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ISBN 979-8-89269-755-2
DOI 10.46299/979-8-89269-755-2

Kupchuk I., Yemchyk T., Gontaruk Ya., Tarasova O., Shevchuk H., Okhota Yu.

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Monograph

2023

UDC 620.92

Author's:

Kupchuk Ihor – Candidate of technical sciences, Associate Professor, Vinnytsia National Agrarian University, Ukraine. ORCID: https://orcid.org0000-0002-2973-6914

Yemchyk Tetiana – Candidate of Economics Sciences, Associate Professor, Vinnytsia National Agrarian University, Ukraine. ORCID: https://orcid.org/0000-0001-6998-4325

Gontaruk Yaroslav – Candidate of Economics Sciences, Associate Professor, Vinnytsia National Agrarian University, Ukraine. ORCID: https://orcid.org/0000-0002-7616-9422

Tarasova Oksana – Postgraduate Student, Vinnytsia National Agrarian University, Ukraine ORCID: https://orcid.org/id-0000-0001-5397-8449

Shevchuk Hanna – Candidate of Economics Sciences, Senior Lecturer, Vinnytsia National Agrarian University, Ukraine. ORCID: http://orcid.org/0000-0001-6094-0414

Okhota Yuliia – PhD in Economics, Assistant, Vinnytsia National Agrarian University, Vinnytsia, Ukraine. ORCID: http://orcid.org/0000-0001-9943-2206

Editor:

Kupchuk Ihor – Candidate of technical sciences, Associate Professor, Vinnytsia National Agrarian University, Ukraine. ORCID: https://orcid.org0000-0002-2973-6914

Library of Congress Cataloging-in-Publication Data

ISBN – 979-8-89269-755-2
DOI – 10.46299/979-8-89269-755-2

UDC 620.92

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ABSTRACT

Energy production from renewable resources is currently one of the main topics discussed both in Europe and around the world. While the prospects for the production of both bioethanol and biodiesel are controversial, and the costs of their production are significant, the number of biogas production enterprises in the EU has been steadily increasing in recent years. Bioenergetics defines the use of biomass energy, namely organic matter, which is formed by photosynthesis. "Green fuel" is sometimes called fuel that is made from plants, the raw material for obtaining which is biomass. However, the more bioenergy is discussed, the more the concept of "biofuel" means liquid biofuels, namely biodiesel, bioethanol, methanol, and forget about solid and gaseous ones, which include biogas, synthesis gas, household and agricultural waste, as well as residues from wood processing.

Despite the significant scientific contribution of domestic and foreign authors to the solution of the mentioned problems, questions remain open regarding the definition of the essence, formation and implementation of biofuel production, which can be used for further research, that is, the transformation of external and internal possibilities aimed at the production of biofuels agribusiness enterprises. Therefore, we consider it necessary to reconsider the existing developments and developments, as well as to offer our vision of solving the above problems.

The volume of gas oil consumption in the state and scientific approaches to stimulating the development of biodiesel production were studied. The volume of rapeseed production was studied and the inexpediency of exporting this crop and oil products in full was determined. The leading technologies of biodiesel production were studied and their economic feasibility was substantiated. It was established that the organization of biodiesel production on the basis of medium-sized agricultural enterprises will provide an opportunity to: maximally satisfy the needs of this sector of the economy in fuel for machinery; to ensure the development of related industries, including animal husbandry. It was determined that, based on today's economic and social realities, the most rational is the creation of small processing enterprises with

partial compensation for the cost of appropriate domestically produced equipment for the production of biodiesel. The directions for the development of biodiesel production as a way to ensure food security of Ukraine are defined, which consist in limiting the export of rapeseed, developing a model of public-private partnership in the field of improving the technologies of rapeseed cultivation and its further processing.

It was determined that the most promising crops for the production of biofuels based on the available production potential are rapeseed, corn and switchgrass. The development of production technology based on an ecologically efficient approach will make it possible to increase the yield of these crops and their energy efficiency.

It was determined that corn and rapeseed are potential bioenergy crops that can be used for the production of liquid biofuels. In order to increase the economic efficiency of growing these crops and reduce crop losses, it is necessary to improve the technological methods of growing, using the rationalization of work, new varieties (hybrids) of seeds with high resistance to adverse conditions and an integrated system of protection against pests and diseases. Also identified are the main obstacles to the development of biofuel production and potential ways of forming Ukraine's energy independence.

As a result of the study, it was established that pre-sowing tillage with rolling is an effective way to improve the yield of dry biomass and has a positive effect on the height of plants and the number of stalks of millet for both experimental varieties "Cave-in-rock" and "Sarthage". An increase in the linear diameters of the plant height and an increase in the density of planting contributes to an increase in productivity. These results can be useful for improving the technologies of growing millet and increasing the efficiency of agrobiomass production to meet the needs of the agro-industrial complex in fuel energy resources. It is important to take into account the influence of varietal characteristics on the height and number of plant stems, which ultimately are the main factors in yield formation. In addition, other factors must be considered, such as weather conditions and applied fertilizers, which also have an impact on biomass yield.

According to the results of the research carried out on the basis of Agronomichne

State Agricultural Research and Development Company, it can be concluded that the rapeseed hybrid "Persei" is better for use in the production technology of biodiesel fuel, compared to the hybrid "Lagonda". It was established that the "Persei" hybrid has the highest oil content when fertilizers are applied at the level of N188P98K188 with the sowing date from August 24 to September 4 and additional feeding with digestate. In addition, the analysis of the fatty acid composition of methyl esters of rapeseed oil produced from the seeds of the Perseus hybrid showed that the high content of methyl ester of oleic acid allows its use as biodiesel fuel. The value of the lower heat of combustion of methyl esters of rapeseed oil, made from the seeds of the hybrid "Persei", also confirms the high energy efficiency of this biofuel, compared to the hybrid "Lagonda".

Studies have proven the prospects of using rod-shaped millet for the production of solid biofuel. A high yield of dry biomass and yield of solid fuel is observed when applying pre-sowing tillage with the use of 2 cultivations. The variety "Cave-in-rock" showed a higher energy value compared to the variety "Sarthage" and has a better yield of dry biomass.

The monograph was written as part of the implementation of the state theme on the basis of the Vinnytsia National Agrarian University Development of scientific and technical support of energy autonomy of agro-industrial complex on the basis of ecologically efficient use of agrobiomass for biofuel production. State registration number: 0122U000844.

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1. Scientific and theoretical principles of management of growing of agricultural crops for the production of biofuels

In today's world, more and more attention is paid to the development of alternative renewable energy sources, since the raw material reserves of fossil fuels tend to be depleted, and their price periodically increases. Therefore, renewable energy sources are currently of particular interest not only from the point of view of their use, but also from the point of view of the economic feasibility of developing new areas of business and its diversification.

It has been established that the organization of production of raw materials for biofuel is one of the most important factors in increasing its efficiency. In fig. 1.1 shows the interrelationships of organizational factors due to which it is possible to increase the efficiency of the biofuel raw material base.

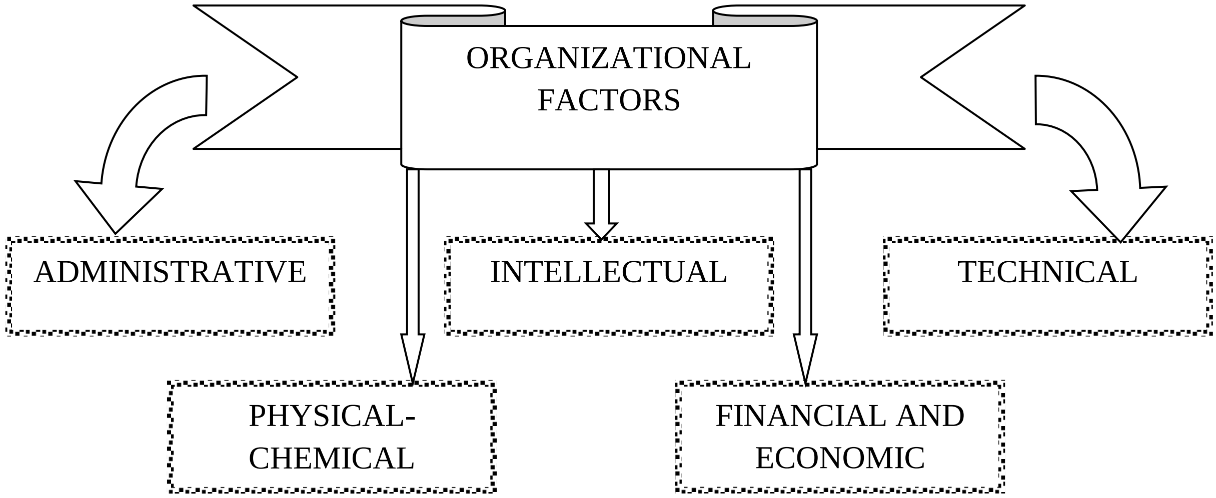

Fig. 1.1. A system of organizational factors for increasing the production efficiency of the raw material base for biofuel

Source: systematized by the author based on [1-5]

To characterize the potential of agricultural enterprises for the production of biofuel, a mixed method of scientific research (Mixed Method Research - MMR) was used based on a questionnaire, as well as content analysis of the received data.

The mixed method of scientific research is a growing field of scientific methodology used by many scientists and researchers from various fields of knowledge [11, p. 810].

According to research data on scientific publications in the most cited international journals devoted to social and behavioral sciences [1, p. 105, 8, p. 4], 77% of all sociological studies were conducted within the framework of a quantitative approach. Of these, 71% are correlational studies or studies devoted to the study of connections between social phenomena. The simplest type of correlational research is the study of paired relationships or joint variability of two variables. This kind of research is suitable for solving two scientific problems:

– evidence of the existence of a cause-and-effect relationship between variables (the presence of a relationship is an important, but not the only, condition of cause-and-effect dependence);

– prediction: if there is a relationship between variables, it is possible to predict the value of one variable with a certain level of accuracy, if we know the value of the other.

A mixed method of scientific research (Mixed Method Research - MMR) was used to determine the goals of forming the marketing policy of agricultural enterprises for the production of biofuels based on questionnaires and statistical processing of the results using correlation analysis, as well as content analysis of the obtained data.

The mixed method of scientific research is a growing field of scientific methodology used by many scientists and researchers from various fields of knowledge [11, p. 812].

Thus, the method of collecting primary information was used to carry out the research - a survey (questionnaire) using open questions and closed questions for choosing answer options from the listed ones. Type of questionnaire - online questionnaire. The methods of processing the received data are content analysis.

The survey was carried out by filling out an electronic form on the Survio resource [1-14].

To carry out the questionnaire, a direct link to the questionnaire was sent to the e-mail addresses of agricultural enterprises. This made it possible to collect data from an experimental group of representatives of agricultural enterprises of different sizes and forms of ownership.

The total number of visits to the questionnaire was 75. The total share of filling the questionnaire among visitors was 10.7%. 75% of respondents spent 10 to 30 minutes filling out the questionnaire.

The questionnaire contains the title ("Analysis of the potential, awareness and current state of the use of agricultural waste to ensure the energy autonomy of agricultural enterprises"), the address and 53 questions, divided into 5 meaningful blocks:

(1) a general block intended for establishing the name and location of the enterprise, collecting information about the manager (age, gender, education, work experience in the agricultural sector, work experience in a managerial position); collection of information about the economic activity of the enterprise;

(2) awareness in the field of production and use of biofuel, which is intended to establish the fact of the existence of knowledge about the Law of Ukraine "On Alternative Fuels", "green tariff", the possibility of exemption from import duty and VAT in the production of biofuel, exemption from taxation of profit from sales biofuels, types of biofuels, possibilities of their production by agricultural enterprises, possibilities of obtaining loans on preferential terms and sources of obtaining information about various aspects of production, use and sale of biofuels;

(3) the potential of the enterprise in relation to the production and use of biofuel, which is intended to establish the fact of the cultivation of plant and animal products by agricultural enterprises, the types of waste produced in the course of the economic activity of the agricultural enterprise, the directions of waste use, as well as to establish the presence in the agricultural enterprise of sub- objects of creation of innovations, intellectual property for the production of biofuel and free funds for investing in innovations;

(4) implementation by the enterprise of production and use of biofuel, which is intended to establish the state of implementation of biofuel production in an agricultural enterprise, technology of straw baling and its subsequent burning,

production of solid biofuel, technology of anaerobic digestion of waste with biogas production;

(5) the readiness of the enterprise to produce and use biofuel, which is intended to establish the state of readiness of the agricultural enterprise to invest in the production of biofuel, cooperation with the subjects of the organization of biofuel production, the conclusion of business contracts, license agreements, and the improvement of the qualifications of employees in the field of bioenergy.

Proposed hypotheses.

Agricultural enterprises spend a lot of money on the purchase of fuel and energy resources, which affects the cost of final products.

Agricultural enterprises have a significant potential for crop production waste and livestock by-products for biofuel production.

The bioenergy potential of agar enterprises is represented by the raw material component

(waste that can be used for biofuel production).

The available raw material bioenergy potential is practically not used.

Awareness of the potential for waste-based biofuel production is low; it is somewhat higher among managers under the age of 45 and with higher education.

The main source of obtaining information about the possibilities of energy use of waste is the mass media.

Managers of the enterprise have practically no information about state support for bioproduction (legislative acts, support programs, tax and other benefits, "green tariff", possibilities of using credit support from international financial organizations).

To confirm the proposed hypotheses, the questionnaire includes questions, the answers to which can serve as a basis for the formation of a clear understanding of the state of the investigated problem and are capable of confirming or refuting these hypotheses. Also, some questions that correspond to the proposed hypotheses at this stage of the research contain signal variants of answers, the choice of which by the managers of the investigated agricultural enterprises indicates the need for further research in a certain direction.

Content analysis cannot be considered a complete analysis of the received data. After it is determined that a certain indicator is of scientific or practical interest, it is necessary to check it for statistical significance, since establishing the significance of the indicator on the basis of content analysis in the experimental group does not mean its significance in the general population. Such tasks are solved using methods of statistical inference, which form the basis of further research in the field of determining the potential of agricultural enterprises for the production of biofuel.

According to the results of the research, it was established that 88% of the investigated enterprises grow grain, legumes and seeds, and 12% carry out mixed agricultural activities.

According to the survey results, 87.5% of surveyed agricultural enterprises use cereal straw for plowing, 25% - use cereal straw as bedding, 12.5%

- grain straw is used for baling and 12.5% - for the production of briquettes and pellets. Sunflower and corn waste at the studied agricultural enterprises is used for plowing (75%), for the production of briquettes and pellets (25%), for burning in the fields (12.5%) and as litter (12.5%). 62.5% of investigated agricultural enterprises use leguminous waste for plowing, 12.5% - for burning in the fields, for baling and burning in boilers, and for the production of briquettes and pellets. Garden trimmings are used by 37.5% of surveyed agricultural enterprises for burning on the ground and for burning in boilers, 12.5% - for the production of briquettes and pellets and for other purposes (without specifying the method of use). 62.5% of those agricultural enterprises producing by-products of animal husbandry use manure for spreading on fields, 37% - for storage in banks with further use as fertilizers, 37% - for other purposes (without specifying the method of use). In further work, to improve the quality of the analysis, it is planned to specify the ways of using waste generated by agricultural enterprises.

Among the managers of the surveyed agricultural enterprises, 57.1% reported readiness to invest in innovation, and 25% reported the presence of a specialized innovation department or a person responsible for innovation activity.

62.5% of managers of the investigated enterprises report knowledge of the advantages of different types of biofuel. 75% of the managers of the studied enterprises know about the possibilities of agricultural enterprises for the production of biofuel.

At the same time, only 75% of managers of the investigated enterprises declare their knowledge of the Law of Ukraine "On Alternative Fuels" (No. 1391-VI dated 05/21/2009). Have information about the "Green" tariff (which is established in accordance with the Law of Ukraine "On Alternative Energy Sources" No. 555-IV of 20.02.2003 and the Law of Ukraine "On Amendments to Article 91 of the Law of Ukraine "On Alternative Energy Sources" regarding the regulation of the issue of electricity generation of energy by private households" No. 2755-VIII dated 11.07.2019) 87.5% of managers of the surveyed enterprises. 62.5% of the managers of the investigated enterprises have information about benefits for the import of energy-efficient equipment in the form of exemption from import duty and VAT when importing equipment for the production of biofuel. Only half of the managers of the surveyed enterprises know about the stimulation of the use of renewable energy sources and alternative fuels in the form of exemption from taxation of profit received from the sale of biofuel and profit received from the activity of simultaneous production of electricity and thermal energy and production of thermal energy using biological types of fuel. Only 25% of the managers of the investigated enterprises know about the possibility of obtaining loans on preferential terms for the organization of biofuel production from international financial organizations.

It should be noted that the most popular source of information about biofuels was recognized by 50% of the managers of the studied enterprises as universities, 25% of the managers of the studied enterprises receive information about biofuel from acquaintances/colleagues, and 12.5% of the managers of the studied enterprises receive information about biofuel from mass media and on sites of bioenergy associations and/or manufacturers of bioenergy equipment.

None of the managers of the investigated agricultural enterprises reported the availability of intellectual property for the production of biofuel. This makes it impossible to study the relationship between the availability of intellectual property for biofuel production in the studied agricultural enterprises with other indicators of the potential for biofuel production and use.

According to the results of the questionnaire, none of the managers interviewed confirmed that biofuel production was introduced at his agricultural enterprise. At the same time, in 50% of the investigated agricultural enterprises, straw is baled and then burned

Hypothesis 1 is partially confirmed. 75% of the agricultural enterprises of the experimental group reported spending from 15% to 25% on the purchase of fuel and energy resources.

Hypothesis 2 is partially confirmed. According to the data, agricultural enterprises of the experimental group have a significant potential of plant waste and animal by-products for the production of biofuel.

Hypothesis 3 is confirmed. All agricultural enterprises of the experimental group reported the creation of various crop and livestock wastes as a result of their main activity.

Hypothesis 4 is rejected. The proposed hypothesis in terms of specifying the target use of waste generated in agricultural enterprises in the field of bioenergy requires clarification.

Hypothesis 5 is rejected. More than 60% of managers of agricultural enterprises of the experimental group reported knowledge about types of biofuels and their advantages over traditional types of fuel, 75% of managers have knowledge about types of biofuels that can be created in the agricultural sector, as well as about which of them can be produced by agricultural enterprises.

Hypothesis 6 is rejected. The main source of obtaining information about the possibilities of energy use of waste was recognized by the heads of agricultural enterprises of the experimental group as universities (50% of responses) and colleagues (25% of responses). Mass media recognized only 12.5% of managers as the main source of knowledge about biofuels.

Hypothesis 7 is rejected. The vast majority of managers of agricultural enterprises of the experimental group reported that they have information about legislative acts, support programs, the "green tariff", and 25% of the interviewed managers report knowledge of the possibilities of using credit support from international financial organizations in the field of bioproduction.

The answers of the managers of the investigated enterprises are contradictory in that some enterprises actually produce biofuel, but this is not reported directly. This may be related to the poor understanding of the managers of the investigated enterprises of the processes and technologies related to biofuel production.

The costs of agricultural enterprises for fuel and energy resources remain quite high. At the same time, in agricultural enterprises, as a result of the main type of activity, various plant and animal wastes are created, which have a significant potential for biofuel production.

The majority of managers of the investigated enterprises report that they have knowledge of the advantages of different types of biofuels. The vast majority of managers of the surveyed enterprises report knowledge of the Law of Ukraine "On Alternative Fuels" (No. 1391-VI dated 21.05.2009), the "Green" tariff, information on benefits for the import of energy-efficient equipment in the form of exemption from import duty and VAT at import of equipment for biofuel production. No more than a quarter of respondents know about encouraging the use of renewable energy sources and alternative types of fuel, about the possibility of obtaining loans on preferential terms for the organization of biofuel production from international financial organizations. The most significant contribution to the formation of knowledge in the field of biofuels has higher education and communications in the field of business. At the same time, Internet sources are not particularly popular among the managers of the studied agricultural enterprises.

Further research is needed to determine the sources of animal manure at agricultural enterprises (own creation, purchase, other), as well as to form a sample with the inclusion of enterprises engaged in the cultivation of livestock products to establish the types of the most common types of by-products and directions of use of animal manure. Further research is needed to establish the level of existing knowledge and the ability to apply it in domestic agricultural enterprises.

In further studies, it is planned to expand the geography of the survey, create a representative sample, clarify hypotheses, verify them, and establish a correlation between various indicators of the potential for biofuel production and use.

One of the important factors that is part of the financial and economic complex at the enterprise level is budgeting. It was found that the importance of the budgeting process when growing raw materials for biofuel is an indisputable fact, since a correctly developed budget is the basis for further production. It is noted that the budget for a separate crop is relevant, in particular for rapeseed, corn for grain, wheat, as one of the most promising raw material sources for the production of biodiesel and bioethanol, respectively.

The work substantiates the effect of price factors on the efficiency of growing winter rapeseed, winter wheat and corn for grain. It is noted that environmental factors have a significant impact on the efficiency of production of raw materials for biofuel. Unlike the factors of the internal environment, where efficiency is achieved mainly by reducing the cost of production, in the external environment it can be both price changes and global trends in agricultural markets, which ultimately affect the formation of prices for raw materials.

Agriculture of Ukraine plays a leading role in ensuring food and energy security of the country due to its bioenergy potential. Although having a significant available biomass of agricultural production, the agricultural sector of the country demonstrates the slow development of enterprises and the production of final products - biofuel. The use of the bioenergy potential of agriculture is considered one of the constituent elements of the sustainable development strategy.

Raw materials for the production of bioethanol can be sugar- and starch-containing plants or lignocellulosic biomass [19]. In global practice, the bioethanol market is formed based on the use of the following energy crops: sugar cane, corn, wheat, rye, barley, sugar beets, sugar sorghum, Jerusalem artichoke, cassava, sweet potatoes, and potatoes (Fig. 1.2).

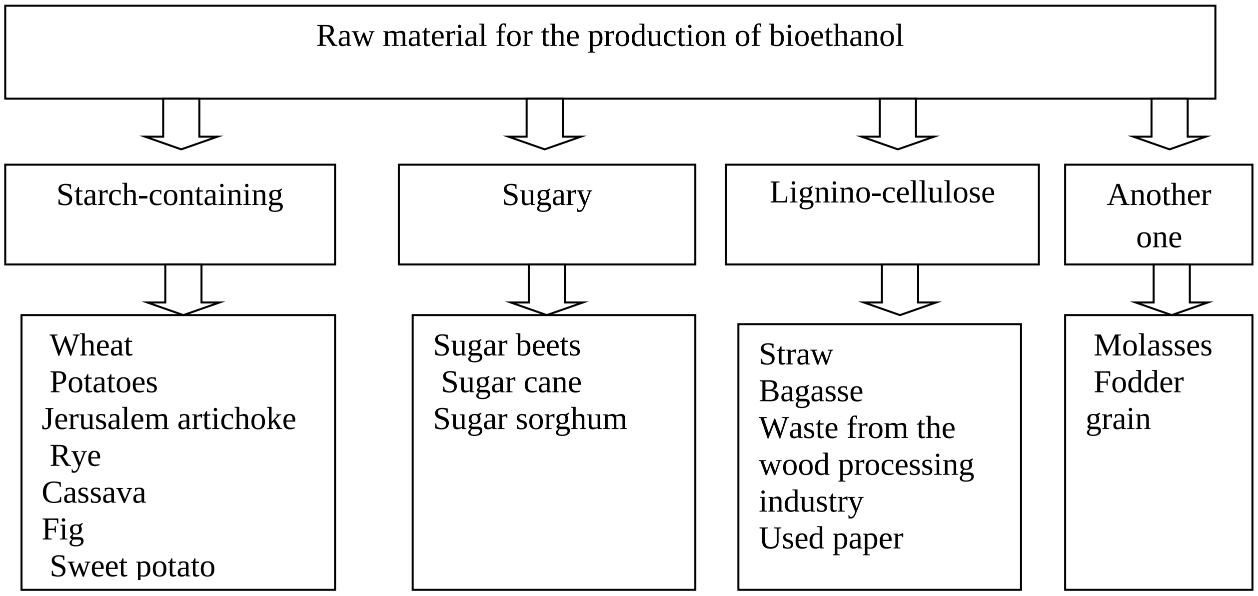

Fig. 1.2. Types of raw materials for bioethanol production*

Source: created by the authors based on the studied literature

In turn, the introduction of intensive energy-saving and waste-free technologies into the country's economy, the rational and effective use of bioresource potential will require the implementation of a complex of technical and technological measures and the use of a system of state mechanisms that ensures the growth of their role in the country. After all, the harmonious development of the economy is impossible without energy provision, which requires the formation of a complementary economic policy in the field of energy.

Therefore, the main factors that encourage the world community to produce biofuels are price and environmental. Since the most important and valuable feature of biofuel is its renewable nature, which creates opportunities for the agricultural sector to act as their producer and consumer.

In particular, one of the main and priority tasks in the country's energy management system for its further development is the development and implementation of a policy to fully meet the existing needs of Ukraine in fuel and energy resources under the conditions of compliance with the requirements of their rational use.

The main requirements for raw materials for the production of bioethanol are:

low cost, convenience and low processing costs, high yield of bioethanol from 1 ton of raw materials and from 1 ha, positive energy balance, low transportation costs. The complexity of bioconversion and the amount of bioethanol production depends on the type of raw material and the amount of starch, sugars or glucose accumulated in it. Estimated data on the yield of bioethanol after fermentation of bio-raw material is presented

The choice of a culture that has the highest economic and ecological efficiency when growing and processing it into bioethanol depends to a large extent on the geographical location of the country, the presence of fertile soils, the total amount of precipitation and solar radiation [14-20].

A positive aspect is also the fact that the production of bioethanol from sugar beets requires 20-30% less energy carriers, compared to the use of grain raw materials. This is due to the fact that in the production of bioethanol from starch-containing crops (corn, wheat, sorghum), it is necessary to first subject the raw materials to hydrolysis (saccharification) with the help of enzymes in order to break down starch and obtain glucose. A generalization of the positive aspects of the use of sugar beets as a raw material for the production of bioethanol is shown in fig. 1.3.

Thus, Ukraine has powerful agriculture and competitive advantages for biofuel production - fertile soils, favorable agricultural infrastructure, and qualified personnel. The analysis of the main types of raw materials for the production of bioethanol revealed that in global practice the bioethanol market is formed based on the use of the following energy crops: sugar cane, corn, wheat, rye, barley, sugar beets, sugar sorghum, Jerusalem artichoke, cassava, sweet potatoes, and potatoes. In the conditions of Ukraine, the most promising types of raw materials for the production of bioethanol are sugar beets and molasses, fodder grain, and corn.

In today's world, more and more attention is paid to the development of alternative renewable energy sources, since the raw material reserves of fossil fuels tend to be depleted, and their price periodically increases. Therefore, renewable energy sources are currently of particular interest not only from the point of view of their use, but also from the point of view of the economic feasibility of developing new areas of business and its diversification.

As a result of the economic characteristics of the cultivation of raw materials for the production of biofuel, it was determined that Ukraine has a powerful raw material base, which includes the main starch-containing, sugar-containing agricultural crops that give a high yield of biofuel.

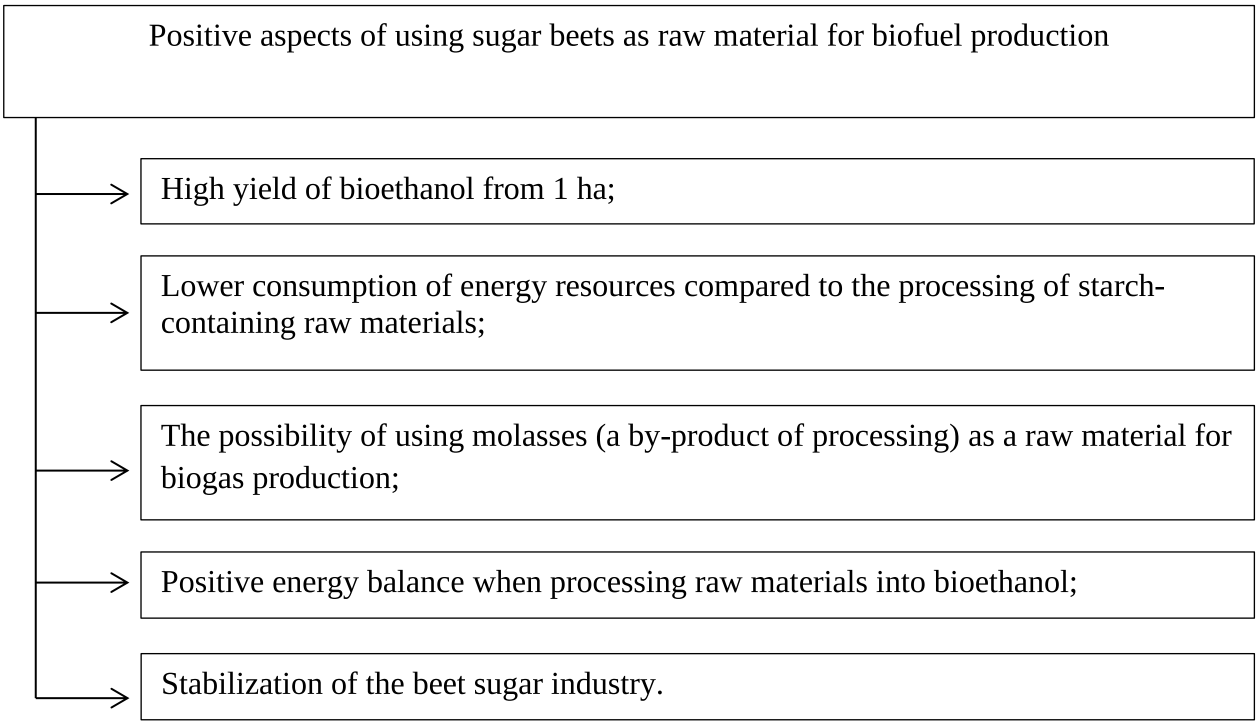

Fig. 1.3. Calling aspects of the use of sugar beets as raw materials for the production of bioethanol

Source: formed by the authors on the basis of the studied literature [18-20]

Thus, on the basis of calculations of the variation of factors and interdependencies of the investigated indicators to identify the specifics of the formation of the raw material base and ensure the competitive production of biofuel, the feasibility of expanding the sown areas within the framework of scientifically based crop rotations under corn to grain, soy, sunflower and rapeseed, and sugar beet was established , potatoes and corn for silage and green fodder require increased levels of productivity per unit area. The expansion of acreage under corn for grain, sunflower, soy, and rapeseed has a direct positive effect on the growth of the yield of the main agricultural crops of the bioenergy direction, which allows to reduce the level of the cost of produced biofuels. At the same time, the increase in acreage under sugar beets, potatoes and corn for silage and green fodder has an inverse relationship (decrease) with the yield of these crops. Therefore, the modern management strategy consists in the diversification of agricultural production, giving priority to the development of the national competitive biofuel industry, the raw material base of which should be formed primarily on such crops as corn for grain, soybeans, sunflower and rapeseed, which was established on the basis of the conducted variation and correlation analyzes.

It was established that the level of production of biofuels at agricultural enterprises is significantly lower than the available potential. Necessary for the further development of biofuel production is the creation of ancillary industries to ensure own production needs.

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2. Prospects for the development of biodiesel production as a direction for ensuring energy security of the state

The volume of gas oil consumption in the state and scientific approaches to stimulating the development of biodiesel production were studied. The volume of rapeseed production was studied and the inexpediency of exporting this crop and oil products in full was determined. The leading technologies of biodiesel production were studied and their economic feasibility was substantiated. It was established that the organization of biodiesel production on the basis of medium-sized agricultural enterprises will provide an opportunity to: maximally satisfy the needs of this sector of the economy in fuel for machinery; to ensure the development of related industries, including animal husbandry. It was determined that, based on today's economic and social realities, the most rational is the creation of small processing enterprises with partial compensation for the cost of appropriate domestically produced equipment for the production of biodiesel. The directions for the development of biodiesel production as a way to ensure food security of Ukraine are defined, which consist in limiting the export of rapeseed, developing a model of public-private partnership in the field of improving the technologies of rapeseed cultivation and its further processing.

Currently, in the conditions of martial law and the refusal to import energy carriers from Belarus and the Russian Federation, which creates obstacles for the export of agricultural products and the provision of gas oil to the economy of Ukraine, the implementation of effective directions for the development of biodiesel production is necessary in the short term. The fastest solution is to use the existing potential of rapeseed and create appropriate industries based on agricultural and processing formations. After all, the development of one's own extraction of fossil resources is more expensive than the creation of small processing enterprises focused on the production of biodiesel.

The scientific works of H.M. Kaletnik are devoted to the problems of ensuring the development of the agro-industrial complex and the production of alternative energy sources from the raw materials of the agro-industrial complex. [1], Zhuka G.V.

[2], Shevchuk G.V. [3], Kupchuk I.M. [4], Furman I.V. [6-7] and others. However, the study of prospects for the development of biodiesel production as a means of ensuring the energy security of the state is extremely necessary, which determines the relevance of this study.

Despite the presence of a significant number of scientific works and research conducted by leading scientists in the field of production of alternative energy sources, the development of biodiesel production as a means of ensuring the energy security of the state remains relevant.

Prices for traditional diesel fuel are increasing every year, which at the same time increases the cost of agricultural products produced. At the same time, reserves of oil, which is a derivative raw material for the production of diesel fuel, are limited, and in connection with the refusal of the supply of energy carriers from the Russian Federation and Belarus, a shortage of energy carriers has arisen in the state. It should also be noted that the use of petroleum fuels has a negative impact on the natural environment.

G. Kaletnik claims that for a number of objective and historical reasons, Ukraine belongs to the category of energy deficit countries, because it consumes almost four times more energy than the developed countries of the world. In modern conditions, the process of reducing the supply of traditional energy resources goes beyond the economic sphere and becomes a matter of political direction. Based on the world and EU experience, it should be noted the perspective and economic feasibility of the development and mass introduction of bioenergy technologies into production. Therefore, the urgent issues of today for Ukraine are reliable energy supply and the availability of a sufficient amount of energy carriers for the long term with a gradual reduction of traditional types of fuel in the structure of energy consumption. In view of this, the main tasks are to determine the priorities of economic development during the introduction of modern energy-efficient technologies with a short payback period in the field of alternative energy, as well as the opening and regulation of the bioenergy market in the state [1, p. 128].

As started by G.V. The production of biodiesel fuel in Ukraine is not recorded in statistical data, although the potential is estimated at 2 million t/year, since the raw material for obtaining biodiesel is technical oil, as well as rapeseed and soy, that is, crops that we grow and actively export. This volume, by the way, could replace 20% of diesel imported by Ukraine [2, p. 23].

On the basis of the Scientific and Research Laboratory of Bioenergy of the Educational and Scientific Center of VNAU, the study and practical implementation of best practices in the production of biodiesel are carried out, as well as consultations on the production and use of biofuel are provided to educational and research institutions of the region. It is expedient to modernize the existing laboratory by including in the production cycle equipment for the processing of oilseeds. Currently, specialists have developed and calculated a chain of processing oilseeds into meal and biodiesel for the own needs of farms [3].The use of scientific and practical experience of the Vinnytsia National Agrarian University in the field of biodiesel production is planned to be used for the development of universal business plans for the creation of energy cooperatives, as well as the creation of a small processing enterprise that will provide biodiesel to agricultural enterprises that will be united within the partnership model. According to our calculations, the business will avoid up to 23% of costs.

The development of interaction between agricultural product producers, scientific institutions and manufacturers of the appropriate equipment for biodiesel production is necessary for the launch of relevant productions. That will make it possible to adjust the design and production of equipment according to the required capacities of customers and to carry out training of personnel in the field. Putting biodiesel plants into operation will enable agricultural formations to ensure partial energy independence and reduce costs for fuel and lubricants.

According to the researches of Kupchuk I.M. if the cost of rapeseed is UAH 14,160/t (the purchase price in this year of enterprises), transport costs are at the level of UAH 40/t km, the cost of processing will be UAH 900/t. The total production costs will amount to UAH 16,260 with a planned output of biodiesel of 450 kg, for the production of which an additional investment of UAH 2,050 will be made. The cost of selling by-products will be UAH 5,900, while the cost of biodiesel will be UAH 33/kg or UAH 28.44/l. [4, p. 52].

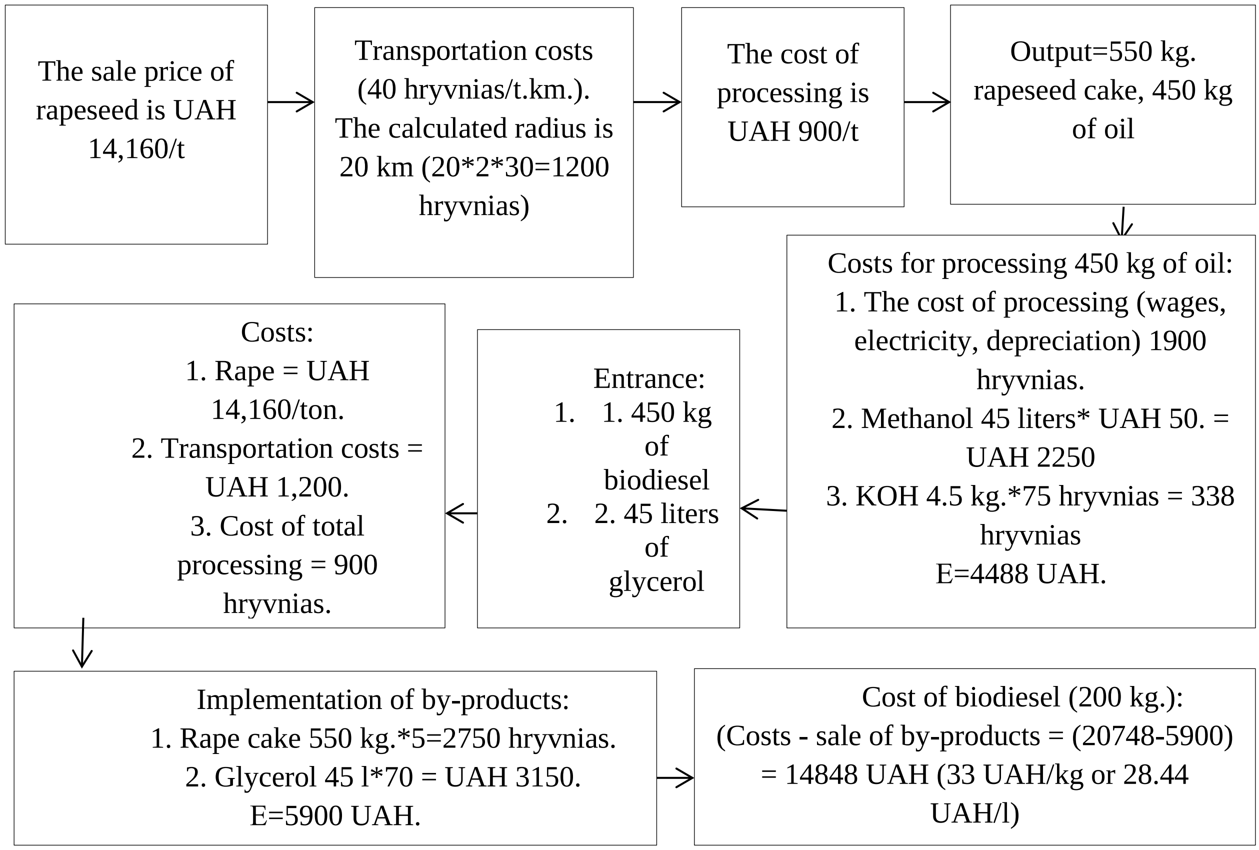

Fig. 2.1. Calculation of the economic feasibility of processing rapeseed into biodiesel

Source: [4, p. 152].

Given the price of diesel fuel and its constant shortage in the market, the corresponding price is extremely competitive.

In the production of biofuel from rapeseed, preference should be given to the "Persei" hybrid, since its methyl ether has a higher heat of combustion by 9.11% higher than the similar indicator for the "Lagonda" hybrid, which ensures more efficient use of biofuel [4, p. 153].

To improve the properties of biofuel, it can be saturated with hydrogen, since a larger number of hydrogen molecules in the compound gives a higher heat of combustion. To improve the properties of biofuel, various processing technologies can be used, for example, catalytic processing, hydrogenation, hydrogen reduction, and others, which allow to increase the heat of combustion and reduce the content of harmful substances

2,134 medium-sized agricultural enterprises and more than 89,000 small and micro-enterprises of the agricultural sector can become potential producers of biodiesel (Table 2.1).

After systematizing I.M. Kupchuk's research [4] and the data of the State Statistics Service of Ukraine [5] established that rapeseed processing in the volume of exports of this crop in 2021 will provide an opportunity to obtain more than 1.2 million tons of biodiesel with a total cost of more than UAH 39.6 billion. And by-products in the form of rape cake in the amount of 1.47 million tons worth more than 8.8 billion UAH. and technical glycerin – 120,000 tons for UAH 9.6 billion. The total volume of possible production will amount to more than UAH 58 billion. that by 20.2 billion hryvnias. more than the cost of selling rapeseed at 2022 prices.

Table 2.1

The number of operating agricultural enterprises, divided into large, medium, small and micro enterprises in 2022

Total, unit	large enterprises		medium enterprises		small businesses		of them are micro-enterprises	
	%	(%) from the total number of operating enterprises	%	(%) from the total number of operating enterprises	%	(%) from the total number of operating enterprises	%	(%) from the total number of operating enterprises
49452	36	0,1	2134	4,3	47282	95,6	42042	85,0

Source: formed by the authors based on [5]

The use of diesel fuel in 2022 in Ukraine amounted to more than 6.1 million tons, of which 1.77 million tons were in the agricultural sector. Without changing the engine design, up to 10% of biodiesel fuel can be added to traditional petroleum diesel. Thus, the demand for biodiesel fuel in Ukraine is more than high, and there are no offers on the market.

The potential volume of biodiesel production based on gas oil consumption in Ukraine will amount to more than 1 million tons. In particular, in the Vinnytsia region, more than 120,000 tons.

The planned indicators are quite attractive given the high prices of diesel fuel and seasonal price fluctuations and problems with exports caused by martial law. In addition, during the processing of rapeseed in the form of by-products, agricultural formations will receive rapeseed cake, which will make it possible to partially provide livestock with concentrated fodder. As well as technical glycerin, which is also in demand on the market among manufacturers of cosmetics and the pharmaceutical industry. The main producers of biodiesel should be agricultural enterprises and farms, which make up more than 70% of the total number of agricultural formations and need to replace traditional gas oils with biodiesel. A significant number of enterprises and their geographical diversity will have a positive effect on the development of biodiesel production, even with the launch of production by 20-30% of the total number of enterprises.

It should be noted that the cost of rapeseed sales by agricultural enterprises is much lower than the export price, and the prospects of processing within the framework of production cooperatives into biodiesel and rapeseed will provide an opportunity to increase the state's GDP and ensure energy independence of agriculture, which is especially relevant in the conditions of martial law.

The main non-market competitive advantage of biodiesel production is the ability to provide energy, environmental and social effects. Indirect competitors for potential biodiesel producers may be gas stations, however, according to calculations, the products manufactured at the expense of the designed factories will have a price advantage.

According to I. V. Furman, the improvement of investment and innovation activities in the agricultural sector requires improvement of the current mechanisms for attracting investments [6, p. 46].

It should be noted that studies by D. M. Tokarchuk indicate that Ukraine has sufficient land areas to guarantee energy security when using agricultural raw materials for the production of biofuel, without endangering food security [7, p. 171].

Therefore, the main directions of development of biodiesel production as a direction of ensuring food security of the state should be:

- introduction of a system of incentives for agricultural producers aimed at compensating 40% of the cost of equipment purchased from Ukrainian producers for the production of biodiesel;

- establishment of quotas for the export of rapeseed and rapeseed oil at the level of 30-40% of the total collection;
- development of public-private partnership between scientific institutions and private investors aimed at the development of advanced technologies for rapeseed cultivation and biodiesel production;
- development of methanol production at distilleries for the purpose of providing biodiesel production.

The implementation of the relevant directions will provide an opportunity to significantly increase the energy independence of the state economy and give impetus to the development of related industries aimed at providing the relevant industries.

Rapeseed production in Ukraine is primarily export-oriented, and there is almost no processing of this crop. At the same time, the constant tendency to increase the cost of gas oils forces entrepreneurs to search for their replacement with biofuel.

Honcharuk I.V. notes the real possibility of using at least 10 million hectares of agricultural land for the cultivation of biomass, which serves as raw material for the production of alternative energy sources, including more than 2 million hectares of rapeseed. The corresponding areas of crops of this crop will make it possible to ensure the production of biodiesel in the amount of 1.5 million t.e. [31, p. 11].

In order to create relevant industries, it is necessary to create cluster associations aimed at improving biodiesel production technologies.

Researches of Kaletnik G.M. testify that in order to form a cluster for the production of biodiesel fuel, it is expedient for it to include the following specialized enterprises and institutions: scientific and educational, which carry out scientific research on the problems of producing alternative fuels; agricultural enterprises growing rapeseed, where its production will not be the main type of production, but an order for a certain amount of marketable rapeseed seeds to load the capacities of cluster enterprises that process seeds into oil; processing enterprises for the processing of seeds into oil, but the production of marketable rapeseed oil for this enterprise should not be the main type of production, but only the order of the cluster for a certain amount of oil for loading the enterprises of the cluster for the production of biodiesel fuel; producer enterprises that process oil into biodiesel fuel, where the production of biodiesel fuel will be the main type of production (enterprises producers of biodiesel fuel); enterprises that sell biodiesel fuel. The integrator of the biodiesel production cluster can be scientific and educational institutions or enterprises producing biofuel [32, p. 11-12].

One of the basic scientific and research institutions of this direction is NNVK "All-Ukrainian Scientific and Educational Consortium" on the basis of which a research and production laboratory focused on the processing of oil crops for the needs of agricultural enterprises, which are part of this institution, has been created and has positive results.

As noted by Furman I.V. one of the main directions of the development of biofuel production in the conditions of reforming land relations in Ukraine should be related to the development of biofuel production in combination with increasing the energy efficiency of agricultural producers [33, p. 64]. It is the processing of rapeseed into biodiesel that will make it possible to partially ensure the energy independence of agricultural enterprises and partially provide the livestock industry with concentrated feed.

Rapeseed production during 2019-2021 had a downward trend due to a decrease in sown areas by almost 28%, but the use of more progressive cultivation methods increases the yield of this crop (Table 2.1). Further improvement of the cultivation technologies of this crop by applying organic fertilizers (digestate) will make it possible to increase the yield of this crop, and the use of biodiesel will reduce the cost of production.

As noted by D.M. Tokarchuk, rapeseed is an important energy crop that is widely used in the world for the production of biodiesel. In Ukraine, rapeseed is one of the most profitable crops, but the vast majority of it is exported, in particular to EU countries [5, p. 23].

Table 2.1

Rapeseed and colza production by regions of Ukraine

	Gross harvest, thousand tons Deviation, +,- Yield,			Gross harvest, thousand tons Deviation, +,- Yield,	Gross harvest, thousand tons Deviation, +,- Yield,			Gross harvest, thousand tons	Gross harvest, thousand tons Deviation, +,- Yield,			Gross harvest, thousand tons Deviation, +,- Yield,
	2019	2020	2021		2019	2020	2021		2019	2020	2021	
Ukraine	3280,3	2557,2	2938,9	-341,4	25,6	23,0	29,3	3,7	1279,2	1112,5	1004,5	-274,7
Vinnytsia	243,1	136,7	202,1	-41	31,1	27,4	33,1	2	78,0	50,0	61,1	-16,9
Volynsk	154,2	142,4	154,6	0,4	29,6	29,4	31,6	2	52,0	48,3	49,0	-3
Dnipropetrovsk	281,3	302,9	200,0	-81,3	24,5	25,4	23,9	-0,6	114,8	119,2	83,7	-31,1
Donetsk	66,5	93,7	к/с	-	20,9	25,5	к/с	-	31,8	36,7	к/с	-
Zhytomyr	127,7	105,4	108,1	-19,6	28,0	21,8	26,4	-1,6	45,6	48,4	40,9	-4,7
Zakarpattia	к/с	–	к/с	-	к/с	–	к/с	-	к/с	–	к/с	-
Zaporizhzhia	167,6	191,1	178,9	11,3	23,9	19,0	24,6	0,7	70,1	100,4	72,8	2,7
Ivano-Frankivsk	73,0	62,6	68,1	-4,9	26,0	26,8	34,6	8,6	28,0	23,4	19,7	-8,3
Kyivska	147,2	64,7	101,8	-45,4	27,4	24,6	30,6	3,2	53,7	26,3	33,4	-20,3
Kirovohradsk	149,2	104,8	67,9	-81,3	24,6	22,8	23,9	-0,7	60,7	45,9	28,3	-32,4
Luhansk	к/с	24,1	0,9	-	к/с	21,5	10,7	-	к/с	11,2	0,9	-
Lviv	184,5	172,1	177,4	-7,1	28,1	25,8	33,9	5,8	65,8	66,7	52,3	-13,5
Mykolayivska	197,8	128,8	163,4	-34,4	22,7	16,9	26,4	3,7	87,1	76,1	61,8	-25,3
Odesa	376,0	124,3	302,5	-73,5	19,7	10,8	25,5	5,8	191,1	115,0	118,6	-72,5
Poltava	34,9	7,0	34,1	-0,8	28,7	21,7	30,7	2	12,2	3,2	11,2	-1
Rivne	100,1	86,8	87,5	-12,6	28,6	24,1	29,8	1,2	35,0	36,0	29,2	-5,8
Sumy	41,8	36,8	71,1	29,3	29,7	32,1	31,9	2,2	14,1	11,5	22,2	8,1
Ternopilsk	226,6	182,3	261,9	35,3	31,1	29,3	38,2	7,1	73,0	62,2	68,7	-4,3
Kharkivska	19,1	33,4	8,4	-10,7	21,2	24,7	22,8	1,6	8,9	13,6	3,6	-5,3
Khersonsk	192,3	197,2	244,0	51,7	22,0	22,0	25,6	3,6	87,5	89,7	95,4	7,9
Khmelnytska	238,0	204,0	298,7	60,7	32,0	27,9	35,9	3,9	74,2	73,1	83,1	8,9
Cherkasy	142,9	36,5	54,5	-88,4	29,5	23,7	31,4	1,9	48,3	15,5	17,4	-30,9
Chernivtsi	28,7	39,7	31,6	2,9	23,4	28,4	27,5	4,1	12,2	13,9	11,5	-0,7
Chernihivska	80,7	79,9	112,6	31,9	24,9	30,3	33,0	8,1	32,5	26,2	34,2	1,7

c/s - data are not made public in order to ensure compliance with the requirements of the Law of Ukraine "On State Statistics" regarding the confidentiality of statistical information

Source: generated by the author based on data [1-8]

As of 2021, more than 91% of the rapeseed produced in Ukraine was exported at an average price of USD 633.1/t with a total value of USD 1.69 billion. USA (Table 2.2).

It should be noted that the cost of rapeseed sales by agricultural enterprises is much lower than the export price, and the prospects of processing within the framework of production cooperatives into biodiesel and rapeseed will provide an opportunity to increase the state's GDP and ensure energy independence of agriculture, which is especially relevant in the conditions of martial law.

Table 2.2

Geographical structure of rapeseed exports in 2021

Country	Volume, t	Cost, USD USA/Vol	Sales revenue, million dollars. USA
In total	2670692,8	633,1	1690,87
Austria	789,3	723,0	0,57
Algeria	1110,8	540,4	0,60
Bangladesh	112828,2	627,3	70,78
Belgium	361603,7	619,3	223,95
Belarus	52428,9	648,8	34,02
Bulgaria	14542,8	452,9	6,59
India	9055,3	646,1	5,85
Indonesia	775,0	661,6	0,51
Spain	8555,5	634,1	5,42
Lebanon	44,5	600,0	0,03
Malaysia	26,0	695,0	0,02
Morocco	35,5	500,0	0,02
Nepal	33495,6	656,4	21,99
The Netherlands	169877,7	637,7	108,33
Germany	813850,6	657,7	535,29
United Arab Emirates	98820,5	572,6	56,58
Pakistan	334091,0	590,5	197,29
Poland	82276,4	620,2	51,03
Portugal	91950,0	683,8	62,88
Romania	60,0	873,0	0,05
United Kingdom of Great Britain and Northern Ireland	238446,5	652,5	155,58
Taiwan, a province of China	43,0	600,0	0,03
Tunisia	43,9	495,0	0,02

Source: created by the author based on [1-5]

Research by Palamarenko Ya.V. testify that the competitive production of biodiesel is able to create favorable conditions for the cultivation and sale of agricultural products for agricultural enterprises, therefore they should make the necessary adjustments to the tactics and strategy of their economic activities in order to take maximum advantage of the current situation on the energy market. With a sufficient supply of biological fuels, rapid development and stabilization of the agro-industrial complex will take place, and the ecological situation in the country will improve.

Carrying out research on the basis of the Vinnytsia National Agrarian University by I.M. Kupchuk. testify that when setting the value of rapeseed at the level of the market price of 2022 – 14,160 UAH/t (the purchase price in the current year of enterprises), transportation costs in the amount of UAH 40/t.km, the cost of processing rapeseed into oil is UAH 900/t. Total production costs will amount to UAH 16,260/ton. The planned output of biodiesel from the "Persey" hybrid will be 450 kg, for the production of which an additional investment of UAH 2,050 will be made. The cost of selling by-products will be UAH 5,900 (glyceryl, cake). The cost price of biodiesel will be UAH 33/kg or UAH 28.44/l

The corresponding indicators are quite attractive given the high prices of diesel fuel and seasonal price fluctuations and problems with exports caused by martial law. In addition, during the processing of rapeseed in the form of by-products, agricultural formations will receive rapeseed cake, which will make it possible to partially provide livestock with concentrated fodder. As well as technical glycerin, which is also in demand on the market among manufacturers of cosmetics and the pharmaceutical industry.

As noted by G.M. Kaletnik, the biomass of oil crops allows solving the energy problems of the agro-industrial complex of the regions and districts of the country independently at the local level

After systematizing I.M. Kupchuk's research and the data of the State Statistics Service of Ukraine established that the processing of rapeseed in the volume of exports of this crop in 2021 will provide an opportunity to obtain more than 1.2 million tons of biodiesel with a total cost of more than 39.6 billion UAH. And by-products in the form of rape cake in the amount of 1.47 million tons worth more than 8.8 billion UAH. and technical glycerin – 120,000 tons for UAH 9.6 billion. The total volume of manufactured products will amount to more than 58 billion UAH. that by 20.2 billion hryvnias. more than the cost of selling rapeseed at the prices of 2022 (Table 2.3).

The development of interaction between agricultural product producers, scientific institutions and manufacturers of the appropriate equipment for biodiesel production is necessary for the launch of relevant productions. That will make it possible to adjust the design and production of equipment according to the required capacities of customers and to carry out training of personnel in the field. Putting biodiesel plants into operation will enable agricultural formations to ensure partial energy independence and reduce costs for fuel and lubricants.

Table 2.3

The potential of rapeseed processing into biodiesel and by-products

The volume of rapeseed, i.e	The value of exports in 2021 prices, billion US dollars	Cost at domestic prices as of 2022.	Biodiesel yield, t (45%)	Production cost, biodiesel	Yield of rape cake, t (55%),	Realization value, billion hryvnias	Glycerin (10% from biodiesel)	Realization value, million, hryvnias
2670692,8	1,69	37817,0	1201811,8	39659,8	1468881,0	8813,3	120181,2	9614,5

Source: generated by the author based on data [4-20]

As a result of the conducted research, the following can be outlined:

– rapeseed production in Ukraine is oriented towards export to EU countries for further use of biodiesel and has a clear tendency to decline due to a decrease in the area of crops, however, an increase in the yield of this crop is observed;

- the increase in the price of gas oil, military operations, partial blockade of ports cause a decrease in domestic rapeseed prices and at the same time stimulate the development of biodiesel production;

- the development of rapeseed processing should be based on the interaction of cluster associations of scientific research institutions, agricultural producers and companies producing biodiesel plants;

- increasing the yield and reducing the cost of rapeseed cultivation can be achieved due to more advanced cultivation technologies with the use of organic fertilizer - digestate and the use of biodiesel in processing, the production cost of which is 60% lower than the cost of diesel fuel.

Application of the proposed measures will make it possible to:

- to increase GDP by UAH 20.2 billion;
- to ensure partial energy independence of the agricultural sector;
- create additional jobs in rural areas;
- to provide the livestock industry with concentrated fodder in the form of rape cake;
- load distilleries with orders for technical alcohol (methanol);
- to reduce the cost of agricultural production due to the partial replacement of diesel fuel with biodiesel;
- partially satisfy the needs of other sectors of the economy in energy resources;
- to provide other industries with technical glycerin.

As started by G.V. The production of biodiesel fuel in Ukraine is not recorded in statistical data, although the potential is estimated at 2 million t/year, since the raw material for obtaining biodiesel is technical oil, as well as rapeseed and soy, that is, crops that we grow and actively export. This volume, by the way, could replace 20% of diesel imported by Ukraine

On the basis of the Scientific and Research Laboratory of Bioenergy of the Educational and Scientific Center of VNAU, the study and practical implementation of best practices in the production of biodiesel are carried out, as well as consultations on the production and use of biofuel are provided to educational and research institutions of the region. Currently, specialists have developed and calculated a chain of processing oilseeds into meal and biodiesel for the own needs of farms

The use of scientific and practical experience of the Vinnytsia National Agrarian University in the field of biodiesel production is planned to be used for the development of universal business plans for the creation of energy cooperatives, as well as the creation of a small processing enterprise that will provide biodiesel to agricultural enterprises that will be united within the partnership model. According to our calculations, the business will avoid up to 23% of costs.

The development of interaction between agricultural product producers, scientific institutions and manufacturers of the appropriate equipment for biodiesel production is necessary for the launch of relevant productions. That will make it possible to adjust the design and production of equipment according to the required capacities of customers and to carry out training of personnel in the field. Putting biodiesel plants into operation will enable agricultural formations to ensure partial energy independence and reduce costs for fuel and lubricants.

According to its characteristics, biodiesel fully corresponds to traditional diesel fuel from oil. In the EU, this type of fuel is in demand due to its environmental friendliness.

First, internal combustion engines on this fuel emit less carbon dioxide into the air (about 80%), and there is no sulfur dioxide in the exhaust. Secondly, when it gets into the soil or water, it decomposes into biocomponents within a month.

Biodiesel can be used in its pure form (B100). But the mixed type is more popular, when 10% or 20% of biodiesel (B10 and B20) is added to conventional diesel fuel.

Residues of biodiesel that are not used for own consumption can either be sold on the domestic market or, if there is an appropriate certificate, exported to EU countries where mixed fuels are mandatory. By the way, this industry is quite developed in the Czech Republic and Poland, which buy Ukrainian rapeseed and then deliver the biofuel produced from it to EU countries.

Here is an example of how blending plants in the EU work. There, next to oil refineries, there are bioethanol plants, where corn (purchased in Ukraine) is processed into bioethanol. In parallel, there are lines for processing rapeseed into oil (seeds are also purchased in Ukraine). The produced bioethanol and biodiesel are piped to oil refineries for mixing and obtaining mixed types of fuel with their subsequent sale.

Planned indicators are quite attractive for agricultural formations considering the high prices of diesel fuel and seasonal price fluctuations and problems with exports caused by martial law. In addition, during the processing of rapeseed in the form of by-products, the agrarian formation receives rapeseed cake, which will make it possible to partially provide livestock with concentrated fodder. As well as technical glycerin, which is also in demand on the market among manufacturers of cosmetics and the pharmaceutical industry.

The work presents theoretical and methodological generalizations and a new solution to the scientific task of managing the management of the cultivation of agricultural crops for the production of biofuels, and the following conclusions are drawn.

The modern management strategy consists in the diversification of agricultural production, giving priority to the development of the national competitive biofuel industry, the raw material base of which should be formed primarily on such crops as corn for grain, soybeans, sunflower and rapeseed, which was established on the basis of the conducted variation and correlation analyses.

The influence of price factors on the efficiency of growing winter rapeseed, winter wheat and corn for grain. It is noted that environmental factors have a significant impact on the efficiency of production of raw materials for biofuel. Unlike the factors of the internal environment, where efficiency is achieved mainly by reducing the cost of production, in the external environment it can be both price changes and global trends in agricultural markets, which ultimately affect the formation of prices for raw materials.

The development and improvement of technologies for growing and processing corn into biofuel is an urgent issue for the strategic development of Ukraine. The proposed measures will make it possible to:

achieve an increase in the volume of corn cultivation;

to improve corn cultivation technologies using digestate;

achieve the maximum use of the energy potential of corn, including waste during its production.

As a result of the conducted research, the following can be outlined:

Rapeseed production in Ukraine is oriented towards export to the EU countries for the further use of biodiesel and has a clear tendency to decline due to the reduction of cultivated areas, however, an increase in the yield of this crop is observed;

an increase in the price of gas oil, military actions, partial blocking of ports cause a decrease in domestic rapeseed prices and at the same time stimulate the development of biodiesel production;

the development of rapeseed processing should be based on the interaction of cluster associations of scientific research institutions, agricultural producers and companies producing biodiesel plants;

increasing the yield and reducing the cost of growing rapeseed can be achieved due to more advanced growing technologies using organic fertilizer - digestate and the use of biodiesel in processing, the production cost of which is 60% lower than the cost of diesel fuel.

It is expedient for agricultural enterprises to create biodiesel production to meet their own needs. If the price of rapeseed is UAH 14,160/t (the purchase price of enterprises), transport costs are at the level of UAH 40/t km, the cost of processing will be UAH 900/t. The total production costs will amount to UAH 16,260 with a planned output of biodiesel of 450 kg, for the production of which an additional investment of UAH 2,050 will be made. The cost of selling by-products will be UAH 5,900, while the cost of biodiesel will be UAH 33/kg or UAH 28.44/l.

Rapeseed oil is a cheap raw material for the production of biodiesel fuel. From a ton of rapeseed, you can get 180-260 kg of vegetable oil, and in further processing - 200-220 kg of biodiesel fuel. The value of this type of fuel is undeniable in its ecological purity and the possibility of production from renewable raw materials.

Rapeseed seeds with a content of erucic acid no more than 2% and glucosinolates up to 3% are used for food purposes. According to the industry standard of Ukraine GOST 46.072 for rapeseed oil, unrefined oil of the highest and first grades, as well as refined non-deodorized and refined deodorized with an erucic acid capacity of no more than 5% and sulfur of no more than 6 mg/kg can be used for food purposes. Achieving the appropriate parameters is quite problematic, therefore, in conditions of shortage of energy resources, it is more appropriate to process rapeseed oil into biodiesel.

During 2020-2022, research was carried out on the experimental fields of the Agronomichne State Farm in the conditions of the Pravoberezhny Forest Steppe. Plant density varied from 25.0 pcs/m2 to 46 pcs/m2 on the hybrids "Persei" and "Lagonda" (table 2.4). It was determined that the hybrid "Persei" has the highest oiliness, when fertilizers are applied at the level of N188P98K188 with a sowing date from August 24 to September 4 and additional feeding with digestate.

Table 2.4

The formation of the structure of the winter rapeseed crop of "Persey" and "Lagonda" hybrids

Term sowing	Level feeding	Plant density, units/m2	Number of pods per plant, pcs.	Number of seeds in a pod, pcs.	Numeric seeds per 1 m2, thousand pcs.	Oil output from 1 t/kg	Biological yield, t/ha
Perseus							
10.08	$N_0P_0K_0$	25,65	98	15,90	42,53	380	1,57
	$N_{62}P_{32}K_{62}$	28,92	101	16,50	49,76	398	1,98
	$N_{124}P_{64}K_{124}$	38,66	102	16,73	63,27	424	2,72
	$N_{188}P_{98}K_{188}$	42,83	102	17,30	75,81	456	3,37
	$N_{244}P_{124}K_{244}$	46,35	105	17,76	85,57	488	4,13
21.08	$N_0P_0K_0$	25,65	100	16,99	69,37	430	2,94
	$N_{62}P_{32}K_{62}$	28,92	101	17,00	86,37	471	4,02
	$N_{124}P_{64}K_{124}$	38,66	101	17,00	98,80	483	4,68
	$N_{188}P_{98}K_{188}$	42,83	101	17,02	106,31	489	5,10
	$N_{244}P_{124}K_{244}$	46,35	101	17,02	119,74	468	5,23
5.09	$N_0P_0K_0$	25,65	99	16,88	51,90	445	2,27
	$N_{62}P_{32}K_{62}$	28,92	100	17,20	66,14	467	3,23
	$N_{124}P_{64}K_{124}$	38,66	101	16,92	96,92	469	4,31
	$N_{188}P_{98}K_{188}$	42,83	102	17,20	109,81	488	4,97
	$N_{244}P_{124}K_{244}$	46,35	101	17,04	109,60	488	5,20
Lagonda							
10.08	$N_0P_0K_0$	25,65	98	15,90	42,53	377	1,57
	$N_{62}P_{32}K_{62}$	28,92	101	16,50	49,76	378	1,98
	$N_{124}P_{64}K_{124}$	38,66	102	16,73	63,27	414	2,72
	$N_{188}P_{98}K_{188}$	42,83	102	17,30	75,81	416	3,37
	$N_{244}P_{124}K_{244}$	46,35	105	17,76	85,57	418	4,13
21.08	$N_0P_0K_0$	25,65	100	16,99	69,37	420	2,94
	$N_{62}P_{32}K_{62}$	28,92	101	17,00	86,37	431	4,02
	$N_{124}P_{64}K_{124}$	38,66	101	17,00	98,80	443	4,68
	$N_{188}P_{98}K_{188}$	42,83	101	17,02	106,31	449	5,10
	$N_{244}P_{124}K_{244}$	46,35	101	17,02	119,74	458	5,23
5.09	$N_0P_0K_0$	25,65	99	16,88	51,90	445	2,27
	$N_{62}P_{32}K_{62}$	28,92	100	17,20	66,14	467	3,23
	$N_{124}P_{64}K_{124}$	38,66	101	16,92	96,92	469	4,31
	$N_{188}P_{98}K_{188}$	42,83	102	17,20	109,81	488	4,97
	$N_{244}P_{124}K_{244}$	46,35	101	17,04	109,60	488	5,20

Source: created by the authors based on their own research

According to calculations, the price of rapeseed is set at the market price in May 2022 - 14,160 UAH/t (purchase price at agricultural enterprises), transport costs are set at 40 UAH/t.·km, the cost of processing will be 900 UAH/t. Total production costs will amount to UAH 16,260. The planned yield of biodiesel fuel from the "Persey" hybrid will be 450 kg, for the production of which an additional investment of UAH 2,050 will be made.

Therefore, the set of measures to improve the cultivation and processing of corn for biofuel should include:

– carrying out practical research on the established experimental fields of the Agronomichne National Agricultural University of Ukraine among hybrids Dx 3623 FAO 290, Dx 3789 FAO 250, Dx 4014 FAO 310 (DEKALB® (Monsanto)) using digestate feeding;

- establishment of a sales system by sugar and alcohol plants for the sale of digestate to potential suppliers of raw materials.

The development and improvement of technologies for growing and processing corn into biofuel is an urgent issue for the strategic development of Ukraine. The proposed measures will make it possible to: to achieve an increase in the volume of corn cultivation; to improve corn cultivation technologies using digestate; to achieve the maximum use of the energy potential of corn, including waste during its production.

As a result of the implementation of the proposed measures in the medium term, the following effects are possible for the energy security of Ukraine: to increase the GDP of the state due to the processing of rapeseed into biodiesel; create additional jobs in rural areas; to provide the livestock industry with concentrated fodder (rape cake); to increase the capacity of distilleries due to the production of methanol (a component for the production of biodiesel); to reduce the cost of growing the main agricultural crops due to the use of cheaper biodiesel fuel; partially satisfy the needs of related industries in alternative fuel in the form of biodiesel; to provide industry with technical glycerin.

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3. Improvement of technological methods of growing rod-shaped millet

Foreign scientists M.A. Sanderson, D.G. Christian and H.V. Elbersen and his co-authors [1-3] determined the peculiarities of the use of millet and miscanthus biomass in the production of energy and fiber and established that these crops have: a high rate of net energy production per hectare; low cost of production; insignificant needs of plants in nutrients; low ash content in raw materials; high coefficient of moisture utilization; wide distribution area of the plant; simplified cultivation technology; high adaptability. They recommend growing energy crops on unproductive soils, degraded lands, and, what is no less important, without changing land use.

Today, millet is researched as a biofuel raw material for the production of thermal energy, cellulose for paper production, fiber reinforcement for plastic composites and other products [4]. Millet is a perennial cereal crop that provides 15 tons of dry mass or 255 GJ/ha of thermal energy from 1 ha with proper care [5]. For the effective use of millet as an alternative fuel resource, it is necessary to study in more detail the influence of elements of growing technology, such as variety, sowing time, seed sowing rate, density, width of rows, pre-sowing tillage, etc., on the yield and energy indicators of the obtained biomass [6].

The experiments included conducting laboratory and field research in the conditions of the experimental field of the Vinnytsia National Agrarian University with millet plants during 2018-2022.

The soil cover is represented by gray forest medium loamy soils. According to the agrochemical survey, it was established that the arable layer of the soil has the following physicochemical parameters: humus content 1.97-2.16% (according to Tyurin), alkaline hydrolyzed nitrogen within

65-77 mg/kg (according to Kornfield), mobile phosphorus (according to Chirikov) 149-251 mg/kg of soil, exchangeable potassium (according to Chirikov) 80-95 mg/kg of soil. Hydrolytic acidity – 1.10-1.21 mg-eq per 100 g of soil. The reaction of the soil solution is 5.5-6.7 pH.

Two varieties of rod-shaped millet were used in the research (Table 3.1).

Table 3.1

Characteristics of varieties of rod-shaped millet

Sort	Ecotype Ploidy	Ecotype Ploidy	Origin	Maturation period	Weight of 1000 seeds, g
Cave-in-rock	high	octaploid	Pd. Illinois	middle-late	1,66
Carthage	high	octaploid	Monday Carolina	late	1,59

Source: [6]

The research program provided for a series of experiments of two types.

Experiment 1. To determine the yield of dry biomass of millet, depending on the methods of pre-sowing soil preparation.

Experiment 1 combined the study of factor A (variety): 1st variant "Cave-in-rock"; 2nd variant of "Carthage" and factor B (pre-sowing soil preparation): 1st variant - 2 cultivations; 2nd option – 2 cultivations + pre- and post-sowing rolling; The 3rd option is sowing in untreated soil using the "no till" technology.

Experiment 2. The formation of productivity of rod-shaped millet depending on the width of the rows.

Experiment 2 combined the study of factor A (variety): 1st variant "Cave-in-rock"; 2nd variant of "Carthage" and factor B (width between rows): 1st variant - width between rows 15 cm; 2nd option – the width of the rows is 30 cm; The 3rd option - the width of the rows is 45 cm. The registered area of the plot was 50 m2, repetition - four times. Placement of plots in experiments was based on a randomized alternation of options in repetitions.

The planning and establishment of experiments was carried out according to typical methodical recommendations [7]. Phenological observations during the growth and development of plants were carried out according to the "Methodology of the state variety testing of agricultural crops" [8] and according to the classification of the phases of the development of perennial grasses [9]. Quantitative indicators of rod millet (plant height, number of stems per 1 m^2, number of leaves and internodes per plant) were recorded at the end of the plant vegetation [10].

According to the research results, the biometric indicators of rod-shaped millet depended on the pre-sowing tillage (Table 3.2).

Table 3.2

Biometric parameters of rod-shaped millet plants in the second-sixth year of growing season depending on pre-sowing tillage and varietal characteristics

Sort (factor A)	Pre-sowing tillage of the soil (factor B)	Plant height, cm						Number of stems, pcs./m²					
		2018	2019	2020	2021	2022	Average	2018	2019	2020	2021	2022	Average
Cave-in-rock	cultivation	88,7	99,7	137,3	145,4	133,4	120,9	397,7	453,5	438,2	411,3	411,2	422,3
	2 cultivation	89,2	113,4	143,7	154,9	176,5	135,5	443,7	422,7	456,0	441,8	444,5	441,7
	2 cultivation and rolling	77,5	123,6	125,7	135,6	154,3	123,3	474,5	467,8	387,7	433,1	481,1	448,8
Carthage	"no till"	76,3	121,4	127,5	145,7	125,6	119,3	337,2	365,1	402,1	367,3	442,5	382,8
	2 cultivation	67,6	188,6	135,8	165,4	189,3	149,3	345,3	422,5	448,5	394,2	467,1	415,5
	«no till»	76,9	145,7	122,1	134,2	165,6	128,9	332,4	398,4	413,4	403,3	442,4	397,9

Source: own research

These tables show the effect of variety (factor A) and pre-sowing tillage (factor B) on plant height and the number of stems per unit area. In 2018, the height of plants in the variety "Cave-in-rock" was higher with the application of 2-cultivations of the soil (88.7 cm), compared to "no till" (77.5 cm) and with 2-cultivations with rolling (67.6 cm). For the variety "Carthage", 2 cultivations and 2 cultivations with rolling affected the reduction of plant height compared to "no till".

In the following years, the height of the plants of the variety "Cave-in-rock" was higher with 2 cultivations with rolling. For the variety "Carthage", the highest plant height was when applying 2 cultivations with rolling in 2019 and 2021, and in 2020 and 2022 - it was higher when applying "no till".

Therefore, the use of pre-sowing tillage with rolling can, in some cases, increase the height of plants. The variety also affects the height of the plants.

As for the number of stems per unit area, in 2018 it was the highest for the variety "Cave-in-rock" when applying 2 cultivations of soil with rolling (397.7 pcs./m²), compared to 2 cultivations (453.5 pcs./m²) and "no till" (474.5 pcs./m²). For the variety "Carthage", the highest number of stems was when using "no till" (413.4 pieces/m²) in 2020 and for 2 cultivations with rolling in 2022 (467.1 pieces/m²).

Therefore, based on the results of the analysis, it can be concluded that the use of pre-sowing tillage with rolling has a positive effect on plant growth and the number of stems for both varieties.

According to the results of table 1.7, it can be seen that the average yield value for the "Cave-in-rock" variety (9.9-11.4 t/ha) is greater than for the "Sarthage" variety (9.3-10.9 t /Ha).

Table 3.3

Yield of dry biomass of millet, depending on pre-sowing tillage and varietal characteristics, t/ha

Сорт (фактор А)	cultivation 2 cultivation	Productivity, t/ha					
		2018	2019	2020	2021	2022	Середнє
Cave-in-rock	2 cultivation and rolling	5,6	9,9	12,5	12,1	14,3	10,8
	"no till"	5,9	10,1	13,3	13,6	14,1	11,4
	2 cultivation	5,1	10,4	11,5	11,5	11,4	9,9
Carthage	«no till»	4,5	10,6	12,4	13,4	12,3	10,6
	cultivation	6,7	9,0	13,2	12,4	13,6	10,9
	2 cultivation	5,2	7,9	10,1	13,1	10,2	9,3

Source: authors' own research

It can also be observed that pre-sowing tillage has a significant impact on productivity. Its average value is the highest for the "2 cultivation and rolling" option (11.4 t/ha), the lowest is the average yield value for the "no till" option (9.9 t/ha). It can also be concluded that the combination of the variety "Cave-in-rock" and the pre-sowing soil treatment "2 cultivation and rolling" is the most effective, as it has the highest average value of yield by year.

Quantitative indicators: stem density and height of millet plants (elements of productivity) determine the productivity of the phytomass of the crop, which depends, first of all, on the width of the rows and is determined to a lesser extent by varietal characteristics [11-24].

According to the results of determining the quantitative parameters of millet plants, their variability was determined, primarily, depending on the width of the rows, varietal characteristics and weather conditions throughout the year (Table 3.4).

Table 3.4

Quantitative indicators of rod-shaped millet plants in the second-fourth years of vegetation, depending on the width of the rows

Sort (factor A)	Row width (factor B)	Plant height, cm						Number of stems, pcs./m²					
		2018	2019	2020	2021	2022	Середнє	2018	2019	2020	2021	2022	Середнє
Cave-in-rock)	15 см	99,4	132,4	109,8	167,8	145,8	131,04	198,4	302,7	305,5	305,6	303,6	283,16
	30 см	103,6	115,7	125,8	198,6	167,7	142,28	297,5	401,2	399,3	431,4	443,6	394,6
	45 см	100,4	145,8	154,8	145,5	156,3	140,56	367,7	503,7	376,5	378,7	501,6	425,64
Carthage	15 см	106,6	132,6	114,5	134,7	178,7	133,42	199,5	302,5	287,7	288,7	307,5	277,18
	30 см	115,6	147,5	134,6	138,6	153,7	138	236,7	321,4	299,7	302,4	388,8	309,8
	45 см	96,4	106,6	138,7	178,2	167,9	137,56	377,5	387,6	408,8	431,6	498,5	420,8

Source: authors' own research

The width of the row spacing affects the height of the plants and the number of stems per unit area. In general, an increase in the width of the row spacing led to an increase in the height of the plants. For the Sarthage variety, increasing the row spacing from 15 cm to 30 cm resulted in an increase in plant height and the number of stems per 1 m², however, further increasing the row spacing to 45 cm had no significant effect on plant height.

The best results regarding the number of stems per square meter were obtained for the variety "Carthage" at a row width of 45 cm in 2022, when the number of stems reached the value of 498.5 m2.

In general, in terms of plant height and number of stems per square meter, the cultivar 'Carthage' showed better values compared to the cultivar 'Cave-in-rock', but the differences were not statistically significant.

The highest average yield (table 3.5) was recorded for the "Cave-in-rock" variety (11.92 t/ha) with a row width of 45 cm, while the lowest average yield (6.32 t/ha) was obtained for the same variety with a row width of 15 cm.

Table 3.5

Yield of dry millet biomass, t/ha

Sort (factor AND)	Row width (factor B)	Productivity, t/ha					
		2018	2019	2020	2021	2022	Середнє
(Cave-in-rock)	15 см	4,9	7,8	8,0	9,2	9,7	6,32
	30 см	5,3	9,8	16,2	11,5	12,4	11,04
	45 см	7,1	10,1	12,6	14,1	15,7	11,92
(Carthage)	15 см	5,4	8,6	7,7	8,2	10,5	8,08
	30 см	6,1	7,7	10,4	11,6	9,9	9,14
	45 см	4,9	7,6	11,7	12,5	11,4	9,62

Source: authors' own research

In our opinion, the height of the plants and the number of stems per square meter are decisive in expressing the level of productivity. The structure of millet biomass has typical components for biofuel raw materials: about 50% cellulose, 30% lignin. Dry biomass has a low ash content - up to 2-4%, compared to grain straw, low potassium and sodium content combined with high calcium and magnesium content, which contribute to a high combustion temperature and reduce the likelihood of slag during combustion in solid fuel boilers. The results of the energy assessment of millet varieties for 2022 are presented in Table 3.6.

According to the energy assessment (Table 3.6), it was established that the highest dry biomass yield for the "Cave-in-rock" variety can be obtained when applying pre-sowing soil cultivation using 2 cultivations (14.3 t/ha), for " Carthage" - 2 cultivations and rolling (13.6 t/ha). At the same time, the specific indicator of energy output will be 292.4 GJ/ha for the "Cave-in-rock" variety and 250.92 GJ/ha for the "Carthage" variety.

Therefore, the "Cave-in-rock" variety allows you to obtain a higher yield of solid biofuel and energy, compared to the "Sarthage" variety, both with 2 cultivations and with additional rolling.

Table 3.6

Energy efficiency of growing varieties of rod-shaped millet with different methods of pre-sowing tillage (harvest 2022)

Sort (factor A)	Pre-sowing tillage of the soil (factor B)	Raw biomass yield, t/ha	Суха речовина %	Dry biomass yield, t/ha	Output of solid fuel, t/ha	Energy output, GJ/ha
Cave-in-rock	2 cultivation	18,2	78,5	14,3	17,2	292,4
	2 cultivation and rolling	18,07	78,1	14,1	16,92	287,64
	«no till»	14,8	76,7	11,4	13,68	232,5
Carthage	2 cultivation	15,8	77,8	12,3	14,76	250,92
	2 cultivation and rolling	17,6	77,5	13,6	16,32	277,44
	«no till»	13,2	72,5	10,2	12,24	208,08

Source: authors' own research

To obtain the best results of growing millet plants, it is recommended to use the variety "Cave-in-rock" and the combination of pre-sowing soil treatment "2-cultivation + rolling", as this combination has the highest average yield per year. In the case of the cultivation of the "Carthage" variety, it is recommended to use the pre-sowing tillage "no till" or the combination of "2-cultivation + rolling", depending on the technological methods of cultivation, since these combinations have the highest number of stems per square meter. When growing millet, it is worth paying attention to the width of the rows. For the "Carthage" variety, it is recommended to use a row width of 30 cm to obtain the largest number of stems per square meter.

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4. Prospects for biogas production from waste of enterprises and households on solid waste landfills

The article is devoted to the study of the prospects of biogas production at solid waste landfills from by-products of households and enterprises. The current environmental problems in Ukraine related to waste disposal are considered. It is determined that the important place is occupied by processing and utilization of waste, the volume of which is constantly growing due to the influence of urban mouths, development of services and other factors. The volumes of household waste generation at enterprises and households are determined.

It is determined that the most advanced production in the field of waste disposal is the construction and operation of a complex for the production of electricity by collecting and disposing of landfill gas from the landfill. It is determined that the most advanced production in the field of waste disposal is the construction and operation of a complex for the production of electricity by collecting and disposing of landfill gas from the landfill.

The typical system of collection and initial preparation of landfill gas for utilization and its main components are investigated. The analysis of potential biogas production from solid household waste is carried out. The necessity of industrial restructuring of communal enterprises specialized in waste utilization is argued. The basic model of activity of the modernized municipal enterprises focused on production of biomethane is offered.

A model has been formed that will partially reduce the energy independence of the state from energy, increase the efficiency of agricultural enterprises, providing the crop sector with organic fertilizers and give impetus to the development of equipment for biogas production at landfills.

The necessity of the information model of interaction of waste processing enterprises focused on biogas production is determined, which should include interaction on the basis of public-private partnership of research institutions and relevant enterprises focused on biogas production.

It is proved that the main constraining factor for the development of biogas production at landfills is primarily the lack of government incentives and the necessary amount of investment. By state incentives for the development of alternative energy and subsidies from local budgets for the relevant utilities, it is possible to achieve the solution of the tasks in the short term.

Among the urgent environmental problems in Ukraine, the processing and disposal of waste occupies an important place, the volume of which is constantly increasing due to the influence of cities, the development of the service sector and other factors. Today, society violates one of the main ecological laws - the circulation of substances in nature, introducing into circulation foreign substances. Today, in Ukraine, to solve this problem, outdated waste disposal technologies are mainly used in landfills. The main disadvantage of using this method of disposal is a significant negative impact on the ecological state of the environment.

Modern methods of waste management in Ukraine have certain features, namely:

- focused on the disposal of waste, its placement in landfills and/or spontaneous landfills, most of which do not meet the requirements of environmental safety;
- have an extremely low technological level and state of management information support;
- there is practically no implementation of innovative technologies.

In the conditions of shortage of energy resources and deterioration of the ecological state of the environment, the search for an environmentally safe method of their processing, including biogas, is necessary and urgent.

In Ukraine, the works of I. Honcharuk [1, 6], A. Hrytsenko [4], I. Furman [7] and others are dedicated to the study of the prospects for the development of waste processing into biogas.

Despite the significant scientific results of the above-mentioned works, in our opinion, the prospects for the development of biogas production from the waste of enterprises and households are not sufficiently considered in modern economic science, which determines the relevance of the study.

Among the urgent environmental problems in Ukraine, the processing and disposal of waste occupies an important place, the volume of which is constantly increasing due to the influence of cities, the development of the service sector and other factors. Today, society violates one of the main ecological laws - the circulation of substances in nature, introducing into circulation foreign substances. Today, in Ukraine, to solve this problem, outdated waste disposal technologies are mainly used in landfills. The main disadvantage of using this method of disposal is a significant negative impact on the ecological state of the environment.

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In Ukraine, there are officially 5,455 landfills and landfills with a total area of more than 8.5 thousand hectares. Research by Honcharuk I.V. testify that, despite a number of adopted strategies and program documents on environmental protection in Ukraine, the field of waste management was not properly reflected in them, although such waste harms human health and the environment [1, p. 30].

Today, there is a trend of increasing waste generation in Ukraine. During the period of 2015-2020, this indicator increased by more than 30% and in 2020 it amounted to more than 462 million tons (Table 4.1).

In 2020, more than 11 million tons were household waste and more than 435 million tons of waste from economic activities. Only 25 percent of this volume was disposed of.

Table 4.1

The main indicators of waste generation and management

	2010	2015	2018	2019	2020
Formed, thousand tons	425914,2	312267,6	352333,9	441516,5	462373,5
including from economic activity	419191,8	306214,3	346790,4	435619,8	456423,8
Waste generated per person, kg	9285	7288	8335	10505	11074
Collected and received household and similar waste, thousand tons	9765,5	11491,8	11857,2	11792,7	12634,9
Imported, thousand tons	4,1	3,4	89,4	22,0	2,7
Total burned, thousand tons	1058,6	1134,7	1028,6	1059,0	1008,0
including for the purpose of obtaining energy	840,3	1086,3	951,2	960,1	902,2
Recycled, thousand tons	145710,7	92463,7	103658,1	108024,1	100524,6
Prepared for disposal, thousand tons	…	1940,5	3193,6	2810,4	2641,3
Removed to specially designated places or objects, thousand tons	313410,6	152295,0	169523,8	238997,2	275985,3
including to specially equipped landfills	207445,1	31142,8	26305,6	90883,0	25815,3
Removed by other removal methods, thousand	24318,0	55248,1	57674,1	57503,1	46768,1
Neutralized, thousand tons	…	2616,0	212,2	379,9	464,8
Placed on spontaneous landfills, thousand tons	87,4	14,4	2,5	3,4	…
Exported, thousand tons	281,3	675,4	190,8	260,6	257,8
Removed as a result of leakage, evaporation, fires, thefts, etc	1367,6	6,5	6,7	12,0	…
Accumulated waste during operation at waste disposal sites at the end of the year, million tons	13267,5	12505,9	12972,4	15398,6	15635,3
calculated per 1 km2 of the country's territory, i.e	21984,2	21692,8	22498,9	26706,9	27115,9
per person, kg	289236	291888	306896	366392	374457

Source: created by the authors based on [2]

In the structure of waste generation, the extractive industry occupies a prominent place, namely the extraction of metal ores (Table 4.2). Waste from agricultural enterprises, agricultural processing enterprises, and households amounts to more than 15 million tons by 2020. The main part of this raw material (waste) can be used for biogas production.

The total volume of waste disposal in 2020 was 100.5 million tons, mainly this volume accounted for recycling or disposal of inorganic materials (Table 4.3). Unfortunately, composting of organic waste, primarily from household landfills, was practically not used. In 2020, more than 15,000 tons were subjected to mechanical and biological processing of waste at the facilities, which, unfortunately, is almost 4 times less than in 2015.

Table 4.2

Generation of waste from economic activity and in households, thousand tons

	2010	2015	2018	2019	2020
That's all	425914,2	312267,6	352333,9	441516,5	462373,5
Type of economic activity	419191,8	306214,3	346790,4	435619,8	456423,8
Agriculture, forestry and fisheries	8568,2	8736,8	5968,1	6750,5	5315,4
Mining and quarrying	347688,1	257861,9	301448,9	390563,8	391077,9
extraction of stone and brown coal	37071,3	12084,7	10858,5	14149,7	14576,7
extraction of metal ores	267544,9	238156,6	282481,9	367083,9	366901,0
extraction of other minerals and development of quarries	16819,0	1921,6	8038,3	8861,1	9299,7
Processing industry	50011,7	31000,5	31523,2	30751,8	52311,0
including					
food production	7245,4	4222,2	5818,4	5581,4	4158,7
beverage production	1522,2	939,2	447,4	342,0	325,8
production of chemicals and chemical products	2679,0	703,3	1227,8	1199,5	1482,2
production of basic pharmaceutical products and pharmaceutical preparations	615,4	10,8	11,5	15,4	14,7
metallurgical production	32844,2	20725,6	21799,3	21515,3	43650,0
Supply of electricity, gas, steam and air conditioning	8641,0	6597,5	6322,7	5959,2	5333,7
Water supply; sewerage, waste management	1698,7	594,2	397,4	411,8	338,3
collection, processing and disposal of waste; recovery of materials	842,8	180,0	72,5	110,5	10,4
Construction	329,4	376,2	378,8	188,7	14,5
Other types of economic activity	2254,7	1047,2	751,3	994,0	2033,0
From households	6722,4	6053,3	5543,5	5896,7	5949,7

Source: created by the authors based on [2]

It is most expedient to place biogas production from household waste directly on solid household waste landfills.

A solid waste landfill is a kind of biochemical reactor, in the bowels of which, under certain conditions, the processes of anaerobic decomposition of organic components develop, as a result of which biogas is generated (biogas fermentation -

BGZ). The creation of landfill gas (methane fermentation) occurs at temperatures from 10°C to 50°C. At the same time, the humidity accompanying gas formation processes can vary from 8% to 90% (the optimal humidity of waste for gas generation is 40-50%). A necessary condition for the formation of biogas is the absence of oxygen in the massif of the landfill.

Table 4.3

Waste from economic activity and in households was disposed of, thousand tons

	2010	2015	2018	2019	2020
Everything is disposed of	145710,7	92463,7	103658,1	108024,1	100524,6
Disposal / regeneration of solvents	330,6	65,3	103,9	137,1	111,2
Recycling / disposal of organic substances that are not used as solvents	2773,2	443,2	397,6	474,8	320,0
Composting of organic waste	147,4	651,1	671,6	619,8	549,8
Fermentation of organic waste	295,8	86,7	88,5	77,7	63,5
Recycling of paper and cardboard	…	24,0	0,3	0,3	0,3
Recycling / utilization of metals and their compounds	9564,4	6515,8	5798,9	5592,7	5356,2
Recycling / utilization of other inorganic materials	110658,2	58958,1	55930,2	58763,3	43068,9
Regeneration of acids and bases	33,6	0,4	0,8	1,0	2,1
Recovery of components used to reduce pollution	6125,2	13718,7	26649,4	27348,7	36553,7
Recovery of catalyst components	0,0	0,0	0,0	0,0	0,0
Re-distillation of used petroleum products or their other reuse	99,3	29,0	12,5	14,7	13,5
Soil treatment that has a positive effect on agriculture or improves the ecological situation	9244,5	10763,3	12320,3	13263,0	13501,3
Use of waste obtained from any of the above operations	6438,5	1208,1	1684,1	1731,0	984,1
Everything is prepared for disposal	…	1940,5	3193,6	2810,4	2641,3
Exchange of waste for further disposal or disposal	…	34,9	14,2	17,1	2578,4
Waste sorting	…	163,1	28,2	28,3	32,3
Mechanical and biological processing of waste at MBP installations	…	57,6	65,6	38,1	15,3
Dismantling unusable vehicles	…	0,0	0,1	0,0	0,0
Collection and preliminary processing of scrap metal and waste containing metals	…	1684,9	3085,5	2726,9	15,3

Source: created by the authors based on [2]

Currently, the main way of disposing of solid waste around the world is to bury them in landfills and landfills. When burying organic matter (of which 50 to 70% of the waste mass is on average) in the layer of solid waste under anaerobic conditions (without access to oxygen), its bioconversion occurs with the participation of microorganisms. As a result of this process, a bacterial fungal infection is formed, the macrocomponents of which are methane (CH4) and carbon dioxide (CO2).

Utilization of biogas from landfills allows not only to improve the ecological situation, but also to produce electricity and heat, partially replacing minerals. In world practice, the following methods of waste disposal are known:

- flaring, which ensures the utilization of greenhouse gases, the elimination of unpleasant odors and the reduction of fire hazards on the territory of the MSW landfill, while the energy potential of the landfill is not used for economic purposes;
- direct combustion of BGZ for the production of thermal energy;
- use of BGZ as fuel for gas-piston engines in order to obtain electricity and heat;
- use of BGZ as fuel for gas turbines for the purpose of obtaining electrical and thermal energy;
- bringing the methane content in BGZ (enrichment) to 94-97% with its further use in general purpose gas networks and as motor fuel;
- production of commercial carbon dioxide [3].

Thus, the process of collecting and utilizing biogas from a landfill consists of several stages.

1. Landfill gas from each gas discharge well is drawn into the collector (comb) through the loop pipeline connected to the well head due to decompression created by vacuum pumps. The total number of collectors is 10 units. Each collector connects several wells, on the collector each loop pipeline is equipped with a valve, a pressure control sensor and a fitting for gas sampling.

2. All biogas collected from the collectors is transferred to the site of the landfill gas collection and disposal unit using collector (main) pipelines.

3. A gas separator is installed in front of the vacuum pump on the main pipeline, where it is completely dried (separation of droplet and vapor liquid).

4. Purified biogas is fed to the disposal equipment through the monitoring (accounting) system. In the installation for the production of carbon dioxide, biogas is separated into biomethane and marketable carbon dioxide. The main volumes of biomethane will be used at a cogeneration plant, which makes it possible to produce 1 MW of electricity and about 1.2 MW of thermal energy [3-13].

The system of collection and initial preparation of landfill gas for disposal consists of the following components:

- wells;
- loop pipelines;
- plume collectors;
- main pipeline;
- separator.

One of the first and most advanced productions in this field is the construction and operation of a complex for the production of electrical energy through the collection and utilization of landfill gas from the municipal solid waste landfill in the city of Khmelnytskyi. The vertical wells of this complex have a diameter of 0.5 m or more. The wells are equipped according to DBN requirements with a production perforated pipe with a diameter of 110 mm or more. The diameter of the perforation holes is from 10 to 15 mm with a selected step along the surface of the pipe, starting from a distance of 0.5 to 1 m from the depth of the lock of the head of the production pipe. The depth of the wells is at least 7 m. The lower section of the pipe does not reach the level of the filtrate. The annular space is filled with gravel or pebbles of fraction 30...60 mm. The upper part of the well (approximately 1...1.5 m from the upper edge) is compacted with concrete or clay in order to prevent the inflow of atmospheric air into the well and the leakage of biogas into the atmosphere. The radius of action of a well for collecting biogas is on average 30-35 m. The number of wells is 4 wells per 1 hectare of landfill site. Depending on local conditions, the morphological composition of the waste, landfill compaction, and the period of its operation, the output of BGZ ranges from 6 m3/h to 20 m3/h per well [3].

The construction of the gas drainage system can be carried out both on the entire territory of the landfill after the end of its operation, and on its individual sections as it fills up. The configuration of the gas collection wells depends on the features of the landfill, including the differences in depths and heights of the body of the landfill, which will be determined at the design stage. The exact number and density of placement of wells of the future system for collecting BGZ will be determined by the results of test drilling and test pumping. During operation, the landfill subsides by 5-20% or even 30-35% of its depth, so the wells are connected to the collector using a flexible connection. Pipelines made of low-pressure polyethylene (for surface and underground use) and polyvinyl chloride (for underground use) are most widely used for collecting biogas at landfills.

The morphological composition of the organic part at medium-sized solid waste landfills (with an area of 15 hectares) is shown in Table 4.4.

Table 4.4

Morphological composition of the organic part of MSW in landfills

Morphological composition of the organic part of MSW	Proving ground		The content of the main chemical elements in the dry matter of the organic components of solid waste, %					
	Content by mass of solid waste, %	Content in the organic part of solid waste, %	C	H	O	N	S	ash
Paper	21,0	44,5	45,40	6,10	42,10	0,30	0,12	6,00
Food waste	12,0	25,4	41,70	5,80	27,60	2,80	0,25	21,90
Tree	2,1	4,5	48,30	6,00	42,40	0,30	0,11	2.90
Textile	2,6	5,5	46,20	6,40	41,80	2,20	0,20	3,20
Leather, rubber	4,6	9,5	59,80	8.30	19.00	1,00	0,30	11.60
Plastic	3,4	7,2	67.90	8.57	10,30	1,13	0,05	12,02
Bones	1,6	3,4	59,60	9.50	24,70	1,02	0,19	4,99
Mixture	47,2	0	48,10	6,53	33,3	1,18	0,15	10,74

Source: formed on the basis of [4-14]

Research, Hryschenko A.V. show that the intensity of biogas formation at a solid waste landfill depends on the composition of waste, its mass, the order of storage, the density of waste per square kilometer, the access of oxygen and water to landfill waste, air and soil temperature. In view of this, it is necessary to first of all assess the composition of solid waste at the landfill. As a rule, the basis of MSW of Ukraine is organic matter (paper, food waste, plant residues, etc.), which is 70...80% capable of biological decomposition in aerobic and anaerobic conditions [4, p. 39].

If there is a percentage content in the organic matter of MSW and the atomic weight of carbon, hydrogen, oxygen, nitrogen, sulfur, the number of gram-moles of these elements in 1 kg of MSW is determined (Table 4.5).

Table 4.5

The mass of starting substances during the anaerobic decomposition of organic substances is 1 kg of MSW

Input chemical elements		Initial compounds				
chemical sign	mass, g mass,	chemical formula	g mass	fraction, %	volume, m^3	volume share, %
C	102,00	CO_2	162,20	66,70	0,0923	42,36
H	13,78	CH_4	77,20	31,80	0,1210	55,53
O	70,70	NH_3	3,06	1,36	0,0044	2,02
N	2,50	H_2S	0,34	0,14	0,0002	0,09
S	0,32					
H_2O	53,50					
	242,80		242,80	100	0,218	100

Source: [4, p. 40]

During the storage of solid waste at the landfill, the anaerobic process of decomposition of organic matter takes place, during which new chemical compounds are formed - carbon dioxide (C02), methane (CH4), ammonia (NH3), hydrogen sulfide (H2S). These are gaseous substances that, when mixed, form biogas. Knowing the molecular weights of the formed compounds C02 (44), CH4 (16), NH3 (17), H2S (34) and H20 water (18), it is possible to determine the masses of substances formed during the decomposition of 1 kg of MSW [4, p. 41].

The production of biogas at solid waste landfills is most expedient to be carried out at those enterprises where waste sorting and processing has already been developed.

It is also advisable to partially use agricultural products for processing into alternative energy sources [5].

The priority directions for the long term should be: the introduction of waste-free production, biotechnology as the main condition for the production of products with high-quality consumer properties; expansion of the range of ecologically clean and dietary dairy products; increasing the level of competitiveness of dairy products both on the domestic and foreign markets, creating waste processing plants [6, p. 37].

According to Furman I.V. in the future, it is expedient to consider the possibilities of implementing technologies for processing waste into biogas, focused on the internal needs of the enterprise through the implementation of the experience of the leading countries of the world, which will make it possible to obtain not only biofertilizers, but also energy resources [7-19].

Based on the above, calculate the volume of biogas generation (Gmax) at the average landfill for the example of KP "Dobrobut" in Illintsi (currently processing and sorting solid waste) using the formula:

G = M x V (m3),

where M is the annual amount of solid waste entering the landfill; V is the volume of biogas produced from 1 kg of MSW (V = 0.218 m3/kg).

M = H x h,

where H is the rate of accumulation of solid waste per 1 inhabitant in one year (H = 300 kg);

Ch is the number of city residents.

Thus, for example, for Illinetska TG with a population of approximately 20,000 inhabitants, the volume of biogas generation at the solid waste landfill per year is:

G = 300 x 20000 x 0.218 = 1308000 m3.

As can be seen from the calculation, it is possible to obtain significant volumes of biogas for the production of both heat and electricity.

Based on the relevant calculations, it should be noted that in terms of methane and carbon dioxide, according to the data in Table 5, the volumes will be 726,000 m3 of methane and 582,000 m3 of carbon dioxide (9,720 tons).

It is appropriate to compare the announced costs for projects in Ukraine. The planned cost of the projects being developed in Ukraine ranges from 120 to 250 Euros/ton of solid waste per year [8, p. 38].

The capacity of the existing landfill exceeds 60,000 tons of solid waste per year, so the project cost will be about 7.2 million euros. The cost of the project is prohibitive for the community, so the development of this project is possible only with the involvement of an investor.

Based on the calculations, production volumes will make it possible to sell methane at a cost of UAH 49,104/thousand m3 and carbon dioxide at UAH 2,196/t (61 Euros). Therefore, the total amount of income will be UAH 35.6 million - methane, UAH 21.3 million - the sale of carbon dioxide (total of UAH 56.8 million annually).

In our opinion, an information model of the interaction of waste processing enterprises focused on the production of biogas is necessary, which should include interaction on the basis of public-private partnership of research institutions and relevant enterprises focused on the production of biofuel (Fig. 4.1).

The appropriate model should include the following measures for the production and promotion of biogas to the energy market:

- public-private financing of scientific research in scientific institutions in accordance with the needs of the enterprise (design of biogas plants, production at solid waste landfills);

- training of employees who will be involved in the production of biogas at the landfill in the scientific institution;

- conclusion of contracts with enterprises focused on the production of equipment developed by scientific institutions for the production of biogas at solid waste landfills;

- compensation of interest by the state budget for the purchase of equipment for the production of biogas to communal enterprises;

- establishment of the biomethane market in Ukraine;

- transfer of by-products from biogas production (digestate) for use as organic fertilizer for agricultural crops;

- establishment of cooperation with buyers of biogas (industrial enterprises - biogas).

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It should be noted that for agricultural formations, in addition to the financial effect of saving money on the purchase of mineral fertilizers, the use of such organic fertilizers for the needs of farms will allow to obtain a positive agrotechnical effect caused by their advantages, namely: maximum storage and accumulation of nitrogen, a high level of assimilation of organic substances, absence of weed seeds and pathogenic microflora, resistance to soil leaching, etc. Thus, their use will allow not only to improve the physical and mechanical properties of the soil, to increase the yield of agricultural crops, but in the future to help produce competitive environmentally friendly products for sale on domestic and foreign markets.

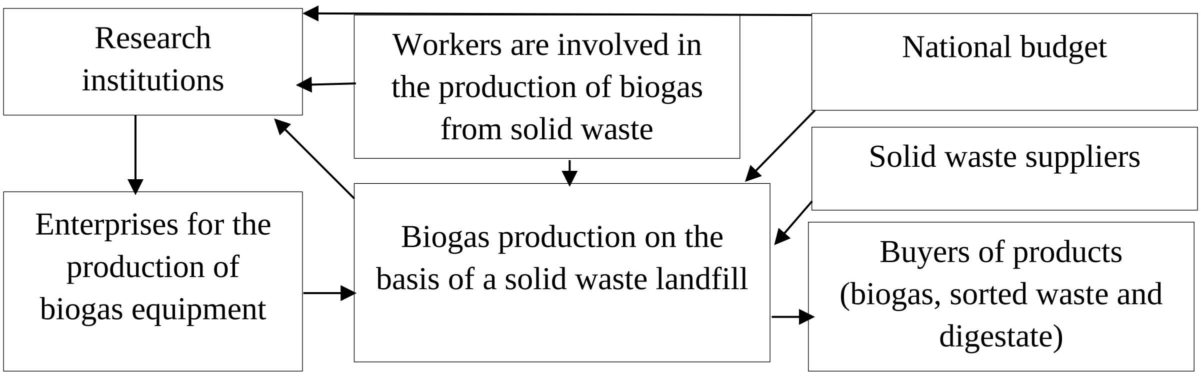

Fig. 4.1. Model of interaction of waste treatment enterprises focused on biogas production

Source: own development

Therefore, the implementation of the corresponding model in practice will make it possible to partially reduce the state's energy independence from energy carriers, increase the efficiency of agricultural enterprises, providing the crop industry with organic fertilizers, and give an impetus to the development of equipment for biogas production at landfills.

When reforming the territorial management system, it is necessary to take into account potential threats, including political ones, associated with decentralized management, and to implement the processes of fiscal decentralization at those levels of management at which it is possible to effectively provide the population with public goods. Decentralization should primarily concern the local level with financial strengthening of the functions and responsibilities of local self-government of basic administrative-territorial units, while the issue of financial strengthening of regions should be considered in a more distant perspective. The effectiveness of the functioning of the local level of the administrative-territorial system presupposes the existence of a close relationship between the subjects of the territorial community and the resources that are formed within the framework of local reproduction cycles - financial, material, administrative, spiritual, human, natural. Accordingly, the local resource base should be reflected in local budgets by expanding their revenue base at the expense of both real estate taxes and income generated by the local economy [5, p. 60].

One of the primary tasks of local councils is to resolve the issue of disposal and processing of waste at solid waste landfills. Based on the modern practice of solid household waste management in territorial communities, the need to develop the processing of the organic component of waste to ensure the environmental safety of the community and increase the level of energy independence through the production of biogas from a certain type of waste has been determined.

The concept of a cluster approach to grouping by geographic features was first explored by M. Porter, who described a "cluster" as a geographically concentrated group of interrelated companies, specialized suppliers, service providers, firms in relevant industries, as well as related to them activities of organizations (universities, standardization agencies, and trade associations) in certain regions or areas that compete and cooperate at the same time [6, p. 205]. A.A. Migranyan defined a cluster as a concentration of the most effective and interconnected groups of firms that successfully compete and form a "golden intersection" (in the Western linguistic interpretation, "diamond") of the entire economic system of the state and ensure competitive positions at the sectoral, national and global level markets [7]. In turn, domestic scientist M.P. Voynarenko defined the organizational structure "cluster" as "territorial sectoral voluntary association of enterprises that closely cooperate with scientific institutions and local authorities in order to increase the competitiveness of their own products and the economic development of the region" [8, p. 31].

Accordingly, analyzing the available data and other interpretations of this phenomenon, there are reasons to assert that a cluster is a geographical concentration of economically related organizations that voluntarily combine into territorial associations and cooperate to achieve a common goal.

The formation of a bioenergy cluster on the basis of solid waste landfills for the production of liquefied biomethane (LBG) (will provide an opportunity to solve a significant number of problems of the territorial community, namely:

- create additional jobs in the community;

- increase the community's energy independence;

- partially provide infrastructural facilities of the community with liquefied biomethane;

- to provide agricultural producers of the community with organic fertilizer - digestate and biohumus.

In our opinion, the corresponding cluster should be formed on the basis of the development of cooperation between the territorial community and the population in the field of sorting and processing of the organic component of solid waste:

- the city (village) council conducts explanatory work with the population with the aim of forming citizens' environmental awareness;

- on the basis of communal enterprises that serve solid waste landfills, sorting factories are created, at the capacities of which waste is sorted and partially incinerated;

- organic waste from the sorting factory, agar formations of the territorial community is transferred to the biogas complex for further processing into biogas, biohumus and digestate;

- digestate and biohumus are transferred for further cleaning and sale by the agricultural enterprise as fertilizers;

- a refueling complex is being created for the sale of liquefied biomethane to the population and enterprises.

In order to provide this cluster with solid household waste, we propose the implementation of a set of measures to improve solid waste management for the socio-economic development of territorial communities.

The development of the material and technical base of the relevant communal enterprises, which is an integral part of territorial clusters due to the purchase of equipment for processing and disposal of solid waste, will cause an increase in costs from the local budget. However, the local authorities focus on the ecological component of this cluster's activities - creating the image of an ecologically clean city and its unique business card, which corresponds to the main goal of this project - ensuring the ecologically safe development of the community.

Despite the insignificant profit, the activities of the enterprises will have a positive impact on the ecological situation in the community. In order to improve the company's financial results, it is planned to process the organic waste available at the landfill into biohumus and biomass. Today, one of the most advanced technologies for composting is the use of vermibiota. The most widespread are such species as: Dendrobena, Staratel and California worm.

Development and improvement of biogas production technologies from the waste of enterprises and households of the development of Ukraine. The proposed measures will make it possible to:

- achieve an increase in the volume of waste processing at solid waste landfills;
- to improve methods of waste management of enterprises and households;
- to increase the indicator of the gross regional product and the profitability of communal enterprises focused on the improvement of communities.

Therefore, the current ecological state of the environment and the inadequacy of the structure of energy generation in the face of an ever-increasing shortage of energy resources justify the need for scientific research aimed at the development and implementation of highly efficient autonomous energy supply systems for processing enterprises based on the use of renewable energy sources, including biogas.

It becomes obvious that such studies are strategically important and relevant not only for the formation of energy independence of the agricultural sector and ensuring food security of the state, but also in the context of sustainable development of the national economy with further integration of Ukraine into the EU.

On average, gas generation in the landfill body continues for 10–50 years, while the specific gas output is 140–280 m3/t of solid waste. The process of gas formation can be described by the following stoichiometric reaction equation: $C_6H_{10}O_5 + H_2O \rightarrow 3CH_4 + 3CO_2$ (The reaction occurs with the release of heat). The speed of the process and the gas productivity are determined by the conditions of the environment formed inside the landfill (humidity, temperature, pH, percentage ratio of organic fractions) [41]. Under natural conditions, part of the biogas from the surface, as well as the slopes of the landfill, enters the atmosphere, and part burns during self-ignition of waste under the influence of high temperature in the layers of the landfill.

To extract biogas from the body of the solid waste landfill, a biogas collection system is built on it, which contains:

– a network of specially equipped vertical wells;

– horizontal gas pipelines of the 1st order for transporting biogas from wells to gas collection points;

– gas collection points;

– main gas pipelines for moving biogas from gas collection points to facilities for disposal.

The Ministry of Community and Territorial Development of Ukraine recommends calculating the expected amount of biogas released during the anaerobic decomposition of 1 ton of deposited solid waste according to formula 1:

Vr.b. = PTPV × Kl.o. × (1-Z) × Cr.,

where Vr.b is the estimated amount of biogas m3;

MSW - total mass of solid household waste deposited at the MSW landfill, kg;

Kl.o. - the content of easily decomposable organic matter, type of waste (K t = 0.5 - 0.7);

Z - ash content of organic matter (Z = 0.2 - 0.3);

Kr - the maximum possible degree of anaerobic decomposition of organic matter during the calculation period (K = 0.4 - 0.5).

Depending on the methane content, biogas has a calorific value of 15 to 20 MJ/m3, which corresponds to 50% of the calorific value of natural gas. The cost of the equivalent amount of natural gas (6,990 hryvnias per 1,000 m3) was used for the financial assessment of the efficiency of utilization of the generated biogas, which in conversion amounts to 160.8 million hryvnias.

One of the economic factors that can have a positive effect on the processes of introducing biogas plants at solid waste landfills is the market mechanisms of the Kyoto Protocol. According to the Kyoto agreements, Ukraine can receive significant funds from the sale of quotas for greenhouse gas emissions [33].

To strengthen the economic argumentation, it is possible to cite a methodology that allows you to calculate losses from unused methane emission of solid waste landfills. As a result of the calculations, it was found that from 1 kg of solid waste deposited at the landfill, 4 m3 of biogas is released, which is 0.34 kg in CO2 equivalent. Taking into account that in 2022, 18,561.7 tons were placed at the landfill of Illintsi MSW, as well as the fact that the cost of 1 ton of CO2. is about UAH 50, the economic loss caused by the release of biogas into the atmosphere from the landfill of Dobrobut KP is about UAH 398,000. in a year.

However, it is important to note that the introduction of biogas plants at solid waste landfills requires significant investments ranging from 200,000 euros to 17 million euros. Provided that money from the sale of greenhouse gas reduction units, according to the Kyoto Protocol, will go to the state budget, it is unlikely that private business will invest in biogas collection and utilization systems at landfills. Therefore, it is urgent to develop state programs for the utilization of biogas, which will involve the use of biogas potential of various business entities on the basis of a mutually beneficial partnership.

Given that the obtained biogas contains, in addition to methane, ballast substances, it is subject to preliminary purification before further use. Condensed moisture during cooling can cause the gas pipeline to freeze.

The potential for obtaining biogas in our country is extremely large. The processing of organic waste in biogas reactors would allow solving the energy problem to a large extent, which would have a positive effect on the development of the economy of Ukraine. Thus, on the basis of the conducted analysis, it has been proven that the most acceptable form of energy saving for the domestic economy is the processing of solid household waste, which is due to the availability of resources for this, and also does not require significant financial investments.

The potential possibilities of biomethane generation are at least 7.8 billion m3 per year, that is, about a quarter of the needs can be met as a result of the development of bioenergy in all its manifestations. So far, only a few percent of the potential is used, the reason for which is the high cost of building biogas plants, the difficulty in choosing sites for construction, and insufficient awareness of solid waste processing methods.

1. The potential for obtaining biogas in our country is extremely large. The processing of organic waste in biogas reactors would allow solving the energy problem to a large extent, which would have a positive effect on the development of the economy of Ukraine. Thus, on the basis of the conducted analysis, it has been proven that the most acceptable form of energy saving for the domestic economy is the processing of solid household waste, which is due to the availability of resources for this, and also does not require significant financial investments. The main direction of increasing the efficiency of the biogas production process from solid waste is its purification from impurities to obtain full-fledged biomethane, which can later be used in the form of fuel for cogeneration plants and gas internal combustion engines, or for traditional consumption by the population through the national gas transportation system.

2. Biogas collected from solid household waste landfills has a high content of nitrogen, oxygen, sulfur compounds, chlorine, and siloxanes. The composition of biogas from agricultural waste and raw materials mainly includes hydrogen sulfide and ammonia. The presence of oxygen in biogas from solid waste landfills promotes corrosion and biofouling in gas storage facilities, which negatively affects the further

transportation and utilization of biogas.

The development of rural areas on the basis of the green economy is an important part of the EU's Common Agricultural Policy, which strengthens the social, environmental and economic sustainability of rural areas.

The use of the bioenergy potential of solid waste landfills is intended not only to increase the efficiency of agro-industrial production, but also to ensure a gradual reduction of the negative impact of economic and household activities of society on the ecological environment.

Among the main directions of improving the collection of processing and disposal of solid household waste, the following are identified, in particular:

- development of the use of biogas from solid waste landfills in combination with increasing the use of biohumus from such landfills in agriculture;
- the maximum reduction in the consumption of carbon-intensive energy resources and the maximization of the use of biofuels;
- increasing the sustainable production of biomass, biofuel and other RES to support the implementation of the "green" transition in other sectors of the economy;
- complete replacement of coal-fired thermal power plants by 2050 due to the development of biofuel production, biomass power plants in combination with new highly maneuverable biogas generating capacities.

Implementation of an effective solid waste management system in territorial communities with high-quality sorting, improved logistics and secondary use of waste for energy and non-energy sectors will provide an opportunity to:

- to provide agricultural producers of TG with organic fertilizer at moderate prices;
- to partially provide fodder in the form of vermibiota to fisheries and poultry processing enterprises of the regions;
- increase the yield of agricultural crops thanks to biohumus fertilization;
- to increase the employment level of the population through the creation of additional jobs in territorial communities;
- increase revenues to local budgets of territorial communities.

The practical significance and scientific novelty of the work lies in the fact that the theoretical conclusions and proposals made in it can be used as a supplement to the Strategies of balanced development of individual territorial communities.

The use of waste biomass and by-products to obtain biogas and meet the energy needs of processing enterprises is one of the priority ways to increase the profitability of production, increase the competitiveness of products and improve the level of energy security of the relevant industry in general. In addition, this practice allows a partial solution to the problem of ecological pollution of the environment, which is acute today, as a result of the imperfection of the national policy in the field of waste management.At the same time, the production of biogas at solid household waste landfills can have the following effect on the economy:

- to increase the energy independence of the state;
- to reduce utility companies' expenses on energy carriers;
- to improve the ecological condition of territorial communities;
- reduce the volume of greenhouse gas emissions;
- to provide agricultural producers with organic fertilizers.

The main restraining factor for the development of biogas production at solid household waste landfills is, first of all, the lack of state incentives and the necessary amount of investment. By means of state stimulation of the development of alternative energy and subsidies from local budgets for the relevant utility companies, it is possible to achieve the solution of the tasks in the short term. In further scientific studies, the peculiarities of the formation of information systems for waste management at solid waste landfills will be considered.

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5. Efficiency of using individual biogas plants for the processing of household waste

A biogas plant is one of the options for the production of electricity and thermal energy, which does not require the use of traditional organic fuels such as coal, natural gas, etc. This is a modern and relevant alternative type of thermal and electrical energy production.

Minerals of fuel of organic origin (coal, natural gas, oil) are an exhaustive amount, therefore, under such conditions, it is necessary to develop technologies for the use of alternative energy sources for power generation systems.

Installations using renewable types of energy raw materials, which include biological waste, are an innovative alternative to the use of organic fuel as a type of heat and electricity production.

This type of soil energy generation is becoming especially popular now, when the prices of oil and gas have started to rise, and mankind has calculated that there will be enough minerals of various types for a period not exceeding 50-300 years.

At the same time, the trends in the use of alternative energy sources for the production of heat and electricity are accompanied by the improvement of the environment due to the purposeful use of large amounts of organic waste of animal and plant origin, which were previously released into the environment without control. At the same time, the latest systems of energy generation from organic waste allow us to approach zero-waste processes with the production of combustible gases (methane, hydrogen) and residues of bioprocessing, which can be effectively used as fertilizers.

Thus, the production of biofuel for biogas plants and fertilizers for agricultural processes of growing various crops is a relevant and innovative direction of using bio-waste.

Analysis of recent research and publications. The works of a number of scientists are devoted to the study of various aspects of the development of alternative energy, in particular biogas production: Kaletnika H.M., Pryshlyak N.V., Honcharuk I.V., Tokarchuk D.M., Logoshi R.V., Hontaruka Y.V. ., Furman I.V., Berezyuka S.V. etc.

It is worth noting that they all point to the importance of such research. However, economic science has not formulated clear proposals and calculations regarding the efficiency of using individual biogas plants, which determines the relevance of this work.

The scientists made a significant contribution to the theoretical and methodological perspective of the research of the mentioned problem, many of its methodological and applied aspects were solved. However, individual issues of this multifaceted problem have not been sufficiently investigated. In particular, the issue of using household waste for biogas production remains debatable.

Increased prices for traditional energy sources create significant pressure on Ukraine's energy sustainability. This negative factor is exacerbated by fuel shortages and geopolitical tensions with Russia, which make our country vulnerable to the supply of energy resources. Accordingly, it becomes extremely important not only to reduce energy costs, but also to actively develop and implement alternative energy sources that would help Ukrainian society to ensure sustainable and affordable energy security. Individual biogas plants are one of the important components of this process. Among the alternative sources of energy that can be available at the level of individual farms, a special place is given to individual biogas plants. These technologies allow households to produce their own biogas from organic materials such as organic waste or crop residues. This biogas can be used for heating, cooking and water heating on site, which helps save energy resources and reduce dependence on external supplies. Analysis of recent research and publications. The topic of biogas production is actively discussed in domestic scientific circles. Such scientists as Ya. V. Palamarchuk, L. M. Sakun, L. V. Riznichenko, B. O. Velkin [4], D. M. Tokarchuk [10], A. V. Doronin [8] considered the current state and prospects for the development of the biogas industry in Ukraine. Cherevko G., Kolodiy A., Shugalo V. [9] studied the ecological and economic efficiency of processing household waste into biogas. Kaletnik G. M., Palamarchuk V. D., Honcharuk I. V., Yemchyk T. V., Telekalo N. V. [1], Tkach N. M., Mirzoyeva T. V. [12] studied the prospects of using corn for the production of biogas, which positively affects the energy-efficient and ecologically safe development of rural areas. Honcharuk I. V. [13], Pantsyreva G. V. [13], Vovk V. Yu. [13], Verholiuk S. D. [13] as a result of research proved that rational use of natural resources due to effective waste management and the formation of the concept of a resource-saving agro-industrial complex due to the development and implementation of bio-organic technologies for growing agricultural crops for the production of biofuels from agro-biomass and animal husbandry waste are of great importance in ensuring the energy independence of the industry and the formation of the country's food security.

Despite the sufficient number of scientific works devoted to the production of biogas in Ukraine and the world, the issue of the effectiveness of the use of individual biogas plants for the processing of household waste has not yet been sufficiently disclosed and determines the relevance of this scientific work. This work is dedicated to researching the possibilities for farms and enterprises to provide themselves with their own, renewable energy from secondary raw materials through the production of biogas. Formulation of the goals of the article.

The need to process manure and droppings opened a new perspective in the design of machinery and equipment for the agro-industrial complex. Back in the 17th century, Jan Baptist Van Helmont discovered that decomposing biomass emits flammable gases. Alessandro Volta in 1776 concluded that there is a relationship between the amount of decomposed biomass and the amount of gas released. In 1808, Sir Humphrey Davy discovered methane in biogas. The first documented biogas plant was built in Bombay (India) in 1859. In the same year, biogas began to be used in Great Britain for street lighting.

The biogas market is currently the most developed in Europe, this is explained by the fact that it was the developed countries of the EU that were the first to implement programs for the transition to alternative energy sources and systematically supported initiatives aimed at introducing new biogas technologies. Currently, the biogas plant is a characteristic element of modern, waste-free production in many branches of agriculture and food industry. If the enterprise has agricultural or food industry waste, there is a real opportunity with the help of a biogas plant not only to get rid of such waste, but also to significantly reduce energy costs, increase the efficiency of the enterprise, and get additional profit.

The leading place among industrialized countries in the production and use of biogas according to relative indicators belongs to Denmark, where biogas occupies up to 18% of its total energy balance. In terms of absolute indicators, the leading place in the number of medium and large installations is occupied by Germany - where more than 8,000 biogas installations are operating.

In Ukraine, today the share of biogas in the total supply of primary energy in the country is only 1.2%. A large part of organic waste falls on the agro-industrial complex, therefore the development of biogas energy is the most promising and can be seen precisely in this sector of the economy.

The agro-industrial sector of Ukraine, producing significant volumes of organic waste and potentially possessing resources for the production of biogas, capable of replacing 2.6 billion cubic meters. of natural gas per year (theoretical potential). With the further development of agriculture and the wide use of plant raw materials (silage, grass), this potential can be proved according to various estimates from 7.711 to 1812 billion cubic meters. / year.

According to the European Environmental Protection Agency, disposal of 1 ton of dry sludge costs from 60 to 400 euros. Food enterprises involved in milk processing, sugar and alcohol production discharge more than 1 million tons of wastewater annually. Another 1 million tons of waste from other food industries (meat, beer, soft drinks, wine, yeast, etc.) should be added to them. These wastes pollute the soil, surface and underground water. BSU will allow not only to save significant funds for the restoration of the ecosystem, but also to receive income from the sale of electricity.

The list of organic wastes that can be used for biogas production includes manure, bird droppings, grain and molasses-post-alcohol waste, brewer's grain, beet pulp, fecal waste, fish and meat production waste (blood, fat, guts, kaniga) , grass, household waste, waste from dairies - salty and sweet milk whey, waste from biodiesel production - technical glycerin from the production of biodiesel from rapeseed, waste from juice production - fruit, berry, vegetable pulp, grape pomace, algae, waste from the production of starch and molasses - pulp and syrup, potato processing waste, chip production - cleaning, skins, rotten tubers, coffee pulp.

In addition, biogas can be obtained from energy crops such as silage corn, silphia (a plant of the genus Ferula) and algae. The output of CH_4 gas from one ton of energy crop can reach up to 300 m^3.

The yield of biogas depends on the content of dry matter and the type of raw materials used. For example, from a ton of cattle manure, you can get 50-65 m^3 of biogas with a methane content of 60%, and from various plants - from 150 to 500 m^3 of biogas with a methane content of up to 70%. The maximum yield of biogas – 1300 m^3 with CH_4 methane content up to 87% – can be obtained from fat.

There is a distinction between theoretical and technically realized gas output. In the past, the technically realized gas yield was only 20-30% of the theoretical one, but the use of new technologies, such as enzymes, boosters for artificial degradation, made it possible to significantly increase this indicator.

Solving the problems of agricultural waste processing has opened a new perspective in the design of machinery and equipment for the agro-industrial complex. Now there is a rapid process of introducing innovative resource-saving technologies into production. Austria, Italy, China, Germany, Poland, the Czech Republic and other countries have taken a significant step in the use of renewable energy sources in the last 20 years and continue to develop their scientific and technical achievements in the field of alternative energy.

Raw materials for the production of biomethane can be technical crops (rape, willow), animal manure, any pulp - beet, berry, vegetable, as well as straw or reed.

It is also convenient to extract biogas in Ukraine - our conditions are even better than in Cyprus or Germany, and the raw materials are no less. Biogas plants in Ukraine began to appear on the horizon only 12 years ago. The first biogas station "Agro-Oven" was built by the enterprise in the Magdaliniv district of the Dnipropetrovsk region in 2003.

Recently, a large biogas plant on beet pulp with a capacity of 2.38 MW started operating in the village of Rokytne, Kyiv region. After reaching the set capacity, it will supply the energy needs of about 800 individual households.

So, the trend - to increase the share of energy produced from biofuel - is currently obvious.

Every owner who has at least five cows on the farm can install such a system and save on gas and electricity. The Lviv newspaper "Express" describes examples of how savvy owners installed biogas plants. We quote this post in its entirety:

Design engineer Ivan Hergard installed a self-made biogas plant in the yard and does not buy gas from now on. Methane, which is produced out of necessity, is enough for complete autonomy, even refueling one's own car with it.

"He made a modern biogas plant quickly. It consists of a waste container, a thermoregulation system, a biomass mixing mechanism, and temperature and pressure sensors. The heart of the unit is a cistern in which junk roams. I collect waste from my own farm and from my neighbors.

These are the remains of food, grass, weeds, green shoots from the garden and vineyard. Every yard is full of organic waste, and the fastest way to produce biogas is through the fermentation of manure. Therefore, manure from livestock farms is a free source of clean energy in the world. If you have a head on your shoulders, let's save!

Peasants who have at least five cows should completely give up gas. Install a biogas plant in the yard, manure is enough to produce 20 cubic meters of gas per day - the most important thing is to extract biogas from organic waste.

It collects at the top of the cistern in which the waste ferments, passes through a pipe, is cleaned and cooled. At the output, I have methane, which can be compressed, stored, and pumped. In order to cook food, biogas needs further purification, because only 60% consists of methane."

Thus, manure fermentation makes it possible to solve economic, ecological and sanitary-epidemiological problems arising from the accumulation of a large amount of livestock waste. Biogas production is one of the zero-waste technologies, which performs an environmental and resource-saving function, because it not only does not lead to the formation of any waste, but also disposes of waste from agricultural, alcohol, food and other industries. And at the same time, it partially allows solving the problem of preserving traditional energy sources.

Modern biogas plants are divided into two types according to the technology of preparation and fermentation of raw materials: liquid-phase technology (moisture of the organic mass to be fermented is more than 85%) and solid-phase technology (moisture of the organic mass is less than 85%).

Solid-phase fermentation is a series of sequential operations (Fig. 5.1). Feedstocks such as bio-waste, manure, sludge, fats or green matter are placed in a hermetically sealed fermenter and typically heated and mixed. At the same time, as a result of anaerobic processes, biogas is formed. Currently, biogas is mainly used for the combined production of electricity and heat in block mini-CHPs.

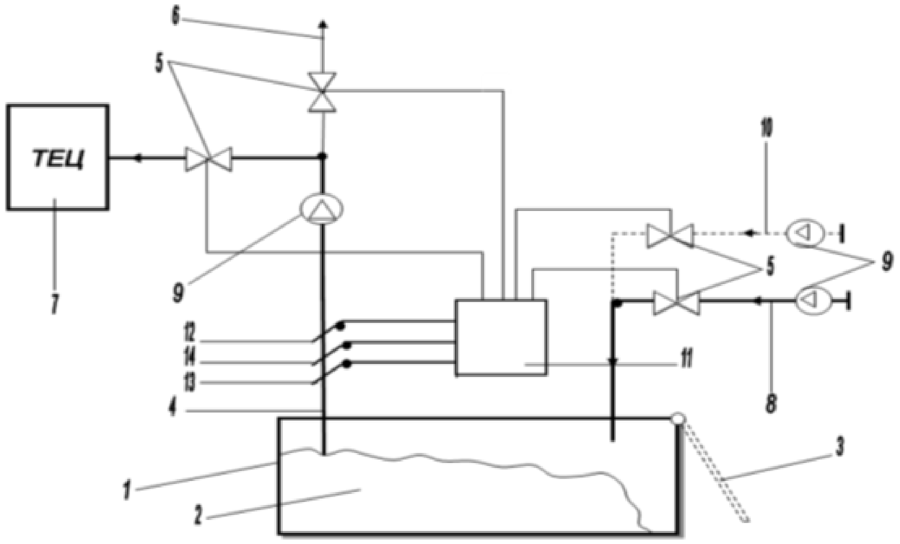

Fig. 5.1. Scheme of a solid-phase biogas plant

1 – fermenter; 2 – biomass; 3 – loading and unloading hole; 4 – biogas output; 5 – valve; 6 – gas pipeline; 7 – CHP block; 8 – CHP waste gas line; 9 – fan; 10 – fresh air line; 11 – control panel; 12 – methane sensor; 13 – carbon dioxide concentration sensor; 14 – a sensor for determining the volume flow rate of biogas

The gas mixture is cleaned of hydrogen sulfide (H2S) and fed to the gas piston engine, which turns the generator. The electric current produced in this way enters the network. The heat from the engine cooling system and the heat of the exhaust gases are removed with the help of a coolant for further use. Part of this heat (15-30%) is necessary for heating the bio-raw material and maintaining the selected fermentation temperature, since the bacterial strains responsible for biomass decomposition are most productive in the temperature range from 37°C (mesophilic) to 55°C (thermophilic).

Surplus heat can be used by different consumers. The most efficient installations with year-round use of heat. In some projects, biogas is enriched and pumped into the gas pipeline. Thus, the chances for the construction of a biogas plant in those areas where there are no heat consumers are increasing. Enriched biogas can also be used as fuel in vehicles. After methane fermentation, the residual substrate has practically no unpleasant odor and is used as an organic fertilizer in agricultural production.

A common method of biogas production is the anaerobic fermentation of liquid biomass (W=88-95%) by methane-generating microorganisms. The use of liquid-phase technological processes is more common in the practice of using biogas plants. This process consists in the continuous introduction of small portions of raw materials into the methane tank, which is a capacity-mixer without air access where the specified humidity and temperature are maintained. The scheme of the bioreactor, which is mainly equipped with foreign BGUs, is presented in (Fig. 5.2).

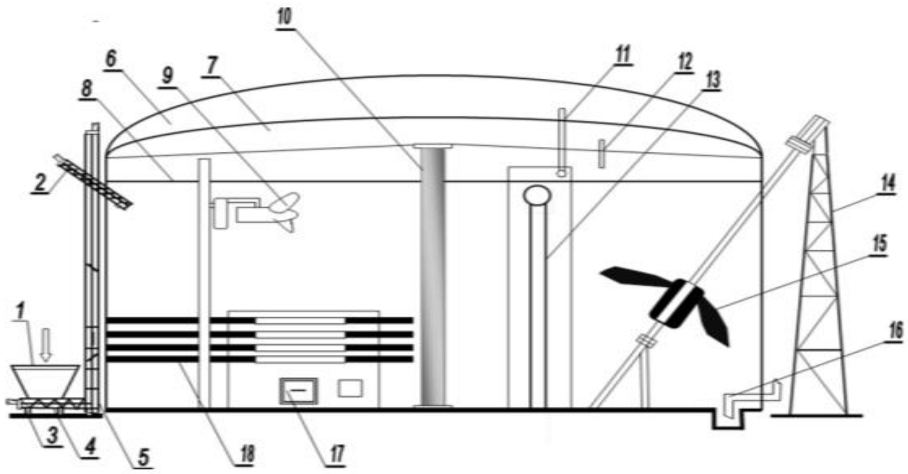

Fig. 5.2 – Diagram of a liquid-phase biogas plant

1 – hopper for loose substrate; 2 – feeding screw conveyor; 3 – weight platform; 4 – screw lower conveyor; 5 – lifting screw conveyor; 6 – air dome; 7 – biogas dome; 8 – filling level; 9 – vertical moving mixer; 10 – central support; 11 – air supply pipe; 12 – nozzle for biogas; 13 – pipe for supplying liquid manure; 14 – stirrer support; 15 – inclined stirrer; 16 – nozzle for biomass removal; 17 – temperature control system; 18 – biomass heating system

Such reactors are made of reinforced concrete or steel and have an anti-corrosion coating. Special mixers ensure the movement of raw materials with the main reactive biomass. This contributes to a certain homogeneity of the fermentation mixture, partially restraining the formation of a surface crust. The biogas released in the fermentation process accumulates under the dome, then passes through the cleaning system and is supplied to consumers (boiler or cogeneration plant).

The principle of modularity is embedded in the designs of biogas plants, which allows to increase their productivity if necessary.

On the market of Western Europe there is a significant variety of biogas plants of different capacities and designs: large (more than 1000 kW), medium (from 500 to 1000 kW) and small plants (up to 500 kW). Cylindrical-shaped reactors predominate in operating BGUs. In such reactors, it is possible to mix the substrate, discharge the fermented substrate, remove biogas and destroy the surface crust with a certain efficiency. Concrete, reinforced concrete, steel sheet, and fiberglass are used in the construction of reactors. The capacity of the fermentation chamber should not have access to air, and the body should have thermal insulation and corrosion resistance. A constant temperature must be maintained in the middle of the fermentation chamber, for which it is equipped with thermal stabilization devices. It should be noted that the presented variant of the bioreactor, like most of the existing ones, has thermal insulation and ensures operability in winter not only in the areas of southern and central Europe with a mild climate, but also in countries with a continental climate.

The disadvantage of this type of biogas reactor is that due to insufficient and uneven heating of different parts of the mixture, temperature fluctuations in the volume of the substrate become significant. This violates the technological requirements and reduces the productivity in terms of biogas output compared to the theoretical one. Due to inconsistencies in the vertical temperature gradient, a cold, slow-moving layer is formed in the lower zone, and the upper zone is overheated. The disadvantages of such reactors include large areas of heat exchangers, which leads to a significant increase in the cost of reactor construction. Fermentation technology in biogas plants requires compliance with defined acceptable limits of the temperature regime and stabilization of the heat exchange between the heater and the substrate.

When using flow reactors, there is a possibility that a small part of the fresh biomass fed into the reactor will immediately be discharged from the reactor. This issue is best solved by supplying the reactor with small portions of the substrate several times a day, as well as using several reactors working both in parallel and in series.

The experience of operating such liquid-phase reactors indicates the difficulties caused by the imperfection of the process, which is performed with the use of mechanical screw mixers, the ability of which to mix the substrate in a specific period of time in a specific volume without mixing the layers of the substrate in a vertical plane does not meet the requirements of the technological process of homogenization and the needs supply of nutrients to the colonies of methane-forming microorganisms throughout the volume of the bioreactor. In addition, in such reactors, the phenomenon of stratification of biomass with the formation of unproductive ballast layers with different specific gravity is not eliminated.

As a result of the accumulation of the mineral component of biomass in the lower part of the reactor during the operation of the BGU, the productivity of the reactors drops and within 2-3 years is 50% compared to the design level, significantly worsening the operational and economic indicators of biogas production. Ballast removal is a labor-intensive operation that must be performed in hazardous conditions. It should be noted that technological processes of biogas production are constantly being improved in the direction of increasing the energy efficiency of biogas plants.

Today, in the conditions of martial law, biogas production is one of the ways to ensure the country's energy independence. In Ukraine, the implementation of advanced technologies for the processing of agrobiomass into biogas is beginning, however, the development of methodical approaches to assessing the ecological and economic feasibility of biogas production at agricultural processing enterprises is currently one of the priority tasks for the development of biogas production in Ukraine.

Modern methods of waste management of enterprises and households in Ukraine have certain features, namely:

- focused on the disposal of waste, its placement in landfills and/or spontaneous landfills, most of which do not meet the requirements of environmental safety;
- have an extremely low technological level;
- incineration of waste in the fields;
- there is practically no implementation of innovative technologies.

In the conditions of the shortage of energy resources and the deterioration of the ecological state of the environment, the methodological toolkit of their processing into biogas is necessary and relevant

According to Lutkovska S.M. in modern conditions, a component of the socio-natural development strategy is ecological modernization. The ultimate goal of this process is the harmonization of the entire complex of relations in the socio-ecological system, its sustainable, balanced development, which ultimately makes it possible to avoid a global ecological catastrophe and ensure the process of co-evolution of man, society and nature. In the aspect of social activity, there is a need for consistency of social development and the conditions and features of the evolution of the environment. Preservation of the biosphere as a natural basis for social development requires primary attention, in particular, giving priority to socio-natural development, which involves the unity of social and ecological aspects [14, p. 22]

According to Hryhoruk I., statistical data on the gross harvest of agricultural crops are used to estimate the energy potential of primary agricultural waste, by entering the formula for calculation:

$$Ep = V * Kv * Kt * Ke * Kp,$$

where: Ep – energy potential, thousand tons of conventional fuel;

B – gross harvest of a certain agricultural crop, thousand tons;

Kv - waste ratio for each type of crops, calculated on the basis;

Kt is the coefficient of technical availability of waste, which characterizes the amount of straw that can be obtained with the existing technology of harvesting agricultural crops, calculated on the basis of

Ke is the coefficient of energy use, which indicates how much of the waste can be used to obtain energy;

Kp is the conversion factor into conventional fuel, calculated on the basis of [15, p. 59].

The change in the profit indicator that remains at the disposal of the enterprise in the calculation period as a result of the implementation of innovative energy-saving measures is determined by the expression that takes into account the change in costs for individual items:

AP= HACP + ACP + AC + AC+ (AE/eC),

P - the number of types of fuel used at the enterprise;

ХАСП - change in the cost of the i-th type of fuel consumed;

ADC - change in the cost of purchased thermal energy;

AC - change in the cost of consumed electricity; ACE — change in the amount of payments for environmental pollution;

AE – change in operational costs for maintenance of technological equipment;

e – internal rate of efficiency;

K – capital costs associated with the implementation of innovative energy-saving measures [15, p. 60].

Methodical approaches to the concept of ecological and economic efficiency remain undefined to the end, therefore Romanchuk S.V. suggests applying a general approach to the methodology for determining ecological and economic efficiency, which will comprehensively cover the problem of increasing the ecological and economic efficiency of waste processing:

EE = a * ((P - CB)* ЗС) + (b* ЕК) + (c * ЗВ)/TC*100%,

where a, b, c are weighting factors for the indicator;

P – the sale price of natural gas at the sugar factory, including all taxes and fees, transportation, etc., hryvnias/1 thousand m3;

CB – cost of own biogas production, taking into account operating and capital costs for its production, hryvnias/1 thousand m3;

ZS – total gas consumption necessary for the operation of the plant, thousand m3;

TC - total costs for the production of sold products, UAH [17, p. 325].

Research by Lutkovska S.M. regionally, it made it possible to identify weaknesses in the information support of the study, in particular:

1. The identity of the tables in the regional section is not maintained.

2. Forms of statistical reporting on individual components of pollution and processes of their flow are not developed on scientific grounds.

3. Many tables are filled with information formally, the given statistical data do not correspond to the real situation.

4. According to the presented statistics, it is difficult to determine the dynamics of pollution processes due to changes in reporting forms [17, p. 114].

The conducted analysis of the methodological principles of the development and application of indicator systems for the assessment of the socio-economic phenomenon proves that in the context of the research direction and the tasks set, it is appropriate to single out the following groups of them:

- social - for the purpose of assessing qualitative and quantitative changes in the level of catastrophic living environment for the population of the regions;

- economic - to assess the effectiveness of environmental protection measures being implemented;

- ecological and natural-anthropogenic hazards - in order to determine the level of burden on the population and the environment [17, p. 115].

At the same time, the production of biogas at processing enterprises of the agricultural sector of Ukraine will be able to have the following effects on the economy:

- increase the energy independence of the state;

– to reduce energy costs of sugar factories;

– to improve the ecological condition of water resources in the region;

- to reduce the volume of greenhouse gas emissions;

- to provide agricultural producers with digestate.

As noted by N.V. Pryshlyak on average, the cost of building such a biogas plant varies from 20 to 30 thousand dollars. USA. But the ecological (absence of unpleasant smell from the accumulation and settling of pig manure in lagoons) and economic (obtaining biogas and high-quality organic fertilizers) effects make it possible to quickly return the cost of the investment. The use of optimized raw materials will make it possible to increase the output of biogas and maximize the effects [18, p. 64].

The main restraining factor for the development of biogas production at distilleries is primarily the high cost of modernization. However, through state stimulation of the development of alternative energy and increasing fines for the emissions of alcohol industry waste, it is possible to solve these tasks. The development of appropriate mechanisms will require further scientific research in this direction [18].

The formation of methodical support for methodical approaches to determining the ecological and economic efficiency of biogas production at Ukrainian agribusiness enterprises in the conditions of overcoming energy independence should take into account both economic and ecological consequences, both for the relevant enterprise and for the socio-economic development of the state. The following calculation method is proposed:

S. econ-ecol= (E v.e.+ E o.v. + V r.d. + E e.z. + V r.+O.d.d.) – (V m./T) + In c.)

E v.e. – cost savings on energy carriers, million UAH

E o.v. - cost savings of the main production due to the use of biogas (alcohol, sugar), million UAH

In the year - cost of sold digestate million hryvnias

E e.z. - savings on environmental measures (maintenance of settling tanks, environmental taxes, etc.), UAH million

In the year - cost of sold biogas or electricity, UAH million

In the city - the cost of modernization of the agro-industrial complex enterprise, million hryvnias

In the – costs for biogas production, UAH million;

Department of - volume of state subsidies;

T - amortization period of use of the biogas plant, years.

The main direction of state support should be subsidizing biogas production, which is aimed specifically at processing waste from animal husbandry complexes.

The creation of an appropriate organizational and economic mechanism for the processing of agricultural products into biogas requires the solution of a number of tasks that will make it possible to overcome the above-mentioned obstacles to the development of this type of activity:

In-depth research in the field of biogas production focused on the processing of agricultural waste is carried out on the basis of NNVK "All-Ukrainian Scientific and

Educational Consortium" aimed at;

Economic substantiation based on the conducted experimental studies of the feasibility of creating processing plants focused on the production of biogas from agrobiomass:

Development of project and estimate documentation for the organization of processing agricultural products into biogas;

Development of directions for improvement of the state program for the development of biogas production with the provision of state subsidies for this production.

The organizational and economic mechanism for the development of enterprises of the processing industry of the agro-industrial complex for the production of biogas should include measures for the development of methodical support for the development of biogas production.

One of the new trends in the development of processing in the agricultural sector should be the development of state concessional lending to enterprises focused on the modernization of production focused on the production of biogas.

It should be noted that for agricultural formations, in addition to the financial effect of saving money on the purchase of mineral fertilizers, the use of such organic fertilizers for the needs of farms will allow to obtain a positive agrotechnical effect caused by their advantages, namely: maximum storage and accumulation of nitrogen, a high level of assimilation of organic substances, absence of weed seeds and pathogenic microflora, resistance to soil leaching, etc. Thus, their use will allow not only to improve the physical and mechanical properties of the soil, to increase the yield of agricultural crops, but in the future to help produce competitive environmentally friendly products for sale on domestic and foreign markets.

Development and improvement of biogas production technologies from the waste of enterprises and households of the development of Ukraine. The proposed methodical toolkit will make it possible to:

- achieve an increase in the volume of waste processing into biogas;
- to improve methods of waste management of enterprises and households;

- to increase the gross regional product and the profitability of sugar and alcohol factories.

The conducted studies confirm the importance of developing a methodology for evaluating the effectiveness of improving the production and processing of agricultural products into biogas.

Therefore, the application of the developed methodical toolkit in the field of biogas production will be able to give the following effect for the economy:

- to increase the level of energy security of the state and, in the long-term perspective, to switch to the export of biomethane;

- to reduce the costs of consumers (households, enterprises, etc.) on energy carriers;

- to improve the ecological condition of the environment;

- to provide agricultural producers with organic fertilizers, which is especially relevant in the conditions of rising prices of mineral fertilizers and decreasing prices for agricultural products.

Since February 2011, Ukraine has been a member of the European Energy Community. The Energy Community was established on July 1, 2006. The members of the Energy Community have committed to liberalize their energy markets and implement the most important EU legislative norms in the fields of electricity, gas, environmental protection and renewable energy sources. Support and control of the process of their introduction is carried out by the Secretariat located in Vienna. Full members of the European Energy Community are EU member states, Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro, Serbia, the UN Transitional Administration in Kosovo and the Republic of Moldova. Norway, Georgia and Turkey have observer status2. In the autumn of 2010, the Commission presented a draft of an extended energy strategy with long-term goals until 2050, as well as the further implementation of the Action Plan in the field of energy, valid for the period from 2011 to 2020. The main thematic points of the EU energy strategy are the internal energy market, energy efficiency, protection consumers, research and development, as well as external relations of the EU in the field of energy. As a member of the European Energy Community, Ukraine must also fulfill the regulatory and legal framework conditions regarding the general principles of the functionality of the internal gas market, which correspond to the European Directive 2003/55/EC "On common rules of the internal gas market". The Directive provides, in particular, the following: "Member States shall ensure that, taking into account the necessary quality requirements, biogas and gas obtained from biomass or other types of gas will receive non-discriminatory access to the gas system, provided that such access will consistently satisfy requirements of relevant technical norms and safety standards. These norms and standards must ensure that similar gases can be safely introduced into and transported through the natural gas system without any technical obstacles; in addition, these norms and standards should determine the chemical characteristics of similar gases"3. The EU Directive (2003/55/EC) had to be implemented into Ukrainian legislation by January 1, 2012.

In the conditions of shortage of energy resources and deterioration of the ecological state of the environment, the search for an environmentally safe method of their processing, including biogas, is necessary and relevant [7]. Biogas is a fuel gas that arises as a result of the natural process of microbial decomposition of organic substances in a humid environment where there is no access to oxygen. This anaerobic process takes place in special hermetic reactors, which can have the shape of a cylinder or be located horizontally or vertically. More technically speaking, biogas is formed during the anaerobic fermentation of organic materials in the absence of oxygen in special reactors, which can be both horizontal and vertical cylinders. The anaerobic fermentation process takes place in hermetic reactors, which are usually cylindrical in shape and can be installed horizontally or vertically. To achieve effective fermentation in the inner space of the reactor, it is necessary to maintain a constant temperature according to the selected fermentation mode: mesophilic (where the temperature of the substrate is 35±35 C) or thermophilic (where the temperature of the substrate is 53±1 C), as well as regularly mix the fermented material. Bioreactors operating in thermophilic mode are considered the most effective, where biogas is produced in the amount of 4.5 liters for each liter of useful volume of the reactor. The fermentation process produces biogas containing 40% to 70% methane, 30% to 60% carbon dioxide, about 1% hydrogen sulfide, and small amounts of nitrogen, hydrogen, and ammonia. The volumetric heat of biogas combustion is 22 MJ/m3. Depending on the source of raw materials from which biogas is obtained, it can be classified as follows:

Individual biogas plants are also very common in China, especially in regions with a warm climate. In China, especially in rural areas, individual biogas plants are widely used to produce biogas from manure, organic waste, and agricultural residues. "Chinese domes" are special structures that recover biogas and are easy to install and operate. This practice helps villagers gain access to energy and improves their living and economic conditions. Such installations can be installed in any farm yard where there are livestock such as cows, pigs, chickens, etc. In addition, they use kitchen food waste, grass, gardening waste. In Germany, individual biogas plants are usually installed on private farms and farms.

They use manure, plant residues and other organic materials to produce biogas, which can be used to generate heat and electricity. Germany is one of the leading countries in the development of biogas energy. In Cambodia, individual biogas plants help families in rural areas produce biogas for cooking and lighting. They are usually based on simple technologies, such as biogas pits, and use organic material, allowing efficient use of waste and resources. In Nepal, individual biogas plants have become an important source of energy for farms and families. They use manure, kitchen waste and other organic materials to produce biogas. This initiative helps reduce dependence on traditional energy sources and promotes more sustainable development in rural communities in Nepal. In the US, individual biogas plants also exist, although less widely. They are usually installed on farms and large farms to process manure and other organic materials. They can produce biogas for heat and electricity.

The practice of installing individual biogas plants is useful for domestic households, as it contributes to the solution of two problems at the same time: the disposal of organic waste and the provision of an alternative source of energy. An individual installation for the production of biogas can be installed in any yard of a household that has cows, pigs, chickens, etc. The raw material enters the reactor by gravity. The hopper for collecting fermented mass is connected to the reactor, which performs the function of a compensating building for the reactor, so that the fermented mass corresponds to the loading dose of fresh raw materials.

Preheating the substrate to the fermentation temperature (37-40°C) enhances the process of further decomposition. The optimal composition of the substrate, which provides the highest biogas yield, contains 5% of a chopped mixture of vegetables, 85% of water and 10% of cattle manure. For the wide distribution of such installations in Ukraine, in addition to informational work, financial stimulation from the state is really needed, similar to how it happens in India and China. For example, China developed a program for the integrated use of biogas as early as 1958 in order to dispose of manure and improve sanitary conditions in rural areas. With the support of the government, in the 1970s, in rural areas of China, sewage treatment plants, which were called "Chinese domes", began to be manufactured. They proved to be easy to use and Chinese farmers could build and operate them themselves. Today, similar installations with a volume of 6–8 m3 produce biogas, which provides 80% of the needs of a family of four for cooking and home. This approach can be fully applied in Ukraine, where the creation of incentives and benefits for farms producing biogas can promote the development of this technology and contribute to the improvement of environmental and energy indicators in the country.

The production of individual biogas plants in Ukraine has potential for development and is marked by several key advantages and opportunities (Table 5.1).

In general, the production of individual biogas plants in Ukraine has the potential to reduce greenhouse gas emissions, improve soil quality, and ensure energy independence of farms. However, achieving these goals requires state support, regulation and investment in the development of this industry.

Table 5.1

Advantages, opportunities and necessary requirements for biogas production in individual biogas plants in Ukraine

Advantages of biogas production in individual biogas plants	Necessary components
1. The potential of raw materials: Ukraine has a significant potential in growing crops and keeping livestock, which creates a large amount of organic waste, ideal for biogas production. 2. Environmental benefits: Biogas production helps reduce greenhouse gas emissions and helps improve the quality of the pound, as waste from the biogas process can be used as organic fertilizer. 3. Technology availability: Biogas production technologies for individual farms are becoming increasingly available and efficient and can be adapted to different farm sizes. 4. Reducing energy dependence: Biogas production allows farms to reduce dependence on traditional energy sources and reduce fuel costs. 5. Development of regional farms: Biogas production can create an opportunity for the development of small enterprises, specializing in waste treatment and maintenance of biogas plants.	1. Financial support: State or regional financial support for the development and implementation of biogas projects at the household level. This may include subsidies, loans or grants for the establishment of such installations. 2. Tax incentives: Establishing tax incentives for farms that produce biogas can make this technology more attractive to investors and farmers. 3. Education and training: Providing adequate education and training for farmers and technical staff responsible for operating biogas plants. 4. Standards and regulation: Development of standards and regulations to ensure the safety and quality of biogas and its production. 5. Development of regional networks: The task of developing the infrastructure for the collection and distribution of biogas can contribute to its further development.

Source: systematized based on [1-24]

This will allow us to more thoroughly assess the prospects of this industry and identify possible ways for its further development. Considering the need for energy independence and environmental protection, consideration of this alternative energy technology becomes an extremely important task for Ukraine. The general conclusion of the SWOT analysis shows that the production of individual biogas plants in Ukraine has significant potential, especially taking into account the environmental and energy challenges of the modern world. However, the successful development of the industry requires government support, financial incentives and an educational program to reduce weaknesses and exploit opportunities. So, biogas production has great potential in various aspects, and it is a really relevant and promising field of research and practical implementation. Here are some of the main benefits and important aspects of biogas production for Ukraine in general: Utilization of organic waste: biogas production allows the use of organic waste such as manure, plant residue, and others that would otherwise lead to environmental pollution and greenhouse gas emissions. This helps to reduce the environmental load. Helping fight climate change: Biogas production helps reduce greenhouse gas emissions, such as methane, which is produced when organic waste decomposes. This contributes to the fight against climate change and global warming. Energy efficiency: Biogas can be used to produce electricity and heat, making it a valuable fuel source for energy production. Reduction of dependence on traditional fuel resources: biogas production allows to reduce dependence on traditional fuel resources such as oil and coal, which can be especially important in the context of their increasing cost and limited reserves. Development of regional economy: production of biogas at the local level contributes to the development of regional economy and creates jobs in rural areas.

Smart Farming is the combined application of modern information and communication technologies in the agricultural sector to optimize crop management, reduce costs, and preserve the environment. The use of farm management information systems (FMIS) supports automated collection, processing and decision making to achieve these goals. As agricultural data collection increases, more FMIS are integrating IT technology to improve precision agriculture management and business goals. While Smart Farming systems for agriculture often have different functions and quality requirements, the general framework can be applied to any type of smart farming technology.

The growth of the M2M market in agriculture is largely due to the large-scale deployment of long-term evolution (LTE) network infrastructure, the implementation of equipment management and monitoring solutions, and the evolution of new business models by telecommunications operators. Machine-to-machine (M2M) data is also used for crop monitoring and weather forecasting with smart weather stations. In the context of intense urban migration, the need for intelligent and simple data collection has forced some governments to adopt regulations to ensure farm monitoring using the latest technologies.

In Ukraine, today the share of biogas in the total supply of primary energy in the country is only 1.2%. A large part of organic waste falls on the agro-industrial complex, therefore the development of biogas energy is the most promising and can be seen precisely in this sector of the economy.

Modern biogas plants are divided into two types according to the technology of preparation and fermentation of raw materials: liquid-phase technology (moisture of the organic mass to be fermented is more than 85%) and solid-phase technology (moisture of the organic mass is less than 85%).

It should be noted that for agricultural formations, in addition to the financial effect of saving money on the purchase of mineral fertilizers, the use of such organic fertilizers for the needs of farms will allow to obtain a positive agrotechnical effect caused by their advantages, namely: maximum storage and accumulation of nitrogen, a high level of assimilation of organic substances, absence of weed seeds and pathogenic microflora, resistance to soil leaching, etc.

The creation of biogas auxiliary productions will make it possible to: - reduce Ukraine's dependence on imported energy sources; carry out processing of waste from own production and life activities of personal peasant households; to minimize costs for heating houses. to provide private peasant farms with high-quality organic fertilizer - digestate (the use of which will make it possible to increase the yield on homestead plots).

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