DEVELOPMENT OF BIOENERGY IN THE CONDITIONS OF CLIMATE CHANGE IN UKRAINE

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Abstract. *Bioenergy is a branch of the energy sector that involves the use of biomass as a fuel. Today, bioenergy confidently takes the place of the leader of the world's renewable energy, playing a significant role in replacing fossil fuels and reducing greenhouse gas emissions, which is especially relevant in the context of global warming and climate change. The purpose of the study is to characterize the peculiarities of the development of bioenergy in the conditions of climate change in Ukraine. Research methods are monographic, statistical, graphical and tabular, methods of comparative analysis. The development of bioenergy does not involve deforestation, environmental degradation or loss of biodiversity. Among the most promising types of biomass in Ukraine, agricultural residues (straw of grain crops and rapeseed, by-products of corn production, sunflower) and energy plants (willow, poplar, miscanthus), which constitute agrobiomass, are distinguished. Agrobiomass is a large underutilized resource that can help achieve European energy and climate goals, while also contributing to the development of rural areas. Ukraine has a significant potential for agricultural residues and energy plants, the implementation of which can significantly reduce the consumption of fossil fuels and increase the country's energy security. Although the share of agro biomass in the total energy potential of Ukraine's biomass is 75-80%, its practical use (except for sunflower husks) remains insufficient. At the same time, the rather limited energy potential of wood biomass is realized almost completely. It is necessary to change the structure of the use of biomass potential in Ukraine, giving preference to agricultural residues and energy plants, which corresponds to the trends laid down in the European Green Course. Therefore, bioenergy is one of the strategic directions of development of the sector of renewable energy sources in Ukraine as well.*
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Introduction. Nowadays, bioenergy has confidently taken a leading position in global renewable energy, playing a significant role in replacing fossil fuels and reducing greenhouse gas emissions. Bioenergy best meets the principles of sustainable development, one of the most important requirements of which is the availability of sufficient fuel and energy resources for their stable consumption in the long term. In view of the ecological crisis, bioenergy has the following important

features: the provision of reliable energy supply; reduction of emissions of greenhouse gases, pollutants; the ability to restore the disturbed state of the environment.

Bioenergy is a branch of the energy sector based on the use of biofuels produced from biomass. Biomass is a non-fossil biologically renewable substance of organic origin that undergoes biological decomposition in the form of products, waste and residues of forestry and agriculture (crop production and animal production), fisheries and technologically related industries, as well as a component of industrial or household waste, capable of biological decomposition.

Biomass is a promising source of renewable energy both in the world and in Ukraine. Currently, biomass ranks fourth in the world in terms of energy use. In recent years, there has been a gradual increase in the number of facilities for the production of thermal and electrical energy from biomass in Ukraine. The sustainable development of bioenergy makes it possible to reduce Ukraine's dependence on expensive imported energy sources and ensure effective use of local resource potential. One of the directions of the fight against Russian aggression is gaining energy independence. And Ukraine, as a member of the energy community, as a candidate for membership of the European Union, strives to ensure the fulfillment of such pan-European goals as decarbonization, energy efficiency, and increasing the use of renewable energy sources. The transition to the use of biomass for energy needs will contribute to the improvement of the country's balance of trade and payments due to a decrease in the volume of imports of energy carriers.

Literature review. The main advantages of bioenergy use are the following: high economic efficiency, investment attractiveness, promotion of improvement of environmental ecology, increase of production competitiveness and reduction of energy dependence of the country. One of the important prerequisites for the successful development of bioenergy in any country is the availability of sufficient biomass resources. Significant advantage of the energy use of biomass is its versatility both in terms of energy conversion technologies and methods of its final use. Biomass can be used for energy needs by direct burning (firewood, wood chips, straw bales, biomass pellets and briquettes), and in processed form as well.

Biomass is a CO_2-neutral fuel, since plants absorb the same amount of carbon dioxide during growth, which is then released when the corresponding type of biomass is burned. Although the full cycle of production and preparation of biomass for energy use is associated with certain energy costs and greenhouse gas emissions, these emissions are much lower compared to emissions from the use of fossil fuels (coal, oil and gas). This difference is especially noticeable during the production of heat and electricity. During the last 20 years, the world's primary energy supply from biomass and biofuels has increased by a third, with an average annual growth rate of 2%, and has reached about 10% of total primary energy supply (WBA, 2020). The role of bioenergy in the thermal energy production sector is particularly important, as biomass can directly replace natural gas and coal.

The problems of the development of bioenergy in Ukraine have become particularly relevant and are due to the need to ensure the implementation of the

European green course. The following Ukrainian scientists have investigated the use of biomass impact issue as a renewable energy source on climate change and the functioning of the biomass market G. Geletukha, T. Zheliezna, I. Mazur, V. Mesel-Veseliak, M. Kobets, O. Shpychak and others.

Research methodology. For the research, it has been used data by State Statistics Service of Ukraine. In carrying out this study, general scientific and comparative methods were used.

Main results. The contribution of bioenergy to the gross final energy consumption in the EU-28 is more than 10%, which is almost 60% of the total contribution of all renewable energy sources. Regarding the structure of biomass consumption, almost 70% of the total volume is wood biomass, 20% is agricultural biomass (agricultural residues and energy crops), (ETIP Bioenergy, 2020; Bioenergy Europe Statistical Report, 2020). More than half of all biomass is used for thermal energy production (this trend is expected to continue in the future). Currently, bioenergy provides more than 80% of all thermal energy from renewable energy sources. Experts of the European Platform for Renewable Heat and Cold predict that in 2040, this indicator will range from 30% to 60% under various development scenarios (Banja, Sikkema, Jégard et al, 2019; RHC-ETIP, 2020). Increasing the volume of energy production from biomass in the EU is possible, first of all, due to the wider involvement of agrobiomass in the energy sector. According to the current practice of collecting agricultural residues in the EU, its potential available for energy is more than 102 million tons (dry matter) per year. When harvesting the optimal amount of residues, this number can increase to 146 million tons (dry matter)per year. According to the estimates of the Joint Research Center of the European Commission, the specified potential (equivalent to about 56 million tons of oil equivalent per year) can be fully used for energy needs without a negative impact on the carbon content in the soil (Monforti et al., 2015).

Global agrobiomass heating systems have numerous areas of application, namely, centralized heat supply, heating of greenhouses, agricultural enterprises, agro-industrial companies, houses, hotels, etc. The most used types of agrobiomass are the following: cereal straw, sunflower husks, energy crops (miscanthus, willow).

Denmark is a well-known European leader in the energy use of straw, where its annual production is, on average, 5.5 million tons, where up to 1.6 million tons are consumed for energy needs. This provides about 2% of final energy consumption and 10% of total energy production from renewable sources. More than a third of the total volume of straw is used in 55 boiler houses of centralized heat supply (Agrobioheat, 2020; Biomass Statistics, 2018; Gawor, 2014).

In Greece, the main types of agrobiomass used for energy production are oilcake and sunflower husks. The oil cake is obtained in large quantities from olive oil factories, and most of it is consumed on site to obtain thermal energy for technological needs. The rest is sold at a small price to other consumers, including general public. The main volume of sunflower husk pellets is imported at an affordable price, which makes them a competitive fuel in the country (Jansen, Stroia, 2019*)*.

Considering Ukraine's high dependence on imported energy sources and the great potential of biomass available for energy production, bioenergy in the country

is one of the strategic directions of the development of the sector of renewable energy sources. Unfortunately, the rate of development of bioenergy in Ukraine is still significantly behind the European ones. Nowadays, the share of biomass in gross final energy consumption is 1.78%. About 2 million tons of conventional fuel peryear of biomass of various types are used annually in Ukraine for energy production. Wood accounts for the highest percentage of the use of the economically feasible potential which is 80%, while for other types of biomass (with the exception of sunflower husks) this indicator is significantly lower. The energy potential of the straw of cereal crops and rape is realized the least actively (at the level of 1%), (Bioenergetics, 2023).

More than 50 million tons of grain crops are harvested annually in Ukraine. Large amounts of straw and plant residues are obtained as by-products of crop production. The annual technically achievable energy potential of solid biomass in Ukraine is equivalent to 18 million tons of oil equivalent, and its use makes it possible to save about 22 billion cubic meters of natural gas annually (Geletukha et al., 2009).

Nowadays, the biomass of agricultural origin (namely, straw of grain crops and rapeseed, by-products of production of corn for grain and sunflower, sunflower husk) remains the main component of the energy potential of biomass in Ukraine.

In Ukraine, the energy potential of agricultural waste and by-products (namely, cereal straw, corn stalks, sunflower stalks, sunflower husks, etc.) is 9-11 million tons of oil equivalent per year, depending on the yield of agricultural crops. One of the uses of biomass of agricultural origin is the production of fuel briquettes and pellets, which are considered "improved" solid biofuels due to their higher calorific value, lower moisture content and generally higher energy density compared to uncompacted types of biomass and biofuels. From an economic point of view, the production of biomass briquettes is more attractive than the production of pellets, since the investment in the briquetting line and the operating costs are significantly lower compared to a pellet line of similar performance. Sunflower husks are actively used in Ukraine for the production of biofuels and energy. Almost all oil extraction plants have equipment for burning husks.

The second component of agrobiomass potential is energy crops (namely, willow, poplar, miscanthus, etc.). Although the share of agrobiomass in the total energy potential of Ukraine's biomass is about 75-80%, its practical use (except for sunflower husks) remains extremely insufficient to achieve national goals in the fields of energy and climate. At the same time, the rather limited energy potential of wood biomass (2.6-3 million tons of oil equivalent per year) is realized almost completely. Therefore, it is necessary to significantly change the structure of the use of biomass potential in Ukraine, giving preference to agricultural residues and energy plants. This corresponds to the trends laid down in the European green course and the views of domestic experts on the future of bioenergy (Geletukha et al., 2020; Zheliezna, 2021).

Energy crops are fast-growing perennial shrubs and special annual plants with a high content of dry mass for use as fuel (yield up to 15–25 t per ha per year). Energy crops are considered as an alternative source of biomass that can be specifically grown for energy needs. This direction became widespread during the first oil crisis in the 1970s with the support of the governments of various countries along with the

development of other renewable sources. Currently, energy crops are used as a source of biomass for the production of thermal and electrical energy, biofuels, and biomaterials.

According to the data of the European association Bioenergy Europe, almost all EU-28 member countries consider energy crops as a promising direction of bioenergy and collectively already have about 118.5 thousand hectares of plantations on their territories, both tree plantations (60.6 thousand hectares), and herbal (57.9 thousand hectares) energy crops (Bioenergy, 2020).

Poland (17.8 thousand ha), Germany (15.8 thousand ha), Great Britain (13.0 thousand ha), Sweden (11.6 thousand ha) and Greece (11.0 thousand ha) is the leader among the EU-28 countries in terms of the total area under energy crops (Geletukha et al., 2022).

Most energy plants provide a harvest for more than one year, thus the minimum payback period for investments in typical projects reaches 2–4 years. The advantage is that you can harvest from one plantation for at least 25 years, spending only on this collection itself, because these crops do not require additional costs for drying, and warehouses for its storage do not require special conditions. As of today, there are about 20 types of fast-growing crops that can be grown to obtain crop biomass, namely, eucalyptus, poplar, willow, switchgrass, miscanthus, and others. The collected biomass is used to produce thermal and electrical energy, it can be a raw material for the production of solid biofuels, such as fuel pellets and briquettes (Energy crops, 2018). These crops, with a clear technology and the achievement of an appropriate level of productivity, make it possible to ensure a fairly high energy yield from 1 hectare of land, and in addition, its main competitive advantage over traditional agricultural crops is that it is not necessary to use agricultural land for its cultivation (Kernasyuk, 2019).

Because of the leaves that fall from energy crops every year and its underground part that remains in the soil, its fertility increases. The field that belonged to a low-productivity and degraded land can be moved into the category of productive agricultural land after growing energy crops on it for 20-25 years. Growing energy crops on unproductive and degraded land is also considered more sustainable because it does not compete with food or feed crops.

Discussion and conclusions. Bioenergy is a branch of renewable energy that plays an important role in replacing fossil fuels and reducing greenhouse gas emissions. According to the Paris climate agreement of 2015, Ukraine has international obligations to reduce greenhouse gas emissions by 40% in 2030 compared to the level of 1990. The development of bioenergy is cost-effective and attractive for investment, contributes to the improvement of the ecological condition of soils, and increases the competitiveness of production and reducing the country's energy dependence.

Nowadays, biomass of agricultural origin (namely, straw of grain crops and rapeseed, by-products of production of corn for grain and sunflower, sunflower husk) remains the main component of the energy potential of biomass in Ukraine. This is due to such factors as the high development of agriculture in the country, the limited resources of wood biomass for energy needs and the relatively slow development of the segment of cultivation and use of energy crops. The result of the widespread use

of biomass is the diversification of sources of energy supply, that is, a gradual transition from traditional energy resources to more ecologically safe types of fuel.

The production of thermal energy from agrobiomass has significant development prospects in Ukraine, which is connected with a great potential of the energy resource and still low level of its practical application. For the further development of bioenergy, it is necessary to significantly change the structure of the use of domestic biomass potential, giving preference to agricultural residues and energy crops. Taking into account the available unused potential of various types of agricultural residues and regional features of crop production, it is important to establish a reliable technology for harvesting and energy conversion of waste and by-products of corn and sunflower production.

Energy crops are an alternative source of biomass for the production of thermal and electrical energy, biofuel. The advantages of using it are the following: the possibility of using low-productive and unproductive land for cultivation; stopping the process of impoverishment and the development of soil erosion; during the combustion of biofuel based on plant biomass, less carbon dioxide is emitted into the atmosphere than is absorbed by plants in the process of photosynthesis; a by-product of the combustion of solid biofuel is an organic substance that can be used as fertilizer; low cost of biomass, etc.

The post-war recovery plan of Ukraine should be carried out through the prism of energy decarbonization and the policy of "green" transition. Certainly, bioenergy is an important component that can systematically affect the improvement of heat supply on the territory of Ukraine and reduce the impact of war losses for the restoration of infrastructure facilities.

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