DRAFT REPORT OF RISK ASSESSMENT OF BIOGAS PRODUCTION POLAND

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I. List of all biogas installations in the country in question, divided by organic material used (municipal wastewater sludge, municipal waste, agricultural sludge/manure, other organic matter e.g. grass) and size

The history of biogas production in Poland is not very long. It started about 20 years ago for other than agricultural feedstock and for agricultural feedstocks in 2005 when the first of such kind was built.
In Poland there is a quite strict division into two groups of biogas plants:

1. Agricultural - using agricultural substrates, agri-food waste, re-food, slurry and manure, animal wastes from slaughterhouses,
2. Other than agriculture - using sewage sludge from municipal wastewater treatment plants, biodegradable municipal waste, recovering biogas from landfills.

This division is caused by the support system for biogas production and the authorization procedure for the production of energy from biogas (concession). Agricultural biogas plants are privileged in two aspects:

1. They do not have to have a concession, but only a registration in the list of agricultural biogas generators,
2. They have a better situation in terms of support both in the current system through certificates of origin of renewable energy (green certificates) and in the new one (auction system).

Other biogas plants (producing biogas from sewage sludge and municipal waste) are required to obtain energy concessions and, they have a separate, less favorable support system. The co-digestion of slurry and municipal waste in Poland is not profitable due to a separate support system for agricultural biogas plants. The addition of municipal waste causes the biogas plant to cease to be agricultural and its operation is much less economically viable. Under current legislation, it is appropriate to digest municipal waste with sewage sludge, and slurry with waste from agri-food processing or crop plants.

NOTE *In Poland co-digestion means production of biogas from most often municipal waste and food residues or sewage sludge with municipal waste or other combination with in the same kind "other than agricultural".*

Figure 1 presents the share of biogas production from different sources as well as the number in different regions of Poland. The highest number of biogas plants (up to 30) is located in Mazowieckie and Silesian provinces.

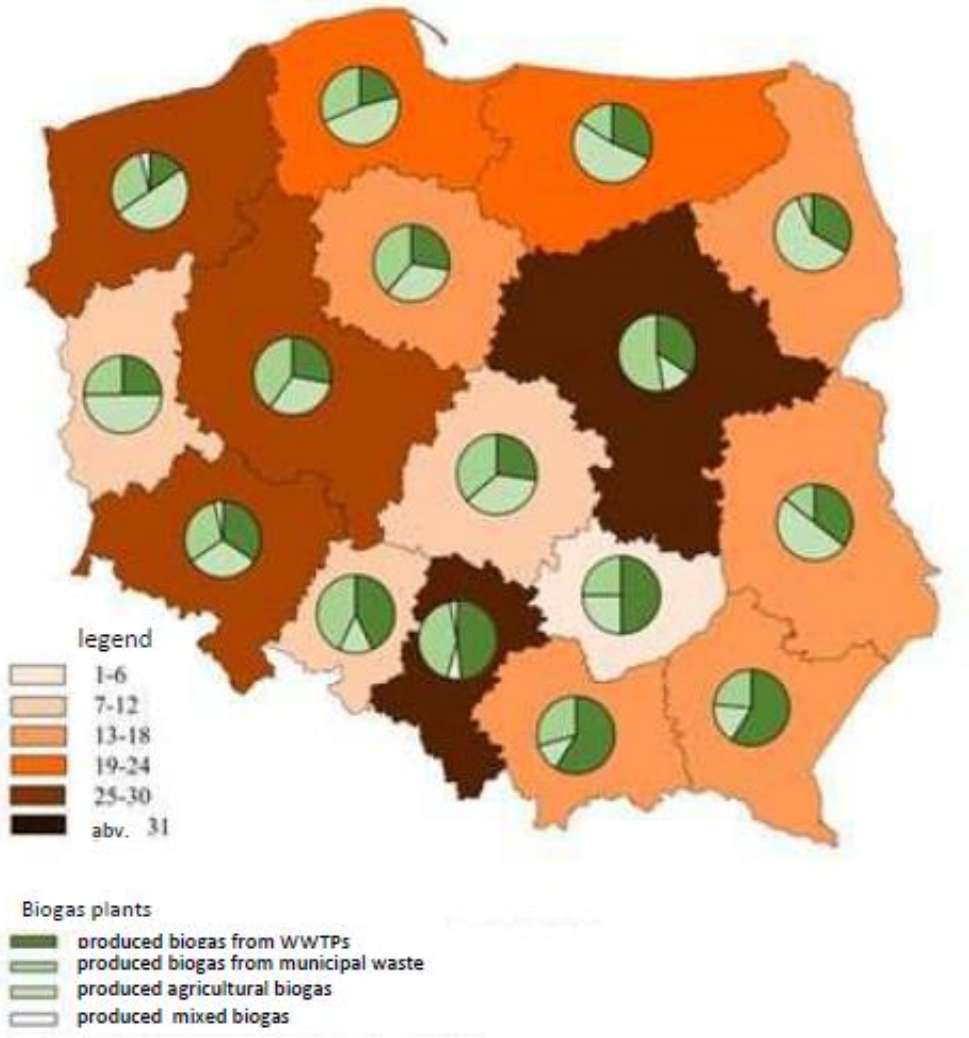

Fig. 1. The number of biogas plants in Poland with the share of substrate (GUS, 2016)

a) Biogas from wastewater treatment plants

In Poland, biogas plants located in wastewater treatment plants (WWTP) have been built since the 1990s. Now there is 99 WWTP biogas plants in operation, which corresponds to 37% of all biogas plants.

Most of them are relatively new and are a result of modernization of so called open anaerobic digestion tanks, which were common in the past. In most of them CHP (Combined Heat and Power production) is applied. In some of them the production of only heat for own WWTP processes is carried out. The heat is used for (i) drying of dewater sludge, and (ii) hot water and

heating production for the buildings at WWTP. The production of energy from biogas from WWTPs is presented in Table 1.

Table 1. The production of biogas from WWTPs, TJ

Year	2011	2012	2013	2014	2015
Biogas production	2775	3321	3572	3810	4043

b) Biogas from municipal waste

Initially, there were biogas removal plants on landfills, where biogas was mostly burned in flare or rarely used to produce energy. Currently, newly built landfill sites must be equipped with degassing installations. There is 98 biogas plants located in landfills. This represents 37% of all biogas plants. The production of energy from biogas from landfills is presented in Table 2.

Table 2. The production of biogas from landfills, TJ

Year	2011	2012	2013	2014	2015
Biogas production	2323	2249	2157	2051	2125

In installations for biogas production from municipal waste, the process of periodic fermentation is most often used. In this process the substrates are loaded into the fermentation chambers which are then closed. The content of the chamber is wetted with leachate. After the retention time the chamber is emptied and reloaded.

Few biogas plants in Poland use so-called common fermentation where the biogas is produced from mixed sewage sludge and municipal waste.

c) Agricultural biogas plants

In Poland the first agricultural biogas plant was put into operation in 2005. Since then, their number has grown, however, very slowly. Polish agriculture has a land area similar to German one, but the development of biogas plants is incomparable in these countries. The number of agricultural biogas plants in Poland is 94 (for December 31, 2016) (Table 3).

Registered entities are obliged to submit quarterly reports containing information about:

1. the total amount of produced agricultural biogas,
2. the amount of produced electricity from agricultural biogas,
3. the amount and the type of all substrates used to produce agricultural biogas or to generate electricity from agricultural biogas.

Table 3. The number of entities and installation in the register of agricultural biogas generators

The number of entities in the register of agricultural biogas generators						
January 1, 2011	*January 1, 2012*	*January 1, 2013*	*January 1, 2014*	*January 1, 2015*	*January 1, 2016*	*December 31, 2016*
4	10	21	35	50	69	84
The number of installations in the register of agricultural biogas generators						
8	16	28	42	58	78	94

Thanks to these reports, the amount of biogas and energy production as well as raw substrates used in this process is well controlled (Table 4).

Table 4. The production of agricultural biogas, electricity and heating from agricultural biogas in 2011-2016 (March 24, 2017)

Year of production	The amount of produced agriculture biogas *[million m^3]*	The amount of electricity produced from agriculture biogas *[GWh]*	The amount of heating produced from agriculture biogas *[GWh]*	The amount of used co-substrates *[t]*
2011	36.646	73.433	82.638	469 416.0
2012	73.152	141.804	160.128	917 121.6
2013	112.412	227.890	246.557	1 574 179.2
2014	174.253	354.978	373.906	2 126 377.6
2015	206.236	429.400	224.996	2 484 499.9
2016	249.800	524.595	no data	3 224 421.6

The type of substrate has changed over the years. The first installations were built to process feedstock crops, mainly maize. Since 2013, biogas plants have increasingly begun to process waste from agriculture and food processing as profitability of biogas production has decreased. The current contribution of the various substrate groups is presented in Table 5. The obligation to submit reports on used substrates should limit risk of using municipal waste and sewage sludge in agricultural biogas plants.

The location of existing and future agricultural biogas plant is shown in Fig. 2. Distribution of agricultural biogas plants in Poland is fairly uniform. There are no regions where the number of biogas plants would be particularly large. As a result, environmental damage due to the biogas plant or the management of the digestate does not cause a risk to any specific region.

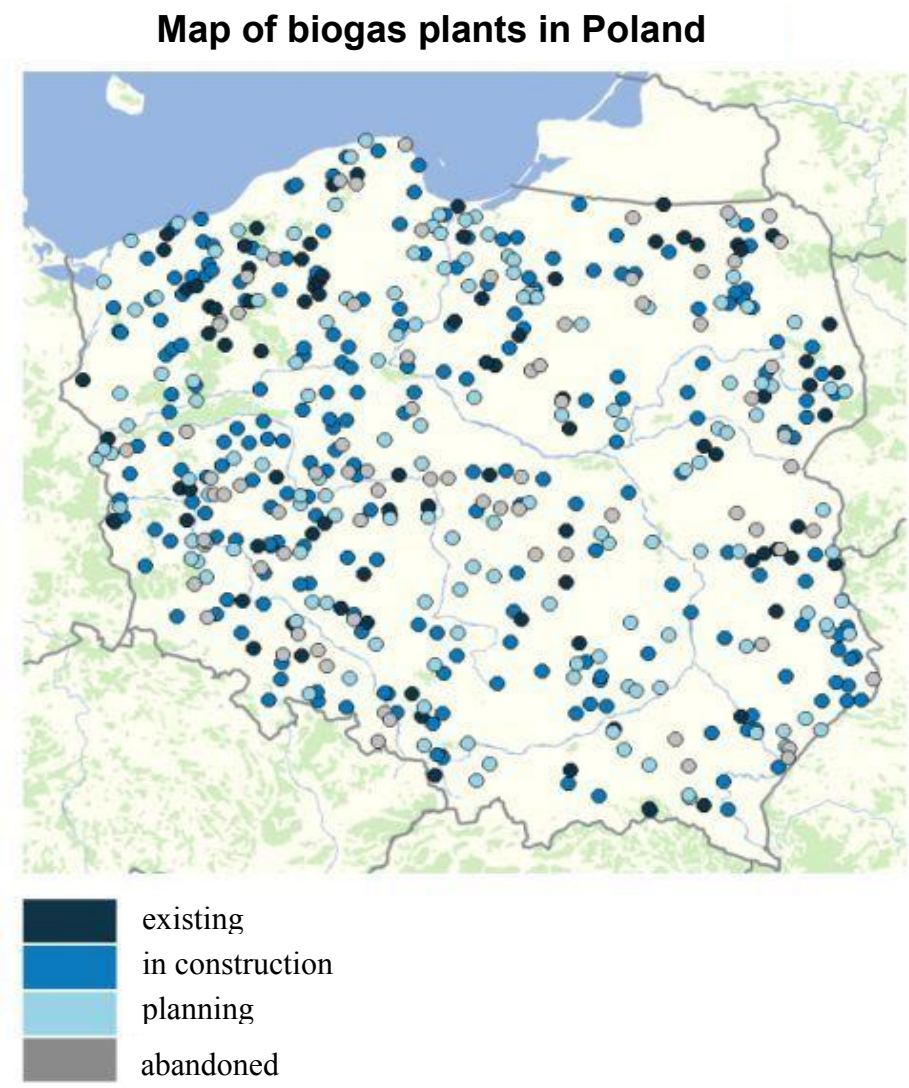

Fig. 2. The map of agricultural biogas plants in Poland **(**report of Bioalians Company, 2016)

Table 5. The raw substrates used for production of agricultural biogas in 2016

No	The type of substrates	The amount [ton]
1	**2**	**3**
1	Slurry	774 997.113
2	Residues from fruit and vegetables	665 338.208
3	Distillery decoction	477 858.199
4	Maize silage	439 135.422
5	Beet pulp	222 157.445
6	Technological sludge from food industry	125 136.429
7	Waste from dairy industry	89 144.969
8	Manure	86 139.887
9	Green crop	56 710.799
10	Waste from plant mass	32 906.420
11	Waste from food industry	30 429.984
12	Expired food	28 596.802
13	Fruit and vegetables	25 962.931
14	Bird's droppings	25 643.064
15	Stomach content	23 145.838
16	Fat sludge	20 213.180
17	Cereal, cereal waste	18 547.090
18	Slaughterhouse offal	17 943.590
19	Silage from grass and cereal	17 170.700
20	Straw	12 869.530
21	Digestate	8 540.000
22	Fodder	6 142.732
23	Fat	5 078.137
24	Fat and protein waste	4 132.601
25	Waste from catering industry	2 851.251
26	Liquid wheat residue	1 490.549
27	Yeast waste	1 368.680

28	Washings	1 355.630
1	**2**	**3**
29	Waste from production of vegetable oil	1 334.733
30	Fat and protein slime	1 282.400
31	Glycerine	379.080
32	Fuse oil	263.720
33	Post-extraction pomace from production of herbal pharmaceuticals	107.560
34	Vegetables oil	46.939
	Total	3 224 421.612

Based on the data in Table 5, the annual amount of digestate produced in agricultural biogas plants can be calculated. It was assumed that the digestate constituted 90% of the substrate. The annual amount of digestate is thus 2 901 979 tonnes.

In all biogas plants in Poland, about 2 238 GWh of energy is produced annually (Table 6). This amount can be higher if the CHP heat is generated in agricultural biogas plants. At present, most of this heat is not used for economic and technical reasons.

Table 6. Energy production in biogas plants in Poland

Type of plant	Number of plants	Production (GWh)
Wastewater treatment	99	1 123.056
Landfill installations	98	590.278
Co-digestion	2*	no data
Farm installation	94	524.595 (electricity)
TOTAL		2 237.929

* Słupsk (sewage sludge + organic waste), Puławy (sewage sludge + garbage)

II. Review of treatment methods used for reject waters and treatment/disposal methods for solid rejects from biogas processes and prevalence of different methods in the country in question

a) Wastewater treatment biogas plant

Sewage sludge is a by-product of wastewater treatment and depending on the size of WWTP it could be processed in different ways. The structure of WWTP in Poland is as follows: 81 over 100 000 PE (population equivalent), 576 of 10 000–100 000 PE, 978 of 2 000–10 000 PE and 1556 below 2000 PE.

During the last twenty years the energy recovery from sewage sludge has become the most promising and advised way of handling sewage sludge in medium sized and big WWTPs. For big WWTPs, over 150 000 PE, sludge processing usually covers a digestion process with biogas production (for CHP - Combined Heat and Power) and then mechanical dewatering, which generates highly polluted liquor, also called reject water, RW (see the Fig. 3).

In big WWTPs, now 11 with incineration in the biggest towns (Gdynia, Gdańsk, Bydgoszcz, Warszawa, Kraków, Szczecin, Poznań, Łódz, Zielona Góra, Bydgoszcz, Olsztyn), the most common way of handling reject water (RW) is to re-circulate it to wastewater treatment, usually to the sedimentation tank. Due to high concentration of pollutants in RW, it is applied in relation to the flow of wastewater but it can still hinder biological processes at WWTPs. When mechanical dewatered sludge is incinerated (Fig 3. lower part), both nitrogen and phosphorous are lost. Nitrogen is removed via biological processes to the atmosphere, while phosphorus is, after incineration, bound in ashes in compounds which are not available for plants. In general, the ashes (usually two types are generated during the incineration of residues after digestion) are very difficult to dispose of since they are treated as a hazardous waste.

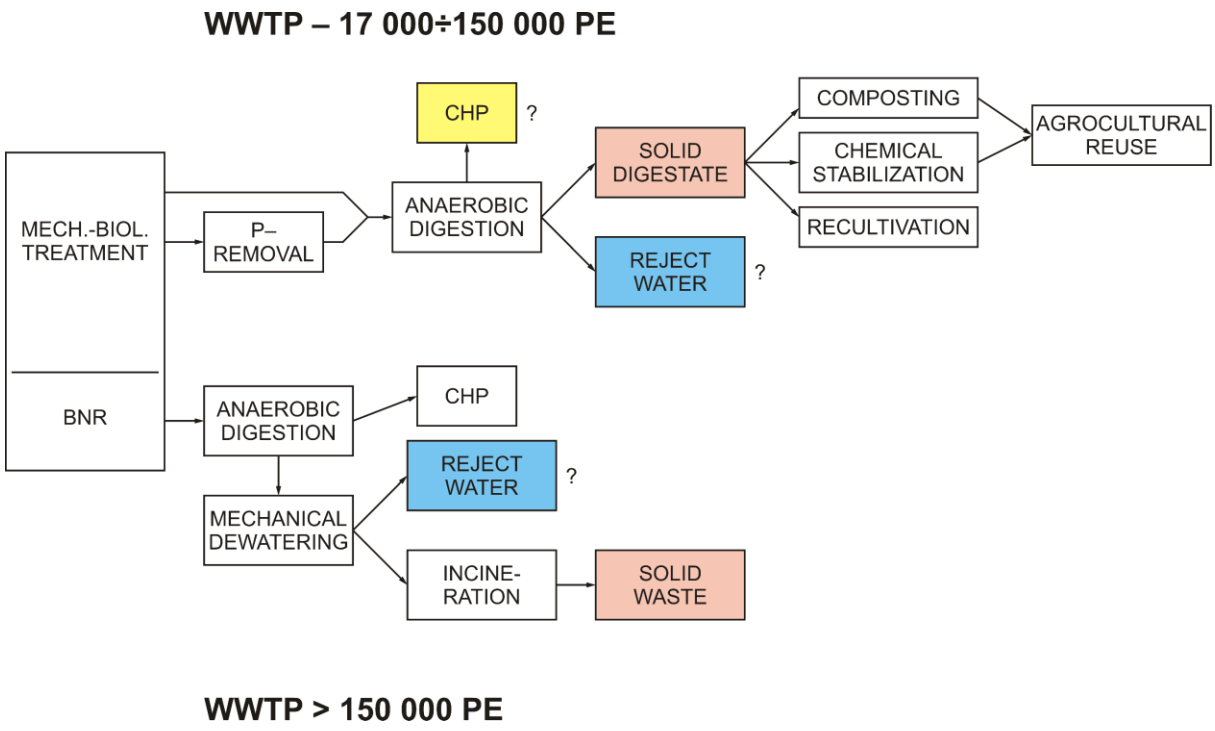

Fig. 3. Most common treatment of wastewater and sewage sludge processing in Poland

For smaller WWTPs, which do not have incineration due to its high cost, the final disposal method for solid digestate after anaerobic digestion cab be agricultural reuse or recultivation (Fig. 3 upper part). Agricultural reuse demands good quality of the end material, proven by special certificate allowing for trade (the certification and demands are described chapter III). Quality of the digestates is monitored and quality requirements cannot always be fulfilled. Another problem regarding composting is that the process requires a lot of oxygen and is very costly. Also, same structural additives are needed to achieve good compost structure, especially when produced from biogas residues. There are 90 composting plants in Poland but only 30 WWTPs produce compost form solid digestate (Fig. 4).

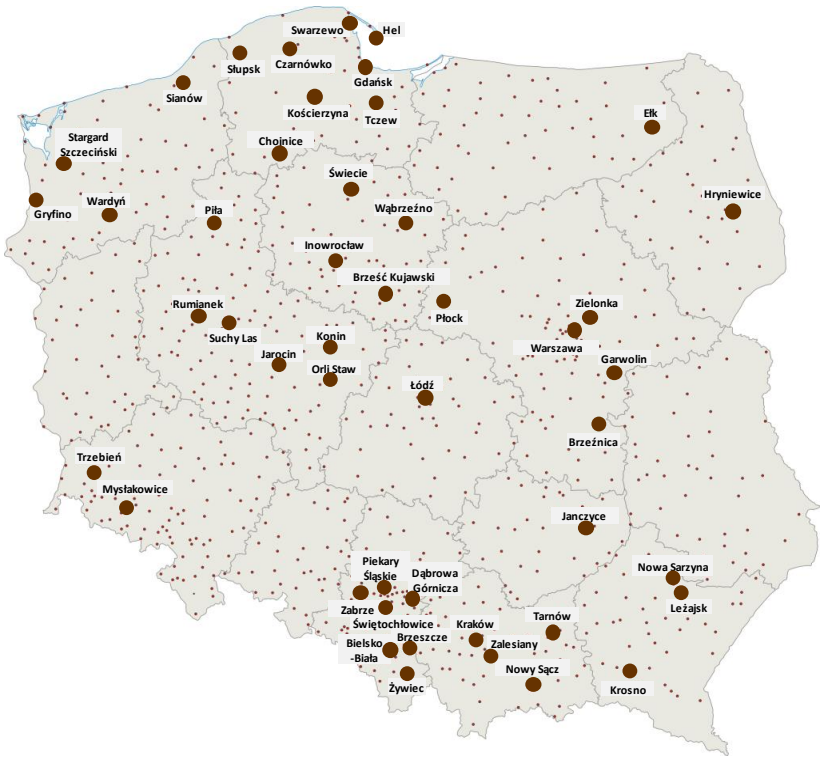

Fig 4. Organic recycling facilities (composting plants) processing solid digest from sewage slugde (end of 2012) by Wójtowicz et al. 2015

Chemical stabilization is relatively uncomplicated process, but it causes increase in volume of the solid digestate, as at least six parts of chemicals, most often in the form of CaO (calcium oxide), is required per one part of digestate.

Use of solid digestate in recultivation means its utilisation in e.g landfill sites or other degraded areas for recreating the soil. The problem is that usually there is only a limited number of such places in the surroundings and as a consequence not enough area to be recultivated.

In all kinds of aerobic methods of sludge processing in small WWTPs (17000 -100 000 PE) the reject water has not caused problems for the plant operations due to the fact of its relatively good quality which is very similar to raw wastewater discharged to WWTP. Thus, the most common way is to return it to the beginning of WWTP treatment, most often after grid and screens and before sedimentation tank.

In all cases of all biogas installations, the biggest source of pollution is the reject water which is generated in all installations during mechanical dewatering – described in Chapter IV, Risks.

Municipal Landfills

According to the Polish legislation, storage of sewage sludge in municipal landfills is forbidden since 2016. Landfills where organic waste (garbage and sewage sludge) was discharged before 2016 are obliged to handle leachates from the compartments in which spontaneous biogas production occurs. This causes a lot of problems, as the quantity and quality of leachate fluctuates. The quantity depends strongly on the season and rain, while quality depends on the time of storage to the landfill. Generally, the biodegradability of landfill leachates (LL) decreased with time. Thus, for older so-called mature compartment, the treatment of LL is more complicated and costlier. Usually landfills are equipped with some installations for LL treatment on site but during rain events the LL are usually discharged by lorries to the WWTPs and then may create the same problems as RW.

b) Agricultural

The easiest and the most common way to use digest from agricultural biogas plants is the direct application into the agricultural land in liquid form directly from storage tanks in the biogas plant (Fig. 4). However, due to low dry matter content (about 3-5 %) the costs of the irrigation of digestate are very high. In this situation, the users of biogas plants try to irrigate digestate as close as possible to the plant to reduce the transport costs. If there is not enough agricultural land nearby which has potential to use digestate, it can lead to violations of the rules and excessive application of digestate. This can result in inflowing of digestate into surface water and its infiltration into groundwater. Special risk is over-fertilizing of land and water.

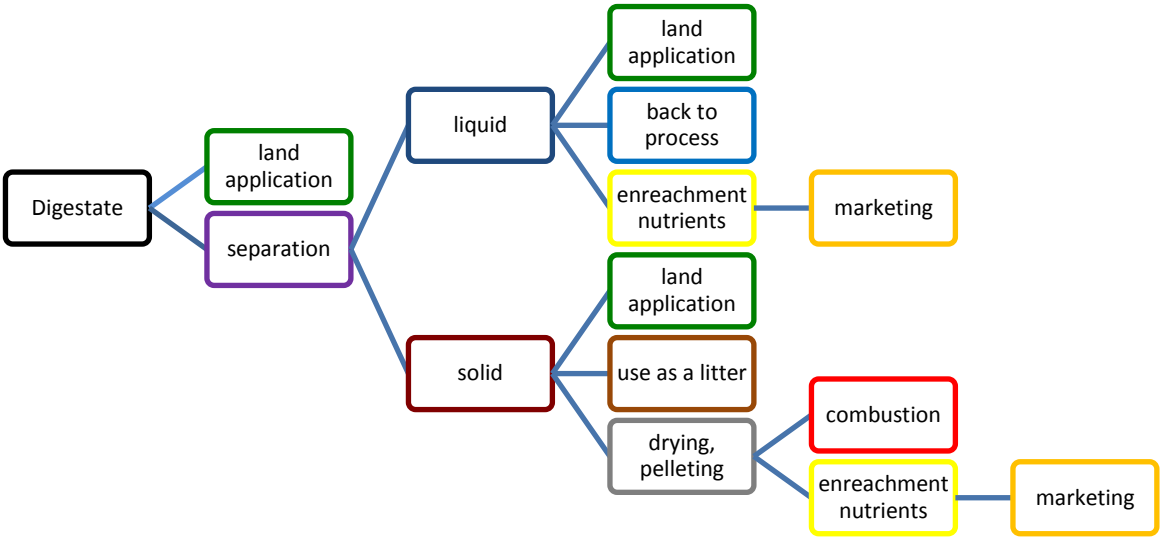

Fig. 5. Most common digestate treatment methods in Poland

Recently a popular solution used in biogas plants is the separation of the liquid digestate. As a result, two fractions, liquid and solid one are formed. These fractions are different in terms of physical-chemical properties. Need of digestate treatment is mainly caused by the need of storage surface reduction. Liquid fraction can be returned back to the digester as technological liquid. Alternatively, it can be used as fertilizer. Most often in biogas plants mechanical separators (such as belt presses or decantation centrifuges) are used. These devices usually provide dry matter constant up to 30%. From the separated liquid fraction minerals can be recovered by the use of reverse osmosis or ultrafiltration membrane. This way, mineral concentrate fertilizer and water can be obtained. For now, these solutions are too expensive for Polish biogas plants.

Of the methods used to develop digestate from agricultural biogas plants (which are presented in Figure 5) the most direct use is land application of liquid, without separation or, after the mechanical separation. Many biogas plants also use a part of liquid fraction as process water. Other methods of using digestate (as litter, for combustion, for sale) are rare: less than 10% of agricultural biogas plants in Poland use these methods.

The solid fraction after the separation is similar to fresh compost. It consists of the structural part of the organic matter, humic acids-building decay, as well as significant quantities of

mineral compounds. Using this fraction to soil leads to obtain high yields. Application of this fraction increases organic matter content in the soil, which has a positive effect on sorption of water, and at the same time it is an excellent source of nutrients for plants, thereby reducing the need of mineral fertilizers. Solid fraction can be applied to the agricultural land by using traditional manure spreaders. About 80% of biogas plants that use digestate separation use a solid fraction as a fertilizer on their own land or sell it to local farmers.

The liquid fraction contains significant amounts of soluble forms of nitrogen, phosphorus and potassium directly available to plants. So after application to the fields, fast effect of crop growth can be observed. This fraction also contains small amounts of organic matter which has a positive influence on the physical, chemical and biological properties of the soil. It can be applied to agricultural land by using cisterns.

Drying of solid fraction

Obtained solid fraction can be further processed. Biogas plants have excess heat, which can be used for drying of digestate solid fraction. In this way a uniform product with good physical parameters and high concentration of nutrients in dry matter can be obtained. Due to evaporation of water, the mass of digestate is reduced and demand of storage surface decreases. Dried solid fraction can be applied to agricultural land by using for example manure spreader. Drying of the solid digestate fraction is used only in several biogas plants before it is granulated or sold in stores.

The granulation of digestate

Another way of processing digestate is its granulation. Dried solid fraction can be directly granulated or, before granulation different mineral additives for enhancing of the chemical composition of the final product can be added. Thanks to mineral additives the chemical composition of the granules can be adapted to the needs of the crops. The concentration of nutrients in granulated digestate is higher than in previously described form of digestate. This digestate is a very good product that can be used as a fertilizer in the production of agriculture and gardening. Production of granulates can increase the consumption of digestate. Most farms specialized in livestock production, have got the equipment for manure application, which can be also used for digestate applications. Farms which lead only crop production have not got such equipment, which prevents them from using digestate from the biogas plant. In this type of farms the soil in particular requires the supply of organic matter from fertilizers. For this

reason, the granules of digestate is very valuable for them as a source of organic matter and nutrients for plants. At the same time, its application can be conducted using the spreaders for mineral fertilizers. Several agricultural biogas plants in Poland have pellet digestion lines, but their use depends on the possibility of selling granules as a fertilizer. Despite having pelleting line, these biogas plants do not always use them because of costs.

Composting of digestate

Digestate can also undergo composting. Composting is the process of aerobic treatment of organic compounds. Digestate in terms of chemical point of view is already compost, so there is no need for its composting. However, when digestate comes from biogas plants which utilizes waste this process can be appropriate. During the composting process thermophilic phase occurs, which causes the hygienization of composted mass. During the composting, additives (most often sawdust or straw) that provide the source of carbon as well as give an appropriate structure for oxygen conditions, should be added. The composting process can be carried out in open piles or in closed chambers. Obtained compost can be used for fertilizer in agricultural production or gardening.

From a biological point of view, the composting of digestate is rational, because it allows obtaining material with stable parameters, with less risk for the environment. However, none of the agricultural biogas plants in Poland apply this process because of the extra costs. The composting of digestate is often used in biogas installations using sewage sludge.

III. Legislative framework and permitting procedures for biogas installations

As a preliminary point, it should be noted that Polish legislation is often changed. Also, the regulations on the use of digestate, its research, the way and the time of application have been amended several times since 2005, i.e. since the start of the first agricultural biogas plant. Another amendment to the law is being prepared as a result of adapting to the new Water Law. However, new regulations are in the design phase. Therefore, the report states the legal status in the second half of 2017. Currently law is very beneficial in regulating of agricultural biogas plants. However, other types of biogas plants have been treated much worse.

The difficult situation of biogas plants is caused by record low prices of green certificates. However, energy production from biogas plants has been subsidized by new a support

instrument called the Blue Certificate This support is very beneficial to agricultural biogas plants, but not so much for biogas plants from WWTPs. On the other hand, it seems that WWTPs will still be interested in biogas plants due to restrictions in the storage of sludge. There is no doubt that biogas plants are one of the most effective ways of sludge management. In addition, they provide added value in the form of electricity and heat recovery.

In Poland there are many regulations regarding the use of digestate. The most important of them are:

- The Act on waste, dated 14 December 2012 (Journal of laws of 2013 item 21),
- The Act on fertilizers and fertilizing, dated 10 July 2007 (Journal of laws of 2007, no. 147, item 1033, as amended),
- The Regulation of the Minister of Environment on the waste catalogue, dated 27 September 2001 (Journal of laws of 2001 no. 112, item 1206),
- The Regulation of the Minister of Environment on the R10 recovery process, dated 20 January 2015. (Journal of laws of 2015 item 132),
- The Regulation of the Minister of Agriculture and Rural Development on the implementation of certain requirements of the Act on fertilizers and fertilizers, dated 18 June 2008 (Journal of Laws No. 119 item 765, as amended),
- The Regulation of the European Parliament and Council (EC) no 1069/2009, dated 21 October 2009, defined health rules concerning animal by-products not intended for human consumption and repealing Regulation (EC) No 1774/2002,
- The Regulation of the Minister of Agriculture and Rural Development on detailed way of fertilizers application and training concerning their application, dated 16 April 2008 (Journal of Laws of 2008, no. 80, item 479, Official Journal of 2014, item 393).

Digestate as waste

In order to limit the amount of waste deposited in landfills, it is recommended to carry out the recovery process of waste containing a significant amount of organic matter. The opportunities for recovery of waste are listed in annex no. 1 to the Act on waste. Rational recovery methods in the case of digestate substances are:

- the R3 process – "recycling or recovery of organic substances which are not used as solvents (including composting and other biological transformation processes)",

- the R10 process – "treatment on the surface of the ground that brings benefits for agriculture or improve the state of the environment",
- in case of separation and drying of solid fraction, it is possible to apply the R1 process "use principally as a fuel or other means to generate energy,"

The most common way of digestate management is the recovery using R10 method (use of digestate for fertilizing of soil). In order to recover digestate using R10 method, a number of the requirements of the Regulation of the Minister of the Environment on the recovery process R10 must be completed. Different requirements for different waste codes are listed in the annex to the regulation. A large part of the requirements and recommendations does not apply to digestate from biogas plant, where waste is not used in the fermentation process. This has been changed in the amendment of the regulation in January 2015. The regulations exempt all agricultural biogas plants from many of the restrictions. For that reason, it is important to specify type of the biogas plant.

The conditions for the R10 recovery process of the biogas plants where the anaerobic treatment of waste treatment is processed:

1) for waste (where waste means digestate, produced during the fermentation of various substrates, including slurry or manure, but with the use of raw materials classified as waste):

a) the requirements are met as for fertilizers, defined in the Act on fertilizers and fertilizing of 10 July 2007 and, requirements for limit values of pollutants referred in legislation based on article 10 point 5 and article 11 point 5 in this Act,

b) the animal origin material after the fermentation process meets the requirements defined in European Parliament and Council Regulation (EC) no 1069\2009 of 21 October 2009, describing health rules concerning animal by-products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (animal by-products regulation).

The most important principles are:

- in the case of waste of category 2, the particles about diameter below 50 mm should be sterilized by heat treatment in saturated steam at 3 bar and 133°C for at least 20 min.
- in the case of waste of category 3, the particles about diameter below 12 mm should be pasteurized by process of hygienization of waste at 70°C for at least 60 minutes.

- although, the waste category 2 includes manure and animal stomach content, these two typical substrates for biogas plants have been exempt from heat treatment and they can be supplied to installations directly.

2) for soil, where the waste will be used:

a) the concentration of heavy metals in surface soil layer (0-25 cm) does not exceed the limit values defined for the application of municipal sewage sludge, according to article 96 paragraph 13 of the Act on waste of 14 December 2012 (Table 7 and 8),
b) the quantity and dose regimen of waste does not cause deterioration in the quality of the soil, ground and surface and ground water, even with long-term use,
c) the requirements for the detailed application of the fertilizers, described in article 22 point 1 of the Act of 10 July 2007 on fertilizers and fertilizer, are fulfilled (Table 6),
d) wastes are applied evenly over the soil surface to a depth of 30 cm and are covered with soil or are mixed with it.

Another duty is that digestate produced in the installations used waste (including waste from the processing of agro-food) must be tested in accredited laboratories. This is associated with the specified costs and the need to transport digestate to these laboratories.

Table 6. Limit values of heavy metals in surface soil layer (depth 0-25 cm) for the application of municipal sewage sludge in agriculture purpose and the reclamation of land

Metals	Permissible values of heavy metals in mg/kg of dry matter of soil		
	light soil	medium soil	heavy soil
Cd	1	2	3
Cu	25	50	75
Ni	20	35	50
Pb	40	60	80
Zn	80	120	180
Hg	0.8	1.2	1.5
Cr	50	75	100

Requirements for R10 recovery process contain many references to other legislations. It is necessary to meet the policy for the use of natural fertilizers described in the Act on fertilizers and fertilizing. The Act says that the using dose of manure in a period of one year cannot contain more than 170 kg of nitrogen (N) in a clean component on 1 ha of agricultural land. On this basis, the maximum allowable dose of digestate for use on the land can be calculated and the area of land needed for the management of digestate from biogas plants can be estimated. The above limitation may be affected by biogas plants which have too small area of land. In Poland, if biogas plants cannot sell the digestate, it is possible that they use it their own fields exceeding of 170 kg N/ha dose. Another cause of exceeding of nitrogen dose is the cost of digestate transport on long distances, as was already mentioned in the section II of the report. Exceeding nitrogen dose is not legal and in the case of controls penalties are imposed for such conduct. The law does not regulate the amount of phosphorus that can be used with fertilizers in the fields. In Poland, there is a very high phosphorus (P) deficiency in soil, so there is currently no risk of ingestion of this macroelement. Notwithstanding, that even if the P balance in soil in Poland would currently be negative, because of the P accumulation with the current digestate spreading amounts, there will be a surplus in the future, so, P balance and accumulation in soil needs to be taken into account in policy and carefully followed.
In addition, article 20 of the Act on fertilizers and fertilizing provides that it is prohibited to use fertilizers in flooded soils, covered with snow, frozen to a depth of 30 cm and during rainfall.

In addition, natural fertilizers must not be used:

- in liquid form on soils without plant sloped more than 10%;
- in liquid form during the growing season of plants intended for direct human consumption.

From the point of view of the digestate management, the recommendation is very important: "natural and organic fertilizers, in solid or liquid form, can be applied during the period from 1 March to 30 November (...)". In accordance to this requirement agricultural biogas plants must assure adequate storage space, enough to collect the produced digestate for a minimum of 3 months. This period may be extended, if before December 1st or after March 1st there is snow or the soil is frozen. Also, during the growing season for some crops, it is not possible to use natural fertilizers. Therefore, it is recommended to prepare the tanks for digestate storing for a period of 6 months. This storage period may be extended as changes in fertilization regulations are being prepared.

Regulation of the Ministry of Agriculture and Rural Development describes in detail fertilizer application and permitted ways of spreading natural and organic fertilizers in liquid form. This Regulation recommends using a special equipment for spilling: soil applicators, sprinkling machines, as well as cisterns equipped with splash plates or hoses.

The solid fraction of digestate can be applied during the growing season only on grassland and, on perennial for perennial crops not intended for direct human consumption. After digestate application, as in the case of natural fertilizers, it should be covered with soil (such as using plowing) or mixed with the soil (e.g. disking) not later than the next day after the application. The exception is fertilizers used in the forests and grassland.

The regulation also specifies the allowable distance from reservoirs and waterways which must be kept when natural fertilizers are used, as well as hydrogeological conditions. Until recently, the digestate from biogas plants was clearly classified as hazardous waste, and its agricultural use was based on the guidelines for waste management. Amendment to the Act of 14 December 2012 on waste has changed it. According to this amendment, in the biogas plant which intends to sell produced digestate, it is a by-product subjected to trade. If it meets the requirements, it may obtain the status of organic or organic-mineral fertilizer. In order to digestate be regarded as a by-product and placed on the market, the biogas plant must follow the path set out in the article 11 of the Act on waste and submit the recognition of the object or substance as a by-product to the province marshal. The submission should contain the place and method of production, a detailed description of the production process and, the process in which the product will be used (in this case it will be used as a fertilizer, but it can also be used for example on energy targets). If the province marshal does not object within 3 months, the notified substance is considered a by-product. Biogas plants do not always follow this procedure, which causes legal problems.

Also, biogas plants are required to demonstrate adequate land on which they will use the digestate or have signed contracts with farmers who will fertilize their fields with a digestate. The average area needed for fertilization with a 1 MW biogas plant is 500-700 ha. This prevents the risk of nitrogen overflow. It is not possible to quantify the quantities of agricultural produce from agricultural biogas. Each biogas plant uses a variety of nutrients in various proportions and compositions. In addition, differences in the technological process (retention time, thermophilic or mesophile fermentation, etc.) cause that the digestate from each biogas plant may have a different composition. Therefore, it is necessary to analyze the composition of post-fermentation which is prescribed by law. The starting value for the digestate dose is the amount

of nitrogen: 170 kg / ha. The competent authority for the control of the correctness of fertilizer use of the digestate, is the Inspectorate of Environmental Protection, although, control may be initiated by the mayor, especially when it is suspected that the use is contrary to the regulations. Biogas plants are often subjected to environmental inspections.

Certification of fertilizers produced from digestate

The term "certification" means the procedure of obtaining a permit from the Ministry of the Agriculture and Rural Development for the marketing of organic fertilizer / soil improver. Using digestate as fertilizer is possible after fulfilling the requirements described in the Act on fertilizers and fertilization (Journal of laws of 2007, no. 147, item 1033, as amended) and the Regulation of Minister of Agriculture and Rural Development on the implementation of certain requirements of the fertilizers and fertilizing (Journal of Laws No. 119 item 765, as amended). This regulation imposes the obligation to carry out tests of organic fertilizers / substances acided of crops (including: soil, growth promoters, substances improved soil properties), for their quality and usefulness to fertilize the soil and plants. In order to digestate be considered as a fertilizer or a substance for improving of soil properties, it must be produced based on constant material composition, have stable properties and it must be tested for chemical and biological properties, as well as for its suitability for using.

These tests are carried out in authorized research units, indicated in the regulation. In the process of assessment of fertilizer or soil improver these properties are also taken into consideration:

- the producer's declaration about fulfilling the quality requirements of the fertilizer or soil improver;
- information the producer gives about the composition and a description of the production technology;
- opinion about meeting the quality requirements issued by the authorized organizational units;
- opinions about the suitability of the above mentioned product for use in a specific range;
- instructions for using of product approved by the competent institutes.

If the digestate product is produced from the waste or by-products of animal origin, the additional documentation is also needed:

- the opinion about the impact of the product on human health issued by the Institute of Medicine in Lublin;

- the opinion about the impact of the product on the environment issued by the Institute of Environmental Protection in Warsaw;
- the opinion about the impact of the product on animal health issued by the State Veterinary Institute in Pulawy;
- the opinion on the compliance by the fertilizer or soil improver the veterinary requirements described in regulation 1069/2009, issued by the State Veterinary Institute in Pulawy;
- the identification number assigned by the district veterinarian.

Table 7. Minimum concentrations of nutrients in organic and organic-mineral fertilizers

Component	**Organic fertilizer in solid form**	**Organic fertilizer in liquid form**
Organic matter (% of dry matter)	30	-
Nitrogen (%)	0,3	0,08
Phosphorus (expressed as % of P_2O_5)	0,2	0,05
Potassium (expressed as % K_2O)	0,2	0,12

The Regulation of the Minister of Agriculture and Rural Development on the implementation of certain requirements of the Act on fertilizers and fertilizers, dated 18 June 2008, also describe permissible values of pollutants, especially heavy metals, which digestate can contain, and minimum nutrients content (Tables 7 and 8). In addition, the regulation specifies the range of tests concerning the presence of intestinal parasites and pathogenic bacteria that are unacceptable.

Table 8. Maximum concentrations of pollutants in organic and organic-mineral fertilizers

Pollutants	**The maximum concentration (mg/kg)**
Cadmium	5
Chromium	100
Nickel	60
Lead	140
Mercury	2

Organic fertilizer produced from digestate can be also used in specific crops. Depending on the intended use, opinions from following units are needed:

- if the product will be used in crops of vegetables and fruit, ornamental plants and lawns, opinion is needed from the Institute of Horticulture in Skierniewice;
- if the product will be used on grassland - opinion is needed from the Institute of Science and Technology in Falenty,
- if the product will be used in forests and forest crops - opinion is needed from the Research Institute of Forestry in Warsaw.

Obtaining a permit for fertilizer or plant growth aid substance (soil improver, growing soil, growth promoter)

A biogas plant, which will collect the required documentation, may apply for a permit from the Minister of Agriculture and Rural Development for the marketing of fertilizer or plant conditioner. The procedure is as follows:

- to check the application for formal and substantive requirements by officials of the Ministry of Agriculture and Rural Development
- to issue of a permit, which includes:

1) the name of the fertilizer or soil improvement agent, the name and address of:

a) producer - for fertilizer or soil improvement agent produced in the territory of Poland,

b) importer - for fertilizer or soil improver, imported from the territory to third countries,

c) producer or other entity introducing fertilizer or soil improver to the territory of Poland for a fertilizer or soil improvement agent produced or marketed in the territory of another Member of the European Union;

2) specification of quality requirements;

3) information that the fertilizer or soil improver has been produced from animal by-products or derived products

4) instructions for use and storage of fertilizer or soil improver, prepared in Polish.

The Minister of Agriculture and Rural Development issues a permit for an indefinite period of time. The Minister may refuse to issue a permit if the documents attached to the application indicate that the fertilizer or soil improver does not meet the statutory requirements.

After obtaining permission from the Ministry, digestate can be used as a fertilizer or a soil improvement agent on biogas plant land and it can be sold outside.

IV. Risk assessment with case examples of installations with potential adverse environmental impacts (and possibly case examples of solved problems if any)

The biggest risk is the wrong management of digestate and its application in excessive amounts as well as at the wrong timing. The regulation specifies that the dosage of digestate applied on the field cannot exceed 170 kg of nitrogen per ha. Biogas plants, which do not have a suitable area of land, could break this regulation. This leads to over-fertilizing of fields and runoff of nitrogen to surface- and ground-water and to runoff of phosphorus. Also, the terms of digestate application can be broken if the biogas plant does not have digestate tanks with suitable capacity. To prevent this, biogas plants are subjected to frequent inspections by authorized institutions.

An example of an agricultural biogas plant that caused contamination of the environment by improper management of digestate, was a biogas plant about power of 2 MW located in the Kujawsko-Pomorskie province. At that time it was the largest agricultural biogas plant in Poland. Unfortunately, the lack of a suitable surface of fields, the lack of agreements with farmers and lack of small farmers' awareness on the digestate properties, caused that biogas plant user discharged digestate in excessive quantities. This led to the destruction of part of the crop, significant runoff of digestate to ditches and large odor problems. Protests of residents caused that the biogas plant was closed. The repair process was carried out: contracts have been concluded with farmers who buy digestate and apply it on a sufficiently large area of fields. After a few months the biogas plant was opened again. Now it works without causing any negative effects.

Another example of environmental risk concerns plants using waste of animal origin. According to local residents, waste of animal origin was used without proper pasteurization in the biogas process. Degradation of digestate on fields caused big odor problems. In this case the audit has been initiated.

As it was mentioned in section III, in Poland digestate cannot be applied during the period between December 1st - March 1st. The above limitation may be often violated by the biogas plants due to construction cost of digestate tanks. The size of tanks for digestate should be chosen so as to ensure its storage for a sufficiently long time. The volume of tanks is controlled already in the planning of the project, and during the operation of the biogas plant. However, if

the larger quantities of liquid substrates are being used or digestate is not used as process water, the amount of digestate will exceed what was assumed in the design. If the tanks are too small, the plant may run out of space to store digestate at a time when the soil is frozen. Sometimes the owner of a biogas plant spreads digestate on the frozen field, causing runoff into rivers, ditches and lakes.

The spreading of digestate on the fields may also cause problems. Many farmers have old equipment with poor quality, which makes it hard to spread digestate evenly. The wrong equipment can cause spilling of digestate in large quantities only in place of its application. As a result, the digestate easily drains into surface waters in these places, causing them to be polluted.

In Poland the regulation requires that digestate applied on fields must be mixed with soil "immediately". Farmers and users of biogas plants do not always apply to this recommendation. Fast mixing of digestate with soil (plowing, disking) requires the appropriate organization of work, and having many equipment such as machinery and agricultural tractors. A farmer with one tractor, which is involved in the process of irrigation of digestate on the field, could not use it to mix digestate with the soil. This causes the release of nitrogen into the atmosphere, the loss of fertilizer value and air pollution. In addition, digestate on the surface of the field gives off an unpleasant smell and causes distress for the surrounding population.

The application of digestate with an appropriate distance from the reservoirs and water courses is not always respected. Often, farmers are not familiar with these rules, but sometimes, due to too small acreage, farmers or users of biogas plants knowingly break these rules.

In case of WWTPs where sludge processing covers a digestion process with biogas production (for CHP) and then mechanical dewatering, which generates highly polluted reject water, cause a great problem to keep the very high quality of final (treated) effluent.

According to Regulation of the Ministry of Environment on 18th November 2014, the important modification of that regulation was adopted because the existing version did not meet the requirements set down in the European Council Directive 91/271/EEC concerning municipal wastewater treatment, in terms of the required standards. As a result of application of this modification, all WWTPs localized in the agglomeration, depending on its size, should meet by 1st January 2016 the requirements set out in the Regulation of the Ministry of Environment from 24th July 2006 (Table 9) Moreover, the minimum required percentage of nutrients reduction was increased for WWTPs with PE in the range of 10,000-14,999 and slightly

decreased for WWTPs with PE bigger than 15,000. The obligations of the Directive 91/271/EEC are also included in the National Municipal Wastewater Treatment Program.

Table 9. The maximum allowable concentrations of water parameters or minimum percentage of pollution reduction of the treated domestic or municipal wastewater for the particular Population Equivalent according to the polish Ministry of Environment (Regulation of the Minister of Environment, 2014)

Parameter	**Unit**	**The maximum allowable concentrations or minimum reduction percentage for Population Equivalent:**				
		< 2,000	> 2,000 < 9,999	>10,000 < 14,999	>15,000 < 99,999	≥ 100,000
BOD_5	mg O_2/L	40	25	25	15	15
	min. reduction %	–	70-90	70-90	90	90
COD_{Cr}	mg O_2/L	150	125	125	125	125
	min. reduction %	–	75	75	75	75
TSS	mg/L	50	35	35	35	35
	min. reduction %	–	90	90	90	90
TN	mg N/L	30	15	15	15	**10**
	min. reduction %	–	–	70-80	70-80	**70-80**
TP	mg P/L	5	2	2	2	**1**
	min. reduction %	–	–	80	80	**80**

Moreover, Poland being one of the contracting parties of the HELCOM it is obliged to fulfill the provisions of the Baltic Sea Action Plan adopted in 2007 in Cracow during the HELCOM Ministerial Meeting (HELCOM, 2007). HELCOM recommendations concerning the reduction of nutrient load to the Baltic Sea are stricter than the obligations arising from the Polish membership in the European Union.

NOTE *The load of pollutant from reject water in case of WWTP is recalculated for person equivalent.*

The reject water is characterized by a very high concentration of nitrogen, mostly in the form of NH_4^+-N up to 900 mg/l and organic matter (mainly expressed by Chemical Oxygen Demand – COD up to 1400 mg/l) as well as total suspended solids (TSS). Another problem with reject water management is connected with its irregular generation and a huge fluctuation of pollutant

concentrations, even for one WWTP. The most common way to handle RW is recirculating it to the beginning of mechanical treatment in WWTP. These return flows of RW contribute up to 15-20% of the nitrogen load of raw wastewater and have relatively small hydraulic load, at most 1.5% of inflow. The remaining COD after anaerobic digestion is generally quite low and poorly biodegradable, which could create a problem during separate treatment of the high nitrogen content in this stream. All these properties cause that WWTPs are facing the problem to keep up the standards of the treated wastewater. And since EU Directive imposed the limit on TN in treated wastewater (10 mg TN L^{-1}) at WWTPs above 10 000 PE in the year 2010, these WWTPs have been trying to minimize the impact of the return flow of reject water on final N concentration in treated wastewater. The most promising way of handling reject water is to pre-treat it before it returns to the first stage of WWTP. High-tech solutions such as unconventional methods (Anammox, SHARON etc), which are still relatively not so trustable, are usually applied.

Usually big WWTPs are coping with the return stream but for smaller WWTPs this "additional" load of nitrogen could create a problem when trying to maintain the outflow quality. Especially when the biogas production is realized as a last step of WWTP construction and was not foreseen during the dimensioning of the main biological part of wastewater treatment plant. The general scheme of wastewater treatment and sewage sludge processing for WWTP below 150 000 PE is shown at Fig. 3. Usually the biogas production was not recommended for WWTPs lower than 60 000 PE but lastly, based on a financial analysis (Wójtowicz et al. 2013), it has been found that the profitability of biogas plants on WWTPs starts at 17,000 PE (population equivalent). Similar conclusions are drawn from analyzes carried out in Germany. These analyses indicate that the minimum profitability threshold is above 15 000 PE and unquestionable threshold for WWTPs working at 25 000 PE. Based on above mentioned analysis it was found that the return of investment costs on WWTP with recovery of biogas is:

- 5.2 year - WWTPs for 10 000 PE,
- 0.6 year - WWTPs for 20 000 PE.

This economic recommendation could create many issues in already existing medium size WWTPs which would like to change from e.g composting to biogas stabilization of sewage sludge. The problems could be as follows:

- generation of highly polluted reject water, much higher than the design capacity of already build WWTPs,
- not prepared the main treatment process for the "extra" load of pollutants, mainly nitrogen, and in consequence not keeping the standards for treated wastewater,

- solid phase of sewage sludge after digestion is not a final product and need to be further treated.

V. Subsidies and profitability (e.g. gate fees, electricity sold out) of production

Biogas production in agricultural biogas plants in Poland is subsidized through a certificate system of energy from renewable sources (so-called green certificates). In addition, biogas plants receive other support: red certificates for energy from cogeneration or brown certificates for agricultural biogas. The support system for energy production in Poland is very unstable, and since the opening of the first agricultural biogas plants (2005) system has changed many times. Currently the support system in the form of auction is implemented. The price of electricity sale will be guaranteed for 15 years for the producer of energy who wins the auction. The auction system is only being implemented in Poland, so it is difficult to assess its effectiveness. The heat produced in a cogeneration with electricity gives biogas plants additional revenue of sales. However, not all the plants sell the heat. This is only possible if the biogas plant is located near the heat receiver: housing estate, industrial plant in need, greenhouses, etc. If the recipient of the heat is far away, construction of installation for heat transfer may be too expensive. An additional income is brought by sales of digestate. However, its prices are very diverse and depend on the local market. Often, the sales price of the digestate to local farmers is slightly higher than the costs of the biogas plant in order to transport the digestate and spread it on the fields. In turn, the sale of a solid digestate fraction in specialized stores is carried out only by several biogas plants in Poland.

Biogas plants that use organic waste can have additional income for its treatment in the plant. The gate-fee can be obtained for certain types of organic wastes, especially of animal origin, as well as re-food and other wastes that need to be utilized. For other wastes, such as vegetable and fruit pomace, the biogas plant must pay, or at least cover transport costs. Gate-fee depends on the location of biogas plant and the availability of organic waste in the region and individual agreement established between the recipient (biogas plant) and the seller (owners of waste). For example, the cost of corn silage can vary from PLN 90 to PLN 120 per tonne and for slurry from PLN 0 to PLN 50 per tonne in 2013.

VI. Case examples (if any) of commercial products from digestates (fertilizers, substrates for industrial processes)

Most of the biogas plants in Poland have carried out the procedure of digestate certification and they have the right to sell it as a fertilizer. Some plants have carried out this procedure partly to avoid difficulties associated with the use of digestate as waste (such as expensive and frequent digestate tests, problems with local residents and inspections by authorities). The use of digestate as a fertilizer is easier for biogas plants, although the procedure of the certificate obtainment is expensive. Some plants offer the fertilizers from digestate on the market. However, the fertilizer market in Poland is difficult. Big companies producing fertilizers with known brands do not allow small producers to enter the market. Fertilizers from digestate are offered in small shops. This is rather a niche market, small-range production. To increase the chances for selling their products, producers of these fertilizers organize meetings with farmers, especially in the surrounding villages. On the meetings they present the exact advantages and properties of these fertilizers. The certification procedure of fertilizer allows to give it its own name, therefore these fertilizers are known under very different names. Currently in the Polish legislation there is a preparation of a serious change on the problem of usage of digestate as a fertilizer. However, at the moment it is not known what new regulations will be like.
Another opportunity to sell digestate is its drying, granulation and sale as fuel pellets. However, this way of digestate use does not gain interest in Poland.

VII. Case examples (if any) of circular economy, where biogas is a part of a larger chain (e.g. combined chain of closed circle fish farming, use of nutrients in greenhouse vegetables production, biodiesel and biogas production, use of rejects in agriculture

1. An example of agricultural biogas plant with circular economy, is the installation of an agricultural company in the Silesian province. The company includes production of dairy and fattening cattle, plant production (about 600 ha) and, a distillery (ethanol is produced on the basis on own production). A decoction from the distillery, slurry, manure, and part of crops (mainly maize) is used for the production of biogas. In biogas plants in cogeneration power 0.998 kWh of electricity is produced. It is sold to electrical network or used on the farm (depending on the price). The produced heat is used in the distillery and the farm buildings. Digestate is separated on the solid and liquid fraction. The liquid fraction is stored in digestate tanks and applicated on own agricultural land (arable land, where plants grow for cattle feed, for distillery

and for biogas plants) as well as on meadows and pastures (where the feed for cattle is produced). The solid dry fraction of digestate is used as bedding for cattle. Then again, it goes to the biogas plants (after addition of cattle manure and straw).

2. Another example of biogas plants in circular economy is a biogas plant located in Lubuskie province, which is also a part of a large farm. Faeces of poultry and swine produced at this farm are fermented together with silage of maize and wastes with drying of cereals. The cogeneration produces electricity (sold to the network) and heat (used for heating of the dryer). The dryer dries grain cereals, maize, rape from own fields about areas of 800 ha. Digestate is separated. The liquid fraction is diluted with water and then applicated on the fields. Dilution is necessary to avoid clogging of holes in the irrigation devices. The solid fraction is spread on fields using a manure spreader.

3. Wastewater treatment plant in Słupsk treats sewage from Słupsk and neighboring communities. It is a mechanical and biological WWTP with deep removal of biogenic compounds in a three-phase process with a pre-denitrification chamber. The loading capacity of the plant is 200 000 PE and the average daily flow is about 19 647 m^3.

The first step in the process of sludge treatment is fermentation. Currently there are 4 closed fermenting chambers (CFC) in the plant. Produced biogas is stored in a tank about volume of 1250 m^3. There is also a biological reactor for reject water. In addition, sewage sludge after the fermentation in the CFC is dewatered in centrifuges. At WWTP about 10 000 tons of sludge is produced with content of dry matter about 21%. After dewatering sludge is composed and sold as fertilizer. WWTP has obtained the certificate on that product.

Fig. 6. Scheme of WWTP in Słupsk

VIII. Solutions and proposals for mitigating adverse environmental impacts of biogas production with e.g. technologies for reject water or digestate treatment, enhanced digestate utilization (processes, logistics), improved planning of biogas installations (locations, scale etc.), improved permitting procedures and legal or economic policy instruments

The mitigating of the adverse effects of biogas production on the environment should go multi-way:

- The establishment of regulations restricting the effect of plants on the environment, together with a system for the enforcement of those regulations. This does not mean, that the regulations should be tightened. Rather they should be adjusted logically to the real threats. For example: currently, the regulations prescribe that digestate must be mixed with the soil immediately after application on the field. Realistically, the mixing with the soil may not occur immediately, because it would require a few tractors and people to handle, etc. In this situation, the term "immediately " means nothing, and can be an

excuse to dissatisfied people of the neighborhood to protest against biogas plants. The adaptation of regulations to the actual environmental threats, requires previous research, carried out by research institutions. To obtain the objective studies, they must be carried out by persons and institutions independent from both producers of biogas, as well as the organizations interested in limiting of biogas plants development.

- The technological development of the biogas plants gives a second opportunity to reduce the impact on the environment. It is particularly important to develop the methods of digestate hygienization, which currently is very expensive. Now the presence of pathogenic bacteria is limited by use of heat, which is associated with energy consumption. The use of lime is often ineffective. Other methods, such as disintegration or micronization are too expensive. The development of alternative methods of digestate hygienization can reduce environmental risk and increase the cost of biogas plants operation.
- In Poland the public awareness raising is needed much. The contradictory information about digestate permanently appears in the media and make difficult to use digestate as fertilizer. Persons and organizations that are reluctant to biogas plants disseminate untrue information. Their reluctance is causes by various reasons: biogas plants can be a competitive source of gas, they can be also an important source of fertilizers and therefore competition for different companies. The reluctance is often caused by internal conflicts of local communities. This information is reproduced and sent to public opinion, causing the reluctance of farmers to use of digestate. In turn this limits ability to use of digestate on a sufficiently large surface. It creates a "closed circle", which on the one hand, impedes the operation of biogas plants, on the other causes the threat to the environment. Raising the public awareness by training, presentations, lectures, meetings, brochures and articles is needed. Information must be communicated in an accessible and simple way. At the same time only true information must be given. Often at such meetings people ask about the odor of digestate. It must be fully truthfully stated that digestate has a peculiar smell. Lying in this area may cause that all other information will be rejected by the audience and all work will be futile.

APPENDIX 1

List of agricultural biogas producer (16.05.2017)

No	*Data of registration*	*Name of producer*	*Address of producer*	**Address of bussiness**	*The annual efficiency of installations for the agricultural biogas production*	*The total capacity of electric installation (MW_e)*
1	*2*	*3*	*4*	**5**	*6*	*7*
1.	01.01.2011	**Poldanor S.A.**	ul. Dworcowa 25 77-320 Przechlewo	ul. Polna 3 77-220 Koczała woj.	9 200 000	2.126
				Pawłówko 77-320 Przechlewo woj.	3 810 000	0.946
				Płaszczyca 77-320 Przechlewo woj.	2 300 000	0.625
				Nacław 14B 76-006 Nacław	3 120 000	0.625
				Świelino 30 76-020 Bobolice	2 640 000	0.625
				Uniechówek 77-310 Debrzno woj.	4 500 000	1.063
				Giżyno 78-540 Kalisz Pomorski	5 000 000	1.063
				Bara 2 74-500 Chojna	1 500 000	0.330
2.	01.01.2011	**Biogaz Agri Sp. z o.o.**	*Łosice 14C 55-095 Mirków*	Niedoradz 67-106 Otyń woj. lubuskie	1 100 000	0.252
3.	18.03.2011	**Biogaz Zeneris Sp. z o.o.**	ul. Sielska 17A 60-129 Poznań	Skrzatusz 64-930 Szydłowo woj. wielkopolskie	2 246 400	0.526
4.	11.04.2011	***Eko- Energia Grzmiąca* Sp. z o.o.**	ul. Sportowa 5 78-450 Grzmiąca	ul. Sportowa 5 78-450 Grzmiąca woj. zachodniopomorskie	7 000 000	1.600
5.	23.08.2011	**BIO-WAT Sp. z o.o.**	ul. Metalowców 22 58-100 Świdnica	ul. Metalowców 22 58-100 Świdnica woj. dolnośląskie	4 000 000	0.900
6.	23.09.2011	**BIO-BUT Sp. z o.o.**	ul Łabędzka 54 Łany Wielkie 44-153 Sośnicowice	ul Łabędzka 54. Łany Wielkie 44-153 Sośnicowice woj. śląskie	3 504 000	0.996
7.	23.12.2011	**Bioelektrownia Sp. z o.o.**	ul. Grzybowska 87 00-844 Warszawa	Uhnin 141 21-211 Dębowa Kłoda woj. lubelskie	4 500 000	1.200
8.	24.02.2012	**Bioenergy Project Sp. z o.o.**	ul. Rajska 4/23 02-654 Warszawa	Konopnica 121 96-200 Rawa Mazowiecka woj. łódzkie	9 353 755	1.998
9.	28.02.2012	**Allter Power Sp. z o.o.**	ul. Chałubińskiego 8 00-613 Warszawa	Mełno 86-330 Mełno woj. kujawsko-pomorskie	6 200 000	1.600

	1	2	3	4	5	6
10.	05.03.2012	**BIOENERGIA PLUS Sp. z o.o.**	ul. Cisowa 11 20-703 Lublin	ul. Zamojska 26C 21-050 Piaski woj. lubelskie	4 250 000	0.999
11.	07.03.2012.	**AWW Wawrzyniak Sp. j.**	Niedźwiady 45 62-800 Kalisz	Zbiersk Cukrownia 61 62-830 Zbiersk woj. wielkopolskie	4 176 558	1.600
12.	09.03.2012	**Biogal Sp. z o.o.**	Boleszyn 7 13-308 Mroczno	Boleszyn 7A 13-308 Mroczno woj. warmińsko-mazurskie	7 840 000	2.000
13.	17.05.2012	**GOSPODARSTWO ROLNE Kargowa - Klępsk Ryszard Maj**	ul. Dworcowa 26 66-120 Kargowa	Klępsk 53 66-111 Nowe Kramsko woj. lubuskie	3 500 000	1.000
14.	22.06.2012	**P.P.-H.-U. "SERAFIN" Sp. z o.o.**	Szklarka Myślniewska 68A 63-500 Ostrzeszów	Szklarka Myślniewska 68A 63-500 Ostrzeszów woj. wielkopolskie	3 500 000	0.990
15.	02.08.2012	**Elektrociepłownia Bartos Sp. z o.o.**	ul. Czarnowska 6 26-065 Piekoszów	ul. Czarnowska 56C 26-065 Piekoszów woj. świętokrzyskie	2 464 000	0.800
16.	12.09.2012	**Polskie Biogazownie "Energy Zalesie" Sp. z o.o.**	ul. Krucza 24/26 00-526 Warszawa	ul. Osiedlowa 4. Zalesie 46-146 Domaszowice woj. opolskie	8 000 000	2.000
17.	23.10.2012	**Südzucker Polska S.A.**	ul. Muchoborska 6 54-424 Wrocław	ul. Ząbkowicka 53 57-100 Strzelin woj. dolnośląskie	9 894 549	2.000
18.	07.01.2013	**DMG Sp. z o.o.**	Koczergi 56B 21-200 Parczew	Koczergi 56B 21-200 Parczew woj. lubelskie	9 000 000	2.400
19.	30.01.2013	**"BIO-POWER" Sp. z o.o.**	ul. Zahajkowska 11 21-560 Międzyrzec Podlaski	Zaścianki 86 21-560 Międzyrzec Podlaski woj. lubelskie	7 850 000	2.199
20.	25.04.2013	**Cargill Poland Sp. z o.o.**	ul. Wołoska 22 02-675 Warszawa	ul. Mac Millan 1 Bielany Wrocławskie 55-040 Kobierzyce woj. dolnośląskie	1 300 000	0.526
21.	08.05.2013	**Biogazownia Rypin Sp. z o.o.**	Starorypin Prywatny 51 87-500 Rypin	Starorypin Prywatny 51 87-500 Rypin woj. kujawsko-pomorskie	6 881 090	1.875
22.	19.06.2013	**Minex-Invest Sp. z o.o.**	ul. Chałubińskiego 8. 00-613 Warszawa	Łęguty 15 11-036 Gietrzwałd woj. warmińsko-mazurskie	4 561 200	1.200

	1	2	3	4	5	6
23.	09.08.2013	**Nadmorskie Elektrownie Wiatrowe Darżyno Sp. z o.o.**	ul. Łozy 21 80-516 Gdańsk	Darżyno. działka Nr 244/6 obręb Darżyno 76-230 Potęgowo woj. pomorskie	7 700 000	2.400
24.	07.08.2013	**Zakład Usługowo-Handlowy "Wojciechowski" Zdzisław Wojciechowski**	Sobawiny 7E 26-300 Opoczno	Opoczno. działki nr 33. 34 i 35 obręb 4 Opoczno 26-300 Opoczno woj. łódzkie	3 700 000	0.860
25.	14.08.2013	**EL-KA Sp. z o.o.**	Byszewo 17 73-150 Łobez	Byszewo 17 73-150 Łobez woj. zachodniopomorskie	3 888 000	0.999
26.	22.08.2013	**BIOGAZ Przemysław "Łąkrol" Sp. z o.o. sp. k.**	Wiewiecko 36C 73-155 Węgorzyno	dz. 27/4 Przemysław 72-315 Resko woj. zachodniopomorskie	7 000 000	1.600
27.	19.09.2013	**FARM FRITES POLAND S.A.**	ul. Abrahama 13 84-300 Lębork	ul. Abrahama 13 84-300 Lębork woj. pomorskie	3 500 000	1.200
28.	20.09.2013	**PFEIFER & LANGEN GLINOJECK S.A.**	ul. Adama Mickiewicza 35 60-837 Poznań	Zygmuntowo 38 06-450 Glinojeck woj. mazowieckie	7 305 840	1.560
29.	16.12.2013	**Agro Bio Sp. z o.o.**	Sławkowo 15 11-400 Kętrzyn	Sławkowo 15 11-400 Kętrzyn woj. warmińsko-mazurskie	1 680 000	0.400
30.	23.12.2013.	**"Eco-Progres" Sp. z o.o.**	ul. Strefowa 7 19-300 Ełk	Giże 4 19-400 Olecko woj. warmińsko-mazurskie	4 240 000	1.063
31.	30.12.2013.	**Ośrodek Hodowli Zarodowej "Gajewo" Sp. z o.o.**	Kałdowo 2 82-200 Malbork	Tragamin 82-200 Malbork woj. pomorskie	2 880 000	0.800
32.	20.01.2014	**ADLER BIOGAZ Sp. z o.o.**	ul. Szosa Baranowicka 62A Zaścianki	Ryboły 1/1 16-060 Zabłudów woj. podlaskie	4 380 000	1.000
33.	05.02.2014	**ENEA Wytwarzanie Sp. z o.o.**	Świerże Górne 26-900 Kozienice	Liszkowo 87-93 88-180 Złotniki Kujawskie woj. kujawsko-pomorskie	7 400 000	2.126
				Gorzesław 83 56-420 Bierutów woj. dolnośląskie	4 750 385	1.698
34.	05.02.2014	**Instytut Zarządzania i Samorządności Sp. z o.o.**	ul. Tadeusza Boya-Żeleńskiego 24 51-160 Wrocław	ul. Lipowa 7A 58-210 Łagiewniki woj. dolnośląskie	3 705 800	1.100

	1	2	3	4	5	6
35.	19.02.2014	**Biogaz Działyń Sp. z o.o.**	Działyń 24. 62-271 Działyń	Działyń 24. 62-271 Działyń woj. wielkopolskie	5 000 000	0.999
36.	28.03.2014	**"UPAŁTY-ROL" Sp. z o.o.**	Upałty Małe 7A. 11-500 Giżycko	Upałty Małe 7A. 11-500 Giżycko woj. warmińsko-mazurskie	4 798 718	0.999
37.	09.04.2014	**BIO-NIK ELEKTRA Sp. z o.o.**	ul. Leszczynowa 6. 80-175 Gdańsk	ul. Szkolna 17. 14-220 Kisielice. woj. warmińsko-mazurskie	3 994 785.550	0.999
38.	18.04.2014	**Wielkopolski Indyk Sp. z o.o.**	Bolesławiec 12A 62-050 Mosina	Bolesławiec 12A 62-050 Mosina woj. wielkopolskie	2 520 500	0.600
39.	06.05.2014	**Polskie Biogazownie "ENERGY-ŻÓRAWINA" Sp. z o.o.**	ul. Blacharska 2 61-006 Poznań	ul. Badawcza 6 Żerniki Wielkie 55-020 Żórawina woj. dolnośląskie	3 508 770	1.200
40.	22.05.2014	**"EKOWOOD" Sp. z o.o.**	ul. Krzemowa 11 19-300 Ełk	Zajdy 15A 19-400 Olecko woj. warmińsko-mazurskie	3 900 000	1.063
41.	27.06.2014	**GOSPODARSTWO ROLNE BIOGAZ T. Z. Śmiechowscy**	Jaromierz 3b 77-300 Człuchów	Jaromierz 3b 77-300 Człuchów woj. pomorskie	4 488 902	0.999
42.	14.08.2014	**Bioelektrownia Buczek Sp. z o.o.**	Buczek 10 86-131 Jeżewo	Buczek 10 86-131 Jeżewo woj. kujawsko-pomorskie	7 000 000	1.800
43.	25.08.2014	**Bioelektrownia Przykona Sp. z o.o.**	ul. Komunalna 10 62-731 Psary	ul. Komunalna 10 Psary 62-731 Psary woj. wielkopolskie	8 000 000	1.897
44.	04.09.2014	**Biogas East Sp. z o.o.**	Grochów Szlachecki ul. Sokołowska 5 08-300 Sokołów Podlaski	ul. Rawicza 153 Grochów Szlachecki 08-300 Sokołów Podlaski woj. mazowieckie	2 628 000	0.700
45.	01.10.2014	**OZE 11 Sp. z o.o.**	Stare Miasto 512 37-300 Leżajsk	Stare Miasto 512 37-300 Leżajsk woj. podkarpackie	4 000 000	0.999
46.	29.12.2014	**Zakład Doświadczalny Instytutu Zootechniki PIB Odrzechowa Sp. z o.o.**	ul. Rymanowska 67 Odrzechowa 38-530 Zarszyn	ul. Rymanowska 67 Odrzechowa 38-530 Zarszyn woj. podkarpackie	2 075 000	0.500
47.	22.01.2015	**Biogazownia Brzeżno Sp. z o.o.**	Brzeżno 30 78-316 Brzeżno	Brzeżno 30 78-316 Brzeżno woj. zachodniopomorskie	3 500 000	0.800

	1	2	3	4	5	6
48.	27.02.2015	**CHP ENERGIA Sp. z o.o.**	Wojny Wawrzyńce 1 18-210 Szepietowo	Wojny Wawrzyńce 1 18-210 Szepietowo woj. podlaskie	4 555 000	1.200
49.	24.03.2015	**"EKOGAZ" Sp. z o.o.**	ul. Hallera 2A 63-900 Rawicz	ul. W. Witosa 13 56-200 Góra woj. dolnośląskie	2 172 612	0.600
50.	29.04.2015	**EKODAMIR Sp. z o.o. sp. k.**	Jarnołtowo 73 14-330 Małdyty	Jarnołtowo 73 14-330 Małdyty woj. warmińsko-mazurskie	865 000	0.250
51.	24.06.2015	**Firma Handlowo Usługowo Transportowa MASTERROAD Katarzyna Kłósek**	Ujazd 80 32-733 Trzciana	Ujazd 80 32-733 Trzciana woj. małopolskie	864 000	0.150
52.	03.07.2015	**P.P.H. "KONTRAKT" Sp. z o.o.**	ul. Grunwaldzka 32 13-200 Działdowo	Orchówek ul. Garbarska 16 22-200 Włodawa woj. lubelskie	3 500 000	1.063
53.	05.08.2015	**EKO-FARMENERGIA Sp. z o.o.**	ul. Lotników Lewoniewskich 11A 16-100 Sokółka	ul. Lotników Lewoniewskich 11A 16-100 Sokółka woj. podlaskie	3 338 700	0.999
54.	11.09.2015	**PGB Development Sp. z o.o.**	ul. Gotarda 9 02-683 Warszawa	ul. Piaskowa 30 78-520 Złocieniec woj. zachodniopomorskie	4 009 120	0.999
				Darskowo 7D 78-520 Złocieniec woj. zachodniopomorskie	4 009 120	0.999
55.	24.09.2015	**Gospodarstwo Rolne Marek Dyczewski**	Przebród 4B 16-402 Suwałki	Czerwonka 11 16-411 Szypliszki woj. podlaskie	420 000	0.100
56.	09.10.2015	**Zielona Energia Michałowo Sp. z o.o.**	ul. Białostocka 78 16-050 Michałowo	ul. Białostocka 78 16-050 Michałowo woj. podlaskie	2 300 000	0.600
57.	16.10.2015	**Przedsiębiorstwo Rolne "PERKUN" Sp. z o.o.**	Pierkunowo 1 11-500 Giżycko	dz. 32/5 Pierkunowo 1 11-500 Giżycko woj. warmińsko-mazurskie	1 840 000	0.496
58.	18.11.2015	**LOREGA BIO Sp. z o.o.**	Brzeźnica 1 11-420 Srokowo	Brzeźnica 1 11-420 Srokowo woj. warmińsko-mazurskie	4 213 195	0.999

	1	2	3	4	5	6
59.	18.11.2015	**ENERBIO Sp. z o.o.**	ul. Wschodnia 23 99-300 Kutno	ul. Wschodnia 23 99-300 Kutno woj. łódzkie	4 000 000	0.999
60.	25.11.2015	**Elektrownia Biogazowa Cychry Sp. z o.o.**	ul. Ratajczaka 26/110 61-815 Poznań	ul. Brunatna 17 62-510 Konin woj. wielkopolskie	7 400 000	2.134
61.	04.12.2015.	**ECO-PHARMA Wojciech Radoszewski**	Długie 2A 87-337 Wąpielsk	Długie 2A 87-337 Wąpielsk woj. kujawsko-pomorskie	440 000	0.090
62.	11.12.2015	**Biogazownia Rolnicza Barbara Gaik**	Chełmo 119A 97-515 Masłowice	Chełmo 119A 97-515 Masłowice woj. łódzkie	4 859 244	1.200
63.	16.12.2015	**PGB ENERGETYKA 13 Sp. z o.o.**	ul. Gotarda 9 02-683 Warszawa	Stary Kornin 2A 17-204 Dubicze Cerkiewne woj. podlaskie	4 009 120	0.999
64.	23.12.2015	**Komis i Handel Maszynami Rolniczymi Sebastian Trzensiok**	ul. Nakło 1 44-180 Kotulin	ul. Nakło 1 44-180 Kotulin woj. śląskie	960 000	0.460
65.	30.12.2015	**BIOGAZOWNIA SZCZEDRZYKOWICE Sp. z o.o.**	Al. Jerozolimskie 65/79 lok.14.21 00-697 Warszawa	Szczedrzykowice 26C 59-230 Prochowice woj. dolnośląskie	4 000 000	0.999
66.	30.12.2015	**PGB ENERGETYKA 2 Sp. z o.o.**	ul. Gotarda 9 02-683 Warszawa	Tończa 88A 07-100 Liw woj. mazowieckie	4 009 120	0.999
67.	30.12.2015	**PGB ENERGETYKA 3 Sp. z o.o.**	ul. Gotarda 9 02-683 Warszawa	Krzywa 48A 17-100 Bielsk Podlaski woj. podlaskie	4 009 120	0.999
68.	01.01.2016	**Spółka Rolna Kalsk Sp. z o.o.**	Kalsk 69A 66-100 Sulechów	Kalsk 69A 66-100 Sulechów woj. lubuskie	5 000 000	1.140
69.	07.01.2016	**PGB ENERGETYKA 7 Sp. z o.o.**	ul. Gotarda 9 02-683 Warszawa	Gorajec Osiedle 9 37-611 Cieszanów woj. podkarpackie	4 009 120	0.999
70.	07.01.2016	**PGB ENERGETYKA 4 Sp. z o.o.**	ul. Gotarda 9 02-683 Warszawa	Dzierżki 27 18-112 Poświętne woj. podlaskie	4 009 120	0.999

	1	2	3	4	5	6
71.	25.01.2016	**Rolnicza Bioelektrownia Rzeczyca Sp. z o.o.**	ul. Ostów 18 04-733 Warszawa	działki nr: 272/1. 274/2. 274/3. 276. 277 obręb Rzeczyca 78-641 Rzeczyca woj. zachodniopomorskie	3 985 000	0.999
72.	19.02.2016	**BIO-ENERGIA STRZYKOCIN Sp. z o.o.**	Strzykocin 18A 72-304 Brojce	Strzykocin 18A 72-304 Brojce woj. zachodniopomorskie	3 861 171	0.999
73.	25.02.2016	**GRUPA PRODUCENCKA AGRO-ŻABICE Sp. z o.o.**	Żabice 52 59-140 Chocianów	Żabice 52 59-140 Chocianów woj. dolnośląskie	780 000	0.499
74.	17.03.2016	**Lubelskie Biogazownie Sp. z o. o. w restrukturyzacji**	ul. Fryderyka Chopina 3 2 lok. 3 20-023 Lublin	Kożanówka 130 21-533 Rossosz woj. lubelskie	3 500 000	0.999
				Przypisówka 59A 21-136 Firlej woj. lubelskie	3 500 000	0.999
75.	30.03.2016	**BIOGAZOWNIE MAŁOPOLSKIE Sp. z o.o.**	Wielopole 62 33-210 Olesno	Wielopole 62 33-210 Olesno woj. małopolskie	4 506 000	1.000
76.	07.04.2016	**BIOGAZOWNIA SKARŻYN Sp. z o.o.**	ul. Świętokrzyska 30/63 00-116 Warszawa	Skarżyn ul. Parkowa 7b 09-100 Płońsk woj. mazowieckie	6 040 620	1.560
77.	15.04.2016	**GREEN ENERGY Sp. z o.o.**	ul. Jana III Sobieskiego 102A lok. U7 00-764 Warszawa	Krasowo Częstki 55 18-212 Nowe Piekuty woj. podlaskie	2 221 153.80	0.700
78.	13.05.2016	**Agroelektrogaz Sp. z o.o.**	ul. Opaczewska 43 02-201 Warszawa	Drzonowo 50 78-133 Drzonowo woj. zachodniopomorskie	1 278 960	1.052
79.	30.05.2016	**"RZEŹNIA-MRÓZ" Sp. z o.o.**	Borzęciczki 29A 63-720 Koźmin Wielkopolski	Borzęciczki 29A 63-720 Koźmin Wielkopolski woj. wielkopolskie	3 600 000	1.200
80.	10.06.2016	**DRP BIOGAZ Sp. z o.o.**	Sieńsk 1 66-620 Gubin	Sieńsk 1 66-620 Gubin woj. lubuskie	1 500 000	0.400
81.	30.06.2016	**ALSTAL BUDOWNICTWO Alojzy Szczupak**	Jacewo 76 88-100 Inowrocław	działki nr 72/1. nr 73/3 Radojewice 88-101 Inowrocław woj. kujawsko-pomorskie	1 752 000	0.500

	1	2	3	4	5	6
82.	13.07.2016	**GAMAWIND Sp. z o.o.**	ul. Droga Dębińska 3a 61-555 Poznań	Piaszczyna 77-200 Miastko woj. pomorskie	6 880 000	2.000
83.	04.11.2016	**Zakład Doświadczalny Instytutu Zootechniki PIB Grodziec Śląski im. Prof. Mieczysława Czai**	Grodziec Śląski 3 43-386 Świętoszówka	Kostkowice ul. Osiedlowa 19 43-426 Dębowiec woj. śląskie	2 300 000	0.600
84.	20.12.2016	**IMA Polska S.A.**	ul. Polna 21 62-095 Murowana Goślina	ul. Polna 21 62-095 Murowana Goślina woj. wielkopolskie	1 559 425	0.480
85.	04.01.2017	**Profarms Sp. z o.o.**	Zielona ul. Robotnicza 16 09-310 Kuczbork-Osada	Zielona ul. Robotnicza 16 09-310 Kuczbork-Osada woj. mazowieckie	500 000	0.080
					387 292 173.35	***100.964***