6. ЕКОЛОГІЯ ТА ПРИРОДНО-ЗАПОВІДНА СПРАВА

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The use of agricultural waste for the renewable energy production

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In addition to hydroelectric power plants, solar and wind power plants, biogas plants are important in the production of electricity and heat from renewable energy sources. It is known that depending on the type of substrate used for processing and the design features of biogas plants, they have their own advantages and disadvantages. Nevertheless, properly localized biomass installation is able to decrease the use of conventional materials reducing greenhouse gas emissions. Bio-waste, plant residues and other by-products can be used to produce electricity, heat and purified methane as fuel for repaired vehicles. Biogas production is a key technology for the sustainable use of agricultural biomass as a renewable energy source. Both, Poland and Ukraine, have a large agricultural area, and well developed animal cattery, which creates opportunities for alternative energy sources from biomass development.

Agricultural biogas plant energy produced from waste such manure, slurry and another agricultural waste, is an excellent source of heat, likewise, electricity. Therefore the importance of using agricultural waste as an energy source in the production of biogas shall be emphasized. A significant drawback of the system is the need to provide low economic and environmental losses. For this purpose, the place of biomass harvesting, transport and its preparation together with storage should be taken into account. To achieve the highest efficiency, small biogas plants should have permanent composition of substrate consisting of various ingredients.

Ukraine and Poland has considerable potential of renewable energy sources development of which can provide significant economic, ecological, and social benefits. The production of biogas has become an attractive source of extra income for many farmers. Biogas production has a useful effect not only on economic, but ecological development, particularly in the rural regions. At the same time, environmental protection aspects have gained additional importance, so that anaerobic treatment processes have become a key technology for environmental and climate protection.

On the basis of the submitted documentation by the municipal administration and the manufacturer, the operation of biogas plants for the processing of organic agricultural waste in Gorajec and Odrzechowa (Poland) has been presented.

Key words: *agriculture waste; biomass; biogas; biogas plant.*

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Introduction. The main reason for the renewable energy development is the environment, especially in relation to global climate change and the need to improve security and diversity of energy supply. The method of waste management is to use them in methane fermentation processes, as a result of which methane-rich biogas, used for energy production, is created. This solution increases the ability of Poland to meet the National Indicative Targets and the provisions of the Climate and Energy Package (15% of energy from renewable sources by 2020). Due to the exhausting resources of fossil fuels, including natural gas resources, the priority of the European Union is the rational use of natural resources and ensuring sustainable waste management. It should also be emphasized that the control of fermentation processes and the subsequent use of the resulting biogas reduces the emission of methane into the atmosphere. The biogas production has positive impact on the environment since less CO_2 is formed during combustion than it is used for photosynthesis by plants from which it is produced. Biomass is the most profitable source of renewable energy in Poland and Ukraine, it has many advantages due to the environmental and economic aspect (Melnyk, Shkarupa & Kharchenko, 2013). Benefits resulting from the combustion and co-combustion of biomass with coal result from a significant reduction of greenhouse gas emissions, in terms of carbon dioxide emissions, biomass is the so-called «neutral» fuel. Biogas is a renewable fuel produced by anaerobic fermentation of organic material. The value of a substrate in the biogas process depends on its potential as a high yield plant species and on the quality of the biogas produced such as the achievable methane content. It usually has 50-70% CH_4, 25-50% CO_2, 1-5% H_2, 03-3% N_2 and traces of H_2S (Bedoya, Arrieta & Cadavid, 2009). Methane is the only combustible constituent of biogas, which is utilized in different forms of energy. Biogas can be used for heating, lighting, transportation, small-scale power generation, and large gas turbines as a complementary fuel (e.g. natural gas) (Bedoya et al., 2009). Nowadays the most commonly used substrate for methane fermentation process is maize silage (Dach, Zbytek, Pilarski & Adamski, 2014). However, due to the conflict «energy vs. food», the risks arising from the crops monoculture and growing prices of this substrate, the alternative sources of biomass are increasingly looked for (White, Latta, Alig, Skog & Adams, 2013). Therefore, an alternative is the use for energy purposes the waste materials from food industry and agriculture or farming at the areas unsuitable for human consumption. Biogas produced in a fermentation tank can be converted into energy or purified to the form of biomethane and sent to a gas distribution grid. Biogas can be used to produce:

– electrical power – in spark ignition engine or turbines,

– heat – in gas boilers,

– electrical power and heat – in cogeneration aggregates used for combined production of electrical power and heat, which is the most common method (and virtually the sole method) of using biogas for energy purposes in Poland (Golusin, Ostojic, Latinovic, Jandric & Ivanovich, 2012, Zapałowska & Bashutska, 2017).

Agricultural biogas plants in Poland most often operate near large livestock farms, using as their substrate the otherwise noxious waste of slurry and manure. Biogas production is a far better alternative to the commonly used method of waste utilization (than directly sprayed onto the fields). The process of biogas generation results in sanitation, which prevents a risk of ground water contamination. Moreover, electrical power and heat is produced whilst the post-fermentation residue is used as a fertilizer (Angelidaki & Ellegaard, 2003, Dach et al., 2009). The main waste generated by agriculture are natural fertilizers such as manure, urine and manure from pig farms and cattle. The possibility of their agricultural use are limited by periods of fertilization and the requirement is not exceeded the limit dose. Fruit and vegetable waste generated mainly such as bagasse, primarily grapes, apples, carrots, potato pulp, and beet pulp (Tarko, Duda-Chodak & Bebak, 2012, Misiura, 2013, Kuczyńska, Nogaj & Pomykała, 2011).

Agricultural waste used in biogas installations. Due to the need of intensification of energy generation from renewable sources, as well as the need for dissemination of the methods to reduce the emission of greenfouse gases into the atmosphere, increasing importance begins to play production and use agricultural biogas.

The agricultural raw materials used for the production of renewable energy may be waste products of this production, such as straw or animal droppings. Agricultural biomass is a relatively broad category of biomass that includes the food based portion (oil and simple carbohydrates) of crops (such as corn, beets) and the nonfood based portion of crops (such as the leaves, stalks, and cobs of corn stover), perennial grasses and animal waste (Chandra, Takeuchi & Hasegawa, 2012). In accordance to the national agricultural policy conducted by the Polish Ministry of Agriculture and Rural Development, emphasis is placed on the use for energy purposes of by-products from agriculture, by-products and waste from the food industry, liquid and solid animal manure as well as energy plants themselves. In case of by-products from agriculture, the use of straw for energy purposes is of particular importance. The use of its surpluses avoids burning it in the fields (Tab. 1, 2).

For the production of biogas it can be used corn stalks, undeveloped cereal crops, decaying hay, contaminated grain, spoiled harvest of root crops, beet leaves, care waste (weeds), disqualified and undeveloped crops in orchards and fruit plantations, leaves of fruit trees and shrubs, branches, fruit fall, broken fruit harvests and spoiled vegetables. As it can be seen from table 2, maze silage, rye, grass silage, brewers grains, pomace and mown grass can provide a large amount of biogas while the highest methane amount can be provided from grain and potato decoction, pomace, and gastric contents. The selection for production must be economically justified. Reliability and continuity of supplies as well as seasonality of work should be taken into account.

Table 1

Qualification of the suitability of waste for the production of agricultural biogas according to applicable codes

Waste code	Groups, subgroups and types of waste	Industry
02	Wastes from agriculture, horticulture, hydroponics, fishery, forestry, hunting and food processing	
02 01	Wastes from agriculture, horticulture, hydroponics, forestry, hunting and fishing	Waste from agriculture
02 01 01	Sludge from washing and cleaning	
02 01 02	Animaltissue waste	
02 01 03	Plant waste mass	
02 01 06	Animal waste	
02 01 07	Waste from forest management	
02 01 82	Dead and slaughtered animals	
02 01 83	Wastes from hydroponiccrops	

Source: Rozporządzenie Ministra Środowiska, 2014

Table 2

Characteristics of selected plants and selected products for biogas yield

Base	The dry matter content (%)	The dry matter content of organic (%)	The yeald of biogas (m^3/t)	The content of methane CH_4 (% vol.)
Natural fertilizers				
cattle slury	8-11	75-82	200-500	60
pig slurry	about 7	75-86	300-700	60-70
cattle manure	about25	68-76	210-300	60
pigs manure	20-25	75-80	270-450	60
hens manures	about32	63-80	250-450	60
Plants				
maize silage	20-35	85-95	450-700	50-55
rye	30-35	92-98	550-680	about 55
grass silage	25-50	70-95	550-620	54-55
Products of the agricultural industry				
brewer's distilleries	20-25	70-80	580-750	59-60
grain decoction	6-8	83-88	430-700	58-65
potato decoction	6-7	85-95	400-700	58-65
pomace	25-45	90-95	590-660	65-70
Other substrates for biogas plants				
waste fittings	5-20	80-90	400-600	60-65
gastric content	12-15	75-86	250-450	60-70
Grass				
mown grass	ok.12	83-92	550-680	55-65

Source: Latocha, 2010.

Method. The analysis was to determine the method of using agricultural waste for energy purposes. It raises the concerns in aspect of processing agricultural waste in biogas installations, where biogas is used for electricity and heat production. The work assumes that agricultural waste is a valuable resource in the production of renewable energy. The research analysis was based on documentation provided by biogas plants in Gorajec and Odrzechowa, as well as on information provided by the Cieszanów and Zarszyn Municipal Offices. A computational analysis was performed to estimate the energy and economic efficiency of biogas plant. The type and weight of substrates to be used in the methane fermentation process were determined. The volume of biogas and methane produced was calculated. The amount of energy produced and the power of the installation was determined.

Results and discussion. The biogas plant in Odrzechowa is located in the administrative district of

Gmina Zarszyn, within Sanok County, Subcarpathian Voivodeship, in south-east Poland (Fig. 1). Zarszyn commune is an agricultural area, agricultural areas occupy a total of over 6 500 ha and constitute 63 % of the total area of commune. In the commune of Zarszyn there are several modern farms that are oriented towards market production. The largest is the Zootechnical Experimental Station of the Institute of Livestock Production in Odrzechowa.

In the Odrzechowa biogas plant, the fermentation process is carried out three times a day, each time 20 tonnes of substrate is added to the fermentation chambers. During the year about 26000-27000 t of substrate are consumed, of which about 50 % is slurry and manure. The produced biogas contains about 50-60 % of methane. The farm uses 17 % of energy produced, and 83 % is sold to PGE, the rate is PLN 0,18 / 1kW.

The construction of the Gorajec biogas plant was completed in 2015. The investment is located in Gorajec, Cieszanow commune, in the Lubaczow agricultural district, near the border of the Podkarpackie and Lubelskie voivodships (Fig. 2). In the biogas plant, biogas is produced as a result of anaerobic digestion of organic substrates of agricultural origin. The produced biogas is used to produce electricity and heat. New technologies and emerging solutions ensure high efficiency of biogas installations, providing excellent conditions for creating a local energy system. Distributed energy sources guarantee the local energy supply for the region. In the vicinity of the power plant there are agricultural lands, mainly intended for maize cultivation. This is a potential for obtaining feedstock for biogas production and for breaking down the digestate. Electric power – 0,999 MWe, thermal power – 1,110 MWt, electric power production – 8,348 MWh, thermal power production – 8,357 MWhth (30085 GJ).

The biogas plant in Gorajec uses 31000 t of substrates throughout the year (Tab. 3). A digestate is used as a fertilizer.

Table 3

The substrates used in operating plant in Gorajec

Substrate	Annual quantity (t)
Pig slurry	3000,00
Pig manure	1500,00
Birdspawn	500,00
Grass	2000,00
Beet pulp	5000,00
Fruit and vegetable pomace	10000,00
Distillery	2000,00
Maize greens	7000,00
Total amount	31000,00

Source: Material submitted by the municipal administration in Cieszanów

In agricultural biogas plants, usually 2-3 substrates are used, mostly slurry and maize silage. Table 4 shows the efficiency of substrates an its processing into biogas and methane.

Table 4

Calculation of biogas and methane volumes for individual substrates and their combined values

Substrate	Volume of produced biogas (m^3)	Volume of produced methane (m^3)
Cattle manure	17280	10368
Pig manure	2867	1720,2
Hen manure	64,8	38,88
Slurry	1899,78	1215,86
Maize silage	5601,96	3025,06
Uneaten particles	666	366,3
Rejected popatos	1020	479,4
Potato sprouts	10,7	5,03
Kitchen waste	61,26	33,69

Source: Czekała et al., 2017

Fig. 1. Operating plant in Odrzechowa (www2)

Fig. 2. Operating plant in Gorajec (www3)

For calculating the amout of energy and power of installation, the biogas plant operating time is assumed to be 8000 hours (approximate 30 days are at service work). Based on table 4 with the results of biogas and methan volumes for individual substrates, the potential for energy supply by a small biogas plant (250 kW) fed

with agricultural waste can be calculated. The power of this biogas plant is 2000000 kWh of energy. If divided this number by 2500 kWh, which corresponds to the annual energy consumption of 4-person households, it can be calculated that the biogas plant can meet the needs of 800 such farms. By multiplying 800 and 4 (the number of people in the household taken into exemplary calculations) it gets 3200 people. Taking into account the 0,5 kW biogas plant, all sizes will be twice as large, in the case of biogas plants with a capacity of 1 kW – 4 times higher. Biogas plant in Gorajec is able to supply 12800 people, while 7 342 people live in the Cieszanow commune (www1).

Conclusions. The conventional energy sources such as oil, hard coal, lignite or natural gas can be exhausted in a short time. They are gradually replaced with energy resources from wind, water, solar radiation, energy of the Earth's interior and biomass. According to nowadays study, biogas production is a process with huge potential. The biogas sector has never before aroused as much attention as it does today. To provide raw materials for biofuel production it is important to use by-products of agricultural origin, mainly those that constitute cumbersome and undeveloped waste, which reduces their quantity. Most often, as in the case of the agricultural biogas plant in Odrzechowa and Gorajec, biogas is used in cogeneration aggregates, it is the combined production of electricity and heat.

Providing a renewable energy development today is an important issue to ensure environmental safety and sustainable development of society. The Energy Strategy of Ukraine for the period until 2035 provides the change of energy consuming structure by reducing the consumption of imported natural gas and diversification of its supplies. The biogas sector is still developing and has a huge potential. The production of biogas has become an attractive source of extra income for many farmers. Besides, biogas production has a useful effect not only on economic, but ecological development, particularly in the rural regions. At the same time, environmental protection aspects have gained additional importance, so that anaerobic treatment processes have become a key technology for environmental and climate protection.

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Використання сільськогосподарських відходів у виробництві енергії із відновлюваних джерел

А. Запаловска[1], У. Башуцька[2]

Поряд із гідроелектростанціями, сонячними та вітровими електростанціями, біогазові установки мають суттєве значення у виробництві електроенергії і тепла від відновлюваних джерел енергії. Залежно від типу субстрату, що застосовується для переробки, та особливостей конструкції біогазових установок, вони мають переваги і недоліки. Тим не менше, правильно локалізована установка з переробки біомаси здатна зменшити використання традиційної енергетичної сировини, забезпечуючи зменшення викидів парникових газів. Біовідходи, рослинні залишки та інші побічні продукти агропромислового виробництва можуть бути використані для виробництва електроенергії, тепла та очищеного метану як палива для відремонтованих транспортних засобів. Виробництво біогазу є ключовою технологією для сталого використання сільськогосподарської біомаси, як джерела відновлюваної енергії. Біоенергетичні установки використовують локально доступну сировину, допомагаючи зберігати енергетичні невідновні корисні копалини. Вони дають змогу утилізувати аграрні відходи, забезпечуючи при цьому високий вихід енергії на культурну площу порівняно із іншими біоенергетиками. Позитивним моментом є збереження штучного добрива за рахунок агротехнічного використання дигестату. Децентралізована генерація електроенергії може зменшити транспортну відстань до кінцевого споживача. Це сприяє збільшенню доданої вартості та альтернативний дохід для сільськогосподарської території. Польща й Україна мають значні площі сільськогосподарських угідь та добре розвинене тваринництво, що створює можливості для розвитку альтернативних джерел енергії із біомаси.

Енергія біогазових установок, вироблена із таких сільськогосподарських відходів, як гній, гноївка та ін., є добрим джерелом тепла, аналогічно електроенергії. Саме тому важливо відзначити доцільність використання сільськогосподарських відходів, як джерела енергії у виробництві біогазу. Істотним недоліком системи є необхідність забезпечити низькі економічні та екологічні втрати. З цією метою потрібно враховувати місце збирання біомаси, транспортування та її підготовку разом із зберіганням. Для досягнення найвищої ефективності невеликі біогазові установки повинні мати постійний склад субстрату із різних інгредієнтів.

Україна та Польща мають значний потенціал розвитку відновлюваних джерел енергії, які можуть забезпечити економічні, екологічні та соціальні вигоди. Виробництво біогазу стало привабливим джерелом додаткового доходу для багатьох фермерів. Воно позитивно впливає не лише на економічний, але й на екологічний розвиток, особливо сільських регіонів. Водночас набули додаткового значення аспекти захисту навколишнього середовища, а анаеробні процеси переробки біомаси стали ключовою технологією захисту навколишнього середовища та клімату.

На підставі наданої муніципальним управлінням та виробником документації проаналізовано роботу біогазових установок із переробки органічних відходів сільського господарства у селах Гораєць і Одрехова (Польща).

Ключові слова: біогазова установка; сільськогосподарські відходи; біомаса; біогаз.

Использование сельскохозяйственных отходов в производстве энергии их возобновляемых источников

А. Запаловска[1], У. Башуцкая[2]

Наряду с гидроэлектростанциями, солнечными и ветровыми электростанциями, биогазовые установки имеют существенное значение в производстве электроэнергии и тепла от возобновляемых источников энергии. В зависимости от типа субстрата, который применяется для переработки, а также особенностей конструкции биогазовых установок, у них имеются свои преимущества и недостатки. Тем не менее, правильно локализированная установка по переработке биомассы способна уменьшить использование традиционного энергетического сырья, обеспечивая уменьшение выбросов парниковых газов. Биоотходы, растительные остатки и другие побочные продукты агропромышленного производства могут исполь-

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зоваться для производства электроэнергии, тепла и очищенного метана в качестве топлива для отремонтированных транспортных средств. Производство биогаза является ключевой технологией для устойчивого использования сельскохозяйственной биомассы, как источника возобновляемой энергии. Биоэнергетические установки используют локально доступное сырье, помогая сохранять энергетические невозобновляемые полезные ископаемые. Они позволяют утилизировать аграрные отходы, обеспечивая при этом высокий выход энергии на культурную площадь по сравнению с другими биоэнергетиками. Положительным моментом является сохранение искусственного удобрения за счет агротехнического использования дигестата. Децентрализованная генерация электроэнергии может уменьшить транспортное расстояние до конечного потребителя. Это способствует увеличению добавленной стоимости и альтернативный доход для сельскохозяйственной территории. Польша и Украина имеют значительные площади сельскохозяйственных угодий и хорошо развитое животноводство, что создает возможности для развития альтернативных источников энергии с биомассы.

Энергия биогазовых установок, произведенная из таких сельскохозяйственных отходов, как навоз, навозная жижа и другие, является хорошим источником тепла, аналогично электроэнергии. Именно поэтому важно отметить целесообразность использования сельскохозяйственных отходов, как источника энергии в производстве биогаза. Существенным недостатком системы является необходимость обеспечивать низкие экономические и экологические потери. С этой целью следует учитывать место сбора биомассы, транспортировку и подготовку вместе с хранением. Для достижения высокой эффективности небольшие биогазовые установки должны иметь постоянный состав субстрата из разных ингредиентов.

Украина и Польша имеют значительный потенциал развития возобновляемых источников энергии, которые могут обеспечить экономические, экологические и социальные выгоды. Производство биогаза стало привлекательным источником дополнительного дохода для многих фермеров. Оно положительно влияет не только на экономическое, но и на экологическое развитие, особенно сельских регионов. В то же время дополнительное значение приобрели аспекты защиты окружающей среды, а анаэробные процессы переработки биомассы стали ключевой технологией защиты окружающей среды и климата.

На основании предоставленной муниципальным управлением и производителем документации проанализирована работа биогазовых установок по переработке органических отходов сельского хозяйства в селах Гораец и Одрехова (Польша).

Ключевые слова: биогазовая установка; сельскохозяйственные отходы; биомасса; биогаз.