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## REGIONAL AND TECHNICAL AND ECONOMIC FEATURES OF ELECTRICITY GENERATION BY RENEWABLE ENERGY SOURCES

## РЕГІОНАЛЬНІ Й ТЕХНІКО-ЕКОНОМІЧНІ ОСОБЛИВОСТІ ВИРОБЛЕННЯ ЕЛЕКТРОЕНЕРГІЇ ВІДНОВЛЮВАНИМИ ДЖЕРЕЛАМИ ЕНЕРГІЇ

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The article is devoted to the study of regional and technical and economic features of electricity generation by renewable energy sources, as well as scientific and methodological approaches, theoretical foundations and practical recommendations have been developed on the subject of the study. The current state of the energy sector in the world is analyzed in terms of the need to move from traditional (non-renewable) energy sources to alternative (renewable) energy sources. Key regional and technical and economic advantages and limitation of energy generation by different types of renewable energy sources have been formed. The study presents the barriers to the development of renewable sources in Ukraine that need to be leveled for the introduction of alternative energy that will reduce harmful emissions by reducing the generation of electricity by fossil fuel technologies and will improve the energy security of the state.

**Keywords:** alternative energy sources, renewable energy, hybrid renewable energy systems, regional development, management, energy, economics, energy supply, energy efficiency.

У XXI столітті енергетика України переживає військову агресію зі сторони Російської Федерації, широко-масштабне вторгнення з лютого 2022 року, планове знищення української економіки, зокрема, руйнування енергетичного сектору, захоплення об'єктів енергетичної інфраструктури та втрати серед фахівців у цій галузі. З зв'язку з чим існує нагальна потреба у досягненні Україною енергетичної незалежності за рахунок розвитку та впровадження інноваційних технологій в енергетиці. Стаття присвячена вивченню регіональних й техніко-економічних особливостей виробництва електроенергії відновлюваними джерелами енергії. Методологічну основу публікації складають сукупність прийомів, загальнотеоретичних принципів і міждисциплінарних методів наукового дослідження. У дослідженні проаналізовано сучасний стан енергетики в світі та зазначено необхідність переходу від традиційних (невідновлюваних) джерел енергії до альтернативних (відновлюваних) джерел енергії. Розвиток сектору відновлюваної енергетики допоможе прискорити економічне зростання України, залучити нові інвестиції, забезпечити регіональну децентралізацію енергопостачання, зменшити вплив на кліматичні зміни та сприятиме збереженню довкілля на шляху до вуглецево-нейтрального майбутнього. За результатами дослідження сформовано основні регіональні й техніко-економічні переваги та недоліки (обмеження) виробництва енергії різними видами відновлюваних джерел енергії (джерела енергії: сонячна, вітрова, припливи, гідро (вода), біомаса (біоенергія) та геотермальна енергія). Також у статті представлені бар'єри розвитку відновлюваних джерел енергії в Україні, які необхідно нівелювати для впровадження альтернативних джерел енергії, що забезпечать зниження шкідливих викидів за рахунок скорочення вироблення електроенергії технологіями на викопному паливі (нафта, вугілля, газ), а також підвищать енергетичну безпеку держави. Впровадження інноваційних енергетичних технологій стане потужним драйвером економічного відновлення України після завершення бойових дій на території нашої держави та сприятиме впровадженню кліматично-нейтральних енергетичних потужностей.

**Ключові слова:** альтернативні джерела енергії, відновлювана енергетика, гібридні системи альтернативних джерел енергії, регіональний розвиток, управління, енергетика, економіка, енергозабезпечення, енерго-ефективність.

**Formulation of the problem.** The energy sector plays an important role in the economic functioning and technological development of the world. In addition, after the completion of the Russian invasion of Ukraine and the coronavirus pandemic, in the process of rebuilding Ukraine, energy should become one of the key industries that provides export earnings and maintains the financial stability of the state. A reasonable approach to the modernization of the Ukrainian energy sector will allow Ukraine to make a significant contribution to ensuring the strategic autonomy of the European Union and reduce dependence on external energy resources.

In an era of society changing lifestyles with the rapid development of technology and decreasing dependence on fossil fuels (coal, oil and gas) for electricity generation, the use of renewable energy sources (wind, solar, water, etc.) without harm to the environment, is becoming increasingly important.

According to the results of the XXI UN Climate Conference, held in December 2015 in Paris, 197 countries of the world signed the Paris Climate Agreement and identified renewable energy as the main tool for reducing greenhouse gas emissions into the atmosphere in order to minimize the effects of climate change (2/3 of the world's electricity should be produced with renewable energy until 2050) [13]. Unlike the Kyoto Protocol [12], which was in force from 1999 to 2020 regarding the preservation of the environment and the fight against climate change, the Paris Climate Agreement provides that all states, regardless of the degree of their economic activity, undertake obligations to reduce harmful emissions into the atmosphere. development.

Therefore, the problem of studying regional and technical and economic features of electricity generation by renewable energy sources is relevant for the decentralization of energy supply and European integration of Ukraine.

**Analysis of recent research and publications.** The scientific and theoretical basis for the study of renewable energy sources is the complex scientific work of such domestic and foreign scientists as S. Kudrya, V. Budko, A. Skrypnyk, D. Panasetsky, D. Karamov, A. Dyachuk, M. Chepelev, R. Podolets, G. Tipolskaya, Z. Dong, P. Ray, S. Vavilapally, D. Almahles, M. Simão, N. Kumar, E. Hernandez, and others.

**Purpose and objectives of the research.** The purpose of the scientific article is to study the

regional and technical and economic features of electricity generation by renewable energy sources. The implementation of a specific goal of the study involves the solution of the following tasks:

- analyze the current state of the energy sector in the world in terms of the need to move from traditional (non-renewable) energy sources to alternative (renewable) energy sources;
- form key regional and technical and economic advantages and disadvantages (limitations) energy generation by different types of renewable energy sources;
- to summarize the barriers to the development of renewable sources in Ukraine.

**The presentation of the basic research material.** Electricity generation from renewable energy sources accounted for 28.3% of electricity generation at the end of 2021 compared to 20.4% in 2011 [1]. During this period, the share of electricity generation from fossil fuels fell by 6% (Figure 1), resulting in a reduction in carbon emissions in the energy sector. While electricity demand in the EU fell by 7% due to COVID-19, electricity generation from renewable sources increased by 5% in 2022 compared to 2019 [1], mainly due to new wind and solar installations.

Renewable energy sources continue to attract much more investment than coal, natural gas or nuclear power [4]. On Figure 2 shows the analytics of world investments in renewable energy and traditional energy sources for 2021. About 69% of global investments were invested in new renewable energy sources and only 31% are in coal, gas and nuclear power plants.

The transition from traditional (non-renewable) energy sources to alternative (renewable) energy sources is determined by the following factors:

- the growth of the world population and the increase in demand for electricity: by the end of 2023, the world's population may reach 8 billion people, and by 2050 – 10 billion people, according to which energy consumption will increase by 30% and more than now;
- depletion of fossil resources: with the further use of traditional energy sources in the world, these reserves will run out in the next 130 years (oil in 42 years, gas – 57 years, coal – 128 years) [2; 10; 15];
- the fight against climate change: excess carbon dioxide in the atmosphere, which is mainly caused by the burning of fossil fuels;
- an increase in socio-economic factors: the creation of new jobs and specializations in the field of renewable energy;

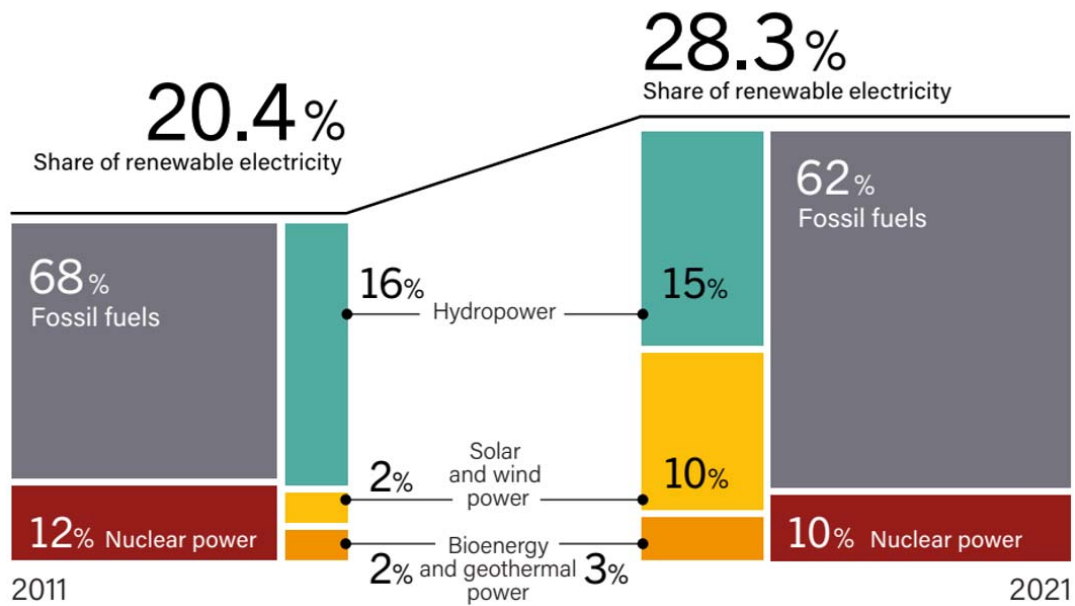


Figure 1. Share of Renewable Energy in Power [1]

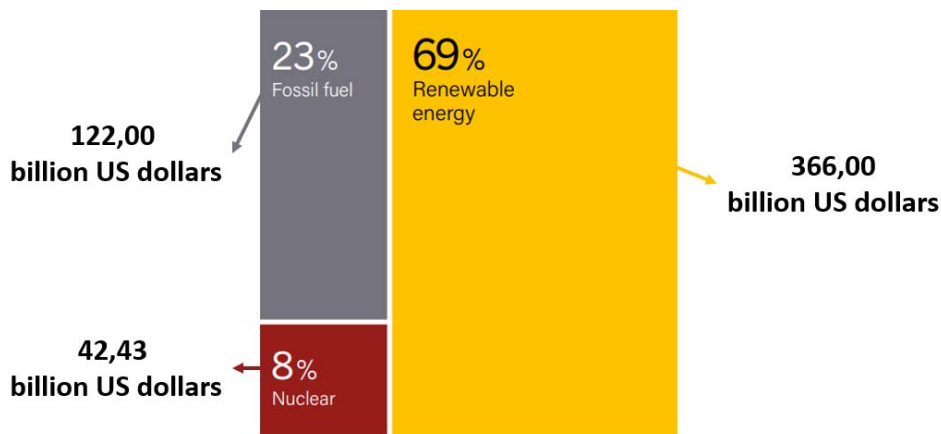


Figure 2. Global investment in new energy capacity in 2021 [4]

– the cost of electricity production: the production of energy from renewable energy is cheaper than fossil fuel technologies in the world;

– the COVID-19 pandemic and the Russian invasion of Ukraine: the transition to renewable energy should contribute to the development of economic, energy and environmental security in the world, stimulate economic recovery after the COVID-19 pandemic and end military operations on the territory of Ukraine, as well as create a powerful driver of climate protection and a practical tool for reducing greenhouse gas emissions and sustainable energy supply.

Electricity generation technologies based on alternative energy sources have inexhaustible properties for continuous use, however, each separately studied source of electricity

generation has its own regional and technical and economic advantages and limitations on the effective implementation of alternative energy sources depending on the region of location [3; 5; 6; 7; 8; 9; 11; 14; 16]:

1. Energy source – sun.

1.1. Advantages:

- an inexhaustible source of energy;
- solar panels are installed separately, but integrated together as solar power plants;
- the operation of the solar power plant is completely silent;
- fast payback period (for example, a solar power plant with a capacity of 30 kW, electricity production of 38 400 kWh/year, own consumption of 3 000 kWh/year, will have a total cost of 590 000 UAH with a profit of 130 944 UAH/year and will pay off in 4–6 years);

– safe disposal of used solar power plants (for example, in Ukraine, solar power plants are produced and accepted for recycling by company «Green Tech Trade», a representative of the American company «First Solar»).

#### 1.2. Disadvantages / limitations:

– solar insolation reaches its maximum value only in a certain period of the day;  
 – the cost of different types of solar panels in accordance with their capacities;  
 – industrial type solar power plant requires a large area (for example, to receive energy from a solar power plant generated by a nuclear power plant with a capacity of 1000 MW, 35 thousand hectares of land are needed);  
 – danger for birds flying near the solar concentrators: the temperature of the sunlight focused by the mirrors on the tower can reach 1000 °C.

#### 2. *Energy source – wind.*

##### 2.1. Advantages:

– an inexhaustible source of energy;  
 – wind turbines are installed separately, but integrated together as wind power plants;  
 – 2–3 times more generation than with 1 kW of installed capacity of solar power plant;  
 – fast payback period (for example, a wind power plant with a capacity of 4 kW, electricity production of 1 000 kWh/year, own consumption of 250 kWh/year will have a total cost of 180 000 UAH with a profit of 30 000 UAH/year and will pay off for 6–8 years old);  
 – small areas of land are required to install a wind power plant (for example, a wind power plant with a capacity of 1 MW requires 30–50 acres of land; a solar power plant of the same capacity requires at least 200 acres of land).

##### 2.2. Disadvantages / limitations:

– wind power plant cannot guarantee a constant load due to changing wind gusts;  
 – the cost of different types of wind power plant in accordance with their capacities;  
 – wind turbines are quite noisy, and therefore dangerous to human health: in accordance with the study, the negative impact of wind power plants infrasound on human health was not found. However, in some countries there are restrictions on the distance for the placement of wind turbines from settlements;  
 – wind turbines cause damage to birds when power plants are located in their migration path.

#### 3. *Energy source – tides.*

##### 3.1. Advantages:

– an inexhaustible source of energy;

– the ability to generate a lot of potential electricity;

– Electricity production could be doubled by integrating tidal barriers, which would also help prevent flooding.

##### 3.2. Disadvantages / limitations:

– the high cost of building a dam (for example, the Boyabat Dam in Turkey with a capacity of 513 MW costs 1.2 billion US dollars);  
 – to realize the potential of the tides, access to the ocean or seas with high tidal potential is required (for example, as in Great Britain, Ireland, Iceland, etc.).

#### 4. *Energy source – geothermal energy.*

##### 4.1. Advantages:

– an inexhaustible source of energy;  
 – you can use the natural heat of the Earth or the energy of volcanic regions (for example, countries such as New Zealand and Iceland successfully use geothermal energy to generate electricity).

##### 4.2 Disadvantages / limitations

– high cost of building a geothermal power plant;  
 – geothermal power plants can be used in areas of volcanic activity or depths of reaching the natural heat of the Earth;  
 – if geothermal and volcanic activity becomes passive, this may lead to a shutdown of the power plant;  
 – underground elements in a geothermal source are explosive.

#### 5. *Energy source – water (hydro).*

##### 5.1. Advantages:

– an inexhaustible source of energy;  
 – one of the traditional methods of using energy from streams, such as rivers, lakes, dams, using a small hydro power plant without damaging the environment;  
 – fast payback period compared to traditional energy sources (for example, a small hydro power plant with a capacity of 382 kW, electricity production of 1.7 million kWh/year, with a total cost of 21 million UAH will pay off in 11–13 years).

##### 5.2. Disadvantages / limitations:

– the cost of building large hydroelectric power plants (for example, Kakhovska Hydro Power Station-2 with a capacity of 250 MW worth 13.47 billion UAH);  
 – hydro power plants (except for small hydro power plants) cause damage to the environment;  
 – hydro power plants need large areas for construction (for example, a 250 MW power plant requires up to 50 hectares of land).

## 6. Energy source – biomass (bioenergy).

### 6.1. Advantages:

- an inexhaustible source of energy;
- use of organic material (raw materials): plant and animal waste – corn silage, bagasse, manure, etc.;
- combustion processes of raw materials can be used to produce biogas and obtain not only electricity, but also heat;
- fuel for power plants is one of the cheapest and always available;
- there is a possibility of using garbage for electricity generation, which will help to preserve the environment and reduce landfills.

### 6.2. Disadvantages / limitations:

- pollution of the environment and atmosphere during combustion, but CO<sub>2</sub> emissions are less than those of traditional energy sources;
- additional costs for the logistics processes for the delivery of raw materials to power plants;
- the cost of building a power plant (for example, a biogas power plant in Khmelnytsky, Ukraine with a capacity of 659 kW with a cost of 37 million UAH and electricity production of 5 million kWh/year will pay off in 14–16 years).

According to the study, renewable sources in Ukraine have the following development barriers:

- military invasion of the Russian Federation on the territory of Ukraine (high risks of project implementation for investors, destruction of renewable energy workers), the global financial crisis and the consequences of COVID-19 potentially affect power plant operators due to credit claims and their investments;
- high energy intensity of the country and the need for significant investment in the

«reanimation» of traditional (non-renewable) energy sources;

- imperfection of the legislative mechanism for electricity producers (debts on payments under the «green» tariff to renewable energy producers);
- insufficient number of qualified specialists who could properly maintain the equipment;
- the need to purchase and deliver elements for renewable energy sources from abroad.

**Conclusions.** As the world's population increases, so does the need for energy to power homes, communities, and regions. Innovation and expansion of the use of renewable energy is the key to supporting the development of sustainable energy and protecting our planet from climate change. The main technologies for generating electricity from renewable sources are solar, wind, tidal, hydro (water), biomass (bioenergy) and geothermal energy.

The availability of various types of technologies based on alternative energy, the scientific and technological progress of mankind and the search for new innovative energy production technologies without depleting the Earth's natural sources contribute to the relevance of the development of various types of renewable energy sources in the world.

The development of renewable sources and an increase in their share in the energy balance of Ukraine will contribute to the development of an energy independent economy and accelerate the implementation of international obligations under the Paris Climate Agreement and the Association Agreement with the European Union.

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