are included in act [42] does not say about possibilities of their thermal processing and recovery in a form of fuel which is not a waste, despite the fact that Minister of the Environment is in charge to determine, by a decree, technical conditions for classification of part of energy recovered from thermal processing of municipal wastes to renewable energy. Due to this, decisions included in acts [42, 43] and in decrees [26, 30, 31] (while decree on emission standards [3] does not include installations in which admixture of co-incinerated wastes does not exceed 1% by weight) refer to all wastes other than hazardous, which can be thermally processed (apart from wastes mentioned among others in §16 of decree [26]).

Thus, it is necessary to introduce changes and supplements to existing legal acts associated with wastes management, including act on wastes [42], among others, in the following range [12]:

- presentation of possibilities of suitable thermal process of wastes, where fuel called e.g. as renewable fuel, which is not classified as waste (for example in relation to sewage sediments only their use for agriculture and reclamation is currently presented, while possible power use is neglected [42]) will be the product;
- completing the content of Article 3, Section 3, Points 1 and 14 of Act on wastes [42] by including in wastes management and recycling definition the option of their transformation into a fuel which is not waste.

Introduction of the mentioned changes would result in the necessity of verification of the remaining regulations associated with power sector, and would open the way to development of state-of-the-art technologies of transformation of wastes into fuel (especially organic fractions of municipal wastes and sewage sediments) [12].

Also a requirement of ecological safety of discussed process speaks for qualifying to RES the above mentioned fuel (also called a secondary fuel), which is produced form wastes other than hazardous, where its thermal processing meets the criteria of authothermal burning and are realized only in installations which have integrated license, meeting both emission standards which are in force and high requirements referring to quality of final product and conditions of its production [36].

SUMMARY

Promotion of development of power industry based on renewable sources mainly results from the tendency to reduce the emission of greenhouse gases, to save fuels and to beco-

me, as much as possible, independent from import of oil and gas. Aspiration for increase of "green" energy produced in Poland is reflected in assumptions and objectives of Polish energy policy.

Biomass, including biomass wastes, is the main RES in Poland. The amount of wastes, which can be used for energy production, is significantly higher than the amount, which is really used. The reasons of such situations can be found, among others, in inaccurate recognition of biomass potential, especially in a local system which is a result of cost-effectiveness of transportation of the discussed raw material (maximum distance between place of production and place of use is about 100 km), as well as in lack of precise technical-and-economic reasons for investing in installations for energy transformation of biomass.

Due to the above, the necessity of creation of the comprehensive database on wastes, which would enable their effective use, should be considered as an important problem to be solved. To increase the level of power use of biomass wastes it is also necessary to make some changes in legislation, mainly as regards classifying the fuel produced as a result of thermal transformation of wastes into "green" energy, not to wastes as it is at present. Creation of mechanisms, which connect interests of wastes generators, producers of alternative fuels and potential users, as well as development of effective systems for transferring the information between them, can also be considered as significant factors on the way to increase the power use of discussed wastes.

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ODPADY BIOMASOWE JAKO ŹRÓDŁO ENERGII ALTERNATYWNEJ

Niniejszy artykuł jest poświęcony energetycznemu wykorzystaniu odnawialnych źródeł energii, ze szczególnym uwzględnieniem odpadów biomasowych. W sposób ogólny scharakteryzowano tu rodzaj i potencjał biomasy odpadowej, która może być stosowana do produkcji energii elektrycznej i cieplnej, omówiono energetyczne zagospodarowanie biomasy w Polsce, oszacowano rezerwy istniejące w tym zakresie oraz przedstawiono podstawowe akty strategiczno-prawne odniesione do rozpatrywanego zagadnienia. W pracy zasygnalizowano również rodzaj działań możliwych do realizacji dla zwiększenia ilości energii alternatywnej produkowanej w Polsce w świetle konieczności osiągnięcia określonych celów ekologiczno-energetycznych, wynikających z umów międzynarodowych i prawodawstwa unijnego.