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## **THE IMPORTANCE OF THE DEVELOPMENT OF ECO-INNOVATIONS IN THE TRANSFORMATION TO A GREEN ECONOMY**

**Анотація.** Стаття присвячена значенню розвитку екоінновацій у трансформації до зеленої економіки. Визначено важливість зеленої економіки та екоінновацій для майбутнього розвитку. Доведено взаємозв'язок між технологією та сталим розвитком. Подано класифікацію екоінновацій та екоінноваторів. Визначено основні кліматичні ризики та економічні втрати від них у Європі. Визначено заходи сталого розвитку, які вживають підприємства в ЄС. Визначено стан інноваційної активності підприємств як основу для розвитку зелених інновацій. Запропоновані шляхи стимулювання розвитку екоінновацій з визначенням основних дій на мікро- та макrorівнях та запропонована схема системи екоінновацій. Метою статті є визначення економічних ризиків глобальної зміни клімату та їх нейтралізація та пом'якшення шляхом використання екоінновацій. Обґрунтовано позитивний синергетичний ефект екоінновацій на економічні показники, рівень життя та сталий розвиток. У статті використано науково-аналітичні статті, дослідження науковців та світових економічних організацій: Групи Світового банку, МВФ, ООН та ін. Використано матеріали окремих організацій та Європейської комісії. Основними методами дослідження були наукова абстракція, логічне узагальнення при визначенні необхідності зелених інновацій на сучасному етапі розвитку; аналітичний метод визначення складових екоінноваційної політики та їх взаємозв'язку; візуальне відображення сталої еко-інноваційної системи в ЄС; ситуаційний аналіз для визначення проблем енергетичної системи. Системно-структурний аналіз – для розробки концептуальної моделі екоінноваційної політики, структурно-логічної схеми формування основних елементів екоінноваційної політики; комплексний емпіричний та прикладний аналіз - для визначення викликів, напрямків зеленої трансформації та розвитку екоінновацій.

**Ключові слова:** зміна клімату, екоінновації, енергетична безпека, зелена економіка, стала економіка, економічні ризики.

**JEL Classification:** O31, O38, O19, O14

**Absztrakt.** A cikk az ökoinnovációk fejlesztésének fontosságával foglalkozik a zöld gazdaságra való átállásban. Meghatározásra került a zöld gazdaság és az ökoinnovációk fontossága a jövőbeli fejlődés szempontjából. Bizonyításra került a technológia és a fenntartható fejlődés kapcsolata. Bemutatásra került az ökoinnovációk és ökoinnovátorok osztályozása. Meghatároztuk a fő éghajlati



kockázatokat és az ezekből származó gazdasági veszteségeket Európában. Meghatároztuk az EU-ban a vállalkozások által alkalmazott fenntartható fejlődés intézkedéseit. A zöld innovációk fejlesztésének lehetőségeként a vállalkozások innovációs tevékenységének állapotát vettük alapul. Az ökoinnovációk fejlesztésének ösztönzéséhez mikro- és makroszintű lépések meghatározását végeztük el, valamint az ökoinnovációs rendszer jobb működéséhez egy sémát dolgoztunk ki. A cikk célja, hogy meghatározza a globális klímaváltozás gazdasági kockázatait, valamint azok semlegesítését, mérséklését az ökoinnovációk segítségével. Bizonyított az ökoinnovációk pozitív szinergikus hatása a gazdasági mutatókra, az életszínvonalra és a fenntartható fejlődésre. A cikk tudományos és elemző cikkeket, tudósok és globális gazdasági szervezetek kutatásait használja fel: a Világbankét, az IMF-ét, az ENSZ-ét stb. valamint egyes szervezetek és az Európai Bizottság anyagait. A főb felhasznált kutatási módszerek között a tudományos absztrakció, a logikai általánosítás volt a zöld innovációk szükségességének meghatározására a fejlődés jelenlegi szakaszában; az ökoinnovációs politika összetevőinek és azok összefüggéseinek meghatározásának analitikus módszere; egy fenntartható ökoinnovációs rendszer vizuális megjelenítése az EU-ban; helyzetelemzés az energiarendszeri problémák azonosítására. Rendszer-strukturális elemzés - az ökoinnovációs politika koncepcionális modelljének, az ökoinnovációs politika fő elemeinek kialakításának strukturális-logikai sémájához; komplex empirikus és alkalmazott elemzés módszere - a kihívások, a zöld átalakulás és az ökoinnovációk fejlesztésének irányainak azonosítására.

**Kulcsszavak:** зміна клімату, екоінновації, енергетична безпека, зелена економіка, стала економіка, економічні ризики.

**Abstract.** The article is devoted to the importance of the development of eco-innovations in the transformation to a green economy. The importance of the green economy and eco-innovations for future development is determined. The relationship between technology and sustainable development is proven. The classification of eco-innovations and eco-innovators is presented. The main climate risks and economic losses from them in Europe have been identified. Sustainability actions taken by enterprises in the EU are defined. Defined the state of innovation activity of enterprises as a basis for the development of green innovation. Proposed ways to stimulate the development of eco-innovations, with the definition of the main actions at the micro and macro levels and a proposed scheme of eco-innovation system. The purpose of the article is determining the economic risks of global climate change and their neutralization and mitigation through the use of eco-innovations. Justification of the positive synergistic effect of eco-innovations on economic indicators, the standard of living and sustainable development is provided. The article used research and analytical articles, studies of scientists and world economic organizations: the World Bank Group, IMF, UN and others. Materials of specific organizations and the European Commission were used. The main research methods were scientific abstraction, logical generalization when determining the need for green innovations at the current stage of development; analytical method for determining the components of the policy of eco-innovation and their interrelationships; a visual reflection of the sustainable eco-innovation system in the EU; situational analysis to identify problems of energy system. System-structural analysis - for the development of a conceptual model of eco-innovation policy, a structural-logical scheme of the formation of the main elements of the eco-innovation policy; complex empirical and applied analysis - to determine challenges, directions for green transformation and development of eco-innovations

**Keywords:** climate change, eco-innovations, energy security, green economy, sustainable economy, economic risks.

**Problem description.** Social balance is very shaky and unstable globally and should always be maintained by the joint efforts of both countries and international organisations. Wars and geopolitical conflicts always have long-term negative consequences for humanity, which are difficult to predict and can lead to the collapse of



civilisation if more countries are involved in conflicts, or nuclear weapons are used. In the 21st century, in addition to geopolitical and military conflicts, the real threat already posed by humanity is climate change and biodiversity loss. The point of no return in change with nature has already been passed. Humans must now not conquer and change the natural environment but try to live in harmony with nature and ensure life in a sustainable environment.

The development of new technologies raises the question of the relationship between technology and sustainable development. The future of humanity directly depends on the actions taken by governments and international organisations to preserve and restore the environment. We need to take care of future generations, providing them with at least the same conditions and natural resources that we have now. The era of an economy based on continuous and growing consumption has come to an end. It is necessary to radically change both economic systems and the worldview of humanity [9].

Humanity has always needed energy resources to sustain life. Since the beginning of the industrial revolution, energy consumption has increased annually worldwide. Digitalization and the creation of cryptocurrencies have further increased the demand for energy in all countries. Consequently, the provision of clean and affordable energy for further development is an urgent issue. It is through new technologies and innovations that we can rectify past mistakes and achieve the UN Millennium Development Goals. Nature provides inexhaustible sources of energy, such as solar, wind, and water, which must be harnessed.

**Analysis of the latest research and publications.** Now is the time to revise the scientific works of V.I Vernadsky, whose worldview and thoughts were much ahead of the time in which he lived. His doctrine of the "noosphere" is an understanding of the need for a synthesis of "nature, life and man", the subordination of science to the global values of human development. V.I. Vernadsky stressed that the noosphere era would begin with the beginning of human responsibility for the planet's future by creating a Harmonia unified "man-technology-nature". Good attitude to the Earth, its resources, prevention of conflicts and wars, thinking not only in the national aspect but also in the planetary. Thus, the passage of time and scientific progress leads to a modern revision of human values [8]. Respondents to the Global Risk Report assess "insufficient effectiveness of climate action" as a primary medium- and long-term threat with potentially severe consequences in the next decade. Climate change is already being felt as an increase in the frequency of abnormal weather conditions. The most significant long-term risks are «Climate action failure» and «Extreme weather»; these risks may soon become critical and affect all areas of human activity. Different countries perceive global challenges differently, such as Climate action failure in the United States, ranking second among short-term risks. In contrast, China ranks 23rd, while these two countries are the world's largest emitters of CO<sub>2</sub>.

The risks to the business from global warming are being felt more and more with time. Respondents' fears are not unfounded, as the frequency and severity of weather events are growing. In 2021, the global damage from the insurance catastrophe exceeded \$ 100 billion - the fourth most significant year in the history of observations [2].



Therefore, both businesses and financial companies need to become more resilient to climate change. Only 15.8% of World Economic Forum respondents are positive or optimistic about the future. The risks of climate change are at the top of the Allianz Risk Barometer, and the risks of natural disasters are among the top three. Economic losses from extreme weather and climate in Europe have reached about half a trillion euros over the last 40 years. Huge losses from weather conditions in Germany, France, Italy and Spain. Extreme weather events such as storms, heat waves and floods have killed between 85,000 and 145,000 people in Europe [2].

**Formulate the purpose of the article.** The purpose of the article is determining the economic risks of global climate change and their neutralization and mitigation through the use of eco-innovations. Justification of the positive synergistic effect of eco-innovations on economic indicators, the standard of living and sustainable development is provided.

**Presentation of the research results.** The United Nations Climate Change Conference of 2021 adopted the Glasgow Climate Pact and identified the need to renew and strengthen national contributions (NDCs) and increase efforts to finance climate adaptation. Despite the numerous steps of both governments and international organisations, achieving the 1.5 ° C target remains unlikely, especially given the global geopolitical crisis [10]. Businesses that do not use ESG may face high reputational contributions, lose consumer confidence, and face government barriers and lawsuits. Total capital expenditures on transformation may reach 8.8% of GDP in 2026-30.

Achieving net-zero emissions by 2050 will lead to a fundamental transformation of the entire global economy. It will be necessary to change economic, social systems, public administration and institutions that may face economic and political challenges. This transition is most smoothly possible only by introducing green innovations and well-formed government support. In order to develop policies and institutional mechanisms for the development of eco-innovations, it is necessary to classify them in detail. Since different types of innovations require different support and approaches to implementation and dissemination (table 1).

**Table 1.**

**Classification of eco-innovations and eco-innovators\***

	aspects	classification
Eco-innovations	Level of impact	Macro; meso; micro
	By the Taxonomy Regulation in EU	Climate change mitigation; Climate change adaptation; The sustainable use and protection of water and marine resources; The transition to a circular economy; Pollution prevention and control; The protection and restoration of biodiversity and ecosystems
	Design	Environmental impacts from the input side; Business model and firm processes/effectiveness; Savings/eco-efficiency; Environmental impact from the output side; Reduction of toxicity of the product or service;
	By environmental technologies	End-of-pipe technologies (additive/curative); Cleaner production technologies (integrated/preventive)
	Classes of eco-innovation	Material flow eco-innovation; Product eco-innovation; Process eco-innovation; Organizational



	aspects	classification
		eco-innovation; Marketing eco-innovation; Social eco-innovation; Infrastructure/System eco-innovation
	characteristics and environmental impacts	technical (product, process); non-technical (marketing, organizational, institutional, system)
	Operational typology of eco-innovation	Add-on eco-innovations; Integrated eco-innovations; Alternative product eco-innovations; Macro-organizational eco-innovations; General purpose eco-innovations
	governance	Scientific-academic cooperation; cooperation with universities and research centers; cooperation with competitors and industrial organizations; cooperation with clients, NGOs, regulators, suppliers
	Users	Internal, external, intermediaries
	Product-Service	Radical deviation from current business bases; relations with suppliers; incremental advances within existing business models; new products/services
	novelty	New to the firm; New to the market
	Type of change	Component addition; Sub-system change; System change
	generic dichotomy	“radical” , “incremental”
Eco-innovators	Size of enterprises eco-innovators	large , medium, small
	Industry sector	Agriculture, mining, energy, manufacturing, construction etc
	Focus market	Business-to-business Business-to-consumer
	Age of firms	New, old
	Legal form (Types and forms of conducting activity)	sole trader (self-employment); civil law partnership; commercial companies; companies (limited liability company and joint-stock company); partnerships (registered partnership; professional partnership, limited partnership, limited joint-stock partnership)
	Novelty of the eco-innovation in the firm	New in the developing/adopting; Not new in the developing/adopting
	Novelty of the eco-innovation in the primary sectors of operation of the firms	New in the primary sector of operation of the firm; Not new in the sector of operation of the firm
	Application of environmental practices	Proactive; reactive
	In relation to the application of environmental practices	Strategic eco-innovators; Strategic eco-adopters; Passive eco-innovators; Non eco-innovators
	Source process leading to the eco-innovation	Internal development; Development with external cooperation; External sources and internal adoption ; Alliances with other firms and joint development; Internal development as the result of continuous improvement processes

\*Source: [5].





It is expedient for the company to create a portfolio of flexible business strategies with the integration of "green solutions" into the functioning processes, to pay more attention to research, development and implementation of green innovations, and staff training. Businesses that are now starting to operate based on ESG and green innovation can take the lead in the future and be more resilient. Most global companies have already realised the need for transformation to new economic realities. For example, the United States spends 2.8 per cent of its GDP on R&D and holds approximately 11,000 patents in technologies such as renewable energy production and low emissions. In South Korea, 4.8% of GDP is spent on research and development, and there are 6,600 patents in similar fields.

The transition to a green economy should be based on innovation, using proven and safe green innovations and government support minimising risks through a well-established institutional structure. The 1.5 ° C target is so fundamental that societies must be prepared to accept the negative consequences of the policies pursued by governments today to avoid the worst results in the future [10].

Thus, the world is facing the need to transition to a green economy and sustainable development. The era of cheap fossil energy is also coming to an end, so it is necessary to look for ways to develop alternative energy, reduce its cost and introduce eco-innovations to reduce the impact of human activities on nature. As energy consumption grows, the need for innovation in energy conservation increases. The main areas of innovation that: reduction of climate risks; energy saving; sustainable transport infrastructure; development of a circular economy.

It is also necessary to change the systems in the management of enterprises, which will be aimed at the strategic vision and implementation of sustainable development and green transformation.

Companies are increasingly adapting their development strategies and technologies to climate neutrality. Changing technological processes to increase energy efficiency and the development and use of renewable energy sources will ensure the sustainability of enterprises. Some industries may face significant challenges in the transition to climate neutrality, as they require technological changes based on innovation (such as energy, cement, chemical).

The world's energy supply is still heavily dependent on coal, oil and gas, so we need to start with energy infrastructure. Many countries have begun to develop carbon capture and storage or sequestration (CCI) technologies. For example, Germany has declared climate neutrality by 2045. The year 2021 was full of climate events, extended national defined contribution plans (NDCs), and green agreements. At the end of October 2021, 114 countries and the EU submitted their new NDCs, covering almost 61% of global emissions [3]. Virtually all countries worldwide are committed to achieving zero carbon emissions by the middle of the century.

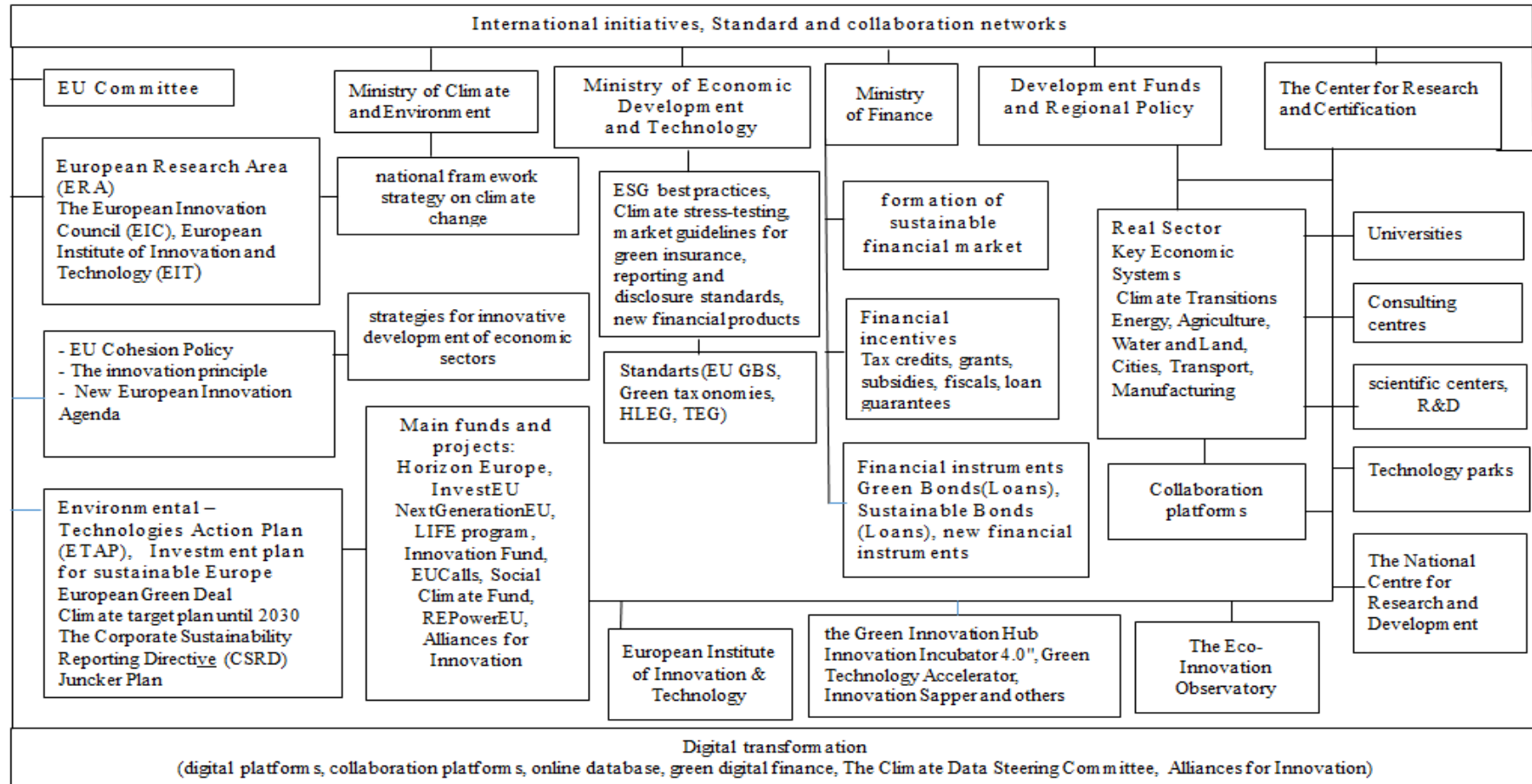
The development of the green economy should be carried out in three dimensions: green innovations and sustainable and inclusive development. What determines the development of the main factors:

- investments in human capital;
- preservation of nature and increase of social capital;

- implementation of macroeconomic and structural policy;
- development of institutions for innovative activity and economic transformation;
- capital mobilisation and attraction of private investments to finance eco-innovations.

The proposed scheme of the eco-innovation system is shown in Figure 1. The main elements of the system and the interconnections between them are given below. The main task of the state is the formation of a single interconnected innovative environment and the construction of effective institutional structures and mechanisms that will function stably and are aimed at sustainable development, ensuring the implementation of strategic goals and tactical tasks of innovative development. Innovative technologies should be used throughout the life cycle of projects.

They are essential for new and existing assets and to increase enterprises' productivity and safety. Still, it will be necessary to carry out significant institutional reforms, mobilise domestic resources, develop private sector innovation initiatives and attract the investments required to transition to a more sustainable and inclusive development based on green innovation. Since the resource requirements for the transformation are enormous, additional involvement of the public and private sectors and the international community and their close interaction is necessary. In addition, changing the education system is critical since the transformation of education in accordance with new requirements can significantly accelerate innovation processes in the country, ensure their continuity and increase the practical implementation of innovations. A properly formed education system can change the consciousness of society within one generation and provide a smooth transformation to a knowledge economy. Also, a developed and stable social protection and insurance system and a developed financial market are necessary to keep innovative and highly professional people in the country. Many programs and international organizations support the development of eco-innovation, such as the World Bank's Lighting Global program, which works with governments to remove political and regulatory barriers to market entry and increase access to clean energy. EU Horizon 2020, the European Commission allocates funding through this program and through the European Structural Investment Funds (ESIF) to encourage the implementation and commercialization of innovations in the market [12]. The combination of eco-innovation and digital technologies can significantly increase the efficiency of innovation implementation. The use of big data and artificial intelligence can reduce maintenance costs and extend the life of assets, and predictive modeling and 3D models will allow you to make informed management decisions [13]. The state can significantly influence the development of eco-innovations by developing a fiscal policy that will stimulate innovative activities at enterprises. This includes setting taxes and adjusting spending priorities, such as green taxes and subsidies, and green procurement. Also, when conducting public procurement, in addition to the ESG assessment of the project, it is necessary to take into account not only the initial construction phase of the contract, but the entire duration of the project, including disposal, and make decisions based on such calculations [14].



**Fig. 1. Proposed eco-innovation system**

Source: own research based on [16].





The profit and social significance of the project, especially if they are considered in the short-term perspective, are no longer the main criteria for selecting projects, it is advisable to take into account the environmental friendliness of the project, its impact on future generations [1].

A technical working group with stakeholders could be created to develop voluntary technical recommendations on how to apply the concept of climate resilience in enterprises. It is also necessary to provide technical assistance to enterprises regarding the introduction of ISO standards [11]. The transformation of the energy sector is important for economy.

Energy use accounts for 73 percent of global greenhouse gas emissions, with coal burning accounting for one-third and fossil fuel-based electricity generation using significant amounts of water.

Energy efficiency is one of the largest untapped sources of energy, and increasing it is a critical element of the energy transition.

This is often the cleanest and cheapest way to expand energy services. It is especially important to carry out projects in the energy efficiency of buildings, since buildings are the largest consumers of energy, so increasing their efficiency can have a great impact on achieving climate goals [6].

Investing in efficiency reduces the need for investment in energy supply, the fiscal costs of subsidies and costs [15]. It is also necessary to invest in energy storage and accumulation systems.

The development of eco-innovations requires the following strategic and tactical measures which summarizing in Table 2.

Therefore, the main strengths in developing eco-innovations are digitization, intellectual assets and the use of information technologies.

The transformation to a green economy should begin with:

- Energy complex of the country;
- Development of green and sustainable cities with the increased energy efficiency of buildings;
- Eco-innovations in the transport sector, as transport systems account for 16 percent of global greenhouse gas emissions.

These tasks require a developed digital infrastructure (cloud technologies, ultra-fast networks) and artificial intelligence solutions [4].

**Table 2.**

**The main areas of support for the development of innovative activities at the macro and micro levels**

On the government level		On the level of enterprises	
Strategic action	Tactical action	Strategic action	Tactical action
<ul style="list-style-type: none"> <li>- development of the national innovation strategy and innovation strategies by economic sectors;</li> <li>- assess cross-sectoral connections and regional impact, clusters and synergies from eco-innovations;</li> <li>- create an infrastructure for conducting research;</li> <li>- develop strategic aspects related to research and production infrastructure and cooperation;</li> <li>- create an institutional environment;</li> <li>- change of the education system (especially higher);</li> <li>- align current infrastructure project plans with long-term climate and development goals and determine the level of eco-innovativeness of each area;</li> <li>- expansion of private investment channels in green infrastructure assets, development of new financial instruments (green bonds, creation of a state green investment bank, etc.);</li> <li>- mitigate the risks for green investments, with the help of guarantees and insurance products that can be subsidized by the state, state packages of shares and other forms of credit improvement, or providing comprehensive risk assessment procedures;</li> <li>- support of InfraTech technologies, this is any technology that significantly affects the development and current operation of the infrastructure</li> </ul>	<ul style="list-style-type: none"> <li>- attraction and stimulation of private investments in innovative activities;</li> <li>- include climate priorities when developing macroeconomic and fiscal policy;</li> <li>- integrate climate planning into the state and local budget, prepare flexible long-term budgets;</li> <li>- provide adequate budget support and create incentives for investments in eco-innovation;</li> <li>- state co-financing of projects with enterprises;</li> <li>- development of software for monitoring and optimizing the use of energy and natural resources for both enterprises and citizens in everyday life, creating smart energy-efficient homes;</li> <li>- supporting creation of new technology companies,</li> <li>- encouraging entrepreneurs to be innovative;</li> <li>- cooperation between enterprises, formation of horizontal connections - clusters and networks;</li> <li>- formation of an open online database on performance indicators of infrastructure sectors, investment flows and performance indicators, to assess investments in eco-innovations in infrastructure and the degree of their implementation;</li> <li>- provision of resources, powers and incentives for enterprises to implement green investments, and attract new investors;</li> <li>- increasing the availability of information about the characteristics of products sold in Poland (for example, the introduction of an electronic passport of a product or service, which can provide information about the product's origin, composition, repair and disassembly capabilities, as well as end-of-life treatment and environmental impact information).</li> <li>- remote monitoring of air and water pollution, land, and radiation level with the opening of these data to the public in real-time;</li> <li>- support for the creation of new technology companies.</li> </ul>	<ul style="list-style-type: none"> <li>- development of a strategic vision of further sustainable activities and determination of necessary innovations and research;</li> <li>- formation of several alternatives and development scenarios in long-term plans;</li> <li>- changing the company's management structure to stimulate the introduction of innovations;</li> <li>- assessment of all projects and activities of the company from the point of view of sustainability and impact on the environment.</li> <li>- Standardization of processes and products according to international requirements and standards</li> </ul>	<ul style="list-style-type: none"> <li>- increase funding for corporate research;</li> <li>- strengthening cooperation between government, research centers, universities and business;</li> <li>- encouraging personnel to be innovative, training personnel in new technologies and innovative approaches;</li> <li>- increased use of remote and automated methods (eg drones, Internet of Things [IoT], robots);</li> <li>- using new digital platforms for forecasting prices, demand and supply of resources, searching for funding and others</li> </ul>

Source: own research based on [6].

**Conclusions and options for further research.** The transformation to a green economy necessitates the accelerated adoption of energy efficiency technologies alongside the expansion of renewable energy sources, all while enhancing energy efficiency. This approach demands systemic innovations across all economic sectors, with the potential for synergistic effects through their concurrent application. Furthermore, the advancement of information technologies, business models, financial instruments, and infrastructure is crucial. Effective policies and measures are essential, including strategic programs to foster innovative activities, tax incentives, pricing mechanisms, and enhanced digitalization [7].

Notably, the development of eco-innovations plays a vital role in the economic progression of Ukraine, acting as a catalyst in the shift towards a knowledge-based economy. Eco-innovations not only address economic and climate challenges but also fortify connections, creating an integrated space among people, nations, economies, and the environment. Recognizing the imperative for green, resilient infrastructure, countries and corporations are pivoting towards innovations that promise substantial development leaps, job creation, and increased shock resilience."

In summary, the strategic integration of eco-innovations and green technologies is pivotal for ushering in a sustainable and resilient economic future. This integrative approach promises to address critical environmental challenges while spurring economic growth and enhancing societal resilience. As such, it is imperative for policymakers and industry leaders to prioritize and implement comprehensive strategies that leverage these innovations to achieve long-term sustainability goals.

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