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ENVIRONMENTAL INNOVATION MANAGEMENT AS A TOOL FOR IMPROVING THE PERFORMANCE OF INDUSTRIAL ENTERPRISES

Against the backdrop of intensifying global environmental challenges, Ukraine's European integration commitments, and growing demands for corporate social responsibility, environmental innovation management is becoming increasingly strategic for industrial enterprises. This article explores the theoretical foundations and practical aspects of environmental innovation management as a tool for enhancing the operational efficiency of industrial enterprises in the context of digital transformation and the implementation of ESG principles.

The article systematizes approaches to defining the concept of 'eco-innovation' and substantiates its typology, encompassing four interrelated categories: product, process, organizational, and marketing innovations. It is demonstrated that these types of eco-innovations function most effectively in a complementary relationship, forming a cyclical model of environmentally oriented enterprise management. Based on an analysis of contemporary empirical studies, the role of ESG principles and digital transformation as key factors enhancing the innovative performance of industrial enterprises is revealed.

A four-stage system for building eco-innovation management has been developed, comprising diagnosis and audit, justification of the choice of eco-innovation types, implementation, and monitoring of results. It is demonstrated that Industry 4.0 digital technologies are not merely supporting elements but a system-forming component of the proposed system. It has been demonstrated that the eco-innovation management system generates dual value: environmental value through reduced resource intensity and improved environmental performance indicators, and economic value through increased profitability, improved ESG ratings, and expanded access to 'green' financing. The results of the study can be used by managers of industrial enterprises to formulate sustainable development strategies and develop programs for environmental modernization of production.

In summary, the value of an eco-innovation management system lies in its capacity to deliver twofold benefits: on the environmental side, through lower resource consumption and reduced ecological impact; on the economic side, through greater profitability, enhanced ESG standing, and a more robust competitive position. This dual contribution elevates environmental innovation management to a genuine strategic instrument for industrial enterprises navigating the shift toward a sustainable economic model.

Keywords: environmental innovation, eco-innovation management, industrial enterprises, ESG principles, digital transformation, environmental performance.

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МЕНЕДЖМЕНТ ЕКОЛОГІЧНИХ ІННОВАЦІЙ ЯК ІНСТРУМЕНТ ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ДІЯЛЬНОСТІ ПРОМИСЛОВИХ ПІДПРИЄМСТВ

В умовах посилення глобальних екологічних викликів, євроінтеграційних зобов'язань України та зростаючих вимог до корпоративної відповідальності бізнесу питання менеджменту екологічних інновацій набуває стратегічного значення для промислових підприємств. Стаття присвячена дослідженню теоретичних засад і практичних аспектів менеджменту екологічних інновацій як інструменту підвищення ефективності діяльності промислових підприємств в умовах цифрової трансформації та імплементації принципів ESG.

У статті систематизовано підходи до визначення поняття «еко-інновації» та обґрунтовано їх типологію, що охоплює чотири взаємопов'язані категорії: продуктивні, процесні, організаційні та маркетингові інновації. Доведено, що зазначені типи еко-інновацій функціонують найбільш ефективно у комплементарному зв'язку, утворюючи циклічну модель екологічно орієнтованого управління підприємством. На основі аналізу сучасних емпіричних досліджень розкрито роль ESG-принципів та цифрової трансформації як ключових чинників, що підсилюють інноваційну результативність промислових підприємств.

Розроблено чотириетапну систему побудови менеджменту еко-інновацій, що включає: діагностику та аудит, обґрунтування вибору типів еко-інновацій, впровадження та моніторинг результатів. Обґрунтовано, що цифрові технології Індустрії 4.0 є не допоміжним, а системоутворювальним елементом запропонованої системи. Доведено, що система менеджменту екологічних інновацій генерує подвійну цінність: екологічну – через зниження ресурсоемності та покращення екологічних показників діяльності, та економічну – через зростання прибутковості, підвищення ESG-рейтингу і розширення доступу до «зеленого» фінансування. Результати дослідження можуть бути використані керівниками промислових підприємств під час формування стратегій сталого розвитку та розроблення програм екологічної модернізації виробництва.

Підсумовуючи, цінність системи управління еко-інноваціями полягає в її здатності генерувати подвійну вигоду: з екологічної точки зору, завдяки зниженню споживання ресурсів та зменшенню впливу на навколишнє середовище; з економічної точки зору, завдяки підвищенню прибутковості, покращенню позицій ESG та більш стійкій конкурентній позиції. Цей подвійний внесок підносить управління екологічними інноваціями до статусу справжнього стратегічного інструменту для промислових підприємств, які орієнтуються на перехід до сталої економічної моделі.

Ключові слова: екологічні інновації, менеджмент еко-інновацій, промислові підприємства, ESG-принципи, цифрова трансформація, екологічна ефективність.

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STATEMENT OF THE PROBLEM

As global ecological pressures mount and supranational regulatory bodies impose increasingly stringent requirements, the question of sustainable development for industrial enterprises has moved to the forefront of both policy and business agendas. For Ukraine, whose manufacturing base has historically been characterized by excessive consumption of energy and raw materials, shifting toward an environmentally responsible economic paradigm is simultaneously an ecological necessity and a condition for preserving competitiveness amid the country's European integration trajectory and alignment with the EU's sustainability agenda. In this context, designing and deploying effective eco-innovation governance instruments is a strategic imperative for domestic industrial actors. Environmental innovation has increasingly become a measurable indicator of competitive strength among manufacturing firms.

Ghosal I., Pareek A., Khandelwal K., Yadav A. K., and Chakraborty C. [3] investigate how elements of dynamic organizational capabilities – including entrepreneurial orientation, technological innovation, and digital transformation – interact with ESG (environmental, social, and governance) principles to shape a company's environmental outcomes. The authors underscore that enterprises bear direct responsibility for preserving ecological stability, given the substantial environmental footprint of commercial activity. Mitigating this impact becomes feasible through the systematic adoption of ESG principles, which, in conjunction with technology-driven innovation, can also yield tangible economic gains.

Separate research [8] has demonstrated that the uptake of digital tools has markedly enhanced the operational capabilities of small and medium-sized enterprises across India, Brazil, and South Africa, enabling them to overcome constraints tied to geography, capital availability, and logistics. The primary catalysts for this shift have been the practical advantages offered by cloud-based platforms, e-commerce infrastructure, and digital marketing channels. Within this broader landscape, three principal forces are commonly identified as drivers of eco-innovation: market demand, technological advancement, and regulatory pressure. These factors collectively stimulate the introduction of eco-innovations in industrial enterprises and, in doing so, give rise to a distinct and increasingly essential managerial function – eco-innovation management.

The concept of "eco-innovation" entered academic discourse in the mid-1990s, attributed to K. Rennings, though it gained widespread scholarly and practical currency only in the early decades of the twenty-first century. Kemp R. and Pearson P. [8] define eco-innovation as the commercial introduction, adoption, or production of a product, process, organizational method, or marketing approach that is novel to the firm and, over its full life cycle, results in a lower environmental burden than existing alternatives.

It is worth acknowledging that the academic literature reflects considerable variation in how this concept is defined. Some scholars emphasize the procedural dimension of eco-innovation, while others prioritize outcomes and measurable benefits [8]. These definitional divergences stem partly from differing orientations: certain researchers frame eco-innovation primarily as a vehicle for gaining market advantage, whereas others treat it as an instrument for achieving environmental objectives in their own right. A complementary perspective positions eco-innovations as hardware or software advancements encompassing green products and cleaner production methods – including energy-efficient technologies, pollution prevention systems, waste recovery solutions, eco-design methodologies, and environmental management practices. From this vantage point, eco-innovations transcend mere regulatory compliance and assume strategic significance: they can generate added value, bolster corporate reputation, and secure a distinctive competitive position in the marketplace.

A critical observation is that eco-innovation management does not stand alone but forms an integral component of a wider corporate sustainability architecture. Schaltegger et al. [11] propose a layered governance model spanning the micro-level of the individual enterprise, the meso-level of the supply chain, and the macro-level of society at large. Within this framework, environmental innovation management functions as the pivotal mechanism at the firm level, facilitating the embedding of ecological objectives into overarching strategic planning. Realizing this potential, however, demands the use of integrated performance measurement systems that go beyond conventional financial metrics.

Complementing this perspective, Prokopenko et al. [10] provide empirical support for the proposition that capital directed toward green technologies and research activities yields positive effects on corporate profitability — albeit with a time lag that places these returns in the medium-to-long-term horizon. This reinforces the view that eco-

innovation management should be regarded not as an expenditure but as a forward-looking strategic investment, one that simultaneously generates ecological and economic value for industrial enterprises as they navigate the transition to sustainable development.

THE PURPOSE OF THE RESEARCH

The aim of this article is to examine the theoretical foundations and practical aspects of environmental innovation management as a tool for ensuring the sustainable development of industrial enterprises, to identify the key drivers and barriers to the implementation of eco-innovations, and to justify the role of ESG principles and digital transformation in establishing an effective system of environmentally oriented management.

PRESENTATION OF THE MAIN RESEARCH MATERIAL

The starting point of this study is the structuring of the concept of eco-innovations, as it is precisely an understanding of their typology that determines the logic behind the development of an eco-innovation management system at an industrial enterprise. At the same time, before proceeding to a typological analysis, it is advisable to verify the relevance of the research topic using real statistical data – in particular, to assess whether there is a statistically significant link in the Ukrainian industry between enterprises’ innovative activity and their environmental investment behavior.

An analysis of the dynamics of industrial enterprises’ expenditure on innovation and capital investment in environmental protection in Ukraine for the period 2015–2023 allows us to establish the nature of the relationship between innovation and environmental activity in the industrial sector. The data from the State Statistics Service of Ukraine reflect general trends in enterprises’ investment behavior across two interrelated areas (Fig. 1).

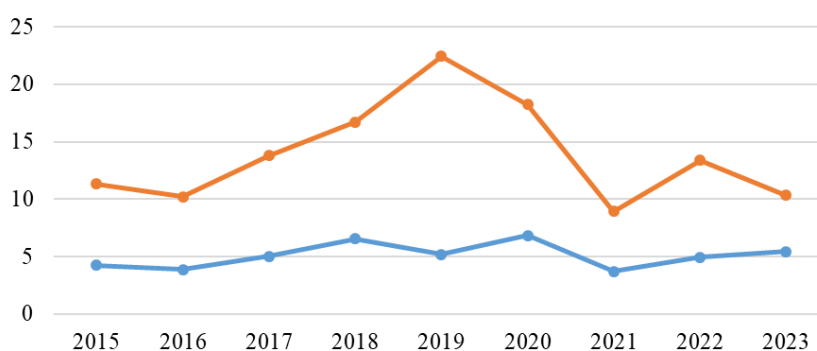


Fig. 1. Trends in innovation expenditure and capital investment in environmental protection
Source: compiled by the author based on [1]

The graph shows that both indicators follow a similar general trend – growth up to 2019–2020, followed by a sharp decline in 2021, driven by the pandemic and external instability. The synchronization of fluctuations in both series indicates a statistical link between innovation activity and environmental investments by industrial enterprises, which is confirmed by the results of the correlation analysis (Table 1). This, in turn, confirms the need for a systematic management approach that integrates environmental and innovation components into a single enterprise development strategy, which constitutes the essence of environmental innovation management.

Table 1

Results of the correlation analysis

Indicator	Innovation expenditure by industrial enterprises, UAH billion	Capital investment in environmental protection, UAH billion
Innovation expenditure by industrial enterprises, UAH billion	1	
Capital investment in environmental protection, UAH billion	0,720218496	1

Source: developed by the author

The results of the correlation analysis show that the Pearson correlation coefficient between industrial enterprises’ innovation expenditure and capital investment in environmental protection for the period 2015–2023 is $r = 0.72$, indicating a strong positive relationship between the two indicators. This may mean that an increase in industrial enterprises’ innovation activity is accompanied by a corresponding increase in environmental investments, and vice versa. The obtained value indicates that environmental innovations are not a separate area of activity, but are organically integrated into the enterprise’s overall innovation process. Thus, the statistically significant correlation between the two indicators supports treating environmental innovation management as an independent managerial function, thereby ensuring targeted coordination of an industrial enterprise’s innovation and environmental activities.

Environmental innovation is a heterogeneous phenomenon that is best considered in four main categories: product, process, organizational, and marketing (Fig. 2).

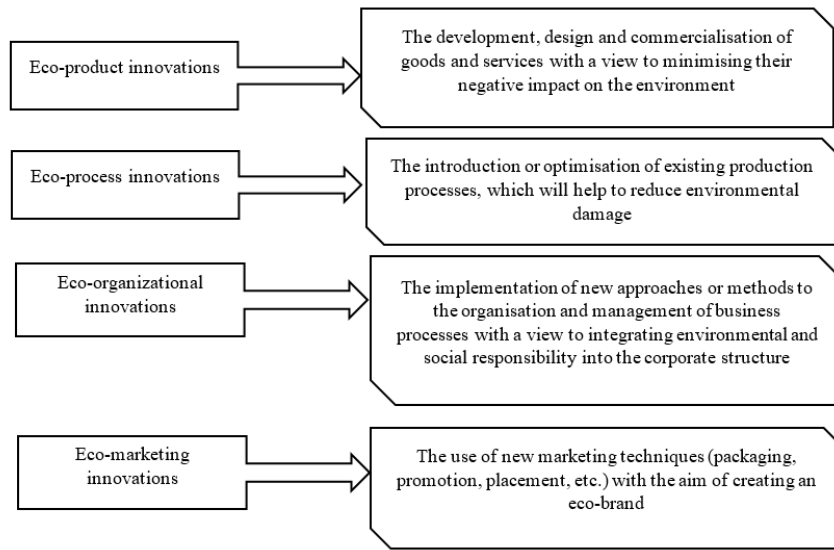


Fig. 2. Types of environmental innovations in industrial enterprises

Source: compiled by the author based on [8]

However, it should be noted that these four types of innovation are most effective when they work in tandem (Fig. 3).

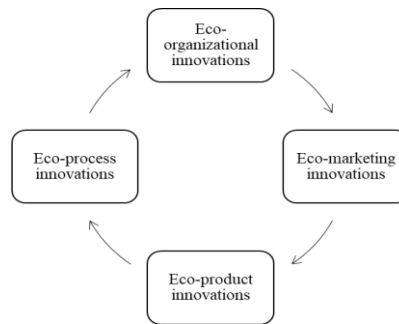


Fig. 3. The relationship between types of innovation in an industrial enterprise

Source: developed by the author

The four-component cyclical framework of eco-innovation types illustrated in the figure is well supported by contemporary empirical literature on ESG-driven corporate governance. Notably, Yang, Zhu & Albitar [15] identified a non-linear, U-shaped pattern linking ESG rating levels to firms' innovation output: only organizations that achieve elevated ESG standings exhibit meaningful acceleration in green innovation across both product development and process improvement dimensions.

Each of the four eco-innovation categories demands adequate digital enablement to function effectively. Liu et al. [6; 7] provide empirical evidence that green innovations positively affect a company's ESG outcomes, with digital transformation serving as a key mediating variable in this relationship. Consequently, eco-organizational and eco-process innovations achieve considerably greater effectiveness when managerial workflows are simultaneously digitized. Li, Y., Pertheban, T. R., Li, Q., & Guang-Wen, Z. [5] reinforce this finding by demonstrating that an entrepreneurially oriented mindset, when combined with ESG commitments and digital toolsets, produces a compounding effect that elevates environmental outcomes – most visibly in the domains of eco-marketing and eco-product development.

The technological prerequisites for operationalizing the entire cyclical model are mapped out by Hammad, Rahamaddulla & Fauzi [4], who show that Industry 4.0 solutions – spanning artificial intelligence, the Internet of Things, and blockchain – substantially raise the accuracy of ESG disclosures and optimize resource utilization, thereby underpinning all four eco-innovation categories within an industrial setting. A bibliometric review of ESG and digitalization research by Tan, Hashim & Zheng [12] corroborates that the fusion of digital strategies with ESG frameworks is one of the fastest-growing areas of scholarly inquiry, reinforcing the practical urgency of developing purpose-fit management instruments in this field.

To consolidate the foregoing, the eco-innovation management system of an industrial enterprise may be characterized as a structured and internally coherent set of managerial functions, instruments, and procedures directed at planning, organizing, executing, and evaluating environmentally oriented innovations across the product, process,

organizational, and marketing dimensions of the enterprise's operations. Its overarching objective is the simultaneous reduction of ecological impact and the creation of economic value. The system operates on a continuous improvement logic, addressing all four eco-innovation types in an integrated rather than piecemeal fashion. It is worth emphasizing that Industry 4.0 digital technologies are not an optional external layer but are embedded within the system itself, fulfilling critical functions in data acquisition, performance tracking, and ESG disclosure.

Translating this cyclical model into a practical governance instrument requires moving from the conceptual framework depicted in Fig. 3 toward a fully elaborated eco-innovation management system. The construction of such a system unfolds across four core stages: environmental screening and audit, selection and justification of the relevant type of eco-innovation, operational implementation, and ongoing performance monitoring (Fig. 4).

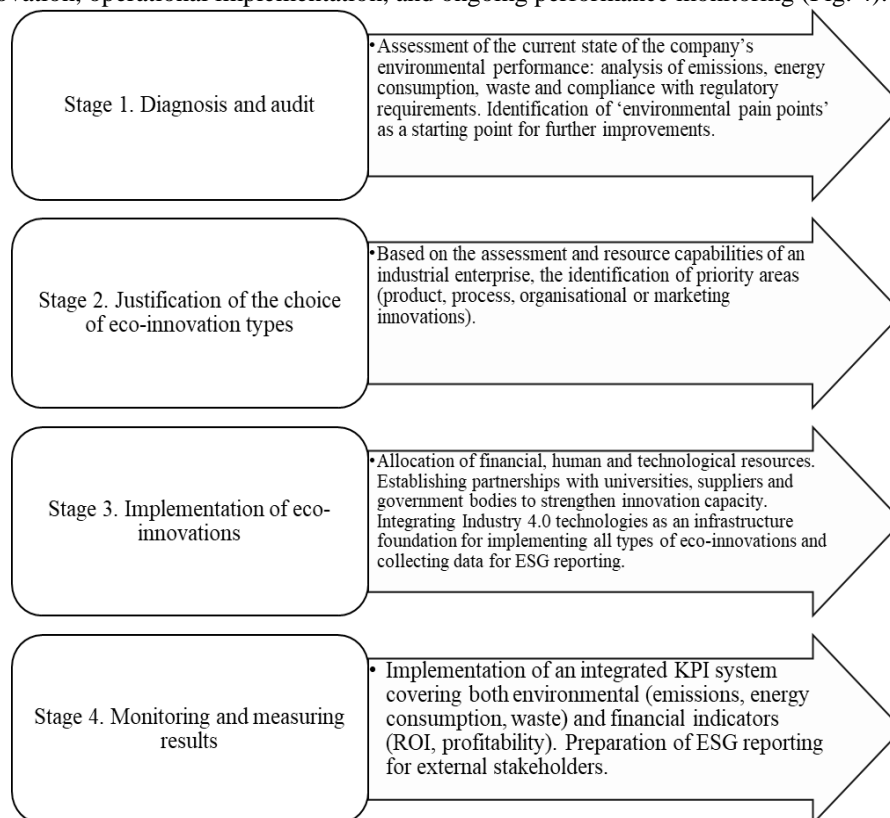


Fig. 4. Stages in the development of an eco-innovation management system

Source: developed by the author

The eco-innovation management model developed for industrial enterprises consists of four interconnected phases that together constitute a closed-loop governance framework.

The initial phase - environmental screening and audit - serves as the foundation of the entire model. Without a thorough understanding of the enterprise's existing ecological footprint, any subsequent strategic decisions would lack empirical grounding. This phase examines key parameters such as pollutant discharge levels, energy consumption per unit of output, waste generation rates, and adherence to applicable environmental legislation. Its outcome is a ranked list of critical ecological vulnerabilities that call for innovation-driven solutions.

The second phase focuses on selecting the most appropriate eco-innovation direction based on both the diagnostic findings and the enterprise's available resources. Here, decision-makers determine which innovation category - whether related to products, production processes, organizational structures, or market positioning - best aligns with the company's current developmental context. This targeted approach prevents the dispersal of effort across too many fronts simultaneously.

The third phase encompasses the hands-on deployment of chosen eco-innovations. It involves mobilizing the necessary financial, personnel, and technological assets, establishing collaborative research arrangements, and embedding Industry 4.0 digital solutions as the backbone of the implementation process. Rather than playing a supporting role, digital infrastructure functions as a core structural component of this phase.

The fourth and final phase - performance tracking and evaluation - completes the cycle by establishing a composite KPI framework that captures both ecological and financial outcomes, while also generating ESG disclosures for external audiences. This approach resonates with scholarly arguments [11] advocating for holistic assessment tools in the context of sustainable development.

The circular architecture of the model guarantees ongoing refinement: data gathered during the evaluation phase feeds directly into the next round of diagnostics, allowing the enterprise to remain responsive to shifting external conditions and to progressively raise its environmental standards.

The model exerts a measurable influence on enterprise performance across two mutually reinforcing dimensions - ecological and economic. Research by Li et al. [5] provides empirical evidence that manufacturers adopting proactive environmental strategies alongside technological capability-building outperform those that merely react to regulatory mandates. This suggests that structured eco-innovation governance is not a financial liability but rather a foundation for lasting competitive strength.

On the economic side, Prokopenko et al. [10] establish that allocating capital to green technologies and research activities yields positive returns for corporate profitability, though these gains tend to materialize over the medium- to long-term. Complementing this, Wang et al. [13] show that digitalizing operations - as the infrastructural core of eco-innovation systems - markedly strengthens ESG outcomes for manufacturing firms, which in turn broadens their access to sustainable finance and improves relations with key stakeholders. Chen, Zhang & Liu [2] add that the convergence of digital transformation and ESG orientation stimulates innovation output, generating a self-amplifying developmental dynamic.

From an environmental standpoint, Weng, Chen & Chen [14] argue from a stakeholder theory perspective that green innovations yield concurrent improvements in both ecological and business performance, satisfying the diverse expectations of regulators, capital providers, and end consumers alike. López Pérez [8] synthesizes evidence indicating that eco-innovations generally yield favorable financial outcomes over time, with upfront investment costs and regulatory uncertainty as the primary obstacles.

In summary, the value of an eco-innovation management system lies in its capacity to deliver twofold benefits: on the environmental side, through lower resource consumption and reduced ecological impact; on the economic side, through greater profitability, enhanced ESG standing, and a more robust competitive position. This dual contribution elevates environmental innovation management to a genuine strategic instrument for industrial enterprises navigating the shift toward a sustainable economic model.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

This study demonstrates that the management of eco-innovations is a distinct managerial function shaped by three key drivers: market demand, technological impetus, and regulatory pressure. Eco-innovations go beyond mere compliance with regulatory requirements and assume strategic significance as tools for creating added value, strengthening reputation, and ensuring competitive differentiation for industrial enterprises in the market.

Eco-innovation is a heterogeneous phenomenon encompassing four interrelated types: product, process, organizational, and marketing. Their complementary interaction within a cyclical model determines the logic of building an eco-innovation management system: effective management requires not isolated but systemic changes across all key areas of the enterprise's operations simultaneously.

The proposed four-stage eco-innovation management system-diagnosis and audit, justification of eco-innovation types, implementation, and monitoring-operates on the principle of continuous improvement and ensures targeted coordination of the enterprise's environmental and innovation activities.

Industry 4.0 digital technologies are not merely a supporting element but a fundamental component of this system. The environmental innovation management system generates dual value: environmental value through reduced production resource intensity and improved environmental performance, and economic value through increased profitability, improved ESG ratings, and expanded access to "green" financing. This confirms that environmental innovation management is a full-fledged tool for improving the efficiency of industrial enterprises during the transition to a sustainable economy.

Prospects for further research include developing quantitative methods to evaluate the effectiveness of the environmental innovation management system at the level of individual industrial enterprises, as well as adapting the proposed system to the conditions of specific industrial sectors in Ukraine, taking into account European integration requirements.

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