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Development of Alternative Energy in the World and Ukraine

Abstract. The relevance of this study is conditioned upon the wide spread of alternative energy sources around the world and in Ukraine, as well as the need for theoretical development and practical implementation of modern methods for establishing non-standard energy mechanisms in Ukraine and in the world. The main purpose of this study was to analyse key trends in the development of alternative energy in Ukraine and the world in the current socio-economic conditions. The methodological approach in this paper was based on a combination of quantitative and qualitative methods of research on issues related to the analysis of key growth vectors of non-standard methods of energy production in modern conditions. During this study, results were obtained that indicate the existence of a clearly structured interrelation between the degree of development of alternative energy sources and the types of fuel used in them, including the presence of prospects for the development of alternative energy sources in the conditions of modern Ukraine, provided the high-quality investment support for projects that are being implemented for the development of alternative energy. The results obtained in this study, as well as the conclusions formulated on their basis, are of significant practical importance for various branches of Ukrainian and world industry, the real technological capabilities of which allow the use of renewable energy sources for their ability to meet the life needs of all types of industrial enterprises, for their further full functioning and solving any technological problems facing these enterprises

Keywords: green energy, biofuels, renewable energy sources, energy consumption, economic development, environmental problems

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INTRODUCTION

Every year, "green" energy supplies an increasing part of the energy needs of the world's leading economies. At present, a new paradigm of world energy is being the developed, which entails the decisive contribution of renewable energy sources (RES) to the total energy consumption and the gradual displacement of conventional fossil energy resources. The category of non-conventional renewable energy sources (NRES), which are often called alternative, includes sources that have not yet become widespread in Ukraine and provide constant energy recovery due to natural processes. These are sources associated with natural processes in the lithosphere (geothermal energy), in the hydrosphere (diverse types of water energy), in the atmosphere (wind energy), in the biosphere (biomass energy), and in outer space (solar energy) [1].

The possibility of successful implementation and development of any technological innovation is determined mainly by a combination of several interrelated factors – these are real needs and opportunities to fully meet them. The energy-related issues only confirm the specified regularity. The situation on the global energy market is characterised by a gradual reduction of conventional energy resources, which indicates the need to find real alternatives, while the development of technological solutions contributes to the search for certain ways of using non-conventional raw materials for the production of energy that would be suitable for use. As a rule, this process involves certain costs for adapting equipment or transport to use this energy. However, the scale of production and use of alternative energy is not sufficient for full-scale replacement of conventional energy sources; qualitative characteristics of non-conventional energy sources also restrain this process [2]. At the same time, great attention should be paid to the quality of biofuel produced to meet the needs of non-conventional energy sources and their high-quality functioning, sufficient satisfaction of real economic needs.

There are many real problems of implementing alternative energy sources in various countries to meet the needs of industry and the residential sector. The expansion of the use of renewable sources of electric energy becomes possible due to significant technological advance in this area, which allowed reducing the cost of electricity production

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by wind and solar power plants of diverse types [3]. Global trends in the spread of alternative energy sources are based on numerous advantages of energy of this kind, namely considerably lower cost of obtaining alternative energy, practicality in using alternative energy generation plants, as well as relative ease of installation of power generation plants. Therewith, the environmental friendliness of alternative energy sources and the absence of harmful emissions into the environment during their use are not the least important. Together, these factors necessitate the development of specific measures to expand the practice of using renewable energy sources in various industries of modern developed countries of the world. In this context, the growth of investment in the development of renewable energy sources in the world is of primary importance. In almost any country, especially in countries with unstable economic conditions, the energy complex exists thanks to investment. An important role in the financing of RES projects is played by the so-called "clean energy funds", as well as modern development banks (namely, the European Investment Bank, the Brazilian BNDES bank, etc.), as well as crowdfunding formations (e.g., the largest crowdfunding platform for RES is the WindCentrale, located in the Netherlands) [3; 4]. This study aims to investigate the main prospects for the development of alternative energy in the world and in Ukraine, considering the investment allocated for the development of RES and with an assessment of the prospects for the development of RES in Ukraine and the world.

MATERIALS AND METHODS

The methodological approach in this paper was based on a combination of quantitative and qualitative methods of research on issues related to the analysis of key growth vectors of non-standard methods of energy production in modern conditions. During this study, key trends in the development of alternative energy in the world and in Ukraine were evaluated, with the provision of a classification of RES. The RES were classified using the system of ideas that has developed to date on the volume of use of alternative energy obtained from various sources, for which the method of comparative data analysis was used.

The conducted quantitative study includes the investigation of a considerable amount of data from several Ukrainian and foreign sources, containing the results of developments of modern authors who have studied numerous issues related to the introduction of alternative energy sources in various industries and in the domestic sphere. The obtained data created a basis for further analysis, with the identification of key growth patterns of non-standard methods of energy production in Ukraine and the world. The study was accompanied by the provision of significant amounts of graphical and statistical information presented in the corresponding tables. This contributed to the objective presentation of research data and obtaining results that efficiently reflect the issues under study [5]. The qualitative method of scientific research involves a systematic analysis of all gathered scientific information to build a clear, structured picture of the presented information. This makes provision for the analysis of information presented in the form of diagrams reflecting the main stages of research with the results obtained, which allows drawing systematic conclusions about the key growth trends of non-standard methods of energy production in modern Ukraine and in the world. Thus, the structural interrelationship of qualitative and quantitative methods of scientific research used in the analysis of the development of alternative energy sources allows forming a clear picture of the work performed on the data obtained during research, as well as to form objective conclusions based on them [6].

The methodology of this study makes provision for the breakdown of the results of scientific research into certain sections corresponding to specific stages of scientific research. Thus, the entire sequence of studies performed was presented as an accurate system for displaying the data obtained. Various aspects of the development of alternative energy complexes in the world and in Ukraine were highlighted, including the dynamics of investment injections in the development of alternative energy, including key aspects of biofuel production for alternative power plants and facilities. Such a model of constructing the methodology of scientific research can be effectively used in the future to conduct further scientific developments in the field of analysing the prospects for the development of RES in the world and in Ukraine.

RESULTS

1. Trends in the development of alternative energy in the world and Ukraine

Currently, non-conventional and renewable energy sources have become essential criteria for economic development and energy security of the world community. The search for new and improvement of existing technologies, their modernisation to a cost-effective level and expansion of application areas is constantly being carried out. The use of renewable energy sources is due to many factors, the main ones being as follows:

– preventing energy instability in countries and reducing dependence on energy imports;

– considerable amount of harmful emissions into the environment from the operation of conventional energy sources and the need to reduce them;

– saving and increasing energy reserves.

Hydroelectric power plants, geothermal, solar, thermal energy, energy from heat pumps, etc. should be considered renewable energy sources [7] (Fig. 1).

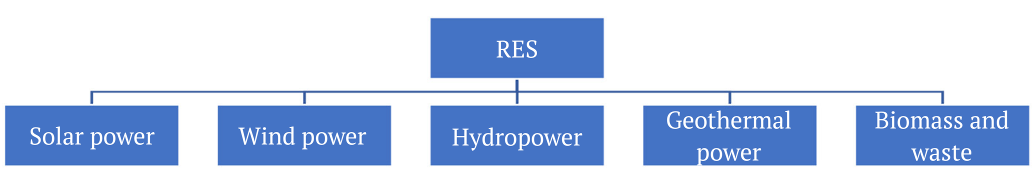

Figure 1. Classification of renewable energy sources

The RES share in the world's energy production is increasing every year, and their potential is several times higher than the level of global consumption of fuel and energy resources. The growth rate of energy production from non-conventional sources is also considerably higher than that of conventional types of energy. The rapid development of alternative energy is largely due to lower prices for equipment for solar and wind power plants, and a variety of biomass processing plants. The finding of significant amounts of investment infusions and, instead, the rapid development of alternative energy under the condition of a considerable decrease in the cost of the main energy carriers proves the need to gradually start the practice of using alternative energy sources in the world. The average annual investment growth in 2004-2016 was 12.5%. The absolute record was set in 2015, when the volume of investment in renewable energy sources amounted to 349 billion dollars at a time when world oil prices were almost at a historic low [8] (Fig. 2).

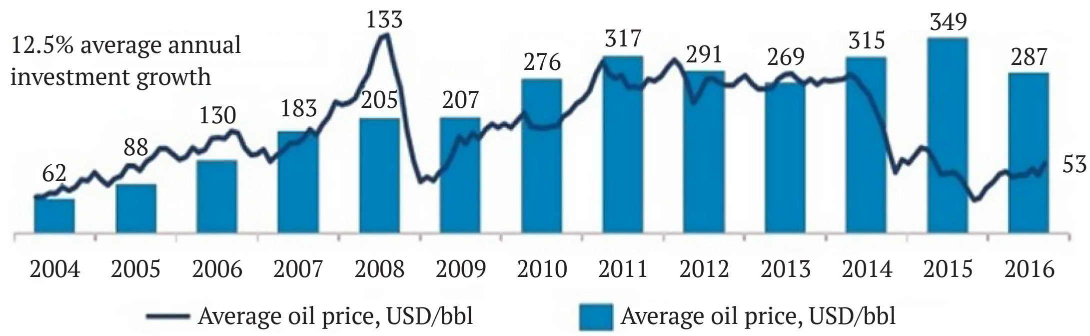

Figure 2. Dynamics of investment in renewable energy in the world

The contribution of renewable energy sources to the world's gross final energy consumption is about 18%, including biomass – 14%, or 76% of the total contribution of non-conventional energy sources (Fig. 3).

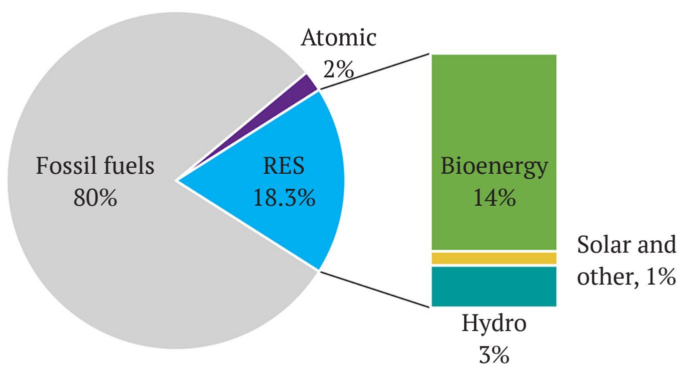

Figure 3. Structure of gross energy consumption in the world

The economic downturn in Ukraine in previous years was accompanied by high inflation and the crisis of the banking system, which created unfavourable conditions for the development of renewable energy in Ukraine. The economic situation in Ukraine has somewhat stabilised recently, and therefore the capacity of RES in Ukraine is growing every year (the decline in 2014 was associated with the loss of energy facilities in the Crimea and the ATO zone) [9] (Fig. 4).

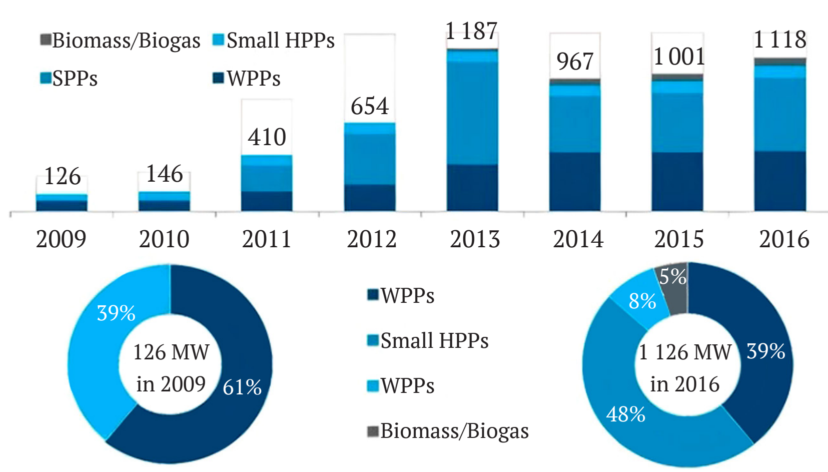

Figure 4. Capacity of renewable energy facilities in Ukraine

The average annual capacity parameter of RES in Ukraine is 31%. As of 01.01.2017, the capacity of alternative energy facilities operating in Ukraine under the "green tariff" was 1,117.7 MW. Bioenergy is one of the key RES sectors in Ukraine and the world.

2. Prospects for the development of bioenergy in Ukraine. Bioenergy is the production of energy from biomass of diverse types. Biomass is organic substances of plant (wood, straw, tree leaves, energy crops, and other plant residues of agricultural production) and animal (manure) origin. At present, technologies for processing biological raw materials are widely used to solve the problems of safe disposal of organic waste, reduce environmental pollution, and obtain alternative energy. The main trend of bioenergy lies in the search for the most effective technologies for the processing of organic waste with the utilisation of biomass due to methane fermentation with the production of biogas. For Ukraine, the use of biofuels is an effective way to get rid of external energy dependence (Fig. 5).

The main components of biomass potential in Ukraine are agricultural processing waste (straw, stems, leaves, manure, etc.) and energy crops (Table 1) [10].

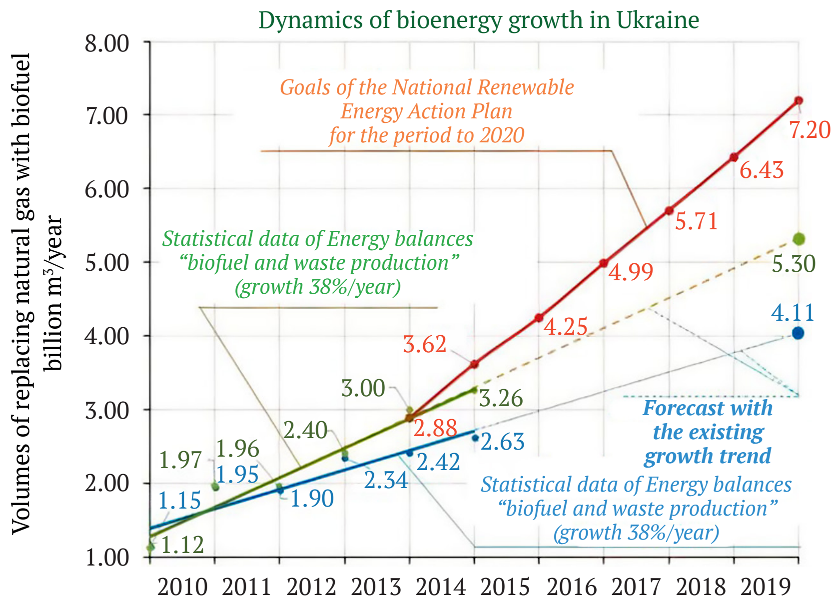

Figure 5. Growth dynamics of the bioenergy sector in Ukraine

Table 1. Energy potential of biomass in Ukraine

Type of biomass	Theoretical potential, million tonnes	Share available for energy, %	Economic potential, million tonnes of conventional fuel
Grain straw	35.1	30	5.22
Rapeseed straw	3.1	40	0.62
By-products of corn production for grain (stems, rods)	30.3	40	3.31
Sunflower by-products (stems, baskets)	21.2	40	1.74
Secondary agricultural waste (husk, pulp)	6.6	47	0.53
Wood biomass (firewood, felling residues, woodworking waste)	6.0	94	1.98
Wood biomass (dead wood, wood from forest belts, pruning of orchards and vineyards)	11.0	58	2.57
Biodiesel (from rapeseed)	–	–	0.27
Grain straw	36.2	35	6.77
Rapeseed straw	3.2	40	0.58
Corn production waste	32.4	35	3.45
Sunflower production waste	20.5	40	1.75
Secondary type waste	6.5	45	0.46
Wood biomass (firewood, felling residues, woodworking waste)	5.8	90	1.86
Wood biomass (dead wood, wood from forest belts, pruning of orchards and vineyards)	10.3	65	3.32
Biodiesel (rapeseed)	–	–	0.21
Bioethanol (corn and sugar beet)	–	–	0.63
Biogas from agricultural waste	1.4 billion m³	55	0.74
Biogas from landfills of household waste	0.4 billion m³	30	0.17

Table 1, Continued

Type of biomass	Theoretical potential, million tonnes	Share available for energy, %	Economic potential, million tonnes of conventional fuel
Industrial and municipal wastewater biogas	1.0 billion m^3	25	0.22
Energy crops:			
Poplar, willow, silvergrass	12.6	85	5.76
Peat	–	–	0.55
Corn (biogas)	2.8 billion m^3	85	2.89
Total	–	–	29.36

Source: [11]

Currently, Ukraine substantially falls behind European countries in the pace of bioenergy development. The percentage of biomass in total primary energy production in the state today is 1.2 %, and in gross current energy consumption – 1.78 %. Every year in Ukraine, about 2 million tonnes of biomass of various types are used for energy production. Therewith, the main contribution is made by wood – its share in the structure of annual biomass consumption is almost 80%. The energy potential of grain straw, fallen leaves, and rapeseed waste is least actively realised [12]. The main ways of obtaining energy from biomass are anaerobic fermentation, fermentation, combustion, hydrolysis, dry distillation, and gasification. The most promising and easy-to-use method is anaerobic fermentation, which produces biogas, and organic waste is a valuable biofertiliser when growing plants in agriculture. An analytical review of the literature sources suggests that biogas obtained during anaerobic fermentation of organic waste with the ability to recover is a highly efficient, non-conventional, and alternative energy source.

3. Anaerobic fermentation in biogas production. The technology of biogas production is relatively simple, energy-saving, economically feasible, and environmentally friendly. In organic waste, under certain conditions, biochemical processes called anaerobic fermentation (fermentation) begin. As a result of these processes, not only biogas is obtained, but also valuable concentrated organic fertilisers.

The main sources of biomass used for the production of biogas are as follows: 1) crop production: grass, straw, fallen leaves, organic waste from agricultural processing; 2) animal husbandry: cattle, pig breeding, poultry farming; 3) solid waste landfills; 4) wastewater treatment.

If necessary, the fermentation material should be conditionally divided into the main (the fermentation of which occurs without the inclusion of auxiliary components) and additional. The key fermentation material is manure, young grass, and waste from industrial fruit processing, organic waste, food residues, fats, molasses, organic products that decompose naturally (biologically), household waste, etc., play an additional role. The yield of biogas, depending on the type of substrate, is presented in Tables 2-7.

Table 2. Biogas yield (substrate-silage and energy crops)

Substrate	Dry matter, %	Organic dry matter, %	Biogas output m^3/t	Methane CH_4 %
Clover silage (1st mowing, beginning of flowering)	35.0	88.6	185.1	55.1
Corn silage	33.0	95.8	185.3	52.2
Grass silage	40.0	89.2	208.3	54.1
Millet, waxy ripeness phase	35.0	88.5	162.7	53.0
Sugar beet leaf silage	18.0	80.5	88.2	54.4
Grain silage (whole plant), full grain	42.0	94.2	214.1	52.1
Wheat silage (whole plant)	40.0	93.6	187.7	52.4
Red clover silage (1st mowing)	30.0	87.0	140.1	55.3

Source: [11]

Table 3. Biogas yield (substrate – root crops, grain, seeds)

Substrate	Dry matter, %	Organic dry matter, %	Biogas output m^3/t	Methane CH_4 %
Double row barley	87.0	97.2	578.5	52.7
Dry corn	87.0	98.3	590.3	52.8
Oats	87.0	96.7	501.1	54.1
Beet and molasses chips	89.6	92.0	569.0	51.9
Fresh sugar beet	23.0	91.9	147.1	50.8
Rye	87.0	97.8	597.0	52.0
Sunflower	88.0	96.6	594.5	63.5
Wheat	87.0	98.1	598.2	52.8
Peas	87.0	96.3	581.4	55.0
Rapeseed	88.0	95.5	644.5	65.7
Potato starch	83.6	99.5	605.6	50.0
Fresh potatoes	26.0	93.4	177.1	51.4

Source: [11]

Table 4. Biogas yield (substrate-vegetable crops)

Substrate	Dry matter, %	Organic dry matter, %	Biogas output m³/t	Methane CH_4 %
Vegetable waste	15.0	76.0	57.0	56.0
Onions	9.6	94.0	80.3	65.0
Onion peel	82.4	67.0	267.8	65.0
Carrot	11.9	88.3	73.3	52.0
Cauliflower	9.6	92.7	59.2	56.0
Fresh pumpkin	8.4	91.5	50.9	55.8

Source: [11]

Table 5. Biogas yield (substrate – fat, oil)

Substrate	Dry substances, %	Dry organic substances, %	Biogas output m³/t	Methane CH_4 %
Fat	95.0	92.0	874.0	68.0
Glycerin	100.0	99.5	845.7	50.0
Linseed oil	99.9	99.9	1222.6	68.0
Rapeseed oil	99.9	99.9	1197.6	68.0
Soybean oil	99.9	99.9	1222.6	68.0
Sunflower oil	99.9	99.9	1222.6	68.0

Source: [11]

Table 6. Biogas yield (substrate – livestock waste)

Substrate	Dry matter, %	Organic dry matter, %	Biogas output m³/t	Methane CH_4 %
Liquid pig manure	6.0	85.0	20.4	60.0
Pig manure with bedding	22.5	82.5	74.3	60.0
Liquid manure of fattening cattle	10.0	85.0	34.0	55.0
Fresh cow manure	25.0	80.0	90.0	50.0
Dairy cow manure	8.5	85.0	20.2	55.0
Manure of dairy cows with feeding residues	8.5	85.0	25.3	55.0
Horse manure	28.0	75.0	63.0	55.0
Chicken faeces, dry	40.0	75.0	80.0	55.0
Fresh chicken faeces	15.0	75.0	100.0	65.0

Source: [11]

Table 7. Biogas yield (substrate – food industry waste)

Substrate	Dry matter, %	Organic dry matter, %	Biogas output m³/t	Methane CH_4 %
Soybean husk	90.0	95.1	516.7	52.7
Potato spent wash, fresh	6.0	86.7	35.0	56.3
Oat flakes	91.0	98.1	619.7	53.5
Brewer's spent grain	24.0	95.5	122.2	59.3
Bran	89.0	86.5	262.4	50.7
Apple pulp	22.0	97.6	111.6	51.7
Soy flour	87.0	93.3	551.6	61.2
Wheat spent wash, liquid	6.0	94.0	36.1	58.9
Corn gluten	90.5	97.9	597.1	66.0
Lactose	100.0	99.7	756.0	50.0
Whole cow's milk	13.5	94.7	114.9	62.8
Brewer's yeast, boiled	10.0	91.8	60.7	62.1
Old bread	65.0	97.2	482.0	52.8
Bakery waste	87.7	97.1	650.6	52.8
Cheese factory waste	79.3	94.0	673.8	67.5
Low-fat, wet food waste	14.4	81.5	75.4	59.8
High-fat food waste	18.0	92.3	126.5	62.0
Various food wastes	40.0	50.0	120.0	60.0

Source: [11]

Having analysed the tables, it can be concluded that the main sources of biogas production are products and waste from crop and animal husbandry. As a result of the analysis of the literature review, it was established that due attention was not paid to the processing of waste of plant origin, namely the disposal of fallen leaves and dry grass.

I believe that the use of fallen leaves is a promising direction for the production of biogas [13].

Anaerobic fermentation for the production of biogas is a complex biotechnological process, which for the effective course of methane fermentation of organic substances requires the interaction and fulfilment of the following conditions: the appropriate temperature regime of the process, a slightly alkaline reaction of the medium, the presence of methane-forming bacteria, an oxygen-free environment. Anaerobic fermentation in a bioreactor is a complex process that is influenced by external and internal factors (Fig. 6).

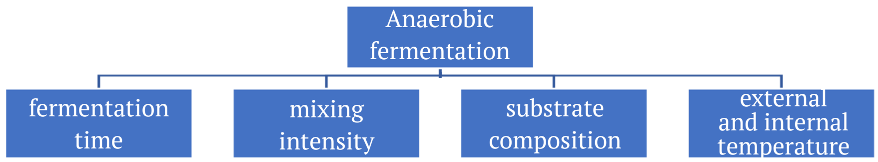

Figure 6. The main factors affecting the fermentation

One of the key factors of an effective fermentation process is the temperature regime of the fermenting biomass. In natural conditions, the production of biogas takes place at temperatures from 0°C to 97°C, but taking into account the process of optimizing the processing of organic waste for the production of biogas and biofertilisers, three temperature modes are distinguished: psychophilic temperature regime (20-25°C); mesophilic temperature regime (25-40°C); thermophilic temperature regime (more than 40°C) [11; 14; 15] (Table 8).

Table 8. C/N ratio of organic waste that can be raw material for obtaining biogas

Raw materials for biogas	Nitrogen, %	Carbon-nitrogen ratio, C/N
	Animal manure	
Cattle	1.7-1.8	16.6…25
Chicken	3.7… 6.3	7.3… 9.65
Horse	2.3	25
Pork	3.8	6.2… 12.5
Sheep's	3.8	33
	Farm waste	
Faeces	6…7.1	6…10
Kitchen waste	1.9	28.60
Potato skins	1.5	25
Cabbage	3.6	12.5
Tomatoes	3.3	12.5
	Plant dry waste	
Corn cobs	1.2	56.6
Grain straw	1.0	49.9
Wheat straw	0.5	100…150
Corn straw	0.8	50
Oat straw	N/A	50
Soybean	1.3	33
Alfalfa	2.8	16.6…17
Beet pulp	0.3…0.4	140…150
Other		
Grass	4	12
Sawdust	0.1	200…500
Fallen leaves	1.0	50

Source: [11]

Certain small particles, namely sand, clay, etc., collectively lead to the occurrence of sediment. In this case, the lightest materials end up on the surface of the raw material and create a hard film on its surface. This reduces gas formation, which is why plant residues should be thoroughly mixed before loading into the reactor: straw, grass, leaves, etc.

The humidity index of raw materials that appears in the reactor of the plant should not exceed 85% in winter and 92% in summer. To obtain the optimal humidity of raw materials, it is mixed with hot water in a volume determined by Formula (1):

$$OV = LF((B2 - B1) : (100 - B2)) \quad (1)$$

where LF is the amount of manure loaded, $B1$ is the primary humidity of manure, $B2$ is the expected humidity of raw materials, and OV is the total volume of water in litres.

The analysis of scientific and technical literature allowed determining the main conditions affecting the biogas production process, which requires improving the quality of equipment used to obtain the highest yield of biogas and improving the economic efficiency of converting biomass into organic fertilisers [16].

The process of processing organic substances into biogas is called methane fermentation. Its essence lies in anaerobic fermentation, which occurs due to the decomposition of biomass by bacteria (methanogens). There are 4 groups of bacteria involved in the formation of biogas. The metabolic products of each group of bacteria serve as nutrients for the next group. Bacteria of the first group convert organic compounds (protein, carbohydrates, fats) using enzymes into low-molecular compounds (amino acids, fatty acids, water). Next, acid-forming bacteria convert the above-mentioned low-molecular compounds into unstable fatty acids (acetic, formic, propionic), ethanol, carbon, and gases (carbon dioxide, hydrogen, hydrogen sulphide and ammonia). Water-producing bacteria handle converting higher fatty acids into vinegar and formic acids, carbon dioxide, and hydrogen. Microorganisms of the fourth group (methane-forming) process vinegar and formic acids into methane [17]. The process of anaerobic fermentation is accompanied by several biochemical reactions, and the process of biogas formation itself comprises three stages:

Stage I – hydrolysis – the decomposition of organic mass (2):

$$(C_6H_{10}O_5)n + nH_2O = nC_6H_{12}O_6; \quad (2)$$

Stage II – acetonogenesis – the reproduction of acid-forming bacteria (3):

$$6H_{12}O_6 + 2CH_0O = 2CH_3COOH + 4H_2 + 2CO_2, \quad (3)$$

Stage III – methanogenesis – the reproduction of methane-forming bacteria (4):

$$CH_0COOH = CH_4 + CO_2, 4H_2 + CO_2 = CH_4 + 2H_2O. \quad (4)$$

At the end of the process, thanks to bacteria capable of creating methane, methane, carbon dioxide and water appear from acetic and formic acids, carbon, and hydrogen. At the same time, 90% of the total volume of methane must be produced at this stage, and 70% of methane is produced using acetic acid. Methane-forming bacteria are completely anaerobic [18-20].

Thus, the process of anaerobic fermentation is influenced by four factors:

– biological: the composition of the fermented mass, the composition of the microflora, the living conditions of organisms;

– physical: fermentation temperature, pressure in the biogas plant, hydraulic mode;

– chemical: concentration, acidity of the medium, volume and composition of the resulting biogas;

– organisational and technological: volume of loading biomass, residual substances.

Consequently, the nature and quality of the course of biochemical reactions largely determine the final quality of the resulting biofuel, which affects the efficiency of its further use.

DISCUSSION

It should be clearly understood that 80% of all energy produced on Earth is obtained by burning something, mainly minerals. And they, according to various estimates of scientists, will not last long: oil for 30-50 years, gas for 50-70 years, coal for about 300 years. Admittedly, considering the constant development of mining technologies, these figures can be extended for several more decades, and in the case of coal, possibly for several hundred. Innovative technologies in energy production will also reduce resource costs. New deposits are found or data on old ones are updated, revealing that the new reserves are slightly higher than previously estimated. But still, this will not solve the problem of depletion of the Earth's interior and environmental pollution. A lot of work needs to be done to avoid an energy crisis. And big steps have already been taken towards a new era [21].

In connection with the approaching threat of depletion of global hydrocarbon reserves, the international expert society declared bioenergy as the main trend in the development of the fuel market, which should become the foundation of the beginning of a new era of energy. In the next 30-40 years, it is bioenergy that will dominate the development of the global energy supply system [22]. The use of biofuels from renewable raw materials can reduce the consumption of oil resources, improve fuel performance, reduce environmental pollution and solve the problem of greenhouse gas emissions. Today, biofuel has substantial advantages over other types of conventional fuel. These include the possibility of obtaining biofuels by processing plant products, which does not adversely impact the structural and chemical composition of soils in crop rotation systems, as well as considerably lower carbon dioxide emissions into the environment than from conventional types of fuels. Furthermore, biofuels practically do not contain sulphur, which distinguishes them favourably from mineral-type analogues, and there is no harm from biofuels when they get to various biological objects, which also distinguishes biofuels from motor fuel. In general, biofuels are subject to complete biological decomposition, which determines their complete environmental friendliness and safety of use compared to motor fuels.

There are considerable differences in the characteristics of biofuel preparation compared to conventional hydrogen liquid fuels, and the same can be said about the composition of these two types of fuels. Therefore, a crucial task is to identify the influence of the properties of biofuels on the final performance of the engines in which it is used (operational, economic, environmental). Furthermore, when preparing biofuels, the stages of its production should be considered, from loading raw materials to obtaining the end product. In this context, the development of biofuel production in any state, high-quality and consistent management of all such processes should be considered as the primary goal of national and international cooperation in the field of energy globalisation, involving all the potential opportunities of different countries. Renewable energy fuel production programmes are often considered as preparing the economy for a possible long-term shortage of hydrocarbons. The development of fuel production from renewable energy sources is determined by the tasks of Sustainable Rural Development – biologisation and greening of agricultural production, consolidation of the rural population and preservation of the rural lifestyle, including by stimulating the production of agricultural products for non-production purposes [23].

The effective fermentation in the bioreactor occurs thanks to maintaining a constant temperature in strict accordance with the established mode of anaerobic fermentation: mesophilic or thermophilic and regular mixing of biomass. Thermophilic bacteria do not have considerably higher productivity compared to mesophilic ones. This circumstance determines the fact that with the same volume of biogas production per day, fermentation tanks hold much less. At the same time, considering the need to support a higher parameter of the fermentation mass temperature, the total heat energy consumption during the implementation of thermophilic processes increases substantially. Due to the low ambient temperature and poor insulation of the tank, a lot of thermal energy is consumed, so biogas is not enough to heat the fermentation mass. That is why, in the climatic conditions of Eastern and Western Europe, the work of fermentation chambers is mostly carried out in the mesophilic range of temperatures. The thermophilic fermentation process has many advantages, which include a significant rate of decomposition of raw materials, a very high yield of biogas, and almost complete destruction of pathogenic bacteria present in the raw material. The disadvantages of thermophilic decomposition are a substantial amount of energy allocated for the preparation of raw materials in the reactor, high sensitivity of the fermentation process at all stages to the slightest fluctuations in temperature changes, as well as poor quality of final biological fertilisers. During the application of the mesophilic fermentation regime, it is possible to preserve the substantial amino acid composition of biological fertilisers; therewith, the period of anaerobic fermentation increases considerably.

A mandatory factor in ensuring the high-quality flow of biochemical processes in the methane tank is a slightly alkaline fermentation reaction, while the 6-8 pH is considered satisfactory (the optimal value is set as 7-7.5 pH). A highly alkaline reaction leads to the undesirable appearance of hydrogen sulphide. In an environment of increased acidity (during fermentation of household waste, pig excrement), methane fermentation can be stopped in the absence of biogas release. One can set the real level of acid-alkaline balance with litmus paper. Its value will correspond to the colour that the paper acquires when it is immersed in fermentation raw materials. Another important factor affecting methane fermentation is the concentration of carbon and nitrogen in raw materials. If the C/N ratio is significant enough, then insufficient nitrogen will be a factor that can considerably limit the entire course of methane fermentation. If the specified concentration is insignificant, then a significant amount of ammonia is formed, which becomes toxic to bacteria. Numerous scientific experiments suggest that the highest yield of biogas when the ratio of carbon and nitrogen is reached in the range of 10-20, the optimal value may be due to the final type of raw material. To achieve high-quality biogas, it is necessary to mix raw materials until the desired C/N ratio is obtained. For the growth and vital activity of methane bacteria, the presence of organic and mineral nutrients in raw materials is necessary. The composition of carbon and hydrogen, the formation of biological fertilisers, requires a large amount of nitrogen, sulphur, phosphorus, potassium, calcium and magnesium, as well as certain trace elements – iron, manganese, molybdenum, zinc, cobalt, nickel, etc. Organic raw materials, namely animal manure, contain a sufficient amount of the above-mentioned elements [18; 20]. High-quality metabolism in raw materials is a mandatory factor for increased bacterial motility. This can only be achieved if the viscosity of the raw material is sufficient for the free movement of bacteria and gas bubbles between the liquid and the solids present in the raw material.

At the initial stage of anaerobic fermentation, hydrolysed bacteria decompose high-molecular compounds with the involvement of enzymes into low-molecular formations. Polymers (the formation of many molecules) gradually become one-dimensional (individual molecules). This process, called hydrolysis, proceeds slowly and is caused by the presence of extracellular enzymes, namely amylases, proteases, lipases, etc. The hydrolysis process will be affected by the pH level and time spent in the bioreactor.

At the stage of acetogenesis, acid-forming bacteria are engaged in uncoupling. This stage of methane fermentation is called the "oxidation phase", in which the pH level decreases. Some molecules end up in bacterial cells, where their breakdown continues [22]. This process also involves aerobic bacteria that need oxygen residues, while creating the necessary anaerobic conditions for methane bacteria, and partially anaerobic bacteria. At this stage, unstable fatty acids (acetic, formic, butyric, propionic), low-molecular alcohols (ethanol, methanol), carbon and gases – carbon dioxide, hydrogen, hydrogen sulphide and ammonia – are produced. Next, water-producing bacteria from organic fatty acids form products to produce methane: acetic and formic acids, carbon dioxide, hydrogen. Microorganisms that reduce the volume of carbon (in the composition of organic acids) are extremely sensitive to changes in temperature conditions.

To date, many developed countries have already appreciated the great prospects that open up in obtaining motor fuel produced from renewable raw materials [22]. The result was an increase in the share of the United States, as well as several European Union states, in the world production of biotechnological products, which largely determined the prospects for the development of alternative energy in these countries. The relevance of the energy issue for the countries taking part in the global energy market is explained by its tension today and even more so in the future. Scientists find new ways of obtaining energy and improving already known extraction methods, politicians develop strategic plans for the large-scale implementation of achievements, economists calculate the effectiveness of projects and measures to save energy and increase energy efficiency, ecologists determine the ecological effect of preserving the share of natural renewable resources and reducing the level of environmental pollution environment In this case, all subjects interact in a certain way [18]. The effectiveness of the mechanism of this interaction obviously affects the quality of results and the speed of their achievement.

There are about several dozen countries in the world whose share of renewable energy sources in the total energy balance exceeds 25 % [24]. Among them are such countries as Iceland, Norway, Scotland, Denmark, Germany, and some other countries. According to the energy strategy adopted in the European Commonwealth, by 2020, the member states of this Commonwealth should ensure a 20% reduction in greenhouse gas emissions, an increase in the share of renewable energy to 20% and a 20% increase in energy efficiency. In the longer term, many countries will go much further. In particular, Germany plans to achieve a 60% share of renewable energy sources in the country's total energy balance and 80% in electricity production by 2050. The development of the modern renewable energy sector is taking place in the context of crisis phenomena in the global economy, although today this energy is one of the main ways to overcome the current economic crisis. Since 2015, wind power has occupied one of the leading positions in terms of capacity and volume of use of wind turbines in the world, which largely determined the possibilities of developing wind energy in the long term. Furthermore, the considerable growth rate of RES production was largely conditioned upon the massive support from the state. It allows some individual countries to produce and implement renewable energy, even in cases where key economic indicators are more than 50% worse than when using minerals and fuel resources.

CONCLUSIONS

Having analysed the energy potential of biomass in Ukraine, the main sources of biogas production are the products and wastes of plant and animal husbandry. As a result of the analysis of the literature review, it was established that the problems of the rational use of livestock waste were considered in many scientific papers. Along with this, due attention is not paid to the processing of waste of plant origin, namely the disposal of fallen leaves and dry grass. According to the authors, the use of fallen leaves is a promising area, and the raw material base itself is not sufficiently involved.

In the autumn, an environmental problem in the cities of Ukraine is the disposal of fallen leaves. The most common methods of disposal of fallen leaves in Ukraine are, at best, removal to landfills of solid household waste; in the worst-case scenario, it is incineration, which leads to atmospheric pollution and is prohibited by law. Removal of leaves to landfills requires significant costs, and upon incineration, harmful substances are released (nitrogen oxide, carbon monoxide, benzopyrene and formaldehydes, etc.). Therefore, the most appropriate solution to the problem of disposing of fallen leaves is biological destruction under anaerobic conditions. This method of disposal of fallen leaves is not only ecological, but also economically viable, since biogas produced during methane fermentation can be used as an alternative source of energy, and fermentation waste can be used as a valuable biological fertiliser.

The analysis of scientific and technical literature allowed finding the main factors influencing the anaerobic fermentation in the production of biogas from fallen leaves, which requires technological improvement of equipment to ensure maximum biogas yield and justify the economic efficiency of processing organic waste into biogas and organic fertilisers. Having considered modern designs of gas bioreactors, it can be concluded that the main criteria for choosing a methane tank for the disposal of fallen leaves are the possibility of its practical use, economic feasibility, and convenience of its maintenance upon operation. For obtaining biogas from fallen leaves, the most optimal design is an egg-shaped bioreactor. Its shape allows reducing hydraulic resistance upon mixing raw materials and avoiding stagnant zones due to the lack of corners in its design. To achieve high efficiency of the bioreactor and obtain the maximum amount of biogas per unit volume of biomass (fallen leaves), it is necessary to create optimal technological parameters in the bioreactor. Their formation is affected by the mixing and heating system of the substrate. When choosing a mixing system, it is necessary to consider its effect on the rate of methane formation and the fermentation time of biomass in the methane tank. An important aspect of the stability of the thermal regime in methane tanks is the heating of biomass and simultaneous thermal insulation of the bioreactor walls to reduce the impact of ambient temperature fluctuations.

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Розвиток альтернативної енергетики у світі та Україні

Анотація. Актуальність наукового дослідження зумовлена широким поширенням практики застосування установок альтернативної енергетики у масштабах усього світу загалом та України зокрема, а також необхідністю теоретичної розробки та практичного впровадження сучасних методик налагодження механізмів нестандартної енергетики в Україні та в світі. Головною метою цього дослідження є аналіз ключових тенденцій розвитку альтернативної енергетики в Україні та світі у сформованих на сьогоднішній день соціально-економічних умовах. Основу методологічного підходу у цій науково-дослідній роботі становить поєднання кількісного та якісного методів досліджень питань, пов'язаних з аналізом ключових напрямів росту нестандартних методів отримання енергії у сучасних умовах. У ході виконання даної науково-дослідної роботи було отримано результати, що свідчать про наявність чітко структурованого взаємозв'язку між ступенем розвитку альтернативних джерел енергії та типами використовуваного в них палива, а також про наявність значних перспектив розвитку альтернативних джерел енергії в умовах сучасної України за умови якісного інвестиційного забезпечення проектів, що реалізуються, з розвитку альтернативної енергетики. Результати, отримані в ході даного наукового дослідження, а також сформульовані на їх основі висновки, мають значне практичне значення для різних галузей української та світової промисловості, реальні технологічні можливості яких допускають використання відновлюваних джерел енергії для їх здатності відповідати потребам життєдіяльності всіх типів промислових підприємств, для їхнього подальшого повноцінного функціонування та вирішення будь-яких технологічних завдань, що стоять перед даними підприємствами

Ключові слова: «зелена» енергетика, біопаливо, відновлювані джерела енергії, енергоспоживання, економічний розвиток, екологічні проблеми