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### RESEARCH OF THE REGULARITIES OF “GREEN” ENERGY AND THE WORLD TRENDS OF ITS DEVELOPMENT

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#### **Summary**

**Introduction.** The article analyzes the causes of the global energy crisis and the role of green energy in its emergence, examines the patterns and global trends of its development, as well as the technological and socio-economic features of its spread. In the 70s of the XX century, green energy, based on the use of new technologies for the production of electricity from renewable sources, gained serious popularity as part of a growing environmental movement. But it wasn't until the beginning of the 21st century that a real breakthrough was made in this area, which may eventually allow these technologies to displace fossil fuels (coal, oil and natural gas) as the main source of energy. **Purpose.** The main goal of the article is to find an answer to the question of to which extent it is possible to achieve the energy transition in the near future, as well as to carry out a critical analysis of published calculations of humanity energy consumption humanity in 2050, based on the need to significantly reduce the gap in the per capita energy consumption of the population of developed countries. **Results.** The authors researched the prerequisites and prospects for the development of renewable energy and considered the world experience of using renewable energy during the new Fourth Industrial Revolution, the feature of which, unlike the previous three, is a special account of the anthropogenic impact of activities on the environment. It is shown that the development of technologies of RES can be a driver of innovative modernization of the economy and a source of formation of a truly green economy, characterized by high-tech solutions, energy independence and reduced impact on the environment. **Conclusions.** Today, the energy problem is one of the most relevant for all mankind.

*Traditional sources such as oil, gas and other fossils are gradually becoming more scarce, expensive and, of course, environmentally. This is why solar panels, wind and solar farms, hydroelectric plants, as well as bioreactors are becoming so popular today as emerging sources of alternative or green energy, which will be discussed in more detail below. The production of electricity from RES is growing in various countries of the world, and this trend will continue in the future, so research in this direction must be continued.*

**Key words:** energy crisis, green energy, energy transition, industrial revolution, renewable energy sources.

### ДОСЛІДЖЕННЯ ЗАКОНОМІРНОСТЕЙ ЗЕЛЕНОЇ ЕНЕРГЕТИКИ ТА СВІТОВІ ТЕНДЕНЦІЇ ЇЇ РОЗВИТКУ

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#### **Анотація**

**Вступ.** У статті аналізуються причини світової енергетичної кризи та роль зеленої енергетики у її виникненні, досліджуються закономірності та світові тенденції її розвитку, а також технологічні та соціально-економічні особливості її поширення. У 70-х роках ХХ ст. зелена енергетика, заснована на використанні нових технологій виробництва електроенергії з відновлюваних джерел, набула серйозної популярності як частина екологічного руху, що зростає. Але лише на початку ХХІ ст. у цій галузі було зроблено справжній прорив, який, можливо, згодом дозволить цим технологіям витіснити викопне паливо (вугілля, нафту та природний газ) як основного енергоносія. Основною **метою** статті є пошук відповіді на питання, наскільки можливо досягти енергопереходу в найближчі терміни, а також проведення критичного аналізу опублікованих результатів і розрахунків потреби людства в енергії у 2050 р., виходячи з необхідності значного скорочення розриву в душевому енергоспоживанні населення розвинених країн. **Результати.** Авторами досліджені передумови і перспективи розвитку відновлюваної енергетики та розглянуто світовий досвід використання відновлюваної енергетики у період нової Четвертої промислової революції, особливістю якої, на відміну від трьох попередніх, є особливий облік антропогенного впливу діяльності на довкілля. Показано, що розвиток технологій відновлюваних джерел енергії може бути драйвером інноваційної модернізації економіки та джерелом формування «зеленої» економіки, що характеризується високою технологічністю, енергетичною незалежністю та мінімальним впливом на навколишнє середовище.

**Висновки.** *Енергетична проблема сьогодні є однією з найактуальніших для всього людства. Традиційні джерела, такі як нафта, газ та інші копалини, поступово, стають дорожчими і, звичайно ж, завдають величезної шкоди навколишньому середовищу. Саме тому сонячні батареї, вітрові та гідроелектростанції, а також біореактори стають настільки популярними сьогодні. Всі вони відносяться до альтернативних або зелених джерел енергії, про що йтиметься нижче. Виробництво електроенергії з ВДЕ зростає в різних країнах світу, і ця тенденція в перспективі збережеться, тому дослідження в цьому напрямку необхідно продовжувати.*

**Ключові слова:** *енергетична криза, «зелена енергетика», енергетичний перехід, промислова революція, відновлювані джерела енергії (ВДЕ).*

### **Introduction**

The modern society lives in an unstable, and unpredictable world. The 21st century imposed on the world a challenging environmental agenda addressing which holds a key to the prosperous future of humanity. The “green transformation” became a buzz word in the energy sector and has been gaining enormous momentum and gathering support worldwide. Green energy is defined as produced in a process using alternative sources, inexhaustible or renewable, as compared to fossil fuels. Furthermore, green energy solutions produce significantly less greenhouse gases and other harmful substances whereas requiring much lower service costs after commissioning. The effectiveness of green energy is largely determined by geographical location allowing easier implementation of solar farms in regions with intense solar radiation. Such traditional renewable organic materials as wood, peat, etc. are not environmentally friendly when used as energy sources or in other words are not green due to production of carbon dioxide. Another good example of green energy technologies that releases carbon back into the atmosphere is processing of organic waste. Implementation of wind and solar solutions is impossible without significant subsidies at the expense of traditional energy, making transition to these types of energy in market economy hard to achieve. Despite the fact that many countries followed Italy in abandoning nuclear energy and shutting down the power plants, more than thirty countries worldwide are still operating nuclear power plants. Belgium, Germany, Spain, Switzerland, Taiwan implement a long-term policy of abandoning nuclear energy, etc. [1, pp. 14-21; 2-4 etc.].

### **Formulation of the problem**

Technically, climate change could be regarded as the result of an increase in concentration of greenhouse gases or an increase in emissions into the atmosphere. The task of reducing this concentration should include development of natural carbon depositing ecosystems to compensate for the negative consequences of anthropogenic emissions from the burning of fossil fuels. The purpose of this study is to analyze the global energy crisis and energy redistribution during the fourth industrial revolution, to identify the priority directions for the development of alternative green energy and renewable energy sources. The authors used the following research methods: the method of theoretical analysis, the method of comparison and generalization of information. **Analysis of recent studies** and publications shows the high significance of the problem under consideration.

### **Main material discussion**

It is generally acknowledged that production of efficient energy is one of the main factors of economic growth, labor productivity as well as individual quality of life. The energy consumers vary from private households to large industrial parks. As a result of population growth and industrial development, energy consumption in the world has increased more than fourteen times over the past hundred years [5, c. 10-20; 6; 7, pp. 16-17; 10, pp. 256-276 etc.].

One of the notable phenomena of recent years has been the energy transformation, that combines technologies for increasing of energy efficiency and technologies for the use of energy produced by renewable energy sources which allows for simultaneous development in several directions. The use of alternative energy accelerates the modernization of the economy, increases the level of economic security of national economies, which fundamentally changes the quality of economic growth. Development of alternative energy sources is a powerful driver for innovation and the basis for the formation of a low carbon green economy of the future, characterized by high-tech solutions, energy security and reduced impact on the environment. Alternative energy sources also reduce dependence of the national economies on fossil fuels.

Oil and gas sources will gradually disappear replaced by the RES. To the most explored sources of renewable energy belong solar, wind, water, including sewage, tides, natural water bodies waves, geothermal sources, land, air, water, biological mass, biological gas. The amount of energy obtainable from the above sources could easily cover all the current energy needs of the mankind. A number of researchers believe that rendering green energy cheaper than traditional energy is unrealistic in the next 15 years. One of the reasons is a high cost related to the localization of generating facilities, requiring creation of supporting industrial base driving the investments up. Another problem with implementing a green energy is related to potential significant losses to the providers of conventional utility services. In this connection, it is crucial to harmonize ecological and economic aspects of the green energy, as well as choose an optimal energy supply model. Traditional energy sources keep playing a dominant role in the world energy balance as well as in individual countries. Fossil fuels have the advantage of the established transportation routes as well as offer significant benefits. However, as available resources begin to run out, the cost of their production increases. On the other hand, the cost of alternative energy sources is falling due to large-scale investments in innovative technologies. According to the calculations of the U.S. Energy Information Administration (EIA), in 2020, 40% of energy in the country was obtained from non-fossil fuel sources. In Europe, the production of solar electricity in 2020 increased by 60% compared to 2019.

Economic benefits from implementing alternative energy sources include creation of new jobs, stabilizing energy cost by reducing dependance on currency fluctuations and supply chain disruptions through increasing localization, however due to the limited-service life of the equipment new challenges arise, mainly related to high cost of recycling as well as ecological impact at the expense of the future generations. On the other hand, to the main disadvantages of fossil fuels belong constantly depleting deposits, releasing of greenhouse gas emissions including carbon monoxide, soil and water pollution, oil spills, etc. The following trends have emerged as possible solutions: gradual transition

to a post-industrial society based on the development and widespread of information technologies, improving standards of education and culture.

The peculiarity of the Fourth Industrial Revolution 4.0 [8, pp. 5-14; 11, pp. 8-22; 12; 13; 14 etc.], unlike the first three, is a major shift into focus of the environmental problems and alternative energy sources.

Below is the list of the most common and rapidly developing types of green energy:

1. *Hydropower* is the most common type of a green energy, with approximately 54% of all generating capacity in the world and China as a world's leader of hydroelectric power production. The main source is the potential of a water flow.

2. *Wind energy* ranks second in terms of production scale. Technological advances and the use of new composite materials have contributed to increasing the service life and reducing the cost of wind turbines. One of the advantages of the wind energy is that it can be effectively used in sparsely populated areas by installing windmills parks. It is important to note that windmills require practically no ordinary fuel for their operations. According to a study by the Massachusetts Institute of Technology, in case of a full scale transition to a wind energy, half of the entire territory of Great Britain will have to be used for the installation of wind turbines. According to Bill Gates, one of the ways to deal with this problem is increase the capacity of batteries by a factor of twenty. Unfortunately, he notes, it is highly likely that this is not possible.

3. *Solar energy* is the fastest-growing type of green energy and the third largest in the world in terms of RES-based production in 2021. The solar energy is at its peak of efficiency in the equatorial countries. The largest solar power plant is located in the United Arab Emirates and produces enough electricity to reduce the carbon footprint equivalent to eliminating 200,000 cars.

4. *Bioenergy* is the fourth largest type of green energy. The production of electricity and heat is based on the innovative use of traditional biomass sources, such as agricultural by-products and household waste. In this case, energy, both electrical and thermal, is produced from organic fuel. Biofuels of the second generation include products obtained by pyrolysis, i.e., rapid conversion of mass into liquid. China, Great Britain, and India are leaders in bioenergy production. Brazil, Germany, the USA, and Sweden are also actively developing these technologies.

5. *Geothermal energy* is a rapidly developing type of renewable energy source. A geothermal plant produces electrical energy from the thermal energy of underground sources (for example, geysers). The largest producer of geothermal electricity in the world is Iceland. Prominent positions in this area are occupied by Indonesia, Italy, Mexico, the Philippines, and the USA.

In our study, we emphasize the impact that several consecutive systemic worldwide crises have on the economy in general and the energy sector in particular. Modern energy sector is at a crossroads, urgently requiring serious qualitative shifts in approach to existing problems. The importance to study and understand these problems and their role in the global economy have been repeatedly discussed at various conferences, summits, and forums.

The world's most powerful energy accumulation and storage systems based on lithium-ion batteries are being created in California, USA. The Gateway Energy Storage facility with capacity of 250 MW, and the Moss Landing facility, will have a significant

capacity to store and send energy to the grid with maximum capacity for four hours during periods of high demand [13-15]. Another problem is the possible shortage of various metals and materials necessary for the development of renewable energy.

The global transformation of energy systems will be carried out along 4 axis: *energy efficiency, decarbonization, digitalization, decentralization*. Energy transition is aimed at solving the climate problem by abandoning coal, oil, natural gas and expanding the use of green energy sources. Analysis of forecasts supporting energy transition shows that the most important condition for achieving these goals is the preservation of energy inequality between the developed and the developing world. The countries of Central and Eastern Europe (CEE), due to their substantial socio-economic differentiation, show significant differences in the scale and structure of energy supply. The development of green energy sector in the region is actively supported by state programs. The aim of this article was not to describe and consider all existing aspects and problems of the energy transition but to focus on the question if energy transition can be achieved at all and to which extent.

There are currently wide debates dedicated to the future of thermonuclear energy. Despite significantly higher efficiency of nuclear power plants compared to conventional energy sources, numerous challenges arise from the differences in nuclear power generation strategies of different countries.

### **Conclusions**

The transition to innovative, and sustainable energy means a transition to a fundamentally different energy system in order to address a number of various challenges and factors. The timing of the energy transition will have to be realistically assessed. Despite the significant progress in the field of new technologies and increasing energy efficiency, the full realization of the energy transition by 2050 is highly unlikely. The transition to green energy is being actively lobbied by the European Union and the United States. At the same time, 85% of the world's energy balance and 75% in EU countries are still accounted for by hydrocarbons. And for one billion people on earth, firewood remains the main source of heat and fuel for cooking. The current trend is still dominated by electricity produced from fossil fuels preventing the “green energy wave” from completely replacing oil and gas producers with solar farm and windmills as a reliable base of a large-scale energy transformation in the coming years.

Despite the foregoing, the discussion of issues related to alternative energy sources, research and development, is still of great interest around the world. Therefore, research in this direction needs to be continued.

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