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The scientific monograph presents the global trends and prospects of socio-economic development of Ukraine. General questions of economics and enterprise management, regional economics, marketing, modern management, general pedagogy and history of pedagogy, theory and methods of vocational education, general questions of historical sciences, and so on are considered. The publication is intended for scientists, educators, graduate and undergraduate students, as well as a general audience.

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PROSPECTS FOR THE USE OF AGRICULTURAL WASTE FOR BIOGAS TO RELIABLY PROVIDE THE INDUSTRY WITH ENERGY RESOURCES

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Abstract. The subject of research is theoretical and applied aspects of energy use of agricultural waste. General scientific methods of cognition and assessment of the objective nature of the transformation of economic phenomena and processes, instrumental and methodological apparatus of research in agriculture were used in the process of research: systematic approach – in learning the works of scientists; abstract-logical method – in determining the purpose and objectives of the study; analytical, statistical methods – in the study of; computational and constructive – improving the biogas reactor in order to increase the yield of biogas; strategic planning – compiling a strategy for efficient use of energy resources for enterprises with the help energy use of waste. The aim of the study is to investigate the use of agricultural waste for biogas to reliably provide the industry with energy resources. The results of the study showed that organic waste has the potential to be used as a raw material for biofuel production, namely biogas. Types of waste with significant bioenergy potential are identified, comparative energy indicators for traditional energy sources and biogas are shown, the concept of using biogas plants in agro-industrial production of Ukraine until 2030 is analyzed, the experience of countries in the organization of biogas production is shown and features of organizational and technological processes of biofuel production are considered. The Strategy for the efficient use of energy resources for agricultural enterprises of Ukraine is proposed and the biogas installation is improved to more efficient work.

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1. Introduction

There is no doubt about the need to take into account the requirements of environmental protection in the formation of economic policy not only of the state but also of enterprises at the present stage of development.

The problems of waste management is are at the forefront. They are complex, because relate to various aspects – resource conservation, environmental security of mankind, ensuring competitiveness at the micro, macro, mega levels and more. At the same time, increasing the efficiency of their activities remains an important condition for enterprises.

Waste today is a concept from the natural, technical or geological sciences and an economic category. After all, waste is an integral part of production and interaction of the enterprise with the environment.

Waste is a powerful internal reserve to increase the efficiency and competitiveness of agricultural enterprises in domestic and international markets. Analysis of international practice shows that the development of a comprehensive system of waste management of agricultural production can not only increase the efficiency of material resources and efficiency of the enterprise as a whole, but also reduce anthropogenic pressure on the environment by returning waste as secondary raw materials. The energy direction of waste use as a raw material for biogas production deserves special attention.

The aim of the study is to define the best practice of energy use of agricultural waste to provide enterprises with energy recourses.

This aim involves the following tasks:

– study of the role of alternative energy sources and biogas production in the energy supply of agricultural enterprises;

– definition of directions to increase the efficiency of fuel and energy resources use by the agricultural enterprises with an emphasis on production of biofuels;

– technical and organizational aspects of the organization of biogas production;

– improving the technical characteristics of biogas equipment in order to optimize the yield of biogas.

2. The role of biogas production in the energy supply of agricultural enterprises

The process of production in agricultural enterprises can be considered as a process of energy consumption due to the conversion of energy factors of production into agricultural products, which forms a specific energy environment of these entities. From a scientific and practical point of view, it is important to study various aspects of the formation of this environment, in particular the assessment of the place of bioenergy processes and their impact on energy efficiency of agricultural enterprises.

Scientists note that energy consumption in agricultural production is the process of using energy for production, services, work to meet the needs of enterprises and the population and obtain a certain economic effect [1].

Agricultural production has the main difference from others that the main means of production are land, plant and animal, forming complex biotechnical systems "man – plant – machine – environment" and "man – animal – machine – environment".

The complexity of these systems is due to the presence of two biological subsystems, each of which is complex in itself, in contrast to technical systems used in industrial production. The energy component of these systems also differs significantly from technical systems in terms of energy origin. The most energy-intensive branch of agriculture is crop production, which consumes about 80% of energy resources of agriculture [2].

Therefore, the most adequate response to current threats in the energy sphere for Ukraine should be radical structural reforms in all areas of energy policy: energy efficiency, formation of competitive energy markets, diversification of energy supply, increasing the share of alternative energy sources and types of fuels.

A special place in alternative energy is occupied by the processing of biomass by methane fermentation to obtain biogas, which contains about 70% methane [3]. Utilization of biomass in agriculture is extremely important, where a large amount of fuel is used for various technological needs and the need for high-quality organic fertilizers is constantly growing. In turn, biomass provides one-seventh of the world's fuel, and ranks third in terms of energy, along with natural gas. In turn, this gas from organic biomass, regardless of origin, is a significant competition to traditional fuels due to the low cost of biomass [4].

Biogas is a generalized name for a combustible gas mixture obtained by the natural decomposition of substances of organic origin as a result of an anaerobic microbiological process, i.e. methane fermentation.

The technology of production of this gas is a biological process in which the decomposition of organic matter is carried out anaerobically, which means that the substrate will decompose without oxygen. Biogas consists mainly of methane, which is rich in energy, as well as carbon dioxide from residual gases, which include ammonia, hydrogen sulfide and water vapor. Fermentation residues can be used as organic fertilizers in the natural cycle of substances. The process of production of this gas helps to prevent the release of methane into the atmosphere, as well as to reduce the use of chemical fertilizers, reduces the risk of groundwater pollution. The most important thing for the economy of Ukraine is that the produced biogas is a by-product in the processing of organic waste [5].

Production waste is an unsuitable for the production of certain products types of raw materials, its residues that are not used, or substances that arise as a result of technological processes that are not subject to disposal in this production.

Waste is divided into primary and secondary. Primary is the waste generated directly during the harvest of agricultural crops (straw of cereals and other crops, stems, baskets of sunflower, waste from the production of corn). Secondary wastes are sunflower husks, buckwheat husks, rice, sugar beet pulp, etc.

A promising area for the use of agricultural waste is energy – the use as a raw material for biogas production. The range of organic wastes suitable for biogas production is quite wide.

– Agricultural waste. The concentration of wastewater impurities on livestock farms reaches 30,000-60,000 mg/liter. The amount of dry sludge is at least 20 million tons per year. Fermented sludge and manure after fermentation are usually neutralized and can be used as fertilizer. Estimates show that biogas production in rural areas can be considered profitable with 20 cows, 200 pigs or 3,500 hens. In agriculture, the substrates of biogas are crops: cereals, vegetables, potatoes, fruits and berries and other crops and plants, grain and molasses post-alcoholic bard, beer pellets, beet pulp.

– Livestock waste. 340 m^3 of biogas can be obtained from 1 ton of dry manure as a result of anaerobic fermentation under optimal conditions.

During fermentation, the microflora develops in the manure, which consistently destroys organic matter to acids, and the latter under the action of syntrophic and methane-forming bacteria are converted into gaseous products – methane and carbon dioxide. At the same time, manure fermentation ensures its deodorization, deworming, destruction of the ability of weed seeds to germinate and transfer of fertilizers into the mineral form. It should be noted that the technology of obtaining biogas by anaerobic digestion in plants is the most economical way to process organic waste from poultry and livestock enterprises into dry fertilizer.

– Poultry waste. To determine the yield of biogas, we can assume that one typical poultry house contains 25 thousand hens, giving up to 5 tons of manure per day, from which 2500 m^3 of biogas is obtained.

– Waste from distilleries – grain and molasses post-alcoholic bard.

– Dairy waste – lactose, whey.

– Biodiesel production waste – technical glycerin from rapeseed biodiesel production.

– Wastes from juice production – fruit pulp, berry, grape pomace.

– Waste fish and slaughterhouse – blood, fat, intestines.

– Wastes from potato processing, production of chips – cleaning, skins, rotten tubers.

– Sewage (aeration) gases are a product of fermentation of municipal sewage, which is a type of biogas containing 60-65% methane (CH_4), 30-35% carbon dioxide (CO_2) and 2-4% hydrogen). As practice shows, the output of sewage gases from the processing station, fed by the sewerage network, which serves a settlement with a population of 100 thousand people, reaches more than 2,500 m^3 per day, which is equivalent to 2,000 liters of gasoline. Given that the population of large cities, as a rule, exceeds 500 thousand people, sewage gases are becoming a real source of alternative fuels.

– Sewage sludge from municipal sewage treatment plants. Depending on the chemical composition of sludge during fermentation, from 5 to 15 m^3 of gas per 1 m^3 of sewage sludge is released.

– Solid household waste. For the production of biogas from solid waste, the shredded waste in the plant is mixed with sewage sludge from septic tanks. The temperature of the mass rises to 65-70°C. The process of anaerobic fermentation takes 1-2 months. According to foreign experts, up to 1.5 m^3 of gas is emitted from 1 m^3 of solid waste. The gases contain up to 50% methane, 25% carbon dioxide, up to 2% hydrogen and nitrogen. This technology is widely used abroad – in the US, Germany, Japan, Sweden.

Thus, almost all types of organic waste can be used as raw material for biogas production. First of all, it is agricultural waste (manure) and vegetable origin. Practice shows that industrial waste (sugar, alcohol, dairy, breweries), as well as municipal wastewater treatment plants are also used. Another possibility is the use of natural anaerobic fermentation processes on the example of solid waste from landfills and dumps [1].

To calculate the yield of biogas from a particular raw material, it is necessary to conduct laboratory tests or look at reference data and determine the content of fats, proteins and carbohydrates. In determining the latter, it is important to know the percentage of rapidly degradable (fructose, sugar, sucrose, starch) and hardly degradable substances (e.g. cellulose, hemicellulose, lignin). Having determined the content of substances, you can calculate the gas yield for each substance separately and then add up. In addition to waste, biogas can be produced from specially grown energy crops, such as silage corn or selfies, as well as algae. Gas output can reach up to 500 m^3 per 1 ton.

Biogas production is growing rapidly in the world and its use in energy is expanding [6; 7].

The EU biogas sector is very diverse, depending on national priorities, financial incentives and relevant raw materials. In particular, Germany and the United Kingdom are the largest producers of biogas in the EU. Germany produces 93% of biogas by fermentation technology, mainly corn silage. The United Kingdom, Estonia, Greece, Ireland, Portugal and Spain produce more than 80% of biogas in landfills. In other countries, combinations of different types of technologies and raw materials are used.

Germany became the leader in the production of biogas from agricultural waste in 2020, the country produces 64% of the total amount of biogas in the EU. Italy, the Czech Republic and the United Kingdom account for 13%, 5% and 4% respectively. Today, there are more than 11,000 biogas plants in Germany with a capacity of 500 kWh to 2 MWh.

The spatial aspect of the use of livestock waste for biogas production in world practice is expressed in 2 development strategies: German and Danish.

The first is characterized by the use of livestock waste in the places of their formation or accumulation (for the needs of the same farms in which this waste will be generated), the second – the creation of centralized bioenergy plants that consume waste from several farms.

The German model is characterized by large specific investments, so it is effective only in the case of stimulating the development of bioenergy by the state, which is typical for Germany and Austria, or in favorable climatic conditions, when there is no need for methane tanks of complex design (Italy).

The Danish model is characterized by three fundamental advantages over the German one: a reduction in specific investment due to an increase in unit capacity; possibility of cogeneration (production of both heat and electricity at the same time); possibility of co-fermentation (the effect of a significant increase in the specific yield of biogas due to the simultaneous use of several types of bioresources in the methane tank) [6].

Of the six largest European companies in the biogas industry three are German: Strabag Umweltanlagen GmbH, Schnack Biogas AG, Biotechnische Abfallverwertung – with a total of 280 plants. There are more than 110,000 anaerobic fermentation plants in Germany today, of which about 4,000 are large and about 7,000 are medium. In the future, 10-20% of the country's natural gas could be replaced by biogas. According to forecasts, the number of installations in Germany by 2025 will reach 20 thousand units.

Denmark is the leader in terms of biogas intensity, where this type of fuel provides almost 20% of the country's energy consumption. Lemvig Biogas Company has the largest biogas plant in Denmark. Waste from approximately 75 farms, as well as residual industrial products, are used to generate heat and energy. More than 21 million kWh of energy are generated annually from biogas produced [1].

The biogas market in the United States is developing much more slowly than in Europe. As of January 2019, there were about 252 biogas plants operating on commercial livestock farms. Most of these facilities use biogas to generate electricity. Several farms use biogas to produce transportation fuels, including Hilarides Dairy in California and Fair Oaks Dairy in Indiana.

Since 2002, the Chinese government has allocated about $200 million annually to support the construction of biogas plants. The subsidy for each installation is approximately 50% of the average cost. Thus, the government has achieved an annual increase in the number of biogas plants to 1 million per year. In total, there are already more than 30 million farms in China, 3.7 million in India and 200,000 in Nepal using biogas. Today, China's rural areas produce about 16 billion m^3 of biogas, which is used as a household fuel by more than 50 million people.

The development of the biogas market in Ukraine is expected to replace 2.6-18 billion cubic meters of natural gas per year, will strengthen the country's energy security, create new jobs, economic development of regions, cover peak loads in the grid, dispose of crop and livestock waste, as well as some food waste. The introduction of biogas projects in Ukraine was launched by the introduction in April 2013 of a "green" tariff (GT) for biogas. However, the corresponding tariff is low and provides for further reduction [8].

The Law of Ukraine "On Amendments to Certain Laws of Ukraine to Ensure Competitive Conditions of Electricity Production Using Alternative Energy Sources" (2015) amended the Laws of Ukraine "On Alternative Fuels" and "On Principles of Functioning of the Electricity Market of Ukraine". It provides GT for electricity produced from biomass (at the level of 12.39 eurocents / kWh), as well as a surcharge to GT for businesses that use Ukrainian components in the construction of energy generating facilities.

The use of biomass and biogas in Ukraine has significant potential for heat and electricity production.

The concept of using biogas plants in agro-industrial production until 2030 (Table 1) provides that given the technical and economic feasibility and current structure and size of agro-industrial enterprises in Ukraine, the market for biogas plants is estimated at about 1,600 mini-CHP plants with a capacity of 100 kW.

The total installed capacity of biogas installations (BGI) can reach 820 MW for electric and 1100 MW for thermal. By 2030, it is necessary to master, respectively, 50% of the economically viable market for biogas plants.

At the same time, the total annual electricity production in 2030 should be 2.5 billion kWh. In general, about two-thirds of biogas will be produced from corn silage and the rest from waste.

Table 1

The concept of using biogas plants in agro-industrial production until 2030

Number of installations	Total biogas production	Total power	Total thermal capacity	Annual electricity production, net	Annual production of thermal energy	Reduction of greenhouse gas emissions	Investments	Job creation	Areas for corn
units	million m^3 per year	MW of current	MW of heat	million kW / hours	million Gcal	million Gcal	million UAH	units	thousand hectares
2020									
143	290	74	97	0.45	0.4	1.2	2645	920	27
2030									
811	1655	420	550	2.5	2235	6.0	14970	5190	155

Source: [9]

A total of about two thirds of biogas will be produced from corn silage, and another third – from waste. 0.15 million hectares of arable land will be needed to grow the required amount of corn silage – 0.5% of its total area in 2020.

The potential for heat use from mini-thermal power plants will be 2.234 million Gcal in 2030. 5,200 jobs will be created by 2030 and greenhouse gas emissions will be reduced by 6 million tons per year [10].

The biogas sector in Ukraine has tended to grow steadily in the last few years. This was partly due to the expected reduction of the "green" tariff for electricity from biogas from January 1, 2020 by 10%. Companies that planned to build a business in this area sought to complete by this date. But the efforts of the Bioenergy Association in particular have extended the "green" tariff for biogas at the same level until 2030.

Projects with "cheap" raw materials, such as manure and sugar beet pulp, have developed well. Today there is progress in biogas, but the growth dynamics of the industry does not coincide with the National Plan for Renewable Energy Development in Ukraine until 2020. RES in general, and biogas in particular, do not feel very comfortable today due to problems with the solvency of SE "Guaranteed Buyer" (a specially created structure for guaranteed redemption of "green" electricity at a "green" tariff).

Biogas projects depend on raw materials, so the inflow of funds should be constant for the stability of operation.

Generating energy from the sun and wind is a little easier – you don't have to buy a natural energy source. There are also alarming signals from the authorities about a possible radical revision of the current rules in the RES market, which will affect the biogas business accordingly. These factors do not motivate new potential investors to invest in such projects. And if businesses that have solar and wind power plants can "survive" the reduction of the "green" tariff due to the zero cost of "raw materials" and the constant reduction in technology, then biomass and biogas – no. Even the current "green" tariff does not allow in most projects to achieve an attractive return on investment in 4-5 years (typically at least in 6-7 years).

Given the problems in the management of complex biogas technologies, a number of projects at the current rate of "green" tariff may not pay off at all. The entry of biogas projects into the new market of "green" auctions is potentially interesting for such business, provided that the difference between the current "green" tariff and the tariff on the results of the auction will not exceed 10%. Therefore, any drastic changes to stimulate the generation of energy from biogas in the direction of reduction, may stop the development of the industry.

The forecast for today indicates that under the current system of incentives, the biogas sector of Ukraine will develop at a rather limited pace by inertia for another 3-5 years, mainly through large-scale projects on cheap raw materials. New prospects may open up with the introduction of the biomethane market in Ukraine. Much depends on the political will, the strategic course of the state. It is necessary to think what will happen after 2030, when the Law on Ensuring Competitive Conditions for the Production of Electricity from Alternative Energy Sources expires.

Of particular importance are biogas technologies to provide agricultural enterprises with energy resources.

According to the Law of Ukraine № 287-VIII "On animal by-products not intended for human consumption" [11], the disposal of animal waste in Ukraine is carried out exclusively by specialized companies and can not be performed by companies producing animal products intended for human consumption. Manure and animal residues belong to the second class of waste and can be converted into organic fertilizer after mandatory sterilization under pressure or into biogas by sterilization under pressure.

Processing facilities for animal waste must be located separately from food companies. Waste disposal companies are market operators, and those market operators who dispose of or remove by-products without pressure sterilization or without processing into biogas under pressure after sterilization should be fined. For legal entities the fine is 23-30 minimum wages, for private entrepreneurs – 8-15 minimum wages. Sometimes companies prefer to pay a fine and not take further action to dispose of livestock waste. However, large agribusinesses are subject to inspections by the Ministry of Health, the Prosecutor's Office, the Sanitary and Epidemiological Service and the Environmental Inspectorate of the Ministry of Environmental Protection and Natural Resources. Therefore, in some cases, biogas plants using Ukrainian equipment are economically feasible even to cover the costs of waste disposal.

Comparative energy indicators for traditional energy sources and biogas are shown in Table 2.

Table 2

Comparative energy indicators for traditional energy sources and biogas

Product	Units of measurement	The equivalent of 1 m³ of crude biogas 23 MJ/m³	The equivalent of 1 m³ of purified biogas 35 MJ/m³
Electricity	kWh	0,63	0,95
Natural gas	m³	0,62	0,94
Coal	kg	0,83	1,26

Source: [12]

The most effective are bioreactors of biogas plants that operate in thermophilic mode with a temperature of 43-62°C. Such plants with three-day fermentation of manure produce 4.5 m^3 of biogas per liter of useful reactor volume.

In turn, the use of biogas makes it possible to obtain heat and electricity, which is necessary for farms. In the case of mass use of biogas technologies in rural areas, significant savings in fossil fuels can be ensured.

In addition to the actual biogas, the biogas instalation makes it possible to obtain organic fertilizers [13; 14].

Mineral fertilizers are expensive and more concentrated. Compared to organic, they are more difficult to digest. Organic fertilization improves soil structure. Macronutrients of this natural fertilizer saturate the soil with almost the full set of necessary substances, increasing the percentage of humus. Namely, the fertilizer is found in the soil in forms accessible to plants.

For example, 350 tons of fertilizer per 1 ha increase the content of potassium and phosphorus by 10 mg/kg. While the average potassium content in the soil is 80 mg/kg. This means that you can annually increase the content of only the main macronutrients by 10 mg/kg. And, as a result, raise the level of ash elements in the soil from medium to high level.

3. Strategic directions for improving the efficiency of fuel and energy resources use and organization of biogas production

The purpose of strategic planning in the field of efficient use of energy resources by agricultural enterprises is to establish an algorithm for forming a base of energy resources (traditional and alternative) and their economical use to reduce energy intensity of products. Ultimately, this is necessary to ensure the competitiveness of agricultural enterprises in the long run. Insufficient development of concepts, strategies and models of development has a negative impact on agriculture, which is not competitive enough in world markets.

We propose the implementation of the Strategy for the efficient use of energy resources for agricultural enterprises of Ukraine, which will guarantee a reduction in energy intensity of products and increase its competitiveness. The main areas of implementation of the Strategy will include:

1. Introduction of energy saving technologies.
2. Introduction of energy management.
3. Use of alternative fuel and energy resources.

1. Introduction of energy saving technologies. An important role in the efficient use of fuel and energy resources is played by organizational

and technological support of the production process, the use of energy-saving equipment and technologies. Tractor and combine fleet of agricultural enterprises of Ukraine is 50-70% older than 10 years. This leads to constant huge costs for spare parts, overspending on fuel and lubricants, a high percentage of breakdowns, more than 15% of crop losses. The optimal equipment of the machine-tractor fleet of farms with modern equipment (both domestic and foreign) with their rational use allows to reduce fuel consumption by 10-40% in some technological operations.

More significant reserves are in modern technologies (minimum and zero tillage, track technology, etc.). Their implementation reduces fuel consumption by up to 70%. This is evidenced by both foreign and domestic experience.

The comparative efficiency of the use of resource-saving technologies in comparison with the classical one is given in Table 3.

Table 3

Efficiency of application of resource-saving machinery and technologies in the conditions of Ukraine in comparison with classical technology, %

Technology	Reduce the use or cost of motor fuel	The share of fuel in the cost of production	Energy intensity of products	The cost of production
Machinery				
Combined units	22	85	69	86
Gas cylinder machinery	37	66	100	93
Technologies				
Precision farming	20	84	70	84
Minimum tillage	65	31	40	83
Track technology	18	92	73	82

Source: [15]

Tillage by traditional methods is the most expensive. This technology in recent years has led to a decrease in humus, to soil degradation. World trends point the way to frugal agriculture. More than 124 million hectares of land in the world have been transferred to these technologies. 7 million hectares are added annually. This is proof of the viability and sustainability of technology. Reducing the mechanical impact on the soil and increasing the content of organic matter due to the constant preservation of plant residues can stop soil degradation.

Savings technologies do not reduce grain yields, but fuel consumption in tillage is reduced by 1 liter while reducing tillage depth by 1 cm. Comparison of plowing and direct seeding technologies indicates savings of fuel and lubricants by 2.5 times by reducing field and use of equipment for less energy-intensive technological operations.

One of the measures to increase energy efficiency and energy saving is the creation of innovative farms – a model of environmentally and economically efficient production with a concentration of modern energy and resource-saving technologies. Such technologies include: mulching crops, direct sowing, efficient irrigation. Precision farming technologies are used: navigation equipment system, field travel system, Controlled Traffic Farming, differential fertilizer application system and plant protection products.

The introduction of energy efficient technologies is impossible without incentives from the state. This regulation is carried out through the use of both administrative and economic methods. In the period of economic recession that Ukraine is currently experiencing, it is necessary to use mainly policy regulators. In the transition to the development phase, economic regulators should dominate [16].

Methods of state regulation should not be opposed. It is advisable to apply them depending on the specific economic situation. At the same time, the state must create common transparent "rules of the game" and guarantee their observance by all economic entities.

In order to carry out applied research and develop new models of equipment and technologies, the creation of technology parks may be justified. To revive the production of complex agricultural machinery (tractors, internal combustion engines and combines), it is advisable to use free or special economic zones with appropriate preferential taxation (zero VAT rate, customs tax on imported components, etc.). According to the experience of the domestic automotive industry, the implementation of this mechanism since 2000 has brought the production of cars and buses on the path of sustainable growth, and budgets at all levels have received more revenue due to multiple increases in production.

Improving the efficiency of energy resources should be stimulated by environmental regulation. The fact is that reducing exhaust emissions requires the use of energy-saving technologies and cost-effective machinery.

It is important to use the subsidy mechanism, which is used to cover part of the costs for the development and implementation of the latest energy-saving technologies and equipment. Together with loans for energy efficient equipment, they have an investment form. Many countries of the European Union use such a policy. Thus, in Germany, 50% of the cost of diesel biofuel plants is compensated at the expense of state funding.

Implementation of the state policy to support the use of biofuels and energy-saving technologies by regulatory methods in market conditions is impossible without the widespread use of economic incentives. Highly developed countries (EU, USA, Japan, etc.) have extensive experience in this area.

At the first stage, they applied the following economic incentives:

– loans at low bank rates;

– sale of energy saving equipment without indirect taxation;

– tax benefits for the production and use of alternative fuels of plant origin;

– accelerated depreciation of machinery and equipment;

– subsidies (direct and indirect) to cover the production costs of enterprises;

– investments.

It is necessary to inform agricultural producers about modern energy-saving technologies, implement pilot projects and constantly monitor the efficiency of energy resources at the state level.

2. Energy management. The problem of energy saving and efficient energy supply can be solved only by implementing an energy management system.

The company's energy management system (EMS) is a set of organizational, technical and software tools that together manage the production process in such a way that only the minimum required amount of fuel and energy resources for the production of a certain number of products or services.

In order to ensure the efficient use of energy in enterprises, an energy management service is created, headed by the energy manager of the enterprise.

His function is to manage the operation of the service and ensure the achievement of the planned energy saving effects. He is responsible for energy managers in various areas of energy conservation (heat supply, electricity, water supply, compressed air supply), whose responsibilities include: control and planning of energy consumption, energy management cycle in energy conservation, development and implementation of measures for generation, distribution, use types of energy.

Energy managers of shops and sections with an annual energy budget of UAH 10 million and more are also subordinated to the energy manager of the enterprise. They control and plan energy consumption in shops and polling stations, organize the elimination of energy losses and implement energy saving measures for all types of energy consumed by equipment in sections.

The Energy Management Service is also a link between businesses and various inspectorates that oversee the efficient use of energy resources. For small agricultural enterprises, we offer the introduction of the position of energy manager only.

The energy manager belongs to the administration of the enterprise (organization), but he does not manage people, but controls energy consumption. The position of energy manager refers to the middle manager with direct subordination to the director or chief engineer of the enterprise (organization).

The energy manager must be able to:

– compile tables of energy consumption at the enterprise (organization), by divisions and equipment and fuel and energy balance of the enterprise (organization);

– analyze energy consumption taking into account the assessment of energy saving measures and prepare proposals for improving the production process;

– determine the efficiency of energy consumers and control the investment of energy saving measures;

– provide consulting services on energy saving at the enterprise;

– conduct an internal energy audit and know the butterfly of energy management assessment at the enterprise and the encouragement of employees of the enterprise who save energy;

– develop proposals to attract staff to save energy;

– check and evaluate energy bills and contracts related to energy consumption;

– analyze energy flows in detail and determine and constantly monitor specific energy consumption rates;

– calculate investments, operating costs and analyze the possibilities of subsidies and their practical use;

– submit proposals to the administration regarding the new investment policy;

– manage staff.

The energy manager must meet the following requirements:

– have basic knowledge of energy management and an idea of the basic technologies used in the enterprise (organization);

– be able to work with new information technologies, analyze data on energy consumption, conduct economic analysis of energy saving measures and develop these measures and conduct internal audit of the enterprise;

– have broad and original views on energy saving and be proactive and persistent in solving problems related to energy conservation;

– be able to communicate with both the administration and the staff of the enterprise.

3. Use of alternative fuel and energy resources. Today, the use of non-traditional and alternative energy sources in agriculture and in the agro-industrial complex as a whole is especially relevant, as such sources are available in Ukraine and their use is still minimal (6.6% of the country's total energy balance in 2020).

Biomass occupies a special place in the structure of possible alternative energy sources, the potential of which in Ukraine is quite large, but not yet fully studied [17].

From the ecological point of view, bio-production in the agro-industrial complex will reduce greenhouse gas emissions, increase soil fertility and improve water quality, as well as contribute to the gradual revival of biodiversity [18]. However, it is always necessary to compare the economic efficiency of energy and food use of agricultural products.

This problem is quite difficult, because on the one hand, providing the population with food is a priority for every government, and on the other – the energy independence of the state is the basis of its sovereignty. Therefore, the analysis of the possibilities of growing bioresources for biofuels should be carried out taking into account the real situation with both the existing needs in the food sector and the available sources of traditional energy resources.

It is expected that the energy use of all types of biomass of Ukraine will be able to provide an annual replacement of 9.2 million tons of conventional fuel (c.f.) fossil fuels at the level of 2030, including due to energy use of crop residues, in particular: straw – 2.9 million tons of c.f., firewood and wood waste – 1.6 million tons of c.f., peat – 0.6 million tons of c.f., solid waste – 1.1 million tons of c.f., production and use of biogas – 1.3 million tons of c.f., fuel ethanol production and biodiesel – 1.8 million tons of c.f., firewood and wood waste – 1.6 million tons of c.f., peat – 0.6 million tons of c.f., solid waste – 1.1 million tons of c.f., production and use of biogas – 1.3 million tons of c.f., fuel ethanol production and biodiesel – 1.8 million tons of c.f.

One of the important ways to increase the efficiency of energy supply of enterprises, especially enterprises of the agro-industrial complex, is the ability to provide electricity and heat to the most important areas of production, which requires backup energy sources and backup (autonomous) energy supply systems.

Despite some changes, the development of alternative energy in Ukraine is slow due to the low level of technical re-equipment of production; low intensity of use of renewable energy resources available at the local (regional level).

4. Technical and organizational aspects of the organization of biogas production

Central Ukraine has a strong potential for alternative energy development through the use of agricultural waste (straw, corn stalks, sunflower husks, biological livestock waste), but underestimating the potential for alternative energy production preserves the solution of Ukraine’s energy problem. The lack of effective mechanisms of economic stimulation and financial responsibility for the rational use and economical use of fuel and energy resources of economic entities of all forms of ownership does not contribute to reducing the level of energy dependence of the Ukrainian economy.

The development of alternative energy in Ukraine will allow to make real structural changes: to reduce energy consumption, to increase energy efficiency and energy savings; modernize the energy sector and energy supply; to implement in practice the principles of sustainable (environmentally oriented) type of economic growth; to deprive the national economy of traditional energy dependence and to increase the competitiveness of national production, to provide social infrastructure with energy resources [19; 20].

Modern agriculture and biogas technologies in modern agriculture stand side by side as two inseparable components [21]. The process has gone so far that, for example, the EU no longer even keeps track of the total number of biogas plants – the technology has become so common and widespread that there is simply no need to calculate biogas capacity.

But the situation in the Ukrainian agricultural sector is a paradox. In general, domestic agricultural enterprises are leading in the introduction of new technologies, and this fact is recognized by both foreign and domestic experts. But this does not apply to the use of bioenergy in general, and especially the problem of agricultural enterprises using biogas installations.

Biogas plants have numerous advantages over fossil fuels and other types of RES:

– the combination of waste from seasonally operating enterprises (for example, sugar factories) with farm waste allows to produce energy throughout the year;

– creation of new jobs or new income opportunities during the year for workers employed in sugar factories, which are located mainly in small towns in Ukraine and are often the main employer of the city;

– disposal of a very wide range of agricultural residues;

– production of organic fertilizers that can be used for organic farming (another way to increase the competitiveness of agriculture in Ukraine);

– modern management of agricultural waste management, especially manure (which helps reduce odor, restore soil, preserve potential agricultural land that could be used for settling tanks);

– the possibility of energy production near the places of origin of agricultural waste (which does not require transportation of fuel over long distances);

– the possibility of covering the peak load in the network and failures of power generation created by intermittent RES;

– gradual transition to a model of decentralized energy supply for local communities;

– increase the use of biogas obtained from sugar production and agricultural waste.

Livestock waste mixes well with any other substrates, as this raw material contributes to the stability of fermentation processes in biogas production. And the addition of corn silage or other substrates increases the overall yield of biogas.

Silage has been used in biogas production for many years in the world. The ancestor is Germany, which introduced a higher tariff for energy derived from biogas. There began to build stations whose total capacity exceeded the capacity of four nuclear units. Of course, there was not enough waste, so they began to use raw materials in a ratio of 30 to 70 – manure and silage. About 1 million hectares of land, equal to 10% of Germany's total land area, were used for silage cultivation. When asked by farmers, seed companies even began to develop special hybrids of plants that behaved best in reactors.

The introduction of technology in Ukraine was delayed due to legislation. Initially (in 2009) the law on bioenergy did not provide for a "green", i.e. increased tariff, for projects that work with biomass – only water, sun and wind. Then (since 2013), when biomass was included in the legally approved list of sources for bioenergy, silage and grass were deleted from it. It was written that biomass is organic waste from agriculture and forestry. The key word is "waste". This means that silage or firewood are no longer suitable as raw materials, because they are not waste. The EU says that biomass is waste, residues and agricultural and forestry products. After all, silage is a product, and straw is a residue. All this was corrected only in July 2015.

The production process of biogas can be described as pre-treatment and fermentation of raw materials (cattle farm effluents with a moisture content of 95%, sheep manure and corn silage) under anaerobic conditions, as well as the use of the manufactured product – biogas.

At the first stage of fermentation (hydrolysis stage) the process of biochemical cleavage of macromolecular compounds (carbohydrates, fats, proteins) into low molecular weight takes place.

At the second stage, with the participation of acid-forming bacteria, the further decomposition of substrate takes place, with the appearance of organic acids and salts, as well as alcohols, CO_2 and H_2, and then H_2S, NH_3.

The final result of anaerobic fermentation is obtained at the third stage of the process – methane fermentation, in which the main role is played by methane-forming microorganisms.

Biogas installations are actively used in farms in Ukraine and in the world nowadays. The disadvantage of most installations is the lack of biomass heater, and due to insufficient and uneven heating of the mixture, there are significant temperature fluctuations in the volume, which violates the technological requirements of anaerobic fermentation.

Known biogas installation [22], which contains a tank covered with insulation, a consumer pipe with a tap, a vertical propeller stirrer on a hollow shaft, a loading hopper with a first slide latch over it and a protective gas distribution grille. There is a hole for the removal of spent biomass substrate under a vertical propeller stirrer with a second gate valve in the lower part of the installation. The tank is wrapped with an electric heating cable with a thermostat, there are two heat exchange circuits, each of which consists of heat exchangers, the first heat exchanger is connected to the gas pipeline, compressor and biomass substrate preparation unit, and the second to the spent biomass substrate pipeline for biomass substrate preparation. The disadvantage of this biogas plant is the low efficiency associated with insufficient mixing and heating of the biomass substrate.

The study is based on the problem of improving the biogas reactor by increasing the efficiency of maintaining the heating temperature of the substrate and its uniform mixing to intensify the process of anaerobic fermentation. The problem is solved by the fact that the biogas reactor with uniform mixing and heating contains the reactor vessel, thermal insulation layer, unloading auger with electric drive, and differs that it is additionally equipped with a cylindrical tubular heater, with cleaning clamps on the turns of it. The heating element is made in the form of a cylindrical tubular spring, on the turns of which there are cleaning clamps, the rotational movement of which is transmitted from the rope system through the pulley, insert and offset pins.

Figure 1 shows a schematic of a biogas reactor with uniform stirring and heating.

The biogas reactor contains a loading neck 1, reactor housing 2, insulating layer 3, unloading auger 4 with electric drive 5, cylindrical tubular heater 6, on the turns of which are fixed three clamps 7, which rotate clean the surface of the heater turns, providing efficient heat dissipation. The clamps 7 through

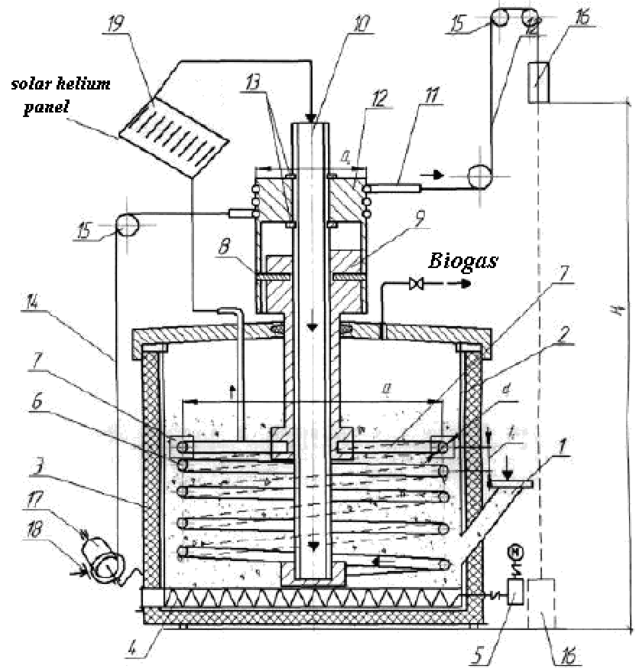

Figure 1. Biogas reactor with uniform stirring and heating

Source: author's patent [23]

the pins 8 are fixed to the insert 9, which can be moved on the Central pipe 10, and rotated by pins 11 from the pulley 12. Axial displacement of the pulley fix locking rings 13. Pulley 12 wraps the cable 14 to which through the guide blocks 15 suspended load 16, the lifting of which is carried out by a lifting mechanism 17, the braking of which is carried out by the latch 18. To heat the substrate solar helium panel 19 is used.

The biogas reactor works this way. The load 16 rises to a height H0 by means of the lifting mechanism 17, while the cable 14, passing through the guide blocks 15, wraps the pulley 12 in several turns, at this time the lifting mechanism is braked by the clamp 18.

To carry out uniform mixing release the clamp 18 gravitational forces are lowered, while the cable 14 rotates the pulley 12, which transmits torque through the pins 11 to the insert 9, which rotates on the central tube 10, which moves the coolant from the solar helium panel 19 to the cylindrical tubular heater 6, which gives heat to the substrate, which is located inside the reactor vessel 2. To unload the spent substrate, the unloading auger 4 is pre-actuated by means of an electric drive 5 located in the lower part of the biogas reactor.

Thus, the use of a cleaning device for the heating element of the biogas reactor makes it possible to increase the efficiency of heat transfer and ensure uniform release of biogas. Uniform mixing and heating of the substrate in an isolated reactor increases the energy efficiency of the bioreactor.

Another product provided by a biogas plant is biofertilizers, which make a significant contribution to the revenue side of biogas projects [24].

Biofertilizer is a product of fermentation of organic matter under anaerobic conditions (without air access). Biofertilizer, as a product of biogas technology for processing cattle manure, pig manure and other organic agricultural waste, contains all the necessary components of fertilizers (nitrogen, phosphorus, potassium, macro- and micronutrients) in dissolved, balanced form in the proportions required for plants, as well as active biological growth stimulants, significantly increase yields.

Biofertilizer, as the end product of the biogas plant completely replaces mineral fertilizer, as it contains all the necessary components of fertilizers: nitrogen-phosphorus-potassium, macro-and micronutrients in dissolved balanced form in the ratios needed for plants, as well as active growth stimulants.

Comparison of different types of fertilizers (biofertilizers, mineral and organic fertilizers) by quality indicators is presented in Table 4.

Based on the data in the Table 8, we can see that biofertilizers are better absorbed by plants, do not have pathogenic microflora and weed seeds, have a useful microflora in large quantities, there is no adaptation period when using them.

Biofertilizers act on the plant immediately after their introduction into the soil. They are used as a year-round fertilizer for all agricultural, ornamental and domestic crops diluted with water, by injection, surface watering or spraying the leaf surface of plants. Having a slightly alkaline environment (pH 7.6-8.2), they reduce soil acidity. They are used in all climatic zones, for all types of soils, increasing their fertility and improving their ecological condition.

Table 4

Comparison of biofertilizers with other types of fertilizers on qualitative indicators

Indicator	Biofertilizers	Mineral fertilizers	Organic fertilizers (manure)
Assimilation by plants, %	100	35-40	80
Nitrogen losses, %	5-8	50	30
Nitrate content in products	no	yes	no
Leaching from the soil, %	15	50	80
The presence of pathogenic microflora	no	no	yes
Presence of weed seeds	no	no	yes
The presence of beneficial microflora	yes in large quantities	no	yes in small quantities
Adaptation period	no	yes	yes

Source: formed by the author according to [25]

Biofertilizers increase the resistance of plants to adverse environmental influences, especially during late frosts, microbiological processes in the root zone of the plant occur with the release of heat needed to protect shoots. The application of biofertilizer improves the survival of newly planted fruit crops, both in spring and autumn.

Biofertilizers are widely used in the Netherlands, Germany, England, Finland, Italy, China, India and other countries. Especially good results of fertilizers are given in Ukraine in the cultivation of potatoes, beets, cabbage, carrots, tomatoes, cucumbers, strawberries, raspberries, currants and other vegetables and berries, as well as cereals, fodder and lawn grasses, ornamental flowers such as roses, daffodils, peonies, etc.

The choice of equipment for biogas production in Ukraine is not so wide, obviously given that this business is still in its infancy.

The most famous world brands are German. These are Schmack, EnviTec Biogas, Biogas Nord, Lipp. The most expensive equipment is produced by Schmack: the cost of a turnkey biogas plant is 4 million euros per 1 MW. Biogas Nord, EnviTec Biogas, Lipp is the middle price segment (3-3.5 million euros). Ukrainian-Swiss brand Zorg offers bio-installations for 2.5-2.7 million. euros (assembled by German technology from German components). In all cases, the components for biogas plants are the same. The price is mainly influenced by the prestige of the brand. In addition, each company includes in the cost of its internal costs (staff salaries, engineering, etc.).

Using the potential of biogas production is an innovative way to meet the energy needs of agricultural enterprises. Complementing the biogas plant with cogeneration installation for the production of heat and electricity will allow the company to make optimal use of energy potential and abandon the purchase of electricity from traditional sources.

5. Conclusions

1. Rapid growth of energy prices, the possibility of reorientation to the cultivation of crops that are processed into biofuels, or the use of livestock products and agricultural plant waste for energy purposes are significant factors for autonomous energy supply of agricultural enterprises and reduce their energy costs in terms of fuel.

2. The types of organic wastes suitable for biogas production are identified: agricultural waste, livestock waste, poultry waste, waste from distilleries, dairy waste, biodiesel production waste, waste fish and slaughterhouse, wastes from juice production, wastes from potato processing, production of chips – cleaning, skins, rotten tubers, sewage (aeration) gases, sewage sludge from municipal sewage treatment plants, solid household waste.

3. The spatial aspect of the use of livestock waste for biogas production in world practice has shown different approaches to the organization of the process. European and world experience of biogas production is analyzed. It is determined that the leaders in Europe are Germany, Denmark and France. Interesting experience of state support and construction of individual biogas plants in China has been studied.

4. Production of biofuels, in particular biogas from waste, and their replacement of purchasing energy resources from traditional sources is currently an effective area of energy supply for agricultural enterprises. The implementation of the Strategy for the efficient use of energy resources for agricultural enterprises of Ukraine is proposed. The main areas of implementation of the Strategy will include: introduction of energy saving technologies; introduction of energy management; use of alternative fuel and energy resources.

5. It is proposed to improve the existing equipment for biogas production based on the development of biogas reactor with uniform stirring and heating which increases the efficiency of biogas production.

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