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Yareмова МарунаDoctor of Economic Sciences, Associate Professor
Polissia National University, Ukraine**Яремова Марина Іванівна**доктор економічних наук, доцент
Поліський національний університет, Україна
ORCID: 0000-0001-5636-3538**Kilnitska Olena**Candidate of Economic Sciences, Associate Professor
Polissia National University, Ukraine**Кільницька Олена Сергіївна**кандидат економічних наук, доцент
Поліський національний університет, Україна
ORCID: 0000-0001-9719-120X**Levkivska Larysa**Candidate of Economic Sciences, Associate Professor
Polissia National University, Ukraine**Левківська Лариса Миколаївна**кандидат економічних наук, доцент
Поліський національний університет, Україна
ORCID: 0000-0002-7304-6814

INTEGRATED MANAGEMENT FRAMEWORK FOR CIRCULAR BIOECONOMY IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Abstract. The article substantiates an integrated management framework for circular bioeconomy development in the context of sustainable development. The study is based on the understanding of the circular bioeconomy as a multidimensional system that combines economic, environmental, technological, and social components and requires coordinated management at different governance levels. The purpose of the research is to develop a methodological architecture for stimulating circular bioeconomy development through the integration of institutional, financial, economic, and market instruments. The proposed framework combines international, national, regional, sectoral, and behavioral levels of management and includes the stages of engagement, support, stimulation, scaling, and monitoring. Particular attention is paid to the role of stimulation as a strategic bridge between political priorities and the practical implementation of bioeconomy initiatives. The study identifies key instruments for sustainable bioeconomic growth, including certification systems, green bonds, environmental taxation, circular investment funds, green public procurement, logistics hubs, reverse logistics mechanisms, and digital tools for environmental awareness. The findings indicate that the coordinated application of management instruments creates conditions for reducing technological and investment barriers, strengthening intersectoral cooperation, and promoting responsible consumption models. The proposed framework may contribute to the formation of an integrated system of sustainable management aimed at accelerating the transition to a circular bioeconomy in Ukraine.

Keywords: circular bioeconomy, sustainable development, management framework, stimulation instruments, sustainable management, green transformation.

ІНТЕГРОВАНА УПРАВЛІНСЬКА АРХІТЕКТУРА ЦИРКУЛЯРНОЇ БІОЕКОНОМІКИ В КОНТЕКСТІ СТАЛОГО РОЗВИТКУ

Анотація. У статті обґрунтовано інтегровану управлінську архітектуру розвитку циркулярної біоекономіки в контексті сталого розвитку. Визначено, що циркулярна біоекономіка є багатовимірною системою, яка поєднує економічні, екологічні, технологічні та соціальні складові



й потребує скоординованого управління на різних рівнях. Актуальність дослідження зумовлена необхідністю формування ефективних механізмів переходу до ресурсоефективної та низьковуглецевої моделі господарювання в умовах глобальних екологічних викликів, посилення кліматичних ризиків, технологічних трансформацій та реалізації стратегічних орієнтирів сталого розвитку. Метою дослідження є розроблення інтегрованої управлінської архітектури стимулювання розвитку циркулярної біоекономіки на основі поєднання інституційних, фінансових, економічних та ринкових інструментів впливу. У процесі дослідження використано системний підхід, методи структурно-функціонального аналізу, логічного узагальнення та багаторівневого моделювання управлінських взаємозв'язків. Запропонована архітектура охоплює міжнародний, національний, регіональний, галузевий та поведінковий рівні управління й включає етапи залучення, підтримки, стимулювання, масштабування та моніторингу. Встановлено, що ключову роль у процесі розвитку циркулярної біоекономіки відіграє система стимулювання, яка забезпечує трансформацію стратегічних цілей у практичні механізми реалізації біоекономічних ініціатив. Дослідженням визначено основні інструменти стимулювання розвитку циркулярної біоекономіки, серед яких системи сертифікації та біомаркування, зелені облігації, екологічне оподаткування, програми зелених закупівель, галузеві фонди підтримки циркулярних технологій, логістичні хаби для біоресурсів, механізми реверсної логістики та цифрові інструменти екопросвітництва. Обґрунтовано, що узгоджене використання управлінських інструментів сприятиме посиленню міжсекторальної взаємодії, активізації інвестиційної діяльності, формуванню моделей відповідального споживання та зниженню технологічних і фінансових бар'єрів розвитку. Практичне значення результатів дослідження полягає у можливості використання запропонованої управлінської архітектури при формуванні державної політики, регіональних програм та стратегій стимулювання циркулярної біоекономіки в Україні.

Ключові слова: циркулярна біоекономіка, сталий розвиток, управлінська структура, інструменти стимулювання, стале управління, зелена трансформація.

Formulation of the problem. Current global challenges related to the depletion of natural resources, intensifying climate change, increasing waste generation, and the need to ensure environmental security highlight the necessity of transitioning to new economic models based on the principles of sustainable development. In this context, the circular bioeconomy becomes particularly important, as it combines the use of renewable biological resources with resource reuse mechanisms, creating the preconditions for environmentally oriented economic growth.

For Ukraine, the development of the circular bioeconomy has strategic socio-economic importance, especially under wartime challenges, energy instability, and the need to adapt to European sustainable development standards. At the same time, the practical implementation of circular bioeconomy models is constrained by insufficient coordination between governance levels and the absence of a comprehensive stimulation system for circular bioeconomy development.

The complexity of the problem is reinforced by the fact that circular bioeconomy development simultaneously encompasses economic, environmental, technological, and behavioral dimensions, which require systematic coordination of state regulation instruments, financial support, market incentives, and institutional provision. Under such conditions, the formation of an integrated governance architecture capable of ensuring coordination among international, national, regional, sectoral, and behavioral governance levels becomes especially relevant.

Addressing this problem is directly related to the implementation of sustainable development goals, the European Green Deal, the EU Circular Economy Action Plan, and the EU Bioeconomy Strategy, as well as to the formation of an effective governance system for Ukraine's green economic transformation. The practical significance of the study lies in the need to develop effective governance mechanisms and stimulation instruments capable of promoting intersectoral interaction and shaping responsible consumption models.

Analysis of recent research and publications. Theoretical and applied aspects of circular bioeconomy development are increasingly explored in the works of foreign and Ukrainian scholars in the context of sustainable development, green economic transformation, and the formation of resource-efficient economic models. The conceptual foundations of the bioeconomy are presented in the studies of M. Bugge, T. Hansen, and A. Klitkou, who consider the bioeconomy as an interdisciplinary system combining innovation-driven development and the efficient use of biological resources [1]. A significant contribution to the modern understanding of the circular economy was made by W. McDonough and M. Braungart, who substantiated the need to shift from a linear production model to circular systems based on resource reuse and waste minimization [2]. An important role in the development of the circular economy concept also belongs to the Ellen MacArthur Foundation, which shaped the modern vision of circular economic development [3].

The integration of the circular economy and bioeconomy is examined in the works of S. D'Amato, N. Droste, B. Allen, and other researchers, who emphasize the importance of combining bio-based and circular approaches to achieve sustainable development goals [4]. Considerable attention in modern studies is also paid to governance aspects of circular transformation. In particular, J. Korhonen, A. Honkasalo, and J. Seppälä analyze the implementation of the circular economy concept within public governance and environmental policy systems [5]. The studies of A. Leipold and P. Petit-Boix focus on the importance of intersectoral coordination, institutional support, and multi-level governance in circular bioeconomy [6].

A separate area of research is devoted to financial and economic instruments for stimulating green transformation. Scientific studies address issues related to green finance, green bond markets, environmental taxation, carbon regulation mechanisms, and state support for bio-based innovations [7; 8]. At the same time, contemporary research increasingly emphasizes the need to move from the application of isolated instruments toward the formation of integrated stimulation systems for circular bioeconomy development [9].

In Ukrainian scientific literature, issues of sustainable development, bioeconomy, and circular economy are explored in the works of V. Heiets, O. Borodina, I. Prokopa, T. Halushkina, L. Melnyk, I. Sotnyk, and other scholars. Their studies examine the ecologization of the economy, resource efficiency, renewable energy development, waste management, and the formation of institutional foundations for sustainable economic systems [10–12]. Separate studies are devoted to environmental management and Ukraine's integration into the European sustainable development framework [13].

Despite the significant scientific contribution in this field, the issue of forming a comprehensive governance architecture for circular bioeconomy development remains insufficiently explored. In particular, limited attention has been paid to the systematic coordination of international, national, regional, sectoral, and behavioral governance levels, as well as to the integrated combination of institutional, financial, economic, and market stimulation instruments in the implementation of sustainable development goals. This determined the choice of the research topic and the direction of the study.

The purpose of the article is to develop an integrated governance architecture for stimulating circular bioeconomy development in the context of sustainable development based on the systemic combination of institutional, financial, economic, and market instruments, as well as to substantiate coordination mechanisms among international, national, regional, sectoral, and behavioral governance levels to ensure an effective green economic transformation.

The main material presentation. Circular bioeconomy development is defined as a multifactorial and dynamic process encompassing economic, technological, environmental, and social dimensions. The complexity of maintaining its development trajectory is determined by the need for coordinated governance based on functional differentiation and the systemic alignment of governance levels ranging from international and national to regional, sectoral, and behavioral. Under conditions of global challenges and continuous technological change, the formation of an integrated methodology capable of reflecting current trends and transforming them into strategically oriented solutions becomes especially relevant.

The generalization of the research results served as the basis for developing the author's methodological targeting framework, which transforms analytical findings into specific governance mechanisms and effective bioeconomy policy instruments. The proposed framework facilitates the transition from identifying existing potential to the development and implementation of strategic guidelines for circular bioeconomy development in Ukraine (Fig. 1).

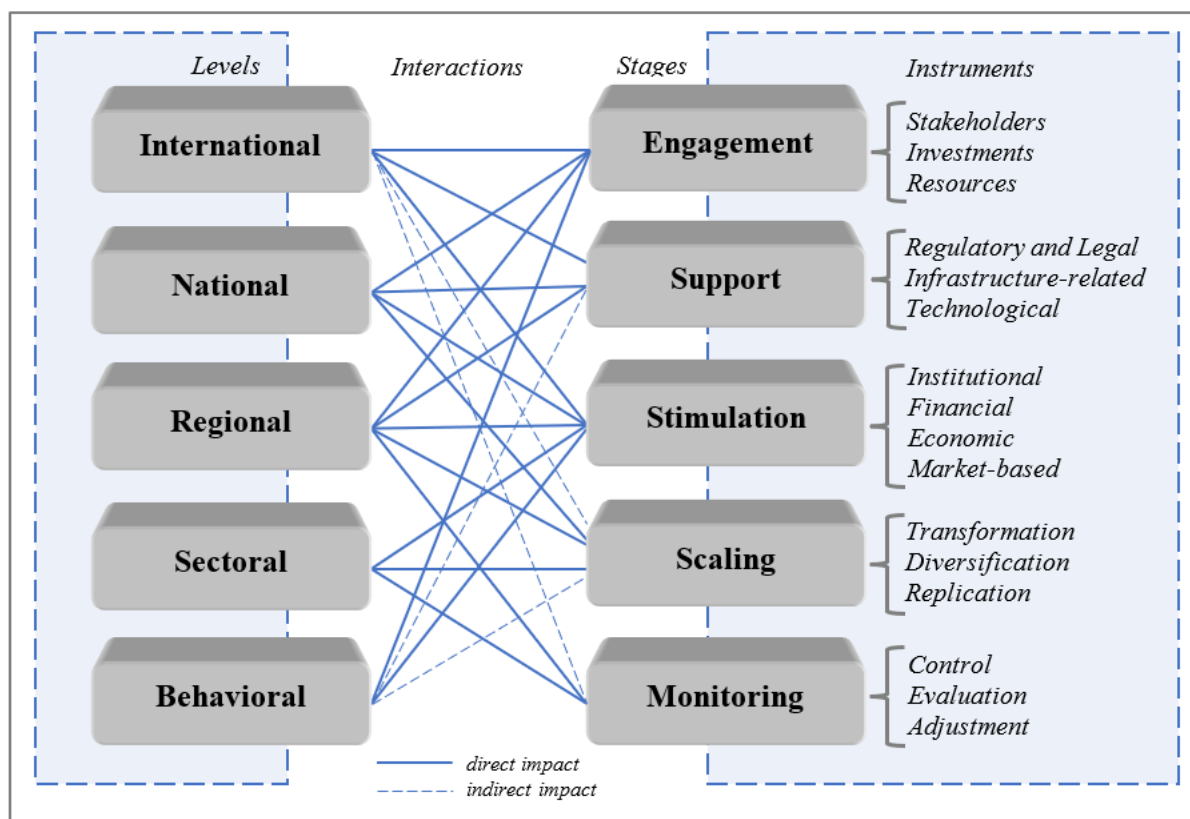


Fig. 1. Methodological framework for step-by-step targeting of circular bioeconomy development
 Source: developed by the authors

The proposed framework reflects the multidimensional nature of impacts generated across different governance levels. The differentiation between direct and indirect impacts makes it possible to assess the effectiveness of strategic interventions, reflecting the complexity of systemic interactions in which both immediate and multiplier effects emerge. The analysis of the model indicates that each functional stage represents an integral component of the overall circular bioeconomy development process.

At the “engagement” stage, the necessary resources are accumulated and stakeholders (government, business, research institutions, and civil society) are consolidated. The “support” stage is characterized by the formation of a favorable regulatory, infrastructural, and scientific-technological environment that creates the basic conditions for implementing bioeconomy initiatives. At the “scaling” stage, the key objective is to transform pilot projects into systematically reproducible practices through the dissemination of their results. The final “monitoring” stage provides feedback, performance control, and the possibility of adjusting policy and governance instruments.

The identification of interconnections between governance levels and functional stages of circular bioeconomy development makes it possible to distinguish “stimulation” as the key element of the model. Its exceptional significance is determined by the direct influence of all governance levels, demonstrating the universality of this systemic lever. In addition, the “stimulation” stage performs a catalytic function by transforming the created preconditions (“support”) and accumulated resources (“engagement”) into the active involvement of economic actors, directly influencing business motivation and changes in consumer behavior patterns.

The absence of appropriate economic, financial, market, or institutional incentives, even in the presence of infrastructure and a regulatory framework, significantly slows the transition to a circular bioeconomy. Thus, the system of incentives supports the transformation of potential opportunities into real investments and practical bioeconomy solutions. At the “stimulation” stage, a strategic bridging function is implemented between policy objectives defined at higher governance levels and the practical implementation of initiatives. This ensures the transition from generalized strategic priorities to specific mechanisms that stimulate business innovation activity and promote responsible consumption models.

Therefore, in the process of effective targeting of circular bioeconomy development, particular attention should be paid to the design and implementation of stimulation instruments, taking into account the specific

features of each governance level (Fig. 2).

Levels	Methods for Stimulating Development			
	<i>Institutional</i>	<i>Financial</i>	<i>Economic</i>	<i>Market-based</i>
International	Harmonization of regulatory standards in the biosector	International harmonization of the green bond market	Reduction of customs rates on biomaterials and bioequipment	Participation in carbon credit trading platforms
National	Formation of a certification system and bio-labeling	Tax incentives (VAT and income tax) for bioenterprises	Improvement of environmental taxation system	Creation of a national biomass market with spot contracts
Regional	Development of regional cluster infrastructure	Targeted financing of regional eco-infrastructure projects	“Green” public procurement programs for state institutions	Regional logistics hubs for bioresources
Sectoral	Sectoral innovation platforms for bioinnovation	Sectoral reinvestment funds in biotechnology cycles	Sectoral energy and eco-efficiency benchmarking programs	Sectoral support funds for reverse logistics
Behavioral	Digital tools for eco-awareness and consumer stimulation	Green cashback systems to encourage responsible consumption	Differentiated waste disposal tariffs depending on sorting	Consumer cooperatives for direct procurement of bioproducts

Fig. 2. Multi-level architecture of stimulation instruments for circular bioeconomy development by methods of influence

Source: developed by the authors

The multidimensional architecture for stimulating circular bioeconomy development in Ukraine is formed through the combination of four methodological approaches to stimulation, whose interaction facilitates vertical coordination from the international to the behavioral level. Each of these approaches performs a specific function in creating the preconditions for sustainable bioeconomic growth.

Institutional approaches provide the regulatory and organizational framework of the system, creating the basis for the effective implementation of environmental and innovation policies at all governance levels. At the international level, the priority task is the harmonization of regulatory requirements and standards in the bioeconomy sector in accordance with the provisions of the European Union and the Organisation for Economic Co-operation and Development (OECD). This can facilitate the unification of bio-based product requirements, increased transparency of market rules, and the integration of national producers into global value chains. At the national level, a key instrument is the development and implementation of certification and bio-labeling systems, which may increase consumer trust in bio-based products, provide competitive advantages for national producers, and simplify access to international markets. At the regional level, the formation of cluster infrastructure becomes particularly relevant, involving the integration of research institutions, manufacturing enterprises, potential investors, and public authorities. Such integration strengthens synergy in production localization through the territorial concentration of resources and the enhancement of bioeconomy-related competencies.

At the sectoral level, an important role is played by the creation of innovation platforms aimed at supporting technology transfer, developing intersectoral partnerships, and commercializing research results,

thereby accelerating the practical implementation of biotechnological innovations. The behavioral level includes instruments aimed at transforming consumer culture and increasing environmental awareness through the introduction of digital tools for environmental education and the promotion of sustainable consumption.

Financial stimulation methods serve as instruments of direct state support that make it possible to compensate for market risks and intensify investment attraction into bio-based technologies. At the international level, the harmonization of the green bond market with international standards is advisable, as it will create the preconditions for attracting long-term capital to circular bioeconomy projects. At the national level, an effective instrument is the introduction of fiscal incentives, particularly tax benefits (reduced VAT or corporate income tax rates) for economic entities implementing bio-based innovative solutions, including recycling, renewable energy, and biomaterial production.

The regional dimension involves targeted financing of environmental infrastructure within state and international programs aimed at developing bio-CHP plants, organic waste processing facilities, and related infrastructure. Within sectoral policy, it is advisable to establish specialized investment funds focused on supporting circular technologies, modernizing production capacities, and fostering intersectoral synergies. At the behavioral level, promising measures include the introduction of financial incentive mechanisms such as green cashback for environmentally responsible behavior (waste sorting, participation in reuse programs, etc.), which may encourage public involvement in the implementation of circular economy principles.

Economic stimulation methods are aimed at indirect influence through taxation systems, tariff regulation, and subsidies designed to change the economic motivation of market participants. At the international level, reducing customs duties on biological raw materials, biocomponents, and technological equipment is considered necessary, as this will accelerate technological modernization and reduce the costs of implementing circular models. National policy involves adapting the principles of environmental taxation, particularly through the implementation of the “polluter pays” and “environmental restoration” concepts, which enable the internal reorientation of business models toward environmental responsibility.

At the regional level, the expansion of green procurement programs aimed at generating demand among public institutions for locally produced bio-based products is of particular importance. Within the sectoral dimension, effective instruments include benchmarking programs for energy efficiency and resource conservation, which can enhance enterprise competitiveness.

Differentiated waste disposal tariffs based on the principle of “the more you sort, the less you pay” can provide economic incentives for consumers to participate in separate waste collection and promote sustainable behavioral models. Market-based stimulation methods are focused on creating a favorable market environment for the circulation of bio-based products, promoting secondary raw material markets, and implementing digital tools to support circular business models. At the international level, strengthening Ukraine’s participation in carbon credit trading systems is a priority, as this will facilitate the introduction of greenhouse gas compensation mechanisms through support for bioenergy initiatives and the monetization of ecosystem services.

At the national level, the creation of a biomass market with standardized contracts is envisaged, which may reduce investment risks and improve revenue predictability. Regional policy should focus on the development of logistics hubs for biological raw materials, enabling lower transportation costs under conditions of territorially dispersed bio-based production. At the sectoral level, the implementation of reverse logistics support mechanisms is important, as they facilitate the return of used materials into the production cycle through repair, reuse, or recycling. The behavioral dimension involves the development of consumer cooperatives aimed at providing direct access to bioresources, minimizing intermediary chains, and increasing trust in locally sourced products. The coordinated application of stimulation instruments for circular bioeconomy development through the main methods of influence may contribute to the comprehensive transformation of the economic system, ranging from institutional changes to the motivational drivers of consumer behavior.

The practical applicability of the proposed governance architecture can be illustrated through the example of bioenergy and organic waste processing systems in Ukraine. At the national level, stimulation mechanisms may include tax incentives for bioenergy enterprises and environmental taxation reform. At the regional level, targeted financing of bioresource logistics hubs and waste processing infrastructure may support local circular initiatives. Sectoral support instruments may involve benchmarking programs for energy efficiency and the creation of reverse logistics systems for agricultural residues. At the behavioral level, digital eco-awareness tools and differentiated waste tariffs may stimulate responsible consumption practices. Such coordination between governance levels demonstrates the practical applicability of the proposed framework for supporting the transition toward a circular bioeconomy in Ukraine.

Conclusions. Thus, the proposed integrated governance architecture for stimulating circular bioeconomy development represents a holistic concept based on the systemic combination of institutional, financial, economic, and market instruments. Unlike fragmented approaches, the proposed architecture facilitates coordination among international, national, regional, sectoral, and behavioral governance levels, creating the

preconditions for the formation of a comprehensive stimulation system for circular bioeconomy development.

The study indicates that the stimulation system plays a key role in the transition to a circular bioeconomy, ensuring the transformation of sustainable development priorities into practical mechanisms for implementing bioeconomy initiatives. The findings suggest that the coordinated application of governance instruments will minimize the main development barriers, including high initial investment costs, insufficient market infrastructure maturity, technological backwardness, and low levels of intersectoral coordination. At the same time, the implementation of the proposed architecture may contribute to the intensification of innovation activity, the development of green investment, the formation of responsible consumption models, and the strengthening of Ukraine's integration into the European sustainable development framework.

The study is primarily conceptual in nature and therefore requires further empirical validation through sectoral, regional, and case-based studies. Further research should focus on the development of methodological approaches for assessing the effectiveness of stimulation instruments for circular bioeconomy development, as well as on modeling scenarios for circular bioeconomy development at the national and regional levels, taking into account the challenges of Ukraine's post-war recovery. The implementation of the proposed governance architecture is expected to contribute to the formation of a systemic foundation for Ukraine's transition toward a resource-efficient, innovation-oriented, and climate-neutral model of national economic development.

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