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N. Petrukha,
PhD in Economics, Associate Professor, Associate Professor of the Department of Management in Construction, Kyiv National University of Construction and Architecture
ORCID ID: https://orcid.org/0000-0002-3805-2215
S. Petrukha,
PhD in Economics, Associate Professor, Associate Professor of the Department of Management in Construction, Kyiv National University of Construction and Architecture
ORCID ID: https://orcid.org/0000-0002-8859-0724
O. Shapovalov,
Independent Researcher
ORCID ID: https://orcid.org/0009-0003-6086-2403
P. Ushchenko,
Postgraduate Student, West Ukrainian National University
ORCID ID: https://orcid.org/0009-0005-5288-0585

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THE ROLE OF THE BIOECONOMY IN THE POST-WAR "GREENING" OF ECONOMIC POLICY

Н. М. Петруха,
к. е. н., доцент, доцент кафедри менеджменту в будівництві,
Київський національний університет будівництва і архітектури
С. В. Петруха,
к. е. н., доцент, доцент кафедри менеджменту в будівництві,
Київський національний університет будівництва і архітектури
О. Б. Шаповалов,
незалежний дослідник
О. Б. Ущенко,
аспірант, Західноукраїнський національний університет

РОЛЬ БІОЕКОНОМІКИ У ПОВОЄННОМУ "ОЗЕЛЕНЕННІ" ЕКОНОМІЧНОЇ ПОЛІТИКИ

The article is devoted to analyzing the role of bioeconomics in shaping Ukraine's environmentally oriented economic policy in the context of post-war recovery, with an emphasis on integrating biotechnological innovations into the national innovation system to ensure sustainable development. It considers the bioeconomy as a key instrument for "greening" the economy, contributing to reducing carbon dependence and harmonizing economic and environmental goals. The relevance of the study is determined by the need to transform Ukraine's economic policy in the context of post-war reconstruction, where the bioeconomy acts as a mechanism for achieving environmental sustainability, rational use of resources, and increasing the country's competitiveness. The aim of the study is to develop a scientifically sound model for assessing the bioeconomic potential of Ukraine's regions to support sustainable development and the "greening" of economic policy by identifying key drivers, constraints, and resource opportunities. The study uses methods of system analysis, econometric modeling, and expert assessment. Based on data on the natural resource, infrastructure, logistics, labor, financial, and organizational and management potential of all regions of Ukraine, a bioeconomy development potential index was calculated. The scientific results demonstrate significant regional differentiation: 13 regions, including Kyiv, Odesa, and Kharkiv, have

a high level of bioeconomic potential, while 14 regions have a low level. The developed assessment tool allows identifying regions with high potential for scaling up bioeconomic projects and regions that require state support. Prospects for further research include improving the Ipbr assessment methodology by including additional parameters, such as environmental indicators, and developing regional bioeconomy development strategies taking into account international practices and the principles of the European Green Deal. Further research could focus on modeling the impact of biotechnological innovations on economic growth and environmental sustainability in individual regions of Ukraine.

Стаття присвячена аналізу ролі біоекономіки у формуванні екологічно орієнтованої економічної політики України в умовах повоєнного відновлення, акцентуючи на інтеграції біотехнологічних інновацій у національну інноваційну систему для забезпечення сталого розвитку. Вона розглядає біоекономіку як ключовий інструмент "озеленення" економіки, що сприяє зниженню вуглецевої залежності та гармонізації економічних і екологічних цілей. Актуальність дослідження зумовлена необхідністю трансформації економічної політики України в умовах повоєнної відбудови, де біоекономіка виступає механізмом для досягнення екологічної стійкості, раціонального використання ресурсів і підвищення конкурентоспроможності країни. Мета дослідження полягає у розробці науково обгрунтованої моделі оцінки біоекономічного потенціалу регіонів України для підтримки сталого розвитку та "озеленення" економічної політики шляхом визначення ключових драйверів, обмежень і ресурсних можливостей. У дослідженні використано методи системного аналізу, економетричного моделювання та експертної оцінки. На основі даних про природно-сировинний, інфраструктурний, логістичний, трудовий, фінансовий та організаційно-управлінський потенціал всіх регіонів України розраховано індекс потенціалу розвитку біоекономіки. Наукові результати демонструють значну регіональну диференціацію: 13 регіонів, зокрема Київ, Одеса, Харків мають високий рівень біоекономічного потенціалу, тоді як 14 регіонів належать до низького рівня. Розроблений інструмент оцінки дозволяє ідентифікувати регіони з високим потенціалом для масштабування біоекономічних проєктів і регіони, що потребують державної підтримки. Перспективи подальших досліджень включають вдосконалення методики оцінки Ipbr шляхом включення додаткових параметрів, таких як екологічні показники, та розробку регіональних стратегій розвитку біоекономіки з урахуванням міжнародних практик і принципів Європейського зеленого курсу. Подальші дослідження можуть фокусуватися на моделюванні впливу біотехнологічних інновацій на економічне зростання та екологічну стійкість окремих регіонів України.

Key words: bioeconomy, circular economy, post-war recovery, environmental policy, sustainable development, regional potential.

Ключові слова: біоекономіка, циркулярна економіка, повоєнне відновлення, екологічна політика, сталий розвиток, регіональний потенціал.

STATEMENT OF THE PROBLEM IN GENERAL TERMS AND ITS RELATIONSHIP TO IMPORTANT SCIENTIFIC AND PRACTICAL TASKS

In the current conditions of transformation of Ukraine's economic model, which has undergone significant changes as a result of full-scale war and deep economic and social upheavals, it is particularly important to reorient towards innovative principles of sustainable development, one of the key elements of which is the bioeconomy, as a concept that combines the rational use of biological resources, the development of biotechnologies, and environmentally responsible economic policies. Abandoning the raw materials-based economic model and transitioning to an economy based on knowledge, innovation, and technologies for the deep processing of biological resources is becoming not only a strategic goal but also a prerequisite for the country's sustainable post-war recovery.

The formation of an effective bioeconomic space requires comprehensive consideration of the latest achievements in science and technology, particularly in the fields of biochemistry, molecular biology, energy, and agriculture, and also involves the large-scale introduction of renewable energy technologies, bioengineering, processing of organic raw materials, and the replacement of carbon-intensive processes with environmentally friendly alternatives. Improving the efficiency of the

innovation cycle, reducing the time to commercialization of biotechnologies, and expanding their application in the manufacturing, energy, food, and medical sectors are creating the conditions for a transition to a green paradigm of economic growth capable of ensuring energy independence, food security, biodiversity conservation, and the health of the nation. Given the global growth of interest in bioeconomic approaches, especially against the backdrop of structural energy and environmental crises exacerbated by the war, Ukraine has a unique window of opportunity to implement a profound bioeconomic transformation [13]. In this context, it is particularly important to study the role of regions in the formation of a single national bioeconomic space, assess their natural potential for the development of the bioeconomy, institutional readiness for the introduction of biotechnologies, and capacity for innovative development within sustainable models of economic recovery.

ANALYSIS OF RECENT SCIENTIFIC RESEARCH AND PUBLICATIONS

The scientific understanding of the role of bioeconomics in shaping Ukraine's "green" economic policy in the post-war period is the subject of growing interdisciplinary interest, covering environmental, economic, technological, and social aspects. According to research by Belova I. M. and Yaroshchuk O. V., the modern bioeconomy should become the basis for an innovative model of Ukraine's integration into the European economic space, where the adaptation of best practices of sustainable development and environmental management plays an important role [1]. In this context, the importance of the state's strategic vision for the development of national bioeconomic potential is emphasized, which involves creating institutional prerequisites for the transformation of the agricultural, energy, and industrial sectors. In turn, the report of the Office of Sustainable Solutions emphasizes that the post-war reconstruction of Ukraine is a unique window of opportunity to launch a bioeconomic transformation focused on resource-efficient, environmentally friendly, and high-tech production, which will ensure synergy between regional development and global climate goals [2]. Bilousko T. Yu. focuses on the circular economy as a key approach to waste minimization, resource reuse, and restoration of natural ecosystems, which is directly related to the concept of bioeconomy and its applied aspects in the sustainable development system [3].

The issue of managing the development of the bioeconomy at the regional level is highlighted in the works of Vostryakova V. I., who proposes a locally-oriented model for the transformation of socio-economic systems based on bioeconomic sustainability and institutional synergy [6]. In turn, Golovnya Yu. I. and Bilousko T. Yu. investigated instruments for attracting investment in green business, emphasizing the need to develop biofinancing through public and private institutions [7]. The scientific and technical prerequisites for the development of the bioeconomy are analyzed in detail in the monograph by Gonta D., Kyryliuk Ye., Proshchalikina A., and Ryzhenko N., which outlines the key areas of technological breakthrough, particularly in the field of agrobiotechnology, pharmacobiology, and industrial biosystems [8]. The results of the research by Talaviri M. P., Gazuda L. M., and Gazuda M. M. deserve special attention, as they substantiate the prospects for the development of a closed-cycle bioeconomy, emphasizing the advantages of integrating biotechnologies into local production systems [17].

The work of Koval O. M., Talaviri M. P., and Dobrivska M. V. analyzes the potential of bioenergy in Ukraine as an important segment of the bioeconomy, opening the way to energy independence through the use of renewable bioresources [12]. The issue of institutional support is also raised in the report of the NGO "SYNERGY," which discusses the need to update the regulatory framework and create regional clusters for the innovative development of the bioeconomy [11]. In conclusion, it is worth noting the research by Vasilyuk S. V., Franiv I. A., and Kiiv D. I., who emphasize the need to integrate the bioeconomy into strategic programs of the national economy and highlight the role of inter-sectoral cooperation in this process [5]. In turn, Dobrivska M. V. defines the bioeconomy as a holistic basis for sustainable development, which requires the formation of a new model of economic thinking and the transformation of public policy towards sustainability [10]. Thus, contemporary scientific opinion on the bioeconomy is multifaceted, but all approaches agree that it has the potential to become not only a mechanism for the ecological reconstruction of the economy, but also a platform for Ukraine's innovative breakthrough in the global system of sustainable development.

FORMULATION OF THE OBJECTIVES OF THE ARTICLE (TASK STATEMENT)

The purpose of the article is to substantiate the role of bioeconomics in the future processes of post-war "greening" of Ukraine's new economic policy by assessing the regional potential for its development.

Objectives of the study:

— to identify structural features of the bioeconomy as a conceptual component of Ukraine's new environmentally oriented economic policy;

— to justify the need to integrate the bioeconomy into the system of strategic economic planning based on the circular model.

— to develop a system for quantitative assessment of the potential of regions for the introduction of the bioeconomy using a comprehensive assessment index.

— to assess the bioeconomic potential of Ukraine's regions based on an integrated indicator and identify regions with high and low levels of development.

— to propose recommendations for the formation of regional policies to stimulate the bioeconomy in the context of the expected post-war recovery.

SUMMARY OF THE MAIN RESEARCH MATERIAL

Within the paradigm of sustainable development that is taking shape in Ukraine in the context of post-war recovery, it is advisable to consider the bioeconomy management system as an integral subsystem of the national innovation system, capable of ensuring its revitalization through the introduction of advanced technological solutions based on biotechnological innovations, as well as through the formation of new

Table 1. Drivers and constraints for the development of the bioeconomy and sustainable "greening" in Ukraine

Drivers	Ponstraints
Increase in government spending on the purchase of high-tech biotechnological products for medical needs	Unstable macroeconomic situation and complex political situation in the context of post-war recovery
Financing of government programs for import substitution in the field of biotechnological medicines	Outdated production facilities of Ukrainian biotechnology companies
Policy for the creation of biotechnological clusters that promote foreign investment	Significant dependence on imports of raw materials and components for biotechnological production
Investment support for development institutions aimed at financing innovative biotechnology start-ups	Insufficient number of qualified specialists and lack of modern educational programs in the field of biotechnology
Expansion of preventive medicine programs, stimulating the development of the vaccine and diagnostic systems market	Non-transparent rules for foreign companies regarding localization of production in Ukraine
Increased demand for biocompatible and biodegradable materials for medical devices due to an increase in surgical procedures	Insufficient funding for biotechnology projects due to preference for investment in information technology
Ukraine's developed IT sector as a foundation for the competitiveness of the bioinformatics market	High logistics costs and imperfect customs regulations
Active development of the agricultural sector, creating opportunities for agrobiotechnology	Lack of modern legislation, environmental standards, and technical regulations for biotechnology
Potential for import substitution in biopharmaceuticals, agrobiotechnology, and industrial biotechnology	Insufficient transparency of public procurement mechanisms and lack of sales guarantees for private companies
Focus on preventive medicine, promoting the development of laboratory diagnostics and the creation of new biomarkers	Lack of government incentives for the introduction of biotechnology in key sectors such as energy and agriculture

Source: based on [14, 19, 20].

products and processes with high added value. Such a system should perform a key function through the stable modernization of existing sectors of the economy through the deep integration of biotechnologies, which will not only reduce dependence on carbon-intensive production, but also adapt national economic policy to modern environmental challenges.

Despite the fact that Ukraine has accumulated significant scientific and technical potential in the field of biotechnology over the past decades, including the availability of qualified personnel, access to innovative developments, the functioning of biotechnology clusters and technology parks, the implementation of a comprehensive bioeconomic model without the active participation and strategic intervention of the state remains virtually impossible, especially in the context of post-war reconstruction of the national economy [4]. In the context of developing a new environmentally oriented economic policy, it is important to consider not only the existing drivers of bioeconomic growth, in particular the natural resource base, scientific institutions, and the agricultural sector, but also the numerous barriers that hinder the effective implementation of green innovations (Table 1).

In the context of Ukraine's post-war economic recovery, it is particularly important to develop economic policies that ensure not only rapid economic growth but also a focus on long-term sustainability and the preservation of natural capital. In this regard, the concept of bioeconomy, closely linked to the principles of ecological balance, acts as a key mechanism for the transformation of economic activity, allowing the harmonization of the economic interests of society with the needs of the environment. The bioeconomy, as part of the broader system of the "nature-based economy," involves a comprehensive study of the economic relations between society, nature, and the institutions that regulate the use of natural resources in order to achieve sustainable development goals.

The study of the natural resource use economy, which underlies the bioeconomy, covers a wide range of issues, including balancing social, economic, and environmental interests, ensuring the reproduction of natural resources, developing mechanisms for regulating environmental risks, and assessing the economic consequences of economic activity. The focus is on socio-ecological-economic systems of various scales, from individual enterprises and regions to the national economy as a whole, including the integration of the natural complex with economic processes [15, p. 21].

In light of the challenges associated with environmental constraints and the need to reduce dependence on fossil resources, it is also important to pay attention to the potential of the circular economy, which is closely linked to the bioeconomic paradigm. Unlike the linear economic model based on the "take→use→dispose" principle, the circular economy is based on renewable and closed processes that involve the reuse of materials, optimization of product life cycles, and minimization of negative impacts on the environment. In practical terms, this means a transition to production and consumption models in which waste becomes a secondary resource and technological chains become cyclical. When considering key approaches to building a circular model within the bioeconomy, it is worth highlighting a resource-oriented vector, which involves the closed circulation of material flows, energy, and waste through repair, modernization, reuse, or complete recycling of raw materials; and an economy-oriented approach, which focuses on creating added value and long-term economic benefits by minimizing losses of natural capital [18]. Together, these approaches form the basis of a modern bioeconomy based on sustainable development, rational use of natural resources, and a high level of environmental responsibility (Table 2).

Table 2. Application of biotechnologies in various fields for the development of Ukraine's bioeconomy

Field of activity	Biotechnology
Healthcare	1. Development of drugs, vaccines, diagnostic methods for detecting diseases and genetic predispositions. 2. Application in reproductive medicine (artificial insemination, early diagnosis of hereditary diseases). 3. Gene and cell therapy for the treatment of complex diseases. 4. Individual selection of medicines based on genetic profiles. 5. Use of biocompatible materials and targeted drug delivery systems.
Agriculture	1. Creation of new and improved plant varieties and animal breeds, optimization of breeding processes. 2. Production of biological plant and animal protection products and bacterial fertilizers. 3. Development of enriched feed and feed additives. 4. Artificial insemination and embryo transfer for livestock breeding. 5. Accelerated reproduction of elite plant varieties, obtaining virus-free planting material.
Food industry	1. Use of biotechnology in food production (bread, cheese, wine, beer, flavor additives). 2. Production of dietary products enriched with additives (sugar substitutes, amino acids, vitamins). 3. Creation of functional products for healthy nutrition.
Sports	1. Selection and training of athletes based on their genetic characteristics to improve performance.
Ecology	1. Processing of household, agricultural, and industrial waste. 2. Biological treatment of persistent pollutants (oil, pesticides, polymers). 3. Production of biodegradable alternatives to traditional materials (biopesticides, bioplastics). 4. Preservation of biodiversity, restoration of rare plant and animal species populations.
Use of natural resources	1. Extraction of useful minerals from waste and low-quality raw materials (biometallurgy, oil well restoration). 2. Development of bioenergy (production of biogas, biofuels, hydrogen). 3. Synthesis of chemicals from renewable raw materials for industrial use.

Source: based on [9, 26].

In the context of forming a new model of post-war economic development in Ukraine based on the principles of sustainability, the bioeconomy emerges as a key instrument for "greening" the state's economic policy, as it integrates knowledge, resources, and innovations aimed at restoring natural capital, improving the efficiency of bio-resource use, and reducing environmental impact. The concept of a circular economy, which is closely linked to the bioeconomic paradigm, involves the creation of a closed production and consumption cycle that mimics natural ecosystems, where all materials and resources, after use, are returned to circulation through reuse, renovation, or recycling, thus eliminating the problem of waste as such (Fig. 1).

The main goal of this model is to ensure maximum efficiency at every stage of the life cycle of a product or service, which necessitates the reorganization of existing distribution systems with a priority on secondary resources, the regenerative use of materials, and reduced dependence on primary raw materials. In scientific terms, the conceptual foundations of the circular economy are not new, but rather summarize achievements in industrial ecology, ecological design, ecological efficiency, and closed-loop material flow management, which together create a scientifically sound platform for the introduction of new approaches to economic policy-making [23].

According to the definition of international organizations, in particular the UN, a green economy is an economic system that promotes the well-being of the population, ensures social equality, and simultaneously reduces environmental risks and degradation. Its strategic goal is to achieve environmental balance through comprehensive solutions to socio-economic problems, in particular by stimulating employment, income growth, and energy efficiency, accompanied by the preservation of biodiversity and ecosystem services [21]. The directions for implementing a green economy include, in particular, modernization of the energy sector, investment in environmental technologies, development of sustainable transport, waste recycling, forest restoration, and other initiatives that have a positive environmental impact (Fig. 2).

Innovation, as a basic element of economic growth, requires not only technical development, but also clearly structured management mechanisms that ensure effective coordination between all participants in the innovation process, which creates a need for the formation of a

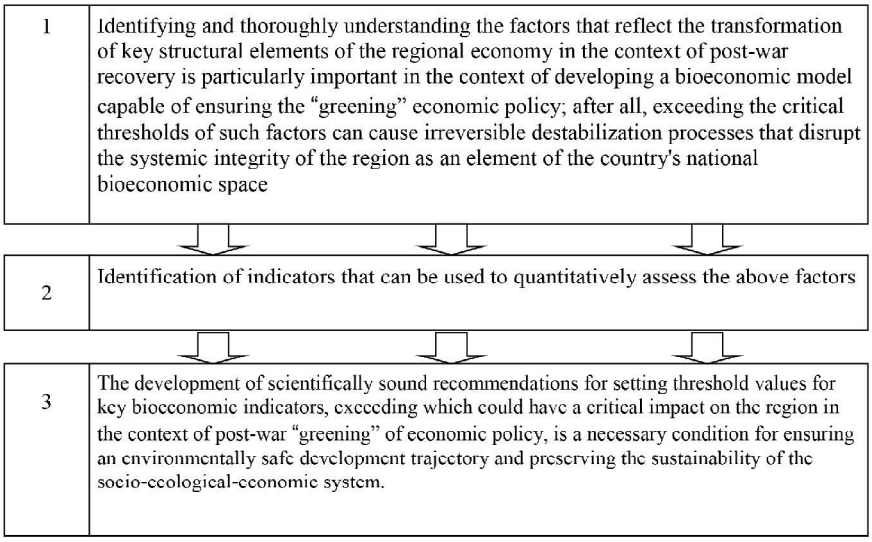

Fig. 1. Algorithm for forming a system of threshold values for bioeconomic factors, exceeding which is critical for the environmentally safe development of a country's economic policy

Source: compiled by the authors.

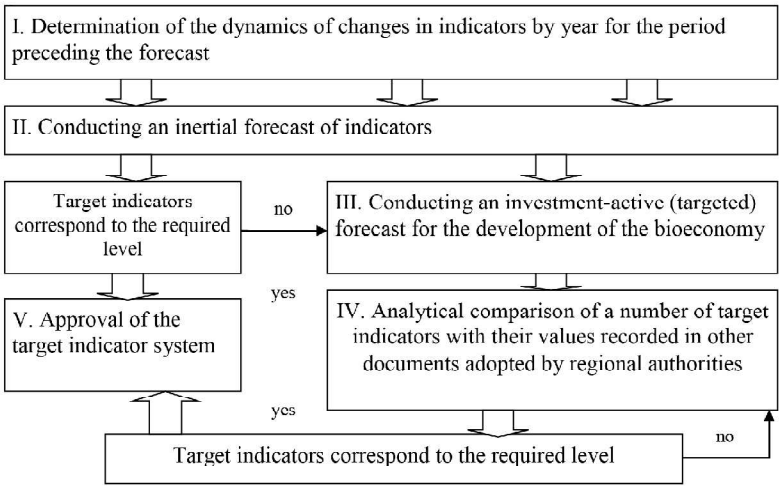

Fig. 2. Logical structure of quantitative indicators assessment in the process of forming a bioeconomically oriented development program for Ukraine's regions

Source: compiled by the authors.

comprehensive innovation strategy that combines state support, academic research, entrepreneurial initiative, and infrastructure capabilities for the implementation of technological solutions in the bioeconomy. The strategy itself should take into account not only national priorities but also regional specificities, which is particularly relevant in Ukraine given the uneven technological development of individual territories and their varying levels of innovation capacity (Fig. 3).

Given the complex structure of the economy, which includes both high-tech and traditional industries, the most flexible and adaptive approach to bioeconomy management appears to be a mixed strategy that combines elements of both gradual modernization and targeted innovative transformation adapted to the conditions of specific regions. This approach allows for more efficient use of existing scientific and resource potential, ensures close integration between science and production, and creates the institutional foundations for long-term sustainable development [25, p. 10]. The development of an effective bioeconomy management model should include the stages of goal setting, strategic planning, implementation, and monitoring mechanisms, which together will ensure the continuity of the innovation process, from scientific development to the commercialization of biotechnology products and solutions. Such a model should

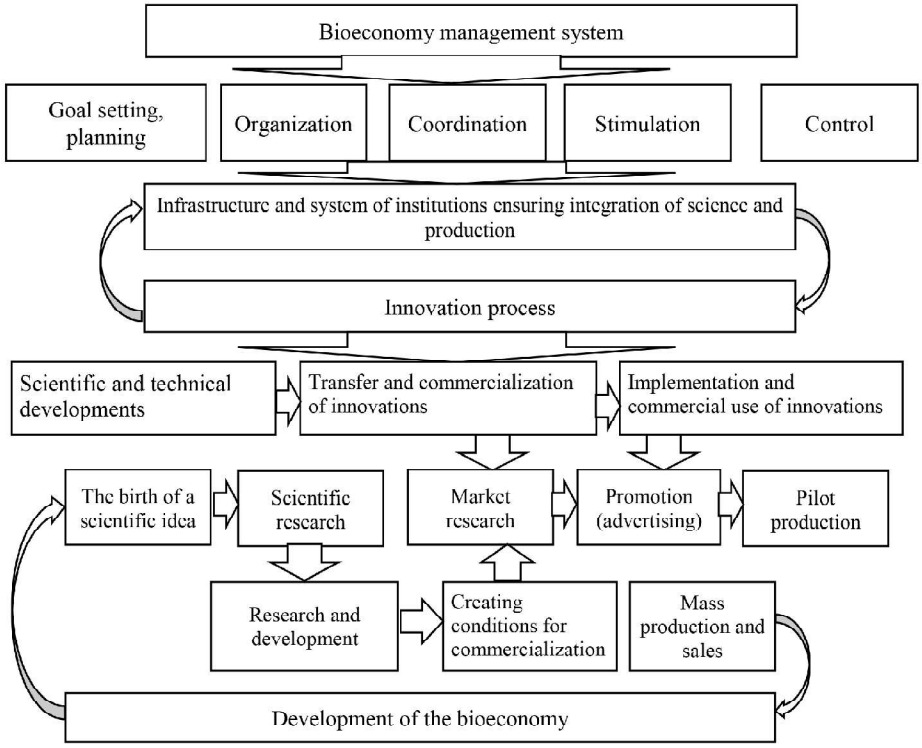

Fig. 3. Model of the innovation development management system for the bioeconomy in the context of post-war "greening" of Ukraine's economic policy

Source: compiled by the authors.

Table 3. Assessment of the bioeconomy development potential of the region

No.	Evaluation parameters	Evaluation criteria	Points	Max points	Weight (wi)
Natural resource potential (NRP)				4	0,20
1.	Availability of raw materials for biotechnology	The region has a raw material base	2		
		Raw materials are available in neighboring regions.	1		
		Lack of raw materials	0		
	Availability of water sources	Well drilling or water extraction from a water body is available	2		
		Only one source type available	1		
		There are no water sources.	0		
Infrastructure potential (IP)				4	0,25
2.	Availability of treatment facilities	The treatment facilities are capable of receiving all wastewater.	2		
		None, but construction is possible	1		
		Not possible to implement	0		
	Availability of spare electricity capacity	Capacities are available in the areas of Balanced Use of Natural Resources and Innovation.	2		
		Electricity can be supplied to the Balanced Nature Management and Innovation zone	1		
		No power available	0		
Logistics potential (LP)				4	0,10
3.	Availability of rail connection	With high throughput capacity in the Balanced Nature Management and Innovation Zone	2		
		With high throughput capacity outside the Balanced Nature Use and Innovation Zone, but with the possibility of connection	1		
		No rail connection	0		
	Availability of motor transport connections	There is road transport connection with other regions.	2		
		No connection	0		
Labor potential (Lab.P)				4	0,15
4.	Availability of highly qualified personnel	There are personnel with relevant education	2		
		There are personnel with higher education and the possibility of retraining.	1		
		Insufficient number of qualified personnel	0		
	Interaction with biotechnology institutes	No interaction	2		
		No interaction	0		
Financial potential (FP)				4	0,10
5.	Funding for innovative development, million UAH/year	> 100	2		
		10-100	1		
		< 10	0		
	Income tax benefits	There are benefits	2		
		No benefits available	0		
Information potential (InfP)				2	0,10
6.	Availability of a network resource with information on innovative development	There is an accessible and informative resource available.	2		
		Resource not available	0		
Organizational and managerial potential (OMP)				4	0,10
7.	Existence of an innovation development strategy	There is a strategy	2		
		No strategy	0		
	Availability of an investment promotion agency	There is an agency	2		
		Agency not available	0		

Source: compiled by the authors

Table 4. Dispersion and standard deviation of bioeconomy development potential elements

Indicators	NRP	IP	LP	Lab.P	FP	OMP	NRP
Total variance	0,001	0,001	0,000	0,005	0,000	0,000	0,001
Standard deviation	0,036	0,025	0,013	0,067	0,020	0,000	0,033

Source: compiled by the authors.

Table 5. Quantitative assessment of regions that fell within the calculation intervals

Level of potential	Sturges	Brooks and Carruzer	Heinhold and Hayedi
	k = 6 (5,17)	k = 7 (6,27)	k = 5 (4,24)
Lack of potential	0	1	0
Low level	1	1	2
Below average	2	1	0
Average	1	3	1
Above average	3	2	4
High	4	5	3
Very high	7	5	8

Source: compiled by the authors.

create a stable environment for partnership with economic and financial actors: investment funds, donor programs, ministries, international organizations, and other stakeholders interested in the implementation of green innovations and the development of bio-oriented sectors [22].

Modern innovation policy in the context of post-war reconstruction should be based on the development of a comprehensive national innovation system that provides for the smooth functioning of a network of interacting organizations capable of generating, scaling, transforming, and effectively disseminating environmentally oriented bioeconomic innovations. Such a system should not only ensure the technological modernization of industries, but also form a new economic model in which development is based on renewable resources, environmental responsibility, and sustainable economic growth as key priorities of state policy. The initial hypothesis of the study is that Ukraine's regions have different resource potentials for the development of bioeconomic projects, which can be quantified using the bioeconomic development potential index ((Ipbr), which will include the following assessment components: 1) natural resources, 2) infrastructure, 3) logistics, 4) labor, 5) financial, and 6) organizational and managerial potential. The rationale is based on modern scientific approaches to regional development assessment, particularly in the context of the bioeconomy, which combines biotechnology, environmental sustainability, and economic growth (Table 3) [24, p. 52].

After collecting all the necessary information, each parameter is evaluated according to the defined criteria, where scores are assigned on a scale from 0 to 2. Next, the relative indicator of each evaluation parameter is calculated using the following formula: the ratio of the actual indicator to the maximum (reference) value:

$$\overline{t_j} = \frac{x_{факт}}{x_{max}} \quad (1),$$

where: tj — potential element parameter;

x_{fact} — the actual value of the parameter criterion;

x_{max} — maximum (reference) value of the parameter criterion.

After that, the integral indicator for each element of the region's bioeconomy development potential is calculated using the following formula:

$$I_j = \frac{\sum_{i=1}^{nj} t_j}{n_j} \quad (2),$$

where:

I_j — Integral indicator of the bioeconomy development potential element;

t_j — calculated parameter of the potential element;

n_j — number of element parameters.

To calculate this, we will use a method adapted to 10 parameters. Since we have reduced the number of parameters, we will adjust the maximum values of the elements and weight coefficients proportionally:

1) Natural resource potential (NRP): 3 parameters (max 6 points), w_i=0,30;

2) Infrastructure potential (IP): 3 parameters (max 6 points), w_i=0,35;

3) Logistical potential (LP): 1 parameter (max 2 points), w_i=0,10;

4) Labor potential (Lab.P): 1 parameter (max 2 points), w_i=0,10;

5) Financial potential (FP): 1 parameter (max 2 points), w_i=0,10;

6) Organizational and management potential (OMP) (1 parameter, max 2 points), w_i=0.05;

7) Information potential (InfP) was excluded due to the removal of parameters..

Final integrated indicator — "Index of the region's bioeconomy development potential" (Ipbr) — can be calculated as the weighted average of all elements of the bioeconomy development potential, taking into account the individual weighting coefficients provided based on the results of expert assessment:

$$I_{ipbr} = \quad \times 0,30 + \quad \times 0,35 + \quad \times 0,10 + \quad \times 0,10 + \quad \times 0,10 + \quad \times 0,05 \quad (3).$$

In order to determine the dispersion of random variables of bioeconomy development potential elements, the dispersion ($\delta 2$) and standard deviation (λ) were calculated for each region using Excel tools. The results show that the dispersion of potential elements is insignificant and that the indicator is correctly calculated based on weighted averages (Table 4).

Next, it is necessary to select the number of intervals in the bioeconomy development potential range. To do this, let us consider several approaches:

1. Sturges' formula:

$$k = \log 2 \times n + 1 \quad (4),$$

where:

k — number of intervals;

Table 6. Gradation of the region's bioeconomy development potential in terms of opportunities for innovative development of the bioeconomy

Rating	NRP	IP	LP	Lab.P	FP	OMP	Ipbr
max	0,20	0,22	0,10	0,15	0,10	0,10	0,94
min	0,03	0,16	0,07	0,04	0,04	0,10	0,55
step	0,06	0,02	0,01	0,04	0,02	0,00	0,13
Low level	0,03≤X≤0,09	0,16≤X≤0,18	0,07≤X≤0,08	0,04≤X≤0,08	0,04≤X≤0,06	0,1≤X≤0,1	0,55≤X≤0,68
Average level	0,09≤X≤0,15	0,18≤X≤0,2	0,08≤X≤0,09	0,08≤X≤0,11	0,06≤X≤0,08	0,1≤X≤0,1	0,68≤X≤0,81
High level	0,15≤X≤0,2	0,2≤X≤0,22	0,09≤X≤0,1	0,11≤X≤0,15	0,08≤X≤0,1	0,1≤X≤0,1	0,81≤X≤1

Source: compiled by the authors.

n — number of research results obtained, participating in the study).

2.Brooks and Carrusher formula;

$$k = 5\lg\times n \quad (5).$$

Table 7. Input data for assessing the bioeconomy development potential of a region of Ukraine (10 parameters)

Region	Raw material base	Land industry	Water	Treatment facilities	Technopark	Electricity	Motor vehicles	Qualified personnel	Financial innovations	Strategic solutions.
Vinnytsia	2	2	2	2	1	2	2	2	2	2
Volyn	1	1	2	1	0	1	2	1	1	1
Dniprop	2	2	2	2	2	2	2	2	2	2
Donetsk	2	1	1	1	1	1	2	2	1	1
Zhytomyr	1	2	2	1	0	1	2	1	1	1
Zakarpattia	1	1	1	1	0	1	2	1	0	0
Zaporizhia	2	2	2	2	1	2	2	2	2	2
Ivano-Frankivsk	1	1	2	1	0	1	2	1	1	1
Kyiv	2	2	2	2	2	2	2	2	2	2
Kirovohrad	2	2	2	1	0	1	2	1	1	1
Luhansk	1	1	1	1	0	1	2	1	0	0
Lviv	2	2	2	2	1	2	2	2	2	2
Mykolaiv	2	2	2	2	1	2	2	2	2	2
Odesa	2	2	2	2	2	2	2	2	2	2
Poltava	2	2	2	2	1	2	2	2	2	2
Rivne	1	2	2	1	0	1	2	1	1	1
Sumy	2	2	2	1	0	1	2	1	1	1
Ternopil	1	1	2	1	0	1	2	1	0	0
Kharkiv	2	2	2	2	2	2	2	2	2	2
Kherson	2	2	2	2	1	2	2	2	2	2
Khmelnytsky	1	2	2	1	0	1	2	1	1	1
Cherkasy	2	2	2	2	1	2	2	2	2	2
Chernivtsi	1	1	1	1	0	1	2	1	0	0
Chernihiv	1	2	2	1	0	1	2	1	1	1

Table 8. Results of the assessment of the potential for development of bioeconomic projects in the regions of Ukraine

Region	NRP	IP	LP	Lab. P	FP	OM P	I_{pbr}	Level
Vinnytsia	1,00	0,83	1,00	1,00	1,00	1,00	0,93	High
Volyn	0,67	0,33	1,00	0,50	0,50	0,50	0,51	Low
Dnipro	1,00	1,00	1,00	1,00	1,00	1,00	1,00	High
Donetsk	0,67	0,50	1,00	1,00	0,50	0,50	0,65	Low
Zhytomyr	0,83	0,33	1,00	0,50	0,50	0,50	0,53	Low
Zakarpattia	0,50	0,33	1,00	0,50	0,00	0,00	0,43	Low
Zaporizhia	1,00	0,83	1,00	1,00	1,00	1,00	0,93	High
Ivano-Frankivsk	0,67	0,33	1,00	0,50	0,50	0,50	0,51	Low
Kyiv	1,00	1,00	1,00	1,00	1,00	1,00	1,00	High
Kirovohrad	1,00	0,33	1,00	0,50	0,50	0,50	0,56	Low
Luhansk	0,50	0,33	1,00	0,50	0,00	0,00	0,43	Low
Lviv	1,00	0,83	1,00	1,00	1,00	1,00	0,93	High
Mykolaiv	1,00	0,83	1,00	1,00	1,00	1,00	0,93	High
Odesa	1,00	1,00	1,00	1,00	1,00	1,00	1,00	High
Poltava	1,00	0,83	1,00	1,00	1,00	1,00	0,93	High
Rivne	0,83	0,33	1,00	0,50	0,50	0,50	0,53	Low
Sumy	1,00	0,33	1,00	0,50	0,50	0,50	0,56	Low
Ternopil	0,67	0,33	1,00	0,50	0,00	0,00	0,46	Low
Kharkiv	1,00	1,00	1,00	1,00	1,00	1,00	1,00	High
Kherson	1,00	0,83	1,00	1,00	1,00	1,00	0,93	High
Khmelnytskyi	0,83	0,33	1,00	0,50	0,50	0,50	0,53	Low
Cherkasy	1,00	0,83	1,00	1,00	1,00	1,00	0,93	High
Chernivtsi	0,50	0,33	1,00	0,50	0,00	0,00	0,43	Low
Chernihiv	0,83	0,33	1,00	0,50	0,50	0,50	0,53	Low

3. The Heinhold and Haedi formula;

$$k = \sqrt{n} \quad (6),$$

Using formula (7), we determine the step for each of the selected approaches.

$$x = \frac{max - min}{k} \quad (7).$$

Table 5 presents the results of comparing approaches to selecting the number of intervals by assessing the number of regions that fell into each of the proposed levels of bioeconomy development potential.

The quantitative assessment clearly reflects the empty and poorly filled levels of the region's bioeconomy development potential, which does not emphasize the significance of the results obtained, since at least three regions have a low level of potential, and at intervals of five to seven, they are distributed across four levels, which cannot be distinguished at this stage of the study. In addition, the inclusion of the "No potential" level, in the author's opinion, is unacceptable, since biotechnology is present in various spheres of human life and every region has at least minimal potential [16]. In this regard, we propose to abandon the intermediate levels and settle on the following: "low," 'medium,' and 'high' (Table 6).

Thus, the following gradation of the region's bioeconomy development potential for the development of the bioeconomy can be proposed:

— from 0 to 0.68 — low level;

— from 0.68 to 0.81 — medium level;

— from 0.81 to 1.0 — high level.

To perform the assessment and econometric modeling, 10 key parameters were selected from the provided methodology for assessing the regional bioeconomy development potential index (Ipbr), which takes into account their significance for the development of bioeconomic projects in Ukraine (Table 7).

From the list of assessment parameters (see Table 3), 10 were selected that have the greatest impact on bioeconomic potential, taking into account the weighting coefficients of the elements (for example, InfP has the highest weight of 0.25, NRP — 0.20) and their relevance to biotechnology:

1) Raw material base — a key factor for biotechnology.

2) Industrial land — necessary for the location of production facilities.

3) Water sources — important for technological processes.

4) Treatment facilities — critical for environmental safety.

5) Technopark — promotes innovation.

6) Electricity — the basis for equipment operation.

7) Road transport links — ensure logistics.

8) Qualified personnel — necessary for high-tech projects.

9) Financing of innovation — determines investment opportunities.

10) Innovation development strategy — reflects organizational support.

Calculations were performed for 24 regions of Ukraine based on the methodology, calculation of integral indicators for six elements of potential, and determination of I_{pbr} as the weighted average value. The data for assessing the parameters (Table 8) were compiled taking into account the geographical, economic, and infrastructural characteristics of the regions. Thus, Kyiv, Odesa, and Dnipropetrovsk regions received high scores (2) for most parameters thanks to their developed infrastructure and human resources, while Zakarpattia and Luhansk regions received lower scores due to limited resources.

The results showed significant regional differentiation: 13 regions (e.g., Kyiv, Odesa, Kharkiv) have high potential (Ipbr $>$ 0.81), no region fell into the medium level (0.68—0.81), and 14 regions (Volyn, Luhansk) belong to the low level ($I_{pbr} \leq 0{,}68$). Highest I_{pbr} (1,00) was recorded in Kyiv and Dnipro regions, which is explained by their developed infrastructure and financing. The lowest I_{pbr} (0.43) is in Zakarpattia, Luhansk, and Chernivtsi regions, where financial and organizational resources are limited. The analysis confirmed the hypothesis: regions with higher I_{pbr} have better conditions for bioeconomy,

in particular thanks to their raw material base, infrastructure, and human resources. The absence of regions with an average Ipbr indicates polarization: developed regions are significantly ahead of less developed ones. The scientific result is the creation of a tool for assessing bioeconomic potential, which allows identifying regions with high potential (for scaling up projects) and regions in need of support (for equalizing development). For example, the low I_{pbr} in the Luhansk region indicates the need for investment in human resources and infrastructure. The data obtained can be used to develop regional bioeconomy development strategies that will contribute to economic growth and environmental sustainability in Ukraine.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH IN THIS AREA

The analysis has established that this sector is a key instrument for sustainable development. The bioeconomy promotes greener production, reduces dependence on fossil fuels, and facilitates the transition to a renewable energy-based economy. For its successful functioning in the post-war period, active state participation, strategic planning, scientific support, targeted investments, and adaptation of global practices to the regional characteristics of Ukraine are necessary. The study identified factors that contribute to the development of the bioeconomy, as well as constraints that demonstrate uneven provision of resources and institutional support between regions, which in turn leads to uneven implementation of bioeconomic principles in different parts of the country. To assess the potential of regions, a "Regional Bioeconomy Development Potential Index" was developed, which takes into account six main components: natural resources, infrastructure, logistics, labor potential, financial capabilities, and organizational and managerial resources. The assessment was based on a number of key parameters.

A combined strategy for the development of the bioeconomy has been proposed, combining the modernization of traditional industries with the introduction of innovative biotechnological solutions. It takes into account the multilevel resource potential of the regions. Based on the Ipbr calculation, the regions were classified into three categories: low, medium, and high bioeconomic potential. Thirteen regions with high potential were identified, including Kyiv, Kharkiv, and Odesa, where bio-oriented projects can be scaled up. The other 11 regions, including Luhansk, Zakarpattia, and Chernivtsi, have low potential and require active state support. A methodological approach based on a system of weighted coefficients for individual elements of potential, adapted to the conditions of post-war Ukraine, has been developed to assess bioeconomic potential. The proposed gradation of regional bioeconomic development levels allows identifying priority areas for investment, developing strategic plans, and stimulating interregional cooperation.

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