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РЕГІОНАЛЬНА ПОЛІТИКА
REGIONAL POLICY

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РЕГІОНАЛЬНИЙ ВИМІР СТАЛОГО РОЗВИТКУ: ОЦІНКА ЕКОЛОГІЧНОЇ СКЛАДОВОЇ ЗАБЕЗПЕЧЕННЯ НА ПРИКЛАДІ ІВАНО-ФРАНКІВСЬКОЇ ОБЛАСТІ

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Анотація. У статті досліджено регіональний вимір сталого розвитку крізь призму оцінювання екологічної складової забезпечення на прикладі Івано-Франківської області. Обґрунтовано, що екологічна складова сталого розвитку регіону не може розглядатися автономно, оскільки вона безпосередньо пов'язана з економічною структурою території, якістю життя населення, інноваційною активністю, енергетичною безпекою, інвестиційною

спроможністю та ефективністю регіонального управління. Метою дослідження є оцінювання ключових тенденцій екологічного розвитку Івано-Франківської області та визначення напрямів її екологічної модернізації у контексті переходу до моделі «зеленої» економіки.

У процесі дослідження використано системний, статистичний, порівняльний, індикаторний методи, а також контент-аналіз стратегічних документів і метод концептуального моделювання. Проаналізовано динаміку викидів забруднюючих речовин від стаціонарних джерел, показників утворення та поводження з відходами, проблем водокористування, природоохоронних витрат, капітальних інвестицій та витрат на наукові дослідження і розробки. Встановлено, що попри поступове зниження окремих показників екологічного навантаження, область зберігає значну залежність від енергетичного сектору та потребує системної модернізації природоохоронної інфраструктури. Позитивними тенденціями є зростання витрат на наукові дослідження і розробки та збільшення загальних природоохоронних витрат, однак нестабільність капітальних інвестицій обмежує довгостроковий ефект екологічної політики.

Запропоновано концептуальну модель екологічної модернізації Івано-Франківської області, що охоплює декарбонізацію, енергоефективність, розвиток циркулярної економіки, водну безпеку, збереження природного капіталу, сталий туризм, екоінновації та зелене фінансування. Доведено, що екологічна модернізація має розглядатися не лише як інструмент зменшення негативного впливу на довкілля, а як чинник формування нових джерел регіонального зростання, підвищення конкурентоспроможності та посилення стійкості громад.

Ключові слова: сталий розвиток регіону, регіональний вимір, екологічна складова, екологічна модернізація, Івано-Франківська область, зелена економіка, декарбонізація. циркулярна економіка, екоінновації.

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REGIONAL DIMENSION OF SUSTAINABLE DEVELOPMENT: ASSESSING THE ENVIRONMENTAL COMPONENT THROUGH THE CASE OF IVANO-FRANKIVSK OBLAST

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Abstract. This study examines the regional dimension of sustainable development by assessing the environmental component, using Ivano-Frankivsk Oblast as a case study. It is substantiated that the environmental dimension of regional sustainable development cannot be considered in isolation, as it is intrinsically linked to the region's economic structure, population quality of life, innovation capacity, energy security, investment potential, and the effectiveness of regional governance. The aim of the study is to evaluate key trends in the environmental development of Ivano-Frankivsk Oblast and identify priority directions for its environmental modernisation in the context of the transition to a green economy model.

The study employed a combination of systematic, statistical, comparative, and indicator-based methods, complemented by content analysis of strategic documents and conceptual modeling. The analysis focused on trends in pollutant emissions from stationary sources, waste generation and management, water resource use, environmental protection expenditures, capital investments, and research and development (R&D) expenditures. The findings indicate that, despite a gradual decline in certain indicators of environmental pressure, Ivano-Frankivsk Oblast remains significantly dependent on the energy sector and requires comprehensive modernization of its environmental protection infrastructure. Positive developments include increased expenditures on research and development and higher overall spending on environmental protection. However, fluctuations in capital investment constrain the long-term effectiveness of regional environmental policy. A conceptual model for the ecological modernization of Ivano-Frankivsk Oblast is proposed, encompassing decarbonization, energy efficiency, the development of a circular economy, water security, natural capital conservation, sustainable tourism, eco-innovation, and green financing. The findings demonstrate that ecological modernization should be regarded not only as a mechanism for mitigating adverse environmental impacts but also as a strategic driver of regional economic growth, enhanced competitiveness, and greater community resilience.

Keywords: sustainable regional development, regional dimension, environmental component, ecological modernization, Ivano-Frankivsk Oblast, green economy, decarbonization, circular economy, eco-innovation.

Introduction. The contemporary concept of sustainable development, formulated within the global policy framework, acquires practical relevance through its implementation at the national and regional levels. Sustainable development is realized not in an abstract context but within specific territories characterized by diverse socioeconomic conditions, resource endowments, and institutional capacities. Consequently, the regional dimension of sustainable development is of particular significance, as it enables the consideration of territorial specificities and facilitates the effective implementation of sustainable development principles.

Substantial contributions to the theoretical foundations of regional sustainable development have been made by Ukrainian scholars, including L. Melnyk, B. Danylyshyn, M. Dolishniy, V. Heyets, V. Kostytskyi and others [2, 5, 8, 12]. Their research highlights the importance of spatial differentiation in socioeconomic development, the strategic role of regional state policy, and the necessity of structural economic transformation. Collectively, these studies provide a conceptual basis for adapting the global sustainable development paradigm to the national and regional context. In the scientific literature, the regional dimension of sustainable development is commonly conceptualised as a process of achieving balanced territorial development by integrating economic, social, and environmental

objectives [1, 6, 7, 13]. Within this framework, a region is understood not merely as an administrative-territorial unit but as a complex socio-economic system characterized by its own institutional structure, resource base, economic potential, and development mechanisms [10, 14].

Previous studies further argue that a region should be regarded as a relatively integrated territorial system distinguished by its economic structure, resource endowment, demographic characteristics, and context-specific development conditions [16, 18]. This perspective extends beyond the conventional administrative interpretation of a region, conceptualising it as an open socio-economic system that continuously interacts with its external environment and adapts to both internal and external challenges. Such an approach is particularly relevant to sustainable development research, as it enables analysis not only of territorial boundaries but also of the functional interrelationships and systemic interactions that shape regional development trajectories.

According to the authors of [11], sustainable regional development is achieved through several interrelated conditions, including the balanced integration of economic, social, and environmental dimensions, the coordinated efforts of all stakeholders within the regional community, and the strengthening of the state's role in promoting sustainable development. The study further identifies key determinants of regional sustainability, including social development, the modernisation of the regional economic structure through innovation, improved resource efficiency, the development of foreign economic and interregional cooperation, and the mitigation of adverse environmental impacts associated with economic activity.

The implementation of the sustainable development concept at the regional level is influenced by a complex set of interrelated factors that shape the conditions and capacities for achieving balanced territorial development. These determinants are multidimensional in nature, encompassing economic, social, environmental, and institutional dimensions. Under contemporary conditions, however, environmental determinants have become increasingly significant due to their growing influence on regional development processes. As demonstrated in previous studies [9], the nature and intensity of these environmental factors vary considerably across regions, thereby underscoring the need for their systematic assessment within the regional context.

Task Statement. In the contemporary context, sustainable regional development has evolved from a declarative principle of socioeconomic policy into a practical framework for ensuring territorial resilience, environmental sustainability, and regional competitiveness. This issue is particularly relevant for regions whose development depends on the interplay between industrial and energy capacities, natural and recreational resources, infrastructure quality, investment potential, and the ability of local communities and institutions to adapt to contemporary security, climate, and European integration challenges.

The Ivano-Frankivsk Oblast exemplifies such a region, as it combines substantial natural and tourism-recreational potential with a range of environmental challenges. These include emissions from stationary pollution sources, waste generation and management, the quality of water resources, the condition of wastewater treatment infrastructure, and the instability of long-term environmental investment. Under these circumstances, the environmental dimension of sustainable development cannot be examined independently of its economic, social, innovation, and institutional dimensions. Rather, the interactions among these components determine the region’s capacity to achieve a transition toward a green economy and a sustainable regional development model.

The research problem arises from the need to develop further methodological approaches to assessing the environmental dimension of sustainable development at the regional level and to substantiate priority directions for environmental modernization that not

only reduce anthropogenic pressure on ecosystems but also promote economic transformation, improve quality of life, stimulate eco-innovation, and strengthen the institutional capacity of local communities. Despite the growing body of research on regional sustainability, insufficient attention has been paid to translating emerging environmental development trends into evidence-based policy instruments that support sustainable regional development.

Against this background, the Ivano-Frankivsk Oblast provides an appropriate case for examining the environmental dimension of sustainable development as an integral component of comprehensive regional transformation. Such a transformation encompasses the transition toward decarbonization, the implementation of circular economy principles, the enhancement of water security, the conservation of natural capital, the promotion of sustainable tourism, the expansion of green financing, and the diffusion of eco-innovations. The purpose of this study is to assess the environmental dimension of sustainable development in the Ivano-Frankivsk Oblast and to identify priority directions for its environmental modernization in the context of contemporary regional development trends.

The study is grounded in a systems approach, which conceptualises the environmental dimension of regional sustainable development as an integral component of an open socio-economic system that interacts with economic, social, innovation, and institutional subsystems. This methodological perspective enables the analysis of environmental performance within a broader regional development framework, rather than as an isolated set of indicators, thereby linking environmental outcomes to the strategic objectives of regional competitiveness, quality of life, energy security, and post-war recovery.

The study employed a combination of complementary research methods. Analysis and synthesis were used to systematize theoretical approaches to sustainable regional development and to clarify the role of the environmental dimension within its conceptual framework. Statistical analysis was applied to evaluate trends in pollutant emissions, waste generation, recycling, incineration, disposal, and environmental protection expenditures. The comparative method was employed to examine regional environmental indicators against national trends and to assess the region’s contribution to key environmental processes.

An indicator-based approach was used to select and evaluate indicators reflecting environmental pressure, resource efficiency, environmental protection expenditures, investment activity, and support for eco-innovation. Content analysis of strategic and policy documents was conducted to assess the consistency of regional environmental priorities with the United Nations Sustainable Development Goals and the Ivano-Frankivsk Region Development Strategy for 2021–2027. In addition, the methods of logical generalisation and conceptual modelling were applied to develop a framework for the region's environmental modernisation and to identify practical mechanisms for its implementation. Finally, data visualization methods were employed to present and interpret the results of the environmental assessment. The empirical foundation of this study is based on official statistical data obtained from the State Statistics Service of Ukraine [4] and the Main Statistics Department of Ivano-Frankivsk Oblast [3], as well as the provisions of the Ivano-Frankivsk Oblast Development Strategy for 2021–2027 [15], international strategic documents on sustainable development [17, 19], and relevant scientific publications by Ukrainian and international scholars.

The scientific novelty of this study lies in the development of an integrated approach to assessing the environmental dimension of sustainable regional development by combining statistical analysis of environmental pressures, the evaluation of investment and innovation support for environmental protection activities, and conceptual modeling of environmental modernization pathways. Unlike conventional approaches that primarily describe individual environmental challenges, the proposed framework conceptualises environmental modernisation as a cross-sectoral mechanism for regional green transformation that can

simultaneously enhance environmental security, strengthen economic competitiveness, improve quality of life, and foster innovation-driven regional development.

Results. In accordance with the integrated concept of sustainable development, the environmental dimension of regional development should be examined not in isolation but in conjunction with economic performance, quality of life, innovation capacity, and the effectiveness of regional governance. Such an integrated perspective provides a comprehensive understanding of the factors influencing regional sustainability and supports the formulation of balanced development policies.

The Ivano-Frankivsk Region Development Strategy for 2021–2027 identifies environmental protection as one of the fundamental priorities of regional development. In particular, Strategic Goal 4 aims to ensure the region's environmentally sustainable, safe, and green development through measures focused on improving environmental quality, strengthening energy security, expanding the use of renewable energy sources, and enhancing climate change adaptation [15]. Multiple interrelated factors, including atmospheric air pollution, water resource management challenges, waste generation and accumulation, land degradation risks, climate change, and anthropogenic hazards, influence the environmental conditions of the region. The Ivano-Frankivsk Region Development Strategy for 2021–2027 identifies climate-related risks as particularly significant for the region, including increasing average temperatures, extreme heat events, intense precipitation, and flash floods. The Strategy also recognizes ski tourism as one of the economic sectors most vulnerable to the impacts of climate change [15].

One of the principal indicators of the environmental dimension of sustainable regional development is the volume of atmospheric pollutant emissions from stationary sources. The dynamics of this indicator, as shown in Figure 1, indicate substantial fluctuations in the environmental pressure exerted on the region over the period 2015–2024. During 2015–2019, emissions remained consistently high, ranging from approximately 197,000 to 224,000 metric tons, reflecting the dominant contribution of industrial and energy-producing activities to the regional economy. The highest level of emissions was recorded in 2015, reaching approximately 224,000 metric tons.

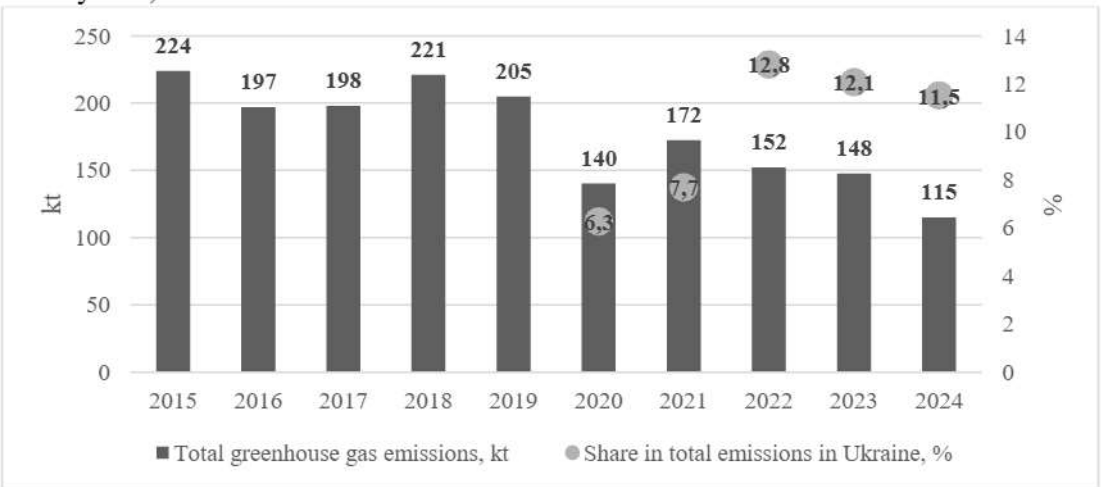


Fig. 1. Trends in atmospheric pollutant emissions from stationary sources in the Ivano-Frankivsk Oblast, 2015–2024

Source: Compiled by the authors based on [3, 4].

Since 2020, atmospheric pollutant emissions from stationary sources have exhibited a sustained downward trend. In 2020, emissions declined by 31.5% to 140.4 thousand metric tons, primarily reflecting the contraction of economic activity associated with the COVID-19 pandemic. Although emissions increased by 22.8% in 2021, reaching 172.4 thousand metric

tons, they subsequently resumed their downward trajectory, declining to 115.1 thousand metric tons in 2024. This represents a 48.6% reduction compared with the 2015 level and the lowest annual volume recorded during the study period.

At the same time, an analysis of the Ivano-Frankivsk Oblast's contribution to total atmospheric pollutant emissions in Ukraine indicates that the region continues to exert a relatively significant environmental impact at the national level. The region's share of total emissions increased from 6.3% in 2020 to 12.8% in 2022 and remained comparatively high at 11.5% in 2024. This pattern suggests that, despite the overall decline in emissions volumes, the region remains one of the principal industrial and energy-producing areas of western Ukraine, reflecting the substantial contribution of its energy-intensive industrial facilities to national emissions.

The observed decline in atmospheric pollutant emissions can be interpreted from two complementary perspectives. On the one hand, it represents a positive trend in terms of environmental sustainability and progress toward achieving the environmental objectives of the United Nations Sustainable Development Goals. On the other hand, a reduction in emissions does not necessarily indicate the successful environmental modernization of production processes. It may also reflect reduced industrial output, structural changes in the energy sector, and the adverse effects of military-related disruptions on economic activity.

The electricity, gas, steam, and air conditioning supply sector remains the dominant source of atmospheric emissions, accounting for 89.2% of total emissions in the Ivano-Frankivsk Oblast. Until 2024, the Burshtyn Thermal Power Plant was the region’s largest single source of air pollution. The manufacturing industry contributes 3.6% of total emissions, followed by the extractive industry (3.2%), the transportation sector (2.2%), and agriculture (1.6%) [15].

An important dimension of the region’s environmental sustainability is the effectiveness of its waste management system, as the levels of waste generation, recovery, and disposal directly influence environmental quality, public health and quality of life, and overall environmental safety. Accordingly, the analysis of waste management indicators provides an important basis for assessing the region's environmental performance and the effectiveness of its transition toward sustainable resource management. The dynamics of the main waste management indicators are presented in Table 1.

Table 1

Dynamics of Waste Generation and Management Indicators in the Ivano-Frankivsk Oblast, 2015–2024

Years	Amount of waste generated	Recycled Waste	Waste Incinerated	Waste Disposed of in Landfills	Waste Recycling Rate, %
2015	2124,8	575,4	147,5	1126,7	27,1
2016	1935,4	681,8	114,1	774,7	35,2
2017	1948,8	651,6	114,8	887,0	33,4
2018	1969,8	553	122,3	1005,5	28,1
2019	2991,7	870,2	130,9	1759,6	29,1
2020	1729,8	525,3	50,0	1164,2	30,4
2021	790,5	499,0	49,3	253,2	63,1
2022	650,0	453,0	45,8	146,5	69,7
2023	729,2	512,0	58,4	168,6	70,2
2024	668,5	706,3	171	202,5	105,7

Source: Compiled by the authors based on [3] and calculated by the authors.

The analysis of statistical data indicates that, over the period 2015–2024, the Ivano-Frankivsk Oblast exhibited an overall downward trend in waste generation. The total volume of waste generated declined from 2,124.8 thousand metric tons in 2015 to 668.5 thousand metric tons in 2024, representing a reduction of approximately 3.2 times. The highest level of waste generation was recorded in 2019, at 2,991.7 thousand metric tons. This decline may be attributed to several interrelated factors, including reduced industrial activity, structural changes in the regional economy, the gradual adoption of resource-efficient technologies, and the implementation of circular economy principles. Nevertheless, the observed reduction in waste generation should be interpreted with caution, as it may reflect not only improvements in environmental performance but also changes in the scale and structure of economic activity.

A notable positive trend is the continuous increase in waste recovery throughout the study period. The volume of recovered waste rose from 575.4 thousand metric tons in 2015 to 706.3 thousand metric tons in 2024, representing an increase of 22.7%. Correspondingly, the waste recovery rate increased substantially, from 27.1% in 2015 to 70.2% in 2023. The results for 2024 are particularly significant, as the volume of recovered waste exceeded the volume of waste generated, resulting in a waste recovery rate of 105.7%. This finding indicates that, in addition to newly generated waste, accumulated waste from previous years was recovered and returned to productive use through recycling and other recovery operations. Such a trend reflects the increasing effectiveness of the regional waste management system and demonstrates progress toward implementing the circular economy principle. At the same time, the analysis indicates that a substantial proportion of waste continues to be disposed of in landfills. Although the volume of landfilled waste declined markedly from 1,126.7 thousand metric tons in 2015 to 202.5 thousand metric tons in 2024, the challenges associated with landfill overcapacity and the insufficient development of waste treatment and recycling infrastructure remain significant. These findings suggest that further improvements in waste management require continued investment in recycling capacity and the expansion of circular economy practices.

Particular attention should be paid to the dynamics of waste incineration. During 2020–2022, the volume of incinerated waste remained relatively low; however, in 2024 it increased substantially to 171 thousand metric tons. This trend may indicate the growing use of waste-to-energy technologies within the regional waste management system. Nevertheless, excessive reliance on waste incineration without advanced emission control technologies may pose additional environmental risks, particularly to air quality and pollutant emissions.

Water resource management also remains a significant environmental challenge in the Ivano-Frankivsk Oblast. The principal sources of surface water pollution include the discharge of untreated or insufficiently treated wastewater, as well as the absence of adequately established water protection zones and riparian buffer strips. According to the Ivano-Frankivsk Region Development Strategy for 2021–2027, the main contributors to surface water pollution are enterprises operating in the energy sector, manufacturing industries, and the water supply, wastewater, and waste management sectors [15]. These challenges have direct implications for the achievement of the United Nations Sustainable Development Goals, particularly Sustainable Development Goal 6 (Clean Water and Sanitation), Sustainable Development Goal 12 (Responsible Consumption and Production), Sustainable Development Goal 13 (Climate Action), and Sustainable Development Goal 15 (Life on Land). This is especially relevant for the Ivano-Frankivsk Oblast, where environmental quality is not only a natural asset but also a critical driver of regional economic development, influencing the competitiveness of tourism, recreation, and agriculture, and ultimately the quality of life for the population.

Financial, investment, and innovation support for environmental protection activities represents a key determinant of the region's capacity to achieve environmentally sustainable economic modernization, promote the adoption of eco-innovations, and advance progress toward sustainable development objectives. The dynamics of these indicators for the period 2020–2024 are presented in Table 2.

Table 2

Financial, Investment, and Innovation Support for Environmental Protection Activities in the Ivano-Frankivsk Oblast, 2020–2024

Indicator	2020	2021	2022	2023	2024
Number of Organizations Engaged in Research and Development (R&D), units	10	10	9	9	12
Research and Development (R&D) Expenditure, thousand UAH	50990	58584	39572	51165	116601
Environmental Protection Expenditure, thousand UAH	854291	875907	645561	921135	1000156
Capital Expenditure on Environmental Protection, thousand UAH	267585	875907	82432	128395	101468
Capital Investment in the Major Repair of Environmental Protection Assets, thousand UAH	155884	19241	3051	5109	13664

Source: Compiled by the authors based on [4].

The analysis indicates that, during the period 2020–2024, the Ivano-Frankivsk Oblast exhibited mixed trends in innovation and investment indicators related to environmental protection. The number of organisations conducting research and development (R&D) remained relatively stable, ranging from 9 to 10 between 2020 and 2023, then increased to 12 in 2024. This growth suggests a gradual strengthening of the region's research and innovation capacity, thereby creating more favorable conditions for the development and diffusion of eco-innovations. Despite this positive trend, the region's share of the total number of R&D organisations in Ukraine remained relatively modest, accounting for less than 2% throughout the study period, though it gradually increased. These findings indicate that, while the region's innovation potential is improving, further efforts are required to strengthen its contribution to the national research and innovation system.

A further positive trend is the substantial increase in research and development (R&D) expenditure. R&D expenditure increased from UAH 50.9 million in 2020 to UAH 116.6 million in 2024, more than twofold. This growth suggests an intensification of innovation activity and an increasing emphasis on strengthening the region's scientific and technological capacity. Despite this progress, the Ivano-Frankivsk Oblast accounted for only 0.23–0.41% of Ukraine's total R&D expenditure throughout the study period, indicating that the scale of research and innovation activity remains relatively modest compared with other regions of the country. An analysis of environmental protection expenditure indicates an overall upward trend during the study period. Total expenditure increased from UAH 854.3 million in 2020 to more than UAH 1 billion in 2024, reflecting a gradual expansion of financial support for environmental protection measures. At the same time, the Ivano-Frankivsk Oblast accounted for approximately 2.0–2.5% of Ukraine's total environmental protection expenditure throughout the period under review. This relatively stable share indicates the region's meaningful contribution to national environmental protection financing and demonstrates a sustained commitment to supporting environmental policy objectives at the regional level.

In contrast, the dynamics of capital investment in environmental protection reveal considerably greater volatility. Following a substantial increase in 2021, when capital investments exceeded UAH 875 million, investment activity declined sharply in 2022, falling to UAH 82.4 million. Although a partial recovery was observed during 2023–2024,

investment volumes remained well below the 2021 peak. A comparable pattern is evident in the region's contribution to Ukraine's total capital investment in environmental protection. After reaching more than 6% in 2021, the regional share declined to approximately 1.3–1.5% in the subsequent years.

These trends indicate the limited stability of long-term environmental investment and suggest that investment activity is highly dependent on a small number of large-scale projects. Such volatility poses a significant challenge to achieving sustainable regional development, as capital investment is a key mechanism for financing technological modernisation, upgrading wastewater treatment infrastructure, improving waste management systems, and introducing advanced, environmentally friendly technologies. Consequently, the inconsistency of investment flows may constrain the region's capacity to implement long-term environmental improvements and strengthen ecological resilience.

The trend in capital investments allocated to the major repair of environmental protection fixed assets is particularly illustrative. In 2020, expenditures on major repairs exceeded UAH 155 million, accounting for more than 9% of the national total. However, these indicators declined markedly during 2022–2023. This contraction suggests that the modernisation and rehabilitation of environmental protection infrastructure were largely deferred due to economic uncertainty and the adverse consequences of the ongoing war. The postponement of major repair activities may have accelerated the deterioration of existing environmental infrastructure, thereby reducing its operational efficiency and limiting the region's capacity to address environmental challenges effectively. Such developments highlight the vulnerability of long-term environmental infrastructure investments to external economic and geopolitical shocks.

Thus, the Ivano-Frankivsk region demonstrates potential for developing eco-innovations and the ecological modernisation of its economy. Positive trends include increasing research expenditures, a growing number of research organizations, and rising overall environmental protection expenditures. At the same time, the effectiveness of environmental protection measures is constrained by the instability of capital investments in environmental protection, insufficient financing of long-term environmental projects, and the region's relatively small share of Ukraine's total innovation expenditures. These findings underscore the need to strengthen regional policies that support eco-innovation, promote the development of a green economy, and ensure a stable system of environmental investment as a fundamental prerequisite for sustainable regional development.

In summary, the environmental situation in the Ivano-Frankivsk region is characterized by a gradual decline in pollutant emissions. Nevertheless, the region continues to account for a substantial share of Ukraine's total emissions, underscoring the need for further environmental modernization of the economy, the adoption of energy-efficient technologies, and the strengthening of environmental protection policies to support sustainable regional development.

In this context, environmental modernisation should be understood not merely as a set of environmental protection measures but as a comprehensive transformation of the regional development model, involving a transition from a predominantly resource-intensive, technologically outdated economy to a green economy that integrates economic efficiency, environmental sustainability, innovation, and social responsibility. This approach is consistent with Strategic Objective 4 of the Ivano-Frankivsk Oblast Development Strategy for 2021–2027, which identifies a range of priorities directly related to ecological modernization, including strengthening regional sustainability in the economic, energy, environmental, and other sectors; preventing floods and other natural hazards; improving the environmental condition of the Kalush Mining and Industrial District; decarbonizing economic and industrial

activities; conserving and expanding the nature reserve network; and modernizing environmental monitoring systems in accordance with European standards [15].

Based on the findings of the study, a conceptual model for the ecological modernization of the Ivano-Frankivsk region is proposed, comprising the following interrelated components (Fig. 2): decarbonization and energy efficiency; modernization of the waste management system; ensuring water security; conservation of natural capital and the development of sustainable tourism; and the promotion of eco-innovation and green financing.

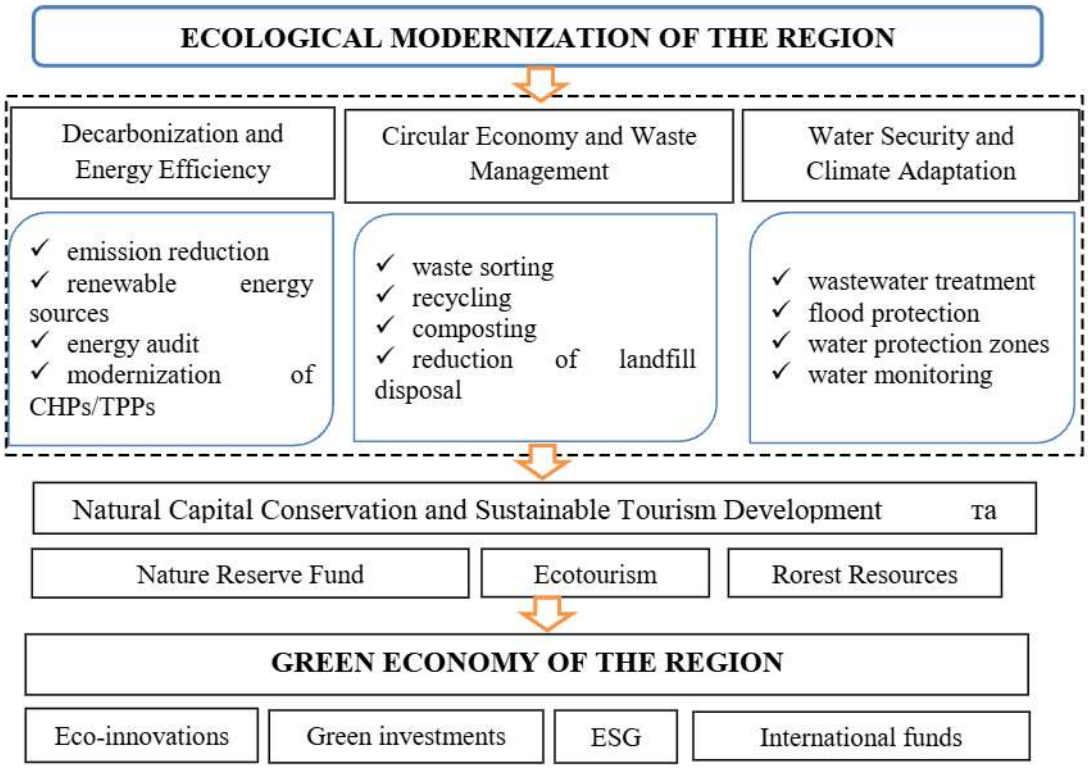


Fig. 2. Conceptual Model for the Ecological Modernization of the Ivano-Frankivsk Region

Source: developed by the authors

The proposed model demonstrates that the ecological modernization of the region should be directed not only toward reducing environmental impacts but also toward generating new drivers of economic growth. In this context, the green economy should be regarded not as a constraint on regional development but as a framework for its qualitative transformation through enhanced energy efficiency, resource conservation, the expansion of green entrepreneurship, the development of sustainable tourism, the promotion of eco-innovation, and the adoption of sustainable natural resource management practices.

A key priority of ecological modernization is the decarbonization of the energy sector and industry. Given that the majority of pollutant emissions in the Ivano-Frankivsk region originate from energy-related activities, priority should be given to measures to improve energy efficiency and reduce the carbon intensity of production. The decarbonization of the regional economy should encompass the modernization of energy infrastructure, the expansion of renewable energy sources, the thermal modernization of public buildings and residential housing, the implementation of energy management systems at the community level, and the promotion of resource-efficient technologies in industrial enterprises. Importantly, decarbonization should extend beyond technological modernization and be

systematically integrated into the region's industrial, investment, and spatial development policies.

The regional development strategy establishes targets to increase the installed capacity of renewable energy facilities to 610 MW by 2027 and to raise the share of electricity generated from renewable energy sources to 17%, thereby providing important benchmarks for regional policies aimed at enhancing energy self-sufficiency and reducing dependence on conventional energy sources [15].

The second priority is the development of a circular economy and the modernization of the waste management system. Particular attention should be given to addressing persistent challenges, including the continued reliance on landfilling, insufficient waste sorting, and the uneven distribution of recycling infrastructure. In this context, a transition from the traditional "generation–collection–landfill" model to a "prevention–reuse–sorting–recycling–energy recovery–minimal landfill" model is required. Key implementation instruments include establishing intermunicipal waste management centres, expanding separate waste collection systems, introducing organic waste composting, supporting recycling enterprises, and promoting environmental awareness among the population.

The regional development strategy establishes targets to increase the number of household and organic waste treatment facilities to seven, expand municipal solid waste collection coverage to 90.2% of settlements, and increase the share of local communities implementing separate household waste collection to 30% [15].

The third priority is to ensure water security and modernise water treatment infrastructure. This area is of particular importance for the Ivano-Frankivsk region owing to its mountainous river systems, the risks of flooding and flash floods, the insufficient coverage of centralized wastewater collection systems, and deficiencies in wastewater treatment infrastructure. As discussed above, the principal challenges in the water sector include the discharge of untreated or inadequately treated wastewater, as well as the insufficient establishment of water protection zones and riparian buffer zones. Addressing these challenges requires implementing a comprehensive set of measures, including the modernisation of wastewater treatment facilities, the upgrading of sewerage networks, the construction of decentralised wastewater treatment systems in small communities, the implementation of water quality monitoring systems, and the restoration of natural floodplains and water protection areas. Particular attention should be given to flood risk reduction through riverbank stabilization, the regulation of development in flood-prone areas, forest restoration, and the implementation of nature-based solutions for water resource management. The regional development strategy also establishes objectives to mitigate the impacts of floods and high-water events, including strengthening infrastructure, riverbanks, and slopes, as well as household and industrial waste disposal sites [15].

The fourth priority area is the conservation of natural capital and the development of sustainable tourism. The Ivano-Frankivsk region possesses significant natural and recreational potential; however, this also necessitates maintaining an appropriate balance between the economic use of natural resources and their conservation. Although tourism and recreation can serve as important drivers of local development, inadequate management may increase pressure on ecosystems, water resources, transport infrastructure, and waste management systems.

In this context, the development of sustainable tourism should be guided by the principles of environmental responsibility, spatial planning, management of anthropogenic pressures, support for small local enterprises, preservation of cultural heritage, and the active involvement of local communities in tourism governance. Priority measures include developing ecotourism routes, certifying tourism facilities, supporting environmentally sustainable accommodation providers, promoting local products, and implementing

monitoring systems to assess tourism impacts on natural areas. The regional development strategy emphasizes the preservation and expansion of the nature reserve network. In particular, one of its target indicators is to increase the share of protected areas and sites within the nature reserve fund to 16.99% by 2027 [15].

The fifth priority area is the promotion of eco-innovation and green financing. The findings presented in the previous section indicate positive trends in research and development, including increased R&D expenditures and a growing number of research organizations. At the same time, the region's share of Ukraine's total R&D expenditures remains relatively low, while capital investments in environmental protection remain highly volatile. These findings highlight the need for a comprehensive policy framework to support eco-innovation by integrating scientific capacity, entrepreneurial activity, environmental priorities, and access to financial resources.

Table 3 summarizes the proposed implementation instruments for the identified priority areas and the expected effects of their application.

Table 3

Priority Directions for Ecological Modernization in the Ivano-Frankivsk Region

Direction	The key issue	Implementation Tools	Expected Effects on Sustainable Development
Decarbonization of the Energy Sector and Industry	High Level of Pollutant Emissions from the Energy Sector	Energy audits; equipment modernization; deployment of renewable energy sources (RES); implementation of energy management systems; support for energy efficiency projects	Reduction of emissions; enhanced energy security; reduced costs
Circular Economy	Underdeveloped Waste Sorting and Recycling System	Separate waste collection; composting; intermunicipal recycling centers; support for recycling enterprises	Reduced landfill disposal; increased resource recovery
Water Resources Security	Inadequate Wastewater Treatment and Flood Risks	Modernization of wastewater treatment facilities	Improved water quality; reduced environmental risks
Protection and Conservation of Natural Capital	Increasing Pressure on Forest, Mountain, and Recreational Ecosystems	Expansion of protected areas; development of ecotourism; management of tourism pressure; forest restoration	Biodiversity conservation; sustainable tourism development
Eco-Innovations	Insufficient Adoption of Innovative and Green Technologies	Grant funding; science–business partnerships; green clusters; digital environmental monitoring	Technological modernization; development of a green economy
Green Financing	Unstable Capital Investment in Environmental Protection	Public–private partnerships (PPPs); international funding programs; green loans; ESG projects; regional environmental fund	Stable financing of environmental projects

Source: compiled by the authors

Eco-innovation should be directed toward addressing specific regional challenges, including reducing energy consumption, improving wastewater treatment, expanding waste recycling, introducing digital environmental monitoring systems, greening industrial processes, advancing the bioeconomy, and producing local goods with a lower carbon footprint. To support these efforts, appropriate financing mechanisms include EU grant programs, international technical assistance, green loans, preferential financing for energy efficiency projects, public–private partnerships, and environmental, social, and governance (ESG) financing instruments.

To translate these priorities into practice, a portfolio of priority green projects should be developed and integrated into regional development programs, community recovery plans, and the public investment system. Such an approach would facilitate the transition from broadly defined environmental priorities to concrete projects with clearly identified implementing institutions, funding sources, and expected outcomes.

From a sustainable development perspective, the ecological modernisation of the Ivano-Frankivsk region should yield not only environmental benefits but also significant economic and social outcomes. In particular, the expansion of renewable energy will strengthen the energy security of local communities; the modernization of water treatment infrastructure will improve the quality of life of the population; the transition to a circular economy will create new employment opportunities in the recycling and logistics sectors; the development of sustainable tourism will increase income generation in mountain communities while preserving the natural environment; and the promotion of eco-innovation will enhance the competitiveness of regional enterprises in European markets. Thus, the ecological modernization of the Ivano-Frankivsk region should constitute a key component of its sustainable development strategy. Its implementation should be based on an integrated approach encompassing decarbonization, energy efficiency, the circular economy, water security, the conservation of natural capital, sustainable tourism, and eco-innovation. These priority areas should not be considered in isolation but rather as interconnected elements of a comprehensive green transformation framework that can simultaneously reduce environmental risks, enhance economic competitiveness, strengthen local communities, and improve quality of life. The effective implementation of the proposed measures requires stable financial support, clearly defined monitoring indicators, active business participation, strong engagement from local communities, and effective utilisation of international partnership opportunities. In the long term, the transition to a green economy has the potential to become not only a mechanism for environmental protection but also a foundation for strengthening the Ivano-Frankivsk region's competitive position in the context of European integration and post-war recovery.

Conclusions. The findings of this study confirm that the environmental dimension constitutes a key component of sustainable development in the Ivano-Frankivsk region. However, its effectiveness depends on its integration with the economic, social, innovation, and institutional dimensions of regional development. Accordingly, regional environmental policy should be directed not only toward mitigating adverse environmental impacts but also toward fostering a new model of economic growth based on resource efficiency, energy self-sufficiency, circular production and consumption systems, and the promotion of eco-innovation. The analysis of pollutant emission trends indicates a gradual decline in emission volumes in recent years. However, this trend should be interpreted with caution, as the observed reduction cannot be attributed solely to environmental modernization. It may also reflect changes in economic activity, the impacts of the ongoing war, structural transformations within the industrial sector, and reduced production activity at individual industrial enterprises. At the same time, the high concentration of emissions in the electricity,

gas, steam, and air-conditioning supply sector underscores the need to accelerate the decarbonization of the regional economy and the modernisation of energy infrastructure.

The waste management sector demonstrates positive trends, including higher recycling rates and a reduction in the volume of waste disposed of in landfills. Nevertheless, persistent challenges related to waste sorting, recycling, infrastructure disparities, and environmentally sound waste disposal underscore the need to transition from a linear to a circular waste management model. At the same time, waste recovery indicators should be interpreted with methodological caution, particularly when the volume of recovered waste exceeds the amount generated in a given year.

Financial and investment support for environmental protection remains uneven. Although increasing expenditures on environmental protection and research and development create favourable conditions for advancing eco-innovation, the instability of capital investments in environmental protection constrains the implementation of long-term modernisation initiatives. These findings highlight the need to establish a stable portfolio of green projects that integrates public funding, international technical assistance, EU grant programs, public–private partnerships, and environmental, social, and governance (ESG) financing instruments.

The proposed model for the ecological modernization of the Ivano-Frankivsk region comprises a set of interrelated priority areas, including the decarbonization of the energy sector and industry, the development of the circular economy, ensuring water security, the conservation of natural capital, the development of sustainable tourism, the promotion of eco-innovation, and green financing. Its implementation has the potential to generate not only environmental benefits but also substantial economic and social outcomes, including reduced environmental risks, enhanced energy security for local communities, job creation, support for local entrepreneurship, improved quality of life, and strengthened regional competitiveness in the context of European integration and post-war recovery.

Future research should move beyond the analysis of individual environmental components toward a comprehensive assessment of the region's sustainable development as a multidimensional system. Given that sustainable development encompasses environmental, economic, social, innovation, and institutional dimensions, an important direction for further research is to examine the interrelationships among these dimensions, assess the strength of their interactions, and identify potential synergies and trade-offs.

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