

DEVELOPMENT OF GREEN ENERGY IN UKRAINE

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DOI: <https://doi.org/10.36004/nier.cecg.I.2024.18.25>

Abstract. *Green energy is a strategic area of development in many countries around the world, aimed at preserving natural resources, reducing greenhouse gas emissions, and combating climate change. Green energy helps to reduce dependence on energy imports, preserve the environment, and improve the quality of life. The purpose of the study is to characterise the peculiarities of green energy development in Ukraine. Research methods are monographic, statistical, graphical and tabular, comparative analysis. Renewable energy sources include: solar energy, which is emitted by the Sun and can be collected and converted into electricity using solar panels. The use of solar energy in agriculture will help to reduce greenhouse gas emissions, improve air and water quality, and reduce agriculture's dependence on traditional energy sources; wind energy - the use of wind energy for energy production, realized through the construction of wind turbines; geothermal energy - production of electricity through the use of potential of underground sources, such as geysers, etc. This is energy that is accumulated in the form of thermal energy under the solid layer of the earth's surface; hydropower - using the potential of water flow to generate energy. It is the most widespread source of renewable energy – accounting for more than half of the world's renewable energy capacity; hydrogen energy is based on the use of hydrogen, the main and most common source of which is the processing of natural gas and oil; biomass energy, which results from the processing of organic materials such as wood, straw, and other agricultural byproducts. Bioenergy is the largest sector among all renewable energy sources. The development of bioenergy does not involve deforestation, environmental degradation or loss of biodiversity. The production of bioenergy from biomass increases the country's energy security, saves energy costs and brings additional income to producers. At the same time, biomass mitigates the negative impact of agricultural production by reducing emissions from agriculture.*

Key-words: *renewable energy sources, green energy, solar energy, bioenergy, biomass*

JEL: *Q 28, Q 42, Q 48*

UDC: *338.43+502.131](477)*

Introduction. Currently, the Ukrainian energy sector is mainly based on non-renewable energy sources, which, having limited reserves, are exhausted and cannot

guarantee sustainable development of the global energy sector in the long term, and their use is one of the main factors that leads to the global environment degradation. The goal of green energy is to create a sustainable, low-carbon and environmentally friendly energy system that meets the needs of modern society, ensures energy security and helps preserve the environment for future generations. Large-scale green energy implementation plans should include strategies for integrating renewable sources into coherent energy systems under the influence of energy saving and efficiency measures. The main economic benefits of switching to renewable energy sources are reduced environmental damage, increased production potential, increased investment attractiveness, new jobs, improved living conditions, inexhaustible renewable sources, and reduced energy imports.

The Paris climate agreement provides for the so-called energy transition based on the principles of sustainable development from fossil energy resources to renewable ones. Alternative energy has long been a global trend: in the EU, Norway ranks first (75.8% of energy is generated by alternative energy sources), Sweden is on second place with 66%, and Finland is third with 47.9%. At the same time, the EU average is 23% (Eurostat, 2023). Denmark is a leader in the development of wind electricity, the country has set a goal of bringing energy production using wind power to 50% of the total energy consumption by 2030; Iceland is a country that by the end of 2018 met 100% of its citizens' electricity needs from alternative energy sources, etc.

Literature review. Most often, researchers' studies highlight the main environmental benefits of green energy. At the same time, researchers also reveal significant economic benefits in their scientific papers. One should agree with the opinion of Gaidai (2018) that the main economic benefits are to reduce the negative impact on the environment, increase the production capacity, improve the living conditions, etc. In the study by Quitzowet et al (2019), the economic benefits of green energy include providing all subjects with safe and affordable energy, mitigating conflicts over limited resources, and reducing energy imports.

The development of alternative energy sources both in Ukraine and in the EU countries has been studied by many scientists. Thus, the scientific works of scientists Chygryn et al (2018) and Yevdokimov et al (2018) proved the importance of the development of alternative energy sources and the competitiveness of the national economy. Prokopenko et al (2017) identified a number of barriers that hinder the attraction of green investments in the development of alternative energy sources. Scientists Melnyk and Kubatko (2013) identified the role of renewable energy sources in achieving sustainable development goals.

Strapchuk (2021) rightly notes that the agricultural sector occupies a central place in the production of an alternative energy source – biomass for its further transformation into commercial products, including bioenergy resources. Biomass is considered to be the energy source of the future, and its global potential can meet almost one-third of the projected energy demand by 2050. In addition, biomass provides lower energy consumption and CO₂ emissions compared to fossil fuels. Bioenergy resources have significant potential to contribute to sustainable

agriculture in the context of providing affordable and clean energy, which improves environmental performance, reduces the country's energy dependence on imports, and provides the population with an affordable fuel.

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 concept of "green energy" is primarily associated with the transition to renewable energy sources, the most common of which are the following.

Solar energy is energy obtained from the sun in the form of light and heat. The sun is our greatest source of energy and thanks to it, plants can carry out photosynthesis, which maintains the level of oxygen necessary for the functioning of all living things. But it can also be a supplier of electromagnetic energy. Solar energy is a renewable energy, a clean and inexhaustible natural resource that is obtained in an earth-friendly way. This is an opportunity to produce energy without polluting the environment. It can be produced as long as the sun shines. Solar radiation can be used to generate heat and electricity, which can be done throughout Ukraine.

The use of *solar energy* in agriculture can help reduce greenhouse gas emissions, improve air and water quality, and reduce agriculture's dependence on traditional energy sources. Agrovoltatics, or agrophotovoltaics, is an innovative practice that combines agriculture and photovoltaic energy production and offers many advantages to both agriculture and solar energy production. By installing solar panels over crops, farmers can harness solar energy while optimizing land use by reducing water use. In agricultural solar energy production systems, it is advisable to consider the minimum installation height of 3 m or more for solar cell modules. Each crop requires a separate calculation, since each plot has its own characteristics and needs.

Partial shading of the field contributes to the growth of some agricultural crops and doubles their cooling: plants protected by panels take carbon for photosynthesis, water evaporates from the leaves, creating a cooler microclimate, which promotes their growth and ensures cooling of the solar modules themselves, which further reduces the loss of the obtained energy (Unisolar, 2021). If agricultural enterprises install solar panels on the roofs of farms, it protects the buildings from overheating by the sun's rays. It is important for livestock to maintain a thermal balance inside the building. Photoelectric modules lower the temperature, which reduces the use of electricity for air conditioning or ventilation.

Agricultural markets in Europe have already switched to agrovoltatics. In Italy, agronomists get higher wheat yields due to shading from solar panels; and French scientists also determined that the yield of berry and vegetable crops is affected by shading; in China, agrovoltatics is dynamically developing in the cultivation of goji berries. For Ukraine, this is still a new area of agricultural development. The only

farm in Ukraine that develops according to the principles of agrovoltatics is located near Berdychiv and is engaged in the cultivation of blueberries and sheep breeding.

Wind energy is the use of wind energy for energy production. Wind power plants rank second in terms of energy production. In recent years, mankind has increasingly used wind energy to generate electricity by creating high-capacity wind turbines that are installed in areas where there are frequent and strong winds. The number and quality of such engines is growing annually. Wind energy reduces greenhouse gas emissions by using turbines that generate energy and electricity when the wind moves, and can reduce the cost of electricity.

The most attractive regions of Ukraine for wind energy are the coasts of the Black and Azov seas, the mountainous areas of the temporarily occupied AR of Crimea, the Carpathian Mountains, Odesa, Kherson and Mykolaiv regions. Unfortunately, in recent years, a significant number of Ukrainian wind farms remain in the temporarily occupied territory. According to the Ministry of Energy, Odesa region received almost 20% of electricity from local wind farms during blackouts. Modern wind turbines are built in areas where the average annual wind speed exceeds 3.5 m/s and they can already operate under such conditions. If a missile hits a wind farm, one or two turbines may be destroyed, but the entire wind farm cannot be damaged.

The disadvantages of wind energy are instability and the inability to generate constant current. But at the same time, it helps to avoid dependence on the import of energy resources. Wind energy does not interfere with agriculture and industrial activities near wind farms.

Long before the full-scale Russian invasion in February 2022, the Ukrainian energy strategy planned that by 2030, 2 TWh of electricity would be generated by wind turbines in Ukraine.

A successful example of the global use of wind energy is the United Kingdom, where this type of energy provides about 10% of the total energy demand.

Geothermal energy is energy obtained from the heat from inside the Earth, which has many different applications – for heating systems, for generating electricity and for use in geothermal heat pumps. All natural heat contained in the earth's crust can be considered as geothermal resources of two types: steam, water, gas; heated rocks.

The main source is a constant flow of heat from the red-hot bowels directed to the surface of the earth. This heat is enough for constant heating of rocks. Groundwater is also very heated by this heat – sometimes up to a temperature of 371°C. Hydrothermal energy sources are divided into thermal waters, steam-water mixtures and natural steam.

Geothermal waters are an ecologically clean source of energy that is constantly renewable. It differs significantly from other alternative energy sources in that it can be used regardless of climatic conditions and the season. Geothermal energy in Ukraine has significant potential resources, and the regions of its possible use are the temporarily occupied AR of Crimea, Transcarpathia, Donetsk, Zaporizhzhya, Poltava, Kharkiv, Kherson and Chernihiv regions.

The advantage of using geothermal energy is its independence from climatic conditions, and the disadvantage is often the impossibility of discharging thermal waters into natural reservoirs due to the presence of harmful compounds. The world's largest producers of this type of energy are Iceland, Indonesia, Mexico, the United States, Italy and the Philippines.

Hydropower is a clean and renewable source of energy. Hydropower is generated using the mechanical energy of moving water. Currently, the construction and use of small hydroelectric power stations has become more popular in the world. The advantages of them are as follows: electricity is generated without using fossil organic and nuclear fuel; a long service life and high operational reliability; predictability and security of operating modes; high maneuverability and availability ratio; the possibility of full automation of the operation process; minimal impact on the environment in the case of an unfriendly choice of location and compliance with the environmental legislation; minimal impact on the landscape and insignificant alienation of land plots; additional opportunities for fishing, irrigation, water supply.

Hydrogen energy is based on the use of hydrogen, the main and most widespread source of which is the processing of natural gas and oil. Hydrogen is expected to transform the economy in four major application areas: transportation, industry, energy, and utilities. These include industrial hydrogen production, storage, transportation and electricity supply, clean energy for buildings, as well as heating and cooling. Ukraine's potential for the production of three colors of hydrogen is currently being explored: "blue" from natural gas, "green" using renewable energy sources, and "pink" from nuclear energy. The national strategy for the selection of hydrogen production technologies should be based on two main criteria - the carbon footprint over the entire life cycle and the competitive production cost (Kosharska et al, 2022).

Bioenergy involves the processing of agricultural by-products, as well as food and wood processing waste. The main essence is obtaining electrical and thermal energy from fuel of organic origin.

Bioenergy makes up about 60% of all renewable energy sources in the world and about 70% in Ukraine. Biomass is considered to be one of the main renewable energy sources, replacing fossil fuels and reducing greenhouse gas emissions in the context of the Paris Agreement. Biomass is a source of renewable energy based on carbon, produced by the combustion of plant materials.

The largest biomass energy potential in Ukraine is in waste and agricultural residues (primary – generated in the field during harvesting, secondary – generated at enterprises during the processing of agricultural crops, manure) and energy crops (for solid biofuels and biogas), which make up agrobiomass. At the same time, the largest share of the agricultural waste potential is accounted for by the grain straw and by-products/waste from corn production (Expoconsulting, 2021).

According to the estimates by the Bioenergy Association of Ukraine, in 2021 the potential of biomass available for energy production amounted to more than 26 million tonnes of oil equivalent, which is 30% of Ukraine's total primary energy supply in 2020. Agricultural residues account for a significant share in the energy

potential – 42% of the total volume, the contribution of biogas obtained from various types of raw materials (waste and by-products of agricultural activities, industrial and municipal wastewater, solid household waste) – 31%, wood biomass and energy crops (for solid fuel) are relatively small – 10% each, liquid biofuels – 7% (UABIO, 2023). Biomass is considered as one of the main renewable energy sources, replacing fossil fuels and reducing greenhouse gas emissions in the context of the Paris Agreement.

Thermal energy can be generated by direct combustion of biomass. Currently, about 10% of heat is produced in Ukraine from renewable sources. Boilers mainly run on wood or husk. Straw as a fuel is not very popular. Research shows that 70% of straw and corn stalks can be buried in the soil to maintain the balance, and 30% can be used as material for biogas. As a result of biofuel production, all nitrogen, phosphorus and potassium remain in the so-called digestate. This fermentation product is already 100% returned to the fields as fertilizer and contributes to a 10% increase in yield (Geletukha, 2024).

The National Energy and Climate Plan approved by the government for the period until 2030 envisages achieving a 27% share of renewable energy sources in the total final energy consumption, of which 25% in electricity, 35% in heat and 14% in transport. Currently, about 70% of wind and 30% of solar energy are located in temporarily occupied territories. New facilities are being built, but not at the pre-war pace.

Discussion and conclusions. The benefits of green energy include reducing greenhouse gas emissions, reducing dependence on imported energy resources, creating new manufacturing jobs, and increasing energy security and reserves. Green energy also promotes the development of energy efficiency technologies and innovative solutions that can improve the overall performance of the energy system.

Bioenergy will remain a key renewable energy sector in Ukraine in the future. The development and implementation of bioenergy technologies makes a significant contribution to the decarbonisation of energy sector, helps the country fulfill its international commitments to reduce greenhouse gas emissions under the Paris Climate Agreement of 2015, contributes to the implementation of the "green" energy transition of Ukraine by 2050, provides additional income for farmers: bioenergy projects involve the ongoing purchase of biomass from farmers and agricultural producers at an attractive price. Ukraine has a significant potential of agricultural waste and energy plants, the implementation of which can significantly reduce fossil fuel consumption and improve the country's energy security.

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