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FEATURES AND TRENDS OF THE DIGITALIZATION PROCESS IN THE DEVELOPMENT OF THE GREEN ECONOMY

The article examines modern digital technologies that have entered our lives and influenced the development of the green economy. It is emphasized that the general use of IoT, Big Data, AI, blockchain and digital energy markets allows accelerating the transition to clean energy and a smart economy, contributing to the creation of sustainable development for future generations. The aim of the work is to study the features and trends in the development of the digitalization process of the economy in the context of environmental problems through the prism and in connection with the "green" economy. The methodology of system analysis, methods of structural, logical and comparative analysis are used. The latest trends in the development of the digitalization of the economy in the context of environmental problems are systematized, including: Internet of Things (IoT) and sensors, Big Data and analytics, Blockchain, digital energy markets, etc. It is concluded that digital technologies are of great importance in the development of a green economy, providing a number of advantages and opportunities for development.

Keywords: green economy, digitalization, digital transformation, sustainable development, digital technologies, global challenges.

JEL classification: O44 O3, O14.

ОСОБЛИВОСТІ ТА ТЕНДЕНЦІЇ ПРОЦЕСУ ЦИФРОВАННЯ У РОЗВИТКУ ЗЕЛЕНОЇ ЕКОНОМІКИ

У статті розглядаються сучасні цифрові технології, які увійшли в наше життя і вплинули на розвиток зеленої економіки. Підкреслюється, що загальне використання IoT, Big Data, AI, блокчейн та цифрових ринків енергії, дозволяє прискорити перехід до чистої енергетики та розумної економіки, сприяючи створенню сталого розвитку для майбутніх поколінь. Метою роботи є дослідження особливостей та тенденцій розвитку процесу цифровізації економіки в контексті екологічних проблем через призму та у взаємозв'язку із «зеленою» економікою. Використана методологія системного аналізу, методи структурного, логічного та порівняльного аналізу. Аргументовано, що загалом цифрові технології Індустрії 4.0 здатні набагато ефективніше вирішувати гострі екологічні проблеми, пов'язані зі зміною клімату. Саме тому перехід до зеленої економіки, що спирається на цифрові технології, визначено як пріоритет національних стратегій посткризового відновлення в багатьох країнах. Доведено, що основні тенденції цифровізації в зеленій економіці включають ряд інновацій і розвитку цифрових технологій, спрямованих, у свою чергу, на поліпшення стійкості та енергоефективності економіки, а також на зниження негативного впливу на навколишнє середовище. Систематизовано новітні тенденції розвитку процесу цифровізації економіки в контексті екологічних проблем, серед яких: Інтернет речей (IoT) та сенсори, Big Data та аналітика, Blockchain, цифрові ринки енергії тощо. Ці тенденції відкривають нові можливості для розвитку зеленої економіки, забезпечуючи більш стійке та ефективне використання ресурсів, скорочення викидів парникових газів та енергоспоживання, а також створення інноваційних та екологічно чистих продуктів та послуг. Зроблено висновок про те, що цифрові технології мають величезне значення у розвитку зеленої економіки, забезпечуючи низку переваг та можливостей для розвитку: збільшують ефективність та продуктивність, покращують якість послуг та продуктів, стимулюють розвиток нових технологій та інновацій у бізнесі та енергетиці, підвищують енергоефективність та ефективність управління бізнесом та енергетичними системами.

Ключові слова: зелена економіка, цифровізація, цифрова трансформація, сталий розвиток, цифрові технології, глобальні виклики.

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Statement of the problem. In today's world, given the impact of global changes in the global economic architecture due to the accelerated digitalization of the economy, key areas of humanities scholarship find themselves in a balancing act between the attractive prospects of technologically driven social transformation and the risks of manipulating human consciousness and behavior in a society driven by mass communications and big data.

A separate area of research focuses on the changing vector of business model transformation under the influence of digital technologies and the interaction between humans and digital technologies. Taking this into account, the prospects for a green economy in a rapidly changing world are also a key driver of growth. The latter appears to be the most rapidly growing trend in the modern world, as it is one of the key conditions for preserving nature and the environment for future generations. The challenges facing our civilization today are leading to large-scale changes in all areas of society.

Therefore, modern companies, as well as transnational and multinational corporations, are faced with the urgent need to transition from traditional management models to management models in a digital economy. In turn, the change in business models determines the need for companies to use modern technologies and create information systems that are able to quickly respond to constant changes in business requirements.

Analysis of recent research and publications. Many contemporary authors have analyzed the implementation of modern digital technologies in the context of the transition to a green economy.

In their works (Gorbach L., Ruban O., Gumenyuk Ya., 2024) [1], Dovgal O.A., 2025) [2], Orlovska Yu.V., Kvaktun O.O., Kakhovych O.O., Drigola K.V., 2021) [3], the stages of societal development under the influence of industrial revolutions are examined, the positive effects are determined, and the risks and threats to economic development from the mass implementation of digital technologies are identified.

In his work (Puschmann, 2017) [14], he concludes that the ongoing process of digitalization not only leads to increasing automation of processes, but also to a fundamental reorganization of the financial services value chain using new business models (e.g., robo-advisors) and new players entering the market (e.g., Apple). The main directions of development of the concept of "financial technologies" are reflected, including special attention paid to the use of big data analysis, for example, in the case of the analysis of industrial enterprises.

Sagraves and Connors (2017) [16] conclude that it is not the data itself and its volume that is new, but the pace of change and the extent and speed with which technology companies have changed the economy and disrupted industries. Data and analytics are at the heart of this new digital economy—and while banks possess vast amounts of data on their customers' behavior, they have been slower to adopt a data-driven culture and maximize the value of this asset. The paper examines both the internal and external

barriers that banks have faced in the digital age over the past decade and suggests ways in which banks' investments in addressing regulatory and compliance requirements to mitigate risk can now be leveraged to better serve customers. The rise of Big Data technology makes data more valuable than it once was. The analysis of the UN Global Trends Report 2030 allowed us to formulate the main trends influencing the socio-economic component of society, the state and economic structures [11], among which the following seem particularly obvious and significant for joint consideration and description:

1. **Rapid technological advances:** Over the next two decades, the pace and impact of technological advances are likely to accelerate, transforming and enhancing human experience and capabilities and offering the potential to address challenges such as aging, climate change, and low productivity growth, while creating new tensions and disruptions.

The coming decades will see intensifying global competition for key elements of technological superiority, such as talent, knowledge, and markets, potentially leading to the emergence of new technological leaders or hegemonies.

2. **Climate change:** Trends closely linked to globalization, including economic activity, lifestyle changes, and urbanization, are impacting our environment and may contribute to climate change. As the global population grows, resource demands will increase significantly. Addressing the challenges of one commodity will impact the consumption of other commodities.

Over the next 20 years, the physical impacts of climate change—higher temperatures, rising sea levels, and extreme weather events—will affect every country. The costs and challenges will fall disproportionately on the developing world, intersecting with environmental degradation to increase risks to food, water, health, and energy security [10]. A «green» economy appears to be a possible solution to this situation.

Despite the large number of works devoted to the analysis of the theory and practice of the transition to a green economy, the study of the characteristics and trends of the development of the digitalization process of the economy in the context of environmental issues through the prism of and in relation to the "green" economy is currently insufficient.

Purpose of the article. The aim of this work is to study the features and trends of the development of the digitalization process of the economy in the context of environmental issues through the prism of and in connection with the "green" economy.

Presentation of the main research material. In general, all digital technologies used in economic activity form the concept of a green economy.

Digital technologies are those that enable the creation, storage, processing, and distribution of data electronically using computers and computer networks (via the internet).

A green economy, on the other hand, is one that aims to preserve natural resources and the environment, as well

as improve people's quality of life. It involves the use of environmentally friendly technologies, the reduction of waste and emissions, and a transition to renewable energy sources [7].

Many modern experts believe that to achieve a higher level of green economy development, the state must actively support companies that use and develop digital technologies, as well as encourage other companies to use mobile technologies, business analytics, digital payments, and other technologies.

In general, it can be said that while a green economy is urgently needed to reduce environmental impacts and combat climate change, digital technologies offer numerous opportunities to improve the efficiency of green economy development. Moreover, digital technologies and the green economy can and should be combined, as together they reinforce each other and ensure sustainable development [6].

The term «green economy» was first mentioned in 1989 in a report by a group of leading economists for the government of the United Kingdom of Great Britain and Northern Ireland [13]. The concept came into widespread use during the global economic crisis of 2008–2009. Thus, in 2009, the United Nations Environment Programme published a report, «A Global Green New Deal», which examined the goals, objectives, elements, incentives, and directions of domestic policies aimed at developing a green economy.

The essence of a green economy is often defined as a practical approach to achieving sustainable development. Experts note that investing in green technologies facilitates its development. According to the Organisation for Economic Co-operation and Development (OECD), green technologies include:

- environmental management (waste management, water and air pollution control, etc.);
- renewable energy production (solar energy, wind energy, biofuels, etc.);
- climate change mitigation;
- reduction of harmful emissions into the atmosphere;
- improved fuel efficiency;
- improved energy efficiency in buildings and lighting [12].

In recent decades, the world has faced increasing environmental challenges, including global warming, degradation of natural resources, and widespread environmental pollution. These problems require an immediate response and have led to increased attention to new concepts of economic development that combine economic growth with environmental protection. Against this backdrop, the concept of a «green economy» comes to the fore, offering approaches that help integrate sustainable resource use and carbon footprint reduction with economic development. [12].

Developing a green economy is a key element of a sustainable economic growth strategy in the era of global climate change. In the face of rapidly changing environmental realities, countries around the world recognize the need to

transition to new economic development models that combine the use of renewable energy sources with innovative clean technologies [9]. This transition not only addresses the challenges of reducing carbon emissions and improving the environmental situation, but also contributes to long-term economic stability, creating new opportunities for attracting investment and strengthening the domestic economy [4].

Technological innovation plays a key role in the transition to a green economy, especially in the context of climate change. Digital technologies have a direct and indirect impact on nature [13]. On the positive side, digital technologies such as artificial intelligence, big data, the Internet of Things, and blockchain are revolutionizing approaches to biodiversity conservation, clean energy development, and disaster management [13].

According to the World Bank, the global economy currently consumes over 100 billion tons of raw materials annually, while simultaneously producing approximately 90 billion tons of waste. The amount of primary resources extracted between 2000 and 2023 already accounts for more than 50% of all raw materials extracted in the 20th century. By 2050, global demand for primary resources is expected to at least double, and rapid population growth and urbanization will lead to an increase in annual waste generation by 73% compared to 2020 levels to 3.88 billion tons. The global waste volume will average 1.09 kg of waste per capita per day. The environmental impacts directly associated with the extraction, consumption, and waste of materials are equivalent to two-thirds of global greenhouse gas emissions, 90% of biodiversity loss, and two-thirds of air quality-related deaths [17].

Digital technologies are defining another global macro-trend in the development of the global economy, playing a vital role in the green transformation process. According to experts, digital technologies used in renewable energy generate direct economic benefits for production by reducing energy costs, increasing energy efficiency, boosting labor productivity, and ensuring an overall increase in innovative potential within the industry [9].

Overall, Industry 4.0 digital technologies are capable of much more effectively addressing the pressing environmental challenges associated with climate change. This is why the transition to a green economy, based on digital technologies, has been included as a priority in national post-crisis recovery strategies in many countries. Financing of such government programs has recently been actively pursued through green financial instruments, including green loans, green bonds, green banks, and green funds. The broader concept of sustainable finance, in addition to green instruments, also includes social financial instruments focused on sustainable development goals [15].

According to Climate Bonds Market Intelligence, the rapid growth of green bond issuance has resulted in a market size of \$1,013 billion in 2023, 67% higher than last year's record of \$678 billion. The market is projected to reach \$5 trillion by 2025 (Figure 1). [4].

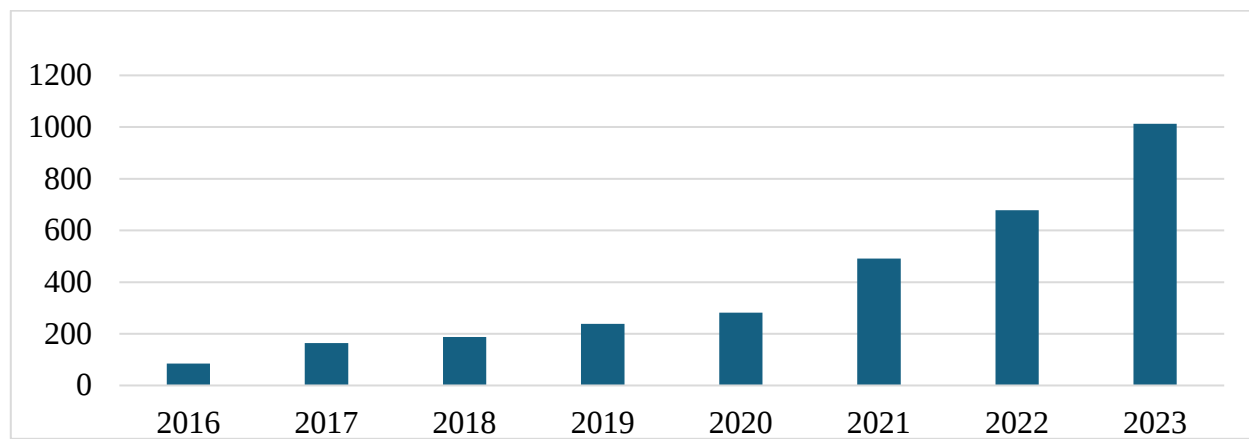


Figure 1. Green bond issuance, trillion US dollars
Source: [4]

The sectors that account for the largest share of green bond issuances are particularly noteworthy. Key sectors traditionally include energy, construction, and

transportation, with energy accounting for the largest share annually (Figure 2) [4].

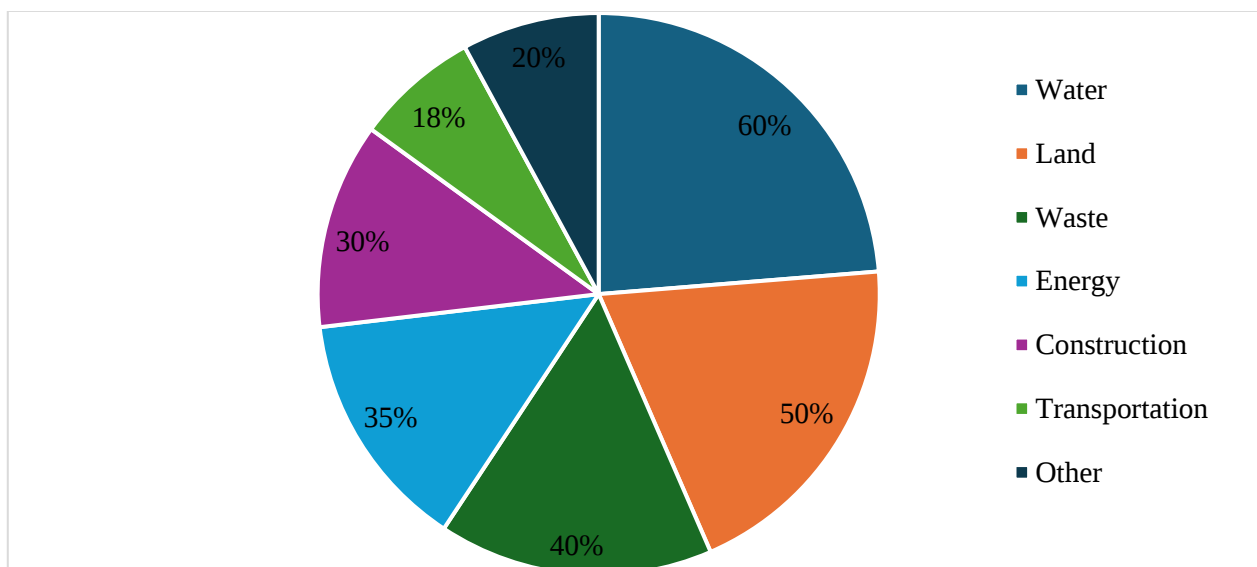


Figure 2. Distribution of green bond issues by economic activity for 2023
Source: [4]

This leadership is explained by the positive economic impact on companies: the environmental benefits of reduced energy consumption and the development of energy efficiency systems reduce a company's electricity costs, which often makes it possible to use green bonds for regular production capacity modernization programs. The construction and transportation sectors are steadily increasing their share of the total volume, capturing the market from projects related to water resources (8% in 2015) and waste recycling (6.2% in 2015) [4].

Thus, a new development trajectory is actively emerging in the global economy, based on a global green economy using digital technologies. To ensure competitiveness and sustainable development in the long term, individual companies and entire countries are striving to create a financial and technological structure that ensures leadership in key markets and control over financial flows. Countries and individual economic entities that are slow to update their economic and technological

development paradigms risk losing the long-term positive effects of the green transformation [5].

The main trends in digitalization in the green economy include a number of innovations and the development of digital technologies aimed, in turn, at improving the sustainability and energy efficiency of the economy, as well as reducing the negative impact on the environment.

Let's consider some of the key trends [18]:

Internet of Things (IoT) and Sensors: The use of sensors and IoT devices to monitor and manage green economy processes. For example, sensors can be used to manage energy consumption, monitor air quality, and manage resources more efficiently.

Big Data and Analytics: The rapid development of green energy requires modern technologies capable of effectively managing large volumes of data and analyzing it to optimize processes.

Blockchain: Blockchain technology enables the

creation of transparent and secure resource accounting and management systems, which contributes to the increased efficiency and sustainability of the green economy.

Digital Energy Markets: The implementation of digital platforms for energy trading and management enables the integration of new renewable energy sources, manages energy supply and demand, reduces costs, and improves resource efficiency.

These trends open up new opportunities for the development of the green economy, ensuring more sustainable and efficient use of resources, reducing greenhouse gas emissions and energy consumption, and creating innovative and environmentally friendly products and services.

Digital technologies are having a significant impact on the development of green energy, providing innovative solutions and technologies that contribute to increased energy efficiency, a greater share of renewable energy sources, and improved energy process management.

Let's examine the key aspects of digitalization's impact on the development of green energy [8]:

Monitoring and Management: Digital technologies enable real-time monitoring and management of energy production and distribution, optimizing processes and reducing losses. Automated control systems ensure efficient resource use and reduced energy costs.

Energy Saving and Optimization: By collecting and analyzing data using digital technologies, it is possible to optimize energy consumption and manage loads in real time. Predictive analytics allows for forecasting changes in the energy system and taking appropriate action.

Smart Grids and Smart Cities: The implementation of Smart Grids and Smart City concepts enables more efficient management of energy consumption, energy distribution, and resource metering. Digital technologies enable the creation of a network in which energy consumers and producers interact with each other and with the system more intelligently.

Innovative Solutions and Developments: Digitalization facilitates the development of new technologies and innovations in green energy, such as energy storage, electric vehicles, energy networks of the future, and much more.

Global examples demonstrate that a green economy can be a significant driver of sustainable economic growth. For example, in Germany and the EU, the development of renewable energy sources has not only reduced carbon emissions but also created hundreds of thousands of new jobs, contributing to economic stability and reducing unemployment. In recent years, China has been able to significantly reduce its carbon emissions thanks to the active deployment of solar and wind power plants.

To remain competitive, companies must now implement changes in the implementation of digital technologies and follow the trend of "green" transformation. Tech companies such as Apple and Google are currently leading the way in terms of capitalization. They are entering markets that are not typical for them, such as the automotive industry, forcing companies in traditional markets to adapt more quickly and develop digital tools. It can be concluded that

digital technologies are accompanying these changes to ensure the environmental development of companies [8].

Conclusions. Digital technologies play a key role in the development of a green economy and energy, providing opportunities to optimize processes, improve energy efficiency, and reduce negative environmental impacts.

Digital technologies are of paramount importance in the development of a green economy, providing a range of benefits and development opportunities.

Key aspects of the importance of digital technology in this area include [5]:

- Increased efficiency and productivity: The implementation of digital technologies in business and energy enables the automation of many processes, optimized resource management, improved data accuracy, and faster decision-making.

- Improved quality of services and products: Digital technologies enable more accurate analysis of consumer needs data, improve the quality of products and services offered, personalize offerings, and enhance customer interactions.

- Digital technologies stimulate the development of new technologies and innovations in business and energy. The use of Big Data, artificial intelligence, the Internet of Things, and other digital tools opens up new opportunities for the creation of new products and services.

- Digital technologies in green energy improve energy efficiency while controlling costs and renewable energy production.

- Digital technologies enable more efficient management of businesses and energy systems, monitoring the condition of equipment and processes, predicting potential problems, and responding promptly.

At the same time, however, it is necessary to update digital infrastructure, strengthen cybersecurity measures, and ensure the accessibility of digital innovations. And yet, even under such imperfect conditions, digital technologies in the green economy and energy sector increase efficiency and optimize resource use towards achieving environmental sustainability.

Furthermore, in the face of macroeconomic uncertainty, it is especially important to understand and anticipate, as well as accurately forecast, the positive and negative scenarios for the expansion of digital technologies into new areas of human life, as well as the development of a "green" economy. A clear understanding and formulation of practical solutions for intensifying technological development and increasing the effectiveness of interactions between all participants in the innovation ecosystem, based on the capabilities and network of connections between science and business, is essential.

Therefore, it is important to understand the key megatrends shaping the technological future. Given the above, the digitalization of the economy and the development of a «green» economy are of the greatest significance. In light of the above, it is also important to determine which approaches to creating a bridge between science and business will be most viable in the coming years, as well as the most

optimal and rapid way for scientific discoveries to be translated into practical application and market entry. Answering the question of what approaches businesses use to create high-tech products capable of changing the world will

allow for the most efficient allocation and redistribution of resources and the optimization of production systems and business models in the future. It is also essential to determine the role of the state in this process.

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