

DOI: 10.15276/ETR.01.2026.10
 DOI: 10.5281/zenodo.19642942
 UDC: 349.6:658.26:330.15:69(477)(4CC)
 JEL: K32, Q58, L74, Q01, M21

REGULATORY AND ECONOMIC FOUNDATIONS FOR INTEGRATING EU ENVIRONMENTAL STANDARDS IN ARCHITECTURAL AND CONSTRUCTION ENTERPRISES

НОРМАТИВНО-ПРАВОВІ ТА ЕКОНОМІЧНІ ЗАСАДИ ІНТЕГРАЦІЇ ЕКОЛОГІЧНИХ СТАНДАРТІВ ЄС У ДІЯЛЬНІСТЬ АРХІТЕКТУРНО БУДІВЕЛЬНИХ ПІДПРИЄМСТВ

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Received 14.12.2025

Кубанов Р.А., Денісюк О.В., Макадьора Д.А. *Нормативно-правові та економічні засади інтеграції екологічних стандартів ЄС у діяльність архітектурно будівельних підприємств. Оглядова стаття.*

У статті досліджено нормативно правові та економічні засади інтеграції екологічних стандартів ЄС у діяльність архітектурно будівельних підприємств України. Актуальність теми визначається потребою гармонізації національного законодавства з європейськими директивами та регламентами, а також необхідністю підвищення конкурентоспроможності галузі в умовах сталого розвитку та кліматичних викликів. Виявлено ключові бар'єри впровадження: правова невизначеність, високі витрати, недостатня обізнаність персоналу та слабка інституційна підтримка. Проаналізовано напрями інтеграції: «зелене» будівництво, політики циркулярної економіки, взаємодія екологічних і кліматичних стратегій, стандарти CEN/TC 350. Методологія поєднує системний, правовий, економічний та порівняльний підходи, використано кейс стади та LCA/LCC. Запропоновано дорожню карту впровадження стандартів, що охоплює аудит, планування, навчання, модернізацію, звітність і моніторинг. Результати підтверджують, що інтеграція екостандартів ЄС є джерелом економічної ефективності, інвестиційної привабливості та позитивного іміджу компанії, формуючи основу для стратегії сталого розвитку будівельної галузі України.

Ключові слова: екологічні стандарти ЄС, архітектурно будівельні підприємства, нормативно правове регулювання, економічні механізми, «зелене» будівництво, циркулярна економіка, екологічний менеджмент, гармонізація законодавства

Kubanov R.A., Denysiuk O.V., Makatora D.A. *Regulatory and Economic Foundations for Integrating EU Environmental Standards in Architectural and Construction Enterprises. Review article.*

The article examines the regulatory, legal and economic foundations for integrating European Union environmental standards into the activities of Ukrainian architectural and construction enterprises. The relevance of the topic is determined by the need to harmonize national legislation with European directives and regulations, as well as by the necessity to enhance the competitiveness of the sector in the context of sustainable development and climate challenges. Key barriers to implementation have been identified, including legal uncertainty, high costs, insufficient staff awareness, and weak institutional support. The main areas of integration are analysed, such as green construction, circular economy policies, the interaction between environmental and climate strategies, and the CEN/TC 350 standards. The methodology combines systemic, legal, economic, and comparative approaches, using case studies and LCA/LCC methods. A roadmap for the implementation of standards is proposed, covering audit, planning, training, modernization, reporting, and monitoring. The results confirm that the integration of EU environmental standards serves as a source of economic efficiency, investment attractiveness, and a positive corporate image, forming the basis for a sustainable development strategy of Ukraine's construction industry.

Keywords: EU environmental standards, architectural and construction enterprises, regulatory and legal framework, economic mechanisms, green construction, circular economy, environmental management, legislative harmonization

The current stage of development of Ukraine's architectural and construction sector is characterized by the need for integration into the European legal and economic space. One of the key directions of this process is the implementation of European Union environmental standards, which define requirements for building energy efficiency, waste management, the use of certified materials, environmental management, and non-financial reporting. However, in practice, a number of problems arise that complicate the adaptation of these standards in the activities of Ukrainian enterprises.

Firstly, Ukraine's regulatory and legal framework requires further harmonization with EU directives and regulations. Although certain provisions have already been implemented, gaps remain in the areas of practical application, control, and liability. This creates legal uncertainty for companies striving to comply with European requirements but facing ambiguities in national regulations.

Secondly, the economic aspect of integrating environmental standards is associated with significant initial costs. Modernization of heating, ventilation, and lighting systems, organization of waste sorting and recycling, procurement of certified materials, and international certification require financial resources that are not always accessible to small and medium-

sized enterprises. At the same time, long-term economic benefits – such as reduced energy costs, optimized waste management, lower penalty risks, and increased investment attractiveness – are often underestimated.

Thirdly, there is a problem of insufficient awareness and training of personnel. The implementation of environmental standards requires new competencies in environmental management, knowledge of international norms, and practical skills in non-financial reporting. Without systematic training and the formation of a corporate culture of environmental responsibility, even the most comprehensive regulatory documents remain merely formal.

Fourthly, the integration of EU environmental standards into the activities of architectural and construction enterprises faces institutional barriers. Insufficient coordination between government bodies, lack of effective control and incentive mechanisms, and weak state support for innovative green technologies slow down implementation processes.

Thus, the problem lies in the need to create a system that combines regulatory and legal harmonization with EU directives and economic mechanisms to support enterprises. Only the integration of legal norms, financial incentives, and educational programs can ensure the real implementation of environmental standards in the construction sector. This, in turn, will contribute to the formation of competitive advantages for Ukrainian companies, their access to the European market, and the development of sustainable construction as a key direction of national economic policy.

Analysis of recent research and publications

Recent studies in the Ukrainian context indicate a systemic need to harmonize the construction sector with European environmental requirements. Research on the state and prospects of the industry (S. Ivanov) [1] outlines institutional and economic challenges of modernization, while the dissertation research by H. Shpakova [2] develops theoretical and methodological foundations of the ecological and economic mechanism of "biosphere-compatible" construction – from policy to management tools. Practical reviews of green residential construction (Yu. Orlovska et al.) [3] and comparative assessments of green construction development in Europe (K. Redko, M. Kot) [4] reveal a gap between regulatory intentions and implementation, emphasizing the importance of economic incentives and process standardization.

A block of publications on the circular economy (collective monograph edited by I. Tatomyr, L. Kvasnii; studies by V. Serdiuk) [5-6] shifts the focus from mere environmental compliance to resource efficiency and closed-loop cycles in construction. These works demonstrate that circularity policies are not only about waste but about rethinking design, materials, and logistics, where economic benefits (cost reduction, new secondary resource markets) become drivers of standard integration. At the same time, the authors note a lack of methodological tools for measuring effects at enterprise and project levels.

Studies on climate policy (analytical report by NISS; educational manual by PSACEA) [7-8] reveal the link between the European Green Deal and national adaptation strategies – from decarbonization goals to resilient urban ecosystems. They emphasize that the integration of environmental standards in construction must be aligned with climate objectives (energy efficiency, emission reduction, adaptation), otherwise "policy antagonisms" arise between material, energy, and urban planning requirements.

Research on sustainable development and life cycle assessment (L. Paliekhova; A. Bilyk) [9-10] provides a methodological basis for assessing environmental and economic efficiency of solutions – from payback periods to life cycle impacts of structures. These studies logically lead to European CEN/TC 350 standards and practical briefings (BRE Group) [20-21], which formalize LCA/LCC approaches and sustainability criteria for materials and buildings.

The EU regulatory framework (Directives 2010/31/EU, 2008/98/EU, 2014/95/EU; the CPR Regulation; ISO 14001), combined with Ukraine's Law "On Environmental Protection", forms a framework of requirements: energy efficiency, waste management, CE marking, environmental management, and non-financial reporting [12-17]. These documents define minimum thresholds and transparency mechanisms but do not address practical integration at company level – where applied methodologies are essential.

International publications (A. Savchenko; G. Marzani et al.; J. Barbosa et al.) [18-20] add a comparative dimension, analysing Ukrainian implementation of green standards and circular economy policies in the EU, the USA, and Japan, as well as synergies and conflicts between circularity and climate policies in construction. They confirm that successful integration depends on combining legal requirements with economic incentives and effective monitoring tools.

A practical case study of a Ukrainian enterprise ("UkrSpetsAhroProdukt") [11] and the authors' own publications (R. Kubanov, D. Makatora et al.) [22-23] close the methodological gap by proposing a step-by-step transition algorithm, tools for assessing integration quality, and generalized economic outcomes (20-25% energy savings; up to 15% waste management cost reduction; reduced penalty risks; increased investment attractiveness). These works demonstrate how regulatory requirements are transformed into business processes, KPIs, and reporting systems, ensuring measurability and manageability of change.

In summary, contemporary academic discourse is shifting from declarative environmental compliance to an integrated model: law → management → economics → assessment standards. At the same time, gaps remain, including insufficient harmonization of control and incentive procedures, limited financing accessibility for SMEs, uneven staff competencies, and the need for standardized performance metrics at project and company levels. The roadmap, effect tables, and methodological approaches proposed in this article address these gaps by combining European norms with change management practices in Ukrainian architectural and construction enterprises.

Methodological framework of the study is based on a combination of systemic, interdisciplinary, and comparative approaches, enabling a comprehensive analysis of the regulatory, legal, and economic aspects of integrating EU environmental standards into the activities of Ukrainian architectural and construction enterprises.

In particular, the following components are identified. The systemic approach is used to analyse the construction sector as an integrated socio-economic system functioning in interaction with legal norms, economic mechanisms, and environmental requirements. This allows the integration of EU standards to be considered not as a separate process but as a comprehensive transformation of enterprise business models. Regulatory and legal analysis is applied to examine EU directives and regulations (2010/31/EU, 2008/98/EU, 2014/95/EU, CPR, ISO 14001:2015) in conjunction with Ukraine's national legislation (Law "On Environmental Protection"). This method identifies the degree of legal harmonization, implementation gaps, and opportunities for improving regulatory policy. Economic analysis is used to assess costs and benefits of environmental standard implementation, including reduced energy consumption, optimized waste management, minimized penalty risks, and increased investment attractiveness. Methods applied include comparative analysis, SWOT analysis, and life cycle assessment (LCA/LCC). The comparative approach enables comparison of Ukrainian practices with those of the EU, the USA, and Japan (based on studies by G. Marzani, J. Barbosa, and BRE Group) [19-21], facilitating adaptation of best international practices to Ukrainian conditions. Empirical research methods include case studies and examples of Ukrainian enterprises ("UkrSpetsAhro Produkt") [11], as well as integrative studies by R. Kubanov, D. Makatora et al. [22-23], which propose transition algorithms and methodological tools for evaluating integration quality. Strategic planning tools involve a roadmap for implementing environmental standards, encompassing diagnostics, planning, staff training, technical modernization, reporting, monitoring, and innovation-driven development.

Thus, the methodological framework integrates legal, economic, and managerial instruments, enabling not only a description of the EU environmental standards integration process but also an assessment of its effectiveness, identification of barriers, and formulation of practical recommendations for Ukrainian architectural and construction enterprises.

The aim of the article is to substantiate and systematically analyse the regulatory, legal, and economic foundations for integrating European Union environmental standards into the activities of Ukrainian architectural and construction enterprises, identify key barriers and opportunities of this process, and develop practical recommendations for forming an effective sustainable development model for the sector.

Achieving this purpose involves analysing the degree of harmonization of Ukrainian legislation with EU directives and regulations; assessing the economic efficiency of implementing environmental standards in

construction companies; examining international experience and opportunities for its adaptation to Ukrainian realities; developing a roadmap for integrating environmental standards into enterprise activities; and formulating practical recommendations to enhance competitiveness and investment attractiveness of Ukraine's construction industry.

Thus, the purpose of the study combines theoretical analysis, legal harmonisation, and economic assessment, which makes it possible to establish a solid foundation for the integration of EU environmental standards into the practical activities of Ukrainian architectural and construction enterprises.

The main part

The scientific and practical understanding of integrating EU environmental standards into the activities of architectural and construction enterprises is formed based on four key research directions. The first involves analysing the implementation of green building standards in Ukraine following the signing of the EU Association Agreement, allowing assessment of legislative harmonization levels and identification of practical implementation barriers [1-4, 18]. The second direction examines circular economy policies in construction and EU experience, demonstrating how material reuse, waste minimization, and closed production cycles form the basis of new environmental standards [5-6, 19].

The third direction – the interaction between EU circular economy and climate change policies in the construction sector – reveals synergies and contradictions between environmental and climate strategies that define regulatory requirements for enterprises [7-8, 20]. This is particularly relevant for Ukraine, as environmental standard integration must simultaneously contribute to greenhouse gas emission reduction and improved economic efficiency. The fourth direction reviews TC 350 standards on environmental performance of materials and buildings, systematizing European approaches to life cycle assessment and construction sustainability, forming a basis for harmonizing Ukrainian norms with European ones [9-10, 21].

The practical significance of these directions is reinforced by integrative studies such as "Adaptation of an architectural and construction company to European norms and standards" and "Methodological Support for assessing the quality of transition stages to European norms and standards in architectural and construction company activities". These works offer concrete transition algorithms and methodological tools for evaluating integration quality [22-23]. Thus, combining theoretical analysis with practical recommendations ensures a comprehensive view of the problem – from the Ukrainian context to European practices and standards – forming a foundation for an effective sustainable development model of Ukraine's construction industry.

The regulatory and legal aspect of EU environmental standards implementation encompasses a complex of directives, regulations, and international standards that define requirements for building energy

efficiency, waste management, use of certified materials, environmental management, and non-financial reporting. Harmonization of these documents with Ukraine's national legislation, particularly the Law "On Environmental Protection", is crucial for establishing an environmentally responsible policy in architecture and construction.

Directive 2010/31/EU [13] establishes minimum energy performance requirements for buildings, stimulating the use of modern technologies and materials. Directive 2008/98/EU [14] defines the waste management hierarchy aimed at reuse and recycling. Regulation (EU) No 305/2011 (CPR) [15] regulates the construction products market, ensuring environmental safety and compliance with European standards. ISO

14001:2015 [16] provides an environmental management system enabling continuous process improvement and reduced environmental impact. Directive 2014/95/EU [17] requires companies to disclose non-financial information, enhancing transparency and investor trust.

For Ukrainian architectural and construction companies, implementing these standards (Table 1) means not only fulfilling international obligations but also creating new opportunities: access to European markets, investment attraction, positive image formation, and improved project quality. At the same time, this requires significant organizational and financial efforts, internal process adaptation, and staff training.

Table 1. Regulatory and legal aspect of implementing EU environmental standards

Regulatory document / standard	Scope of application	Key requirements	Practical significance for architectural and construction companies
Directive 2010/31/EU on energy performance of buildings	Energy efficiency, building materials	<ul style="list-style-type: none"> — Minimum energy performance requirements — Building certification — Use of renewable energy sources 	<ul style="list-style-type: none"> — Design of energy-efficient buildings — Reduced operating costs — Increased competitiveness
Directive 2008/98/EU on waste	Construction waste management	<ul style="list-style-type: none"> — Waste hierarchy — Recycling and reuse — Reduction of landfilling 	<ul style="list-style-type: none"> — Organization of construction waste sorting — Use of secondary materials — Reduced environmental risks
Regulation (EU) No 305/2011 (CPR)	Construction products	<ul style="list-style-type: none"> — Environmental safety requirements — Declaration of performance characteristics — CE marking 	<ul style="list-style-type: none"> — Use of certified materials — Access to the European market — Increased client trust
ISO 14001:2015 (Environmental management system)	Environmental management	<ul style="list-style-type: none"> — Sustainable development policy — Monitoring of environmental aspects — Continuous improvement 	<ul style="list-style-type: none"> — Implementation of environmental management systems — Reduced negative environmental impact — Positive corporate image
Directive 2014/95/EU (Non-financial reporting)	Corporate reporting	<ul style="list-style-type: none"> — Disclosure of environmental indicators — Information on social and governance aspects 	<ul style="list-style-type: none"> — Preparation of non-financial reports — Transparency for investors — Enhanced corporate reputation
Law of Ukraine "On Environmental Protection"	National regulation	<ul style="list-style-type: none"> — Compliance with environmental norms — Liability for violations — Activity licensing 	<ul style="list-style-type: none"> — Alignment with European requirements — Minimization of legal risks — Support for sustainable development

Source: authors' own elaboration

There is an analysis of the main elements of the table:

1. Directive 2010/31/EU on the energy performance of buildings. This document defines minimum energy efficiency requirements for new and renovated buildings and provides for the certification of energy performance characteristics. For Ukrainian companies, this means the need to design energy-efficient buildings and use modern materials and technologies that reduce operating costs and increase competitiveness.

2. Directive 2008/98/EU on waste. This directive establishes a waste management hierarchy: prevention,

reuse, recycling, and minimization of disposal. For construction companies, this implies the implementation of construction waste sorting systems, the use of secondary materials, and the reduction of negative environmental impacts.

3. Regulation (EU) No 305/2011 (CPR). The regulation applies to construction products and sets requirements for their environmental safety, mandatory declaration of performance, and CE marking. For Ukrainian companies, this opens access to the European market, increases client trust, and ensures the use of certified materials.

4. ISO 14001:2015 (Environmental management system). This international standard defines requirements for an enterprise's environmental management system. It provides for the development of a sustainable development policy, monitoring of environmental aspects of activities, and continuous improvement of processes. For construction companies, this means reducing negative environmental impacts and building a positive corporate image.

5. Directive 2014/95/EU (Non-financial reporting). This document obliges large companies to disclose information on environmental, social, and governance indicators. For Ukrainian enterprises, it serves as an incentive for transparency, preparation of non-financial reports, and increased investor confidence.

6. Law of Ukraine "On Environmental Protection" [12]. This national legislative act regulates environ-

mental activities of enterprises, establishes liability for violations, and defines licensing mechanisms. For construction companies, it is a fundamental document aligned with European requirements and provides a legal basis for environmentally responsible operations.

Thus, each element of the table forms a regulatory framework that integrates European directives and standards with Ukrainian legislation. This enables architectural and construction companies not only to comply with environmental safety requirements but also to gain competitive advantages in the market.

It is very important to understand the implementation pathway within the activities of an individual enterprise. The roadmap for implementing EU environmental standards in the activities of a Ukrainian architectural and construction company is analysed in Table 2.

Table 2. Roadmap for the implementation of EU environmental standards for an architectural and construction company

Stage	Tools / Actions	Expected Results
1. Diagnostics and audit	<ul style="list-style-type: none"> — Environmental audit of the enterprise — Analysis of compliance with national legislation and EU directives — SWOT analysis of environmental risks 	<ul style="list-style-type: none"> — Identification of gaps in compliance with standards — Definition of basic needs for modernisation
2. Planning and strategy	<ul style="list-style-type: none"> — Development of the company's environmental policy — Setting sustainable development goals — Alignment with ISO 14001 and EU directives 	<ul style="list-style-type: none"> — Creation of a strategic plan — Integration of environmental requirements into business processes
3. Staff training	<ul style="list-style-type: none"> — Training in environmental management — Familiarisation with EU directives (energy efficiency, waste management) — Implementation of corporate checklists 	<ul style="list-style-type: none"> — Improved staff competencies — Formation of a culture of environmental responsibility
4. Technical modernisation	<ul style="list-style-type: none"> — Use of certified materials (CE marking) — Implementation of energy-efficient technologies — Sorting and recycling of construction waste 	<ul style="list-style-type: none"> — Reduction of energy consumption — Minimisation of waste — Compliance with European requirements
5. Documentation and reporting	<ul style="list-style-type: none"> — Preparation of non-financial reports (Directive 2014/95/EU) — Internal environmental regulations — ISO 14001 certification 	<ul style="list-style-type: none"> — Transparency for investors and partners — Increased customer trust — Legal compliance
6. Monitoring and evaluation	<ul style="list-style-type: none"> — KPIs: energy efficiency, waste utilisation level, environmental risks — Regular audits — Feedback from clients and partners 	<ul style="list-style-type: none"> — Continuous improvement of processes — Reduction of environmental risks — Positive company image
7. Development and innovation	<ul style="list-style-type: none"> — Investment in "green" technologies — Use of BIM modelling for environmentally oriented design — Participation in international sustainable development programmes 	<ul style="list-style-type: none"> — Increased competitiveness — Entry into the European market — Leadership in sustainable construction

Source: authors' own elaboration

The analytical characteristics of the roadmap elements are:

1. Diagnostics and audit. The first step is to conduct an environmental audit of the enterprise and analyse compliance with national legislation and EU directives. This makes it possible to identify gaps in compliance with standards, assess environmental risks, and determine basic needs for modernisation.

2. Planning and strategy. At this stage, the company's environmental policy is formulated, sustainable development goals are defined, and internal

processes are aligned with the requirements of ISO 14001 and EU directives. This creates a strategic plan for integrating environmental requirements into business processes.

3. Staff training. An important element is the preparation of employees, including training in environmental management, familiarisation with European directives, and the implementation of corporate checklists. This contributes to the formation of a culture of environmental responsibility and enhances staff competencies.

4. Technical modernisation. The company proceeds to practical changes, including the use of certified materials with CE marking, the implementation of energy-efficient technologies, and the organisation of sorting and recycling of construction waste. This ensures compliance with European requirements and reduces negative environmental impact.

5. Documentation and reporting. At this stage, non-financial reports are prepared in accordance with Directive 2014/95/EU, internal environmental regulations are developed, and ISO 14001 certification is carried out. This increases the transparency of the company's activities and strengthens the trust of clients and investors.

6. Monitoring and evaluation. Regular audits, the definition of key performance indicators (KPIs), and feedback from clients make it possible to assess the effectiveness of implemented measures. This contri-

butes to continuous process improvement and the reduction of environmental risks.

7. Development and innovation. The final stage involves investment in "green" technologies, the use of BIM modelling for environmentally oriented design, and participation in international sustainable development programmes. This ensures the long-term competitiveness of the company and its leadership in the field of sustainable construction.

Thus, each stage of the roadmap is interconnected and forms a holistic system for implementing EU environmental standards, enabling Ukrainian architectural and construction companies not only to comply with legislative requirements but also to create sustainable competitive advantages.

The issue of economic efficiency is fundamental when an individual enterprise chooses a specific development path (Table 3).

Table 3. Economic efficiency of implementing EU environmental standards

Area of implementation	Initial costs	Economic effect	Long-term results
Building energy efficiency (Directive 2010/31/EU)	Investment in thermal insulation, modern heating and lighting systems	Reduction in energy costs by 20-30%	Payback period of 3-5 years, increase in property value
Waste management (Directive 2008/98/EU)	Organisation of waste sorting, purchase of containers, logistics	Savings on waste disposal up to 15%, possibility of selling secondary materials	Reduction of environmental fines, formation of a "green" corporate image
Use of certified materials (CPR Regulation)	Purchase of materials with CE marking	Reduction of defect and complaint risks	Access to the European market, increased customer trust
ISO 14001:2015 (environmental management)	Costs of certification and audits	Process optimisation, reduction of resource losses by 10-15%	Increased investment attractiveness, business stability
Non-financial reporting (Directive 2014/95/EU)	Preparation of reports, consultancy services	Transparency for partners, attraction of new investors	Growth of capitalisation, long-term contracts
National legislation of Ukraine ("On Environmental Protection")	Costs of compliance with environmental requirements and measures	Reduced risk of fines and litigation costs	Legal security, alignment with European requirements

Source: authors' own elaboration

The explanatory characteristics of the main elements of the Table are:

1. Building energy efficiency (Directive 2010/31/EU). The implementation of energy-saving technologies in construction and renovation requires initial investments in thermal insulation materials, modern heating, ventilation, and lighting systems. However, these costs are rapidly offset due to a reduction in energy consumption by 20-30%. In the long term, companies achieve a payback period of 3-5 years and increase the market value of real estate assets, making them more attractive to clients and investors.

2. Waste management (Directive 2008/98/EU). The organisation of sorting and recycling systems for construction waste requires expenditures on containers, logistics solutions, and staff training. The economic effect is reflected in a reduction of waste disposal costs by up to 15% and the possibility of selling secondary materials. In addition, companies reduce the risk of environmental penalties and form a "green" corporate image, which positively affects reputation and competitiveness.

3. Use of certified materials (CPR Regulation). The procurement of materials with CE marking may be more costly at the initial stage; however, it guarantees compliance with European quality and environmental safety standards. This reduces the risks of defects, complaints, and additional costs related to defect elimination. In the long term, companies gain access to the European market, increase customer trust, and ensure business stability.

4. ISO 14001:2015 (environmental management). Certification and audits in accordance with ISO 14001 require financial resources, but they enable the optimisation of internal processes and a reduction in resource losses by 10-15%. This creates a system of continuous improvement that ensures business stability and increases investment attractiveness. The presence of ISO certification is also a strong argument in negotiations with international partners.

5. Non-financial reporting (Directive 2014/95/EU). The preparation of non-financial reports requires expenditures on consultancy services and the organisation of internal monitoring systems. However, increased transparency enhances the company's ability

to attract investors and partners focused on sustainable development principles. In the long term, this contributes to company capitalisation growth and the conclusion of long-term contracts.

6. National legislation of Ukraine ("On Environmental Protection"). Compliance with environmental regulations and the implementation of relevant measures require financial investments, but they allow companies to avoid fines and litigation costs. This ensures legal security and alignment with European requirements, ultimately providing business stability and opportunities for integration into international markets.

Thus, each element of the table demonstrates that initial investments in the implementation of EU environmental standards are compensated through cost reduction, process optimisation, and increased trust from clients and partners. In the long-term perspective, this forms economic resilience, competitive advantages, and a positive corporate image for Ukrainian enterprises.

In Ukraine, a successful example of implementing most EU environmental standards is "UkrSpetsAgro Product" [11], which has certified its activities in accordance with ISO 14001 and adapted its internal processes to EU directives. This enabled the company to reduce resource costs, minimise environmental risks, and enhance customer trust.

In particular, the implementation pathway of the Ukrainian enterprise can be analysed as following:

1. Implemented standards:
 - ISO 14001:2015 – an environmental management system covering environmental impact monitoring, process optimisation, and continuous improvement.

- EU directives on waste management and energy efficiency – adapted into internal regulations to reduce waste generation and energy consumption.
- CPR Regulation (CE marking) – use of certified materials compliant with European requirements.

2. Economic efficiency:

- Reduction in energy costs by 20-25% due to modernisation of heating and lighting systems.
- Optimisation of waste management – savings of up to 15% on disposal costs and partial use of secondary materials.
- Reduction of penalty risks through compliance with Ukrainian and EU legislation.
- Increased investment attractiveness resulting from transparent non-financial reporting and environmental responsibility.

3. Social and reputational effects:

- Increased trust from clients and partners due to environmental certification.
- Formation of a "green" corporate image aligned with contemporary European sustainable development trends.
- Attraction of new orders and access to international markets.

Thus, the case of "UkrSpetsAgroProduct" demonstrates that the integration of EU environmental standards into the activities of Ukrainian enterprises not only reduces costs and risks but also creates long-term competitive advantages. This confirms the feasibility and effectiveness of systematic implementation of ISO 14001, EU directives, and material certification in the fields of architecture and construction.

For clarity, an aggregated summary is presented in Table 4.

Table 4. Integration of EU environmental standards into the activities of "UkrSpetsAgroProduct": costs → economic effect → reputational Effect

Costs	Economic Effect	Reputational Effect
Investments in thermal insulation, modernisation of heating and lighting systems	Reduction of energy costs by 20-25%; payback period of 3-5 years	Image of a modern and innovative company committed to sustainable development
Organisation of sorting and recycling of construction waste	Savings on waste disposal of up to 15%; additional revenue from secondary materials	Formation of a "green" brand; positive perception by clients and partners
Procurement of certified materials with CE marking	Reduction of defect and complaint risks; access to the European market	Increased customer trust; eligibility to participate in international tenders
Costs for ISO 14001 certification and environmental audits	Process optimisation; reduction of resource losses by 10-15%	Recognition of the company as a reliable partner; increased investment attractiveness
Preparation of non-financial reports and consultancy services	Transparency of operations; attraction of new investors	Reputation of a responsible business; conclusion of long-term contracts
Compliance with national environmental regulations	Reduction of penalty and litigation risks	Legal security; alignment with European requirements

Source: authors' own elaboration

Thus, even substantial initial investments in the implementation of EU environmental standards are transformed into tangible economic benefits (cost reduction, access to new markets, process optimisation) and reputational advantages (trust of clients and investors, positive corporate image). This makes the

enterprise more resilient and competitive in the long term.

Within the framework of comparison and validation of effectiveness, the main results are presented in Figure 1.

The diagram illustrates the key directions of economic efficiency achieved by the Ukrainian

enterprise "UkrSpetsAgroProduct" after the implementation of EU environmental standards. The most significant result is the reduction in energy costs by 20-25%, made possible through the modernisation of

heating and lighting systems. Another important indicator is the optimisation of waste management, which ensured savings of up to 15% in disposal costs and enabled partial use of secondary materials.

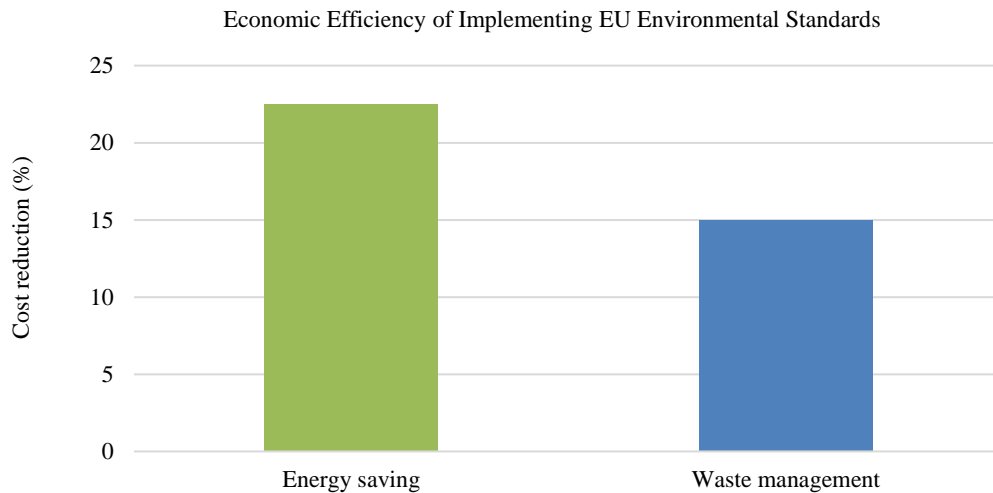


Figure 1. Economic benefits and reputational advantages from the integration of EU environmental standards into the activities of "UkrSpetsAgroProduct"

Source: authors' own elaboration

Qualitative effects that do not have a direct numerical measurement but substantially influence the company's performance are highlighted separately. These include, in particular, the reduction of penalty risks due to compliance with Ukrainian and European legislation, as well as increased investment attractiveness resulting from transparent non-financial reporting and environmental responsibility.

Thus, the diagram demonstrates that the implementation of EU environmental standards combines quantitative benefits (cost reduction, resource savings) with qualitative advantages

(strengthened reputation, investor confidence), creating a comprehensive effect that supports the long-term competitiveness of the enterprise.

Within the presented case study, the economic effect of implementing environmental standards is further illustrated graphically (Figure 2).

The graphical scheme demonstrates the logic of integrating EU environmental standards, using the successful experience of "UkrSpetsAgroProduct" as an example, through consecutive stages – from audit to innovation.

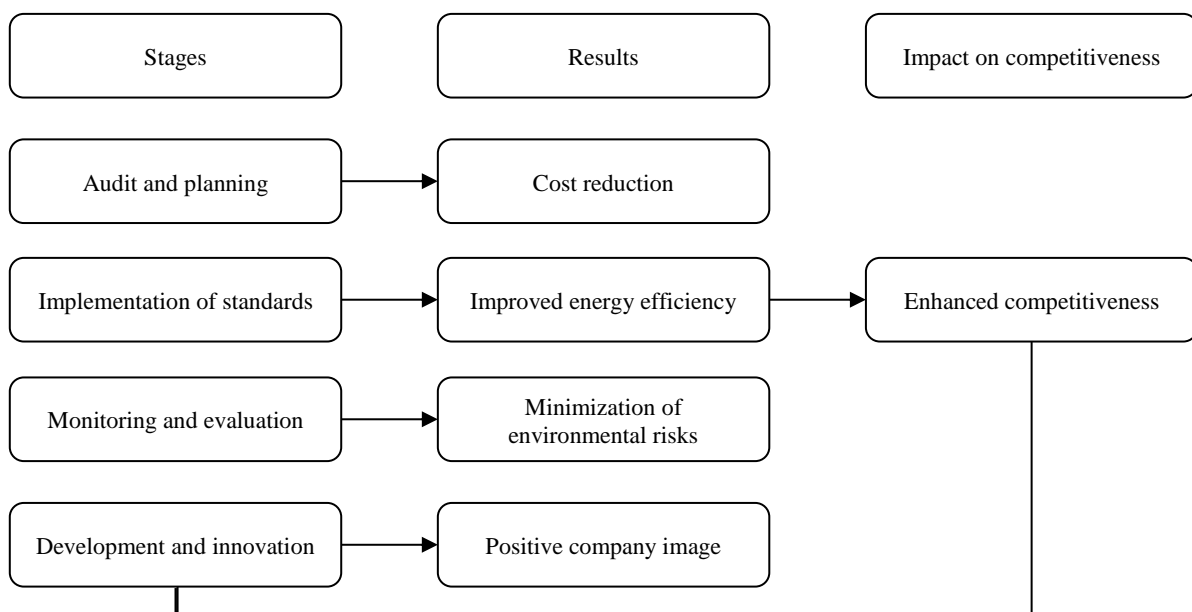


Figure 2. Scheme "Stages → results → impact on competitiveness"

Source: authors' own elaboration

Each stage generates specific results that contribute to cost reduction, improved energy efficiency, risk minimisation, and the formation of a positive corporate image. The cumulative impact of these results ensures a strategic enhancement of the company's competitiveness. The scheme clearly confirms that environmental transformation is not only a response to contemporary regulatory and societal challenges but also a source of economic advantage for a modern enterprise.

Based on the theoretical and methodological framework developed, the following recommendation block can be proposed to enhance the competitiveness and investment attractiveness of Ukraine's construction sector:

1. Harmonisation of the regulatory and legal framework: accelerate the implementation of EU directives and regulations into national legislation; ensure clear mechanisms of control and liability for compliance with environmental standards; develop sector-specific methodological guidelines for construction companies on the application of European norms.

2. Economic incentives and financial support: introduce state and municipal programmes to compensate costs related to energy-efficient modernisation; create dedicated credit and grant

instruments for small and medium-sized enterprises; develop mechanisms for "green" investments and public-private partnerships in the construction sector.

3. Technical modernisation and innovation: implement certified materials with CE marking and technologies for resource reuse; apply BIM modelling for environmentally oriented design and optimisation of the building life cycle; invest in "green" technologies, including energy-efficient systems, renewable energy sources, and circular solutions.

4. Personnel training and development: organise systematic training in environmental management and international ISO standards; foster a corporate culture of environmental responsibility; develop educational programmes in cooperation with universities and professional associations.

5. Transparency and non-financial reporting: introduce regular preparation of non-financial reports in accordance with Directive 2014/95/EU; use environmental KPIs (energy efficiency, waste management, emission reduction); ensure data transparency for investors and partners, which increases trust and strengthens corporate reputation.

The specific features of the recommendation block are presented in Table 5.

Table 5. Roadmap for the integration of EU environmental standards into the dual chain: construction sector – architectural and construction enterprise

Recommendation	Tool / mechanism	Expected effect
Harmonisation of the regulatory and legal framework	Implementation of EU directives and regulations into national legislation; methodological guidelines	Legal certainty; reduction of legal risks; alignment with European requirements
Economic incentives and financial support	State compensation programmes; "green" loans and grants; public-private partnerships	Attraction of investments; accessibility of modernisation for SMEs; increased competitiveness
Technical modernisation and innovation	Use of certified materials (CE); BIM modelling; implementation of energy-efficient technologies	Reduction of energy consumption; waste minimisation; compliance with European standards
Personnel training and development	Training in environmental management; educational programmes; corporate checklists	Increased competencies; formation of a culture of environmental responsibility; effectiveness of implementation
Transparency and non-financial reporting	Preparation of non-financial reports; environmental KPIs; ISO 14001 certification	Increased investor trust; transparency of activities; positive corporate image
Monitoring and evaluation	Regular audits; KPI system; feedback from clients	Continuous process improvement; reduction of environmental risks; development stability
Development and innovation	Investments in "green" technologies; participation in international programmes; innovation projects	Leadership in sustainable construction; access to the European market; long-term competitiveness

Source: authors' own elaboration

The proposed roadmap for integrating EU environmental standards into the dual chain construction sector – architectural and construction enterprise is a practical tool that combines regulatory and legal requirements with economic and managerial mechanisms. It ensures a systematic process – from audit and planning to innovative development – creating conditions for a gradual and controlled transition to European norms. The implementation of the proposed recommendations will contribute to cost reduction, increased energy efficiency, and minimisation of environmental risks. At the same time, transparency of reporting and the adoption of modern

technologies enhance investor confidence and shape a positive corporate image. Thus, the roadmap becomes a key element in strengthening the competitiveness and investment attractiveness of Ukraine's construction sector, ensuring its sustainable development within the European context.

Conclusions

As a result of the study, the following conclusions can be drawn:

1. The integration of EU environmental standards into the activities of architectural and construction enterprises in Ukraine is a strategic direction for

sectoral development, ensuring the harmonisation of national legislation with European norms and creating a legal foundation for sustainable construction.

2. EU regulatory and legal instruments (Directive 2010/31/EU, Directive 2008/98/EC, Regulation No. 305/2011, ISO 14001:2015, Directive 2014/95/EU), in combination with Ukraine's national legislation, form a comprehensive system of requirements covering energy efficiency, waste management, environmental management, and reporting transparency.

3. The economic effectiveness of implementing these standards is reflected in reduced energy and waste disposal costs, minimised penalty risks, increased investment attractiveness, and the formation of a positive corporate image. Initial costs are offset by long-term benefits and competitive advantages.

4. Practical implementation requires a roadmap that includes auditing, planning, staff training, technical modernisation, preparation of non-financial reports, monitoring, and innovative development. This sequence of actions ensures the systematic and effective nature of the process.

5. The main implementation barriers are associated with insufficient legislative harmonisation, high initial costs, a lack of staff competencies, and weak state support for "green" technologies. Overcoming these barriers is possible through a combination of legal norms, financial incentives, and educational programmes.

6. The integrated combination of theoretical and practical approaches makes it possible to develop an effective model for the sustainable development of Ukraine's construction sector, ensuring compliance with European requirements, enhancing enterprise competitiveness, and contributing to environmental safety for society.

Thus, the article demonstrates that the implementation of EU environmental standards in Ukraine's construction sector is not only a requirement of the present time but also a real instrument for economic growth and the formation of a positive international image.

Abstract

Introduction. The article examines the regulatory, legal, and economic foundations for integrating European Union environmental standards into the activities of architectural and construction enterprises in Ukraine. The relevance of the topic is driven by the need to harmonise national legislation with European directives and regulations, as well as by the necessity to enhance the competitiveness of the sector in the context of sustainable development, digital transformation, and climate challenges.

The methodological framework of the study combines systemic, regulatory, legal, economic, comparative, and empirical approaches. Life cycle assessment methods (LCA/LCC), case study analysis, and strategic planning tools are applied. The study draws on examples from Ukrainian enterprises, including the case of "UkrSpetsAgroProduct", as well as iterative methodological developments that propose transition algorithms to European standards and tools for assessing the quality of integration.

The purpose of the study is to substantiate and provide a systematic analysis of the regulatory, legal and economic foundations for integrating EU environmental standards into the activities of architectural and construction enterprises in Ukraine, to identify key barriers and opportunities in this process, and to develop practical recommendations for shaping an effective model of sustainable development for the sector.

Results. The study identifies the main barriers to the implementation of environmental standards, including legal uncertainty, high initial costs, insufficient staff awareness, weak institutional support, and the lack of systematic mechanisms for monitoring effectiveness. Four key theoretical directions forming the basis of integration are analysed: the implementation of "green building" standards following the signing of the EU-Ukraine Association Agreement; circular economy policies in construction and their impact on environmental regulation; the interaction between EU environmental and climate strategies in the construction sector; and the CEN/TC 350 standards for assessing the environmental performance of materials and buildings. Particular attention is paid to international experience, including practices from EU countries, the United States, and Japan, as well as to comparative analysis of regulatory approaches to sustainable construction. The article proposes a roadmap for implementing environmental standards that covers the stages of diagnostics, strategic planning, staff training, technical modernisation, preparation of non-financial reporting, monitoring, and innovative development. Expected outcomes at each stage are defined, including cost reduction, increased energy efficiency, minimisation of environmental risks, the formation of a positive corporate image, and long-term stability. Practical recommendations focus on legislative harmonisation, the introduction of financial incentives, the development of environmental management systems, increased transparency of enterprise activities, and the creation of conditions for attracting "green" investments. Special attention is given to small and medium-sized enterprises, which require accessible tools for modernisation and institutional support.

Conclusions. The results confirm that the integration of EU environmental standards is not only a regulatory requirement but also a source of economic efficiency, investment attractiveness, and a positive international image for architectural and construction enterprises. The article provides a scientific and practical basis for developing a sustainable development strategy for the sector that integrates legal norms, managerial instruments, and economic mechanisms into a unified model of environmental transformation.

Список літератури:

1. Іванов С.В. Будівельна галузь як один з векторів розвитку України: стан, практика та перспективи. Київ: НАН України, Ін-т економіки промисловості, 2020. 264 с.
2. Шпакова Г.В. Теоретико-методологічні засади формування еколого-економічного механізму розвитку біосферосумісного будівництва в Україні: дис. д-ра екон. наук: 08.00.06. Київ: Нац. ун-т будівництва та архітектури, 2020. 519 с.
3. Орловська Ю.В., Вовк М.С., Чала В.С., Мащенко С.О. Економічна політика ЄС з під-тримки зеленого житлового будівництва. Дніпро, 2017. 148 с.
4. Редько К.Ю., Кот М.В. Оцінювання поточного стану та перспектив розвитку «зеленого» будівництва в країнах Європи. *Science and Science of Science*. 2022. № 2. С. 48-64. DOI: 10.15407/sofs2022.02.048.
5. Циркулярна економіка: як новий спосіб господарювання в умовах цифрової трансформації: кол. монографія. За науковою ред. І.Л. Татомир, Л.Г. Квасній. Трускавець: ПОСВІТ, 2021. 124 с.
6. Сердюк В. Циркулярна економіка: українські реалії та перспективи впровадження в будівельні галузі. Сучасні технології, матеріали і конструкції в будівництві. 2023. № 1. С. 156-164. DOI: 10.31649/2311-1429-2023-1-156-164.
7. Іванюта С.П., Якушенко Л. М. Європейський зелений курс і кліматична політика України: аналіт. доп. За заг. ред. А. Ю. Сменковського. Київ: НІСД, 2022. 95 с. DOI: 10.53679/NISS-analytrep.2022.12.
8. Яковшина Т.Ф. Адаптація ЄС до змін клімату та стійкі урбоекосистеми: навчальний посібник. Дніпро: ПДАБА, 2023. 109 с.
9. Палехова Л.Л. Управління сталим розвитком: довідник базових понять. Дніпро: НТУ «ДП», 2020. 330 с.
10. Білик А.С. Екологічний та економічний аналіз життєвого циклу каркасів будівель: монографія. К.: УЦСБ, КНУБА, 7БЦ, 2022. 263 с.
11. ТОВ «УкрСпецАгроПродукт»: офіційний сайт. URL: <https://usap.ua>.
12. Про охорону навколишнього природного середовища: Закон України від 25 червня 1991 р. № 1264-XII. Відомості Верховної Ради України. 1991. № 41. Ст. 546.
13. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. *Official Journal of the European Union*. 2010. L. 153. P. 13-35.
14. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. *Official Journal of the European Union*. 2008. L. 312. P. 3-30.
15. Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products (CPR). *Official Journal of the European Union*. 2011. L. 88. P. 5-43.
16. ISO 14001:2015. Environmental management systems – Requirements with guidance for use. Geneva: International Organization for Standardization, 2015. 37 p.
17. Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups. *Official Journal of the European Union*. 2014. L. 330. P. 1-9.
18. Savchenko A. Green Building Standards and Their Implementation in Ukraine. *Environmental Problems Journal*. 2024. Vol. 9, № 3. P. 45-56.
19. Marzani G., Rossi L., Bianchi M. Embedding Circular Economy in the Construction Sector Policy Framework: Experiences from EU, U.S., and Japan for Better Future Cities. *Smart Cities*. 2025. Vol. 8, Issue 2. P. 112-130.
20. Barbosa J., Schmidt H., Keller P. Synergies and Antagonisms Between EU Circular Economy and Climate Mitigation Policies: Focusing on Construction Sector. *Circular Economy and Sustainability*. 2025. Springer. P. 77-95.
21. BRE Group. Assessing the Environmental Impacts of Construction: European Standards Briefing Paper. London: BRE Group, 2023. 28 p.
22. Kubanov R., Makatora D., Mykhalko A. Adapting architectural and construction companies to European norms and standards: Recommendations and a step-by-step transition algorithm. *Journal of Strategic Economic Research*. 2025. №2. P. 62-80. DOI: 10.30857/2786-5398.2025.2.7.
23. Kubanov R.A., Makatora D.A., Mykhalko A.O., Yakovenko M.K. Methodological support for assessing the quality of transition stages to european norms and standards in activities of an architectural and construction company. *Journal of Strategic Economic Research*. 2025. № 3. P. 59-79. DOI: 10.30857/2786-5398.2025.3.5.

References:

1. Ivanov, S.V. (2020). Construction industry as one of the vectors of development of Ukraine: status, practice and prospects. Kyiv: NAS of Ukraine, Institute of Industrial Economics. 264 p. [in Ukrainian].
2. Shpakova, H.V. (2020). Theoretical and methodological principles of the formation of an ecological and economic mechanism for the development of biosphere-compatible construction in Ukraine: dissertation

- Doctor of Economic Sciences: 08.00.06. Kyiv: National University of Construction and Architecture. 519 p. [in Ukrainian].
3. Orlovska, Yu.V., Vovk, M.S., Chala, V.S., & Mashchenko, S.O. (2017). EU economic policy to support green housing construction. Dnipro. 148 p. [in Ukrainian].
 4. Redko, K.Yu., & Kot, M.V. (2022). Assessment of the current state and prospects for the development of "green" construction in European countries. Science and Science of Science, № 2, P. 48-64. DOI: 10.15407/sofs2022.02.048 [in Ukrainian].
 5. Tatomyr, I.L., Kvasnii, L.H. et al. (2021). Circular economy: as a new way of doing business in the context of digital transformation: a collective monograph. Scientific editors: I.L. Tatomyr, L.G. Kvasnii. Truskavets. 124 p. [in Ukrainian].
 6. Serdiuk, V. (2023). Circular economy: Ukrainian realities and prospects for implementation in the construction industry. Modern technologies, materials and structures in construction, № 1, P. 156-164. DOI: 10.31649/2311-1429-2023-1-156-164 [in Ukrainian].
 7. Ivaniuta, S. P., & Yakushenko, L. M. (2022). The European Green Deal and Climate Policy of Ukraine: Analytical Supplement. Edited by A. Yu. Smenkovskiy. Kyiv: NISD. 95 p. DOI: 10.53679/NISS-analytrep.2022.12 [in Ukrainian].
 8. Yakovshyna, T.F. (2023). EU Climate Change Adaptation and Sustainable Urban Ecosystems: A Training Manual. Dnipro: PDABA. 109 p. [in Ukrainian].
 9. Paliekhova, L.L. (2020). Sustainable Development Management: A Guide to Basic Concepts. Dnipro: NTU "DP". 330 s. [in Ukrainian].
 10. Bilyk, A.S. (2022). Environmental and economic analysis of the life cycle of building frames: monograph. Kyiv: UTsSB, KNUBA, 7BTs. 263 p. [in Ukrainian].
 11. LLC "UkrSpetsAgroProduct": official website. URL: <https://usap.ua> [in Ukrainian].
 12. On Environmental Protection: Law of Ukraine No. 1264-XII of June 25, 1991. Bulletin of the Verkhovna Rada of Ukraine, 1991, № 41, Art. 546. [in Ukrainian].
 13. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. Official Journal of the European Union, 2010, L. 153, P. 13-35 [in English].
 14. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. Official Journal of the European Union, 2008, L. 312, P. 3-30 [in English].
 15. Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products (CPR). Official Journal of the European Union, 2011, L. 88, P. 5-43 [in English].
 16. ISO 14001:2015. Environmental management systems – Requirements with guidance for use. Geneva: International Organization for Standardization, 2015. 37 p. [in English].
 17. Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups. Official Journal of the European Union, 2014, L. 330, P. 1-9 [in English].
 18. Savchenko A. Green Building Standards and Their Implementation in Ukraine. Environmental Problems Journal, 2024, Vol. 9, № 3, P. 45-56 [in English].
 19. Marzani, G., Rossi, L., & Bianchi, M. (2025). Embedding Circular Economy in the Construction Sector Policy Framework: Experiences from EU, U.S., and Japan for Better Future Cities. Smart Cities, 2025, Vol. 8, Issue 2, P. 112-130 [in English].
 20. Barbosa, J., Schmidt, H., & Keller, P. (2025). Synergies and Antagonisms Between EU Circular Economy and Climate Mitigation Policies: Focusing on Construction Sector. Circular Economy and Sustainability, Springer, P. 77-95 [in English].
 21. BRE Group (2023). Assessing the Environmental Impacts of Construction: European Standards Briefing Paper. London: BRE Group. 28 p. [in English].
 22. Kubanov, R., Makatora, D., & Mykhalko, A. (2025). Adapting architectural and construction companies to European norms and standards: Recommendations and a step-by-step transition algorithm. Journal of Strategic Economic Research, № 2, P. 62-80. DOI: 10.30857/2786-5398.2025.2.7 [in English].
 23. Kubanov, R.A., Makatora, D.A., Mykhalko, A.O., & Yakovenko, M.K. (2025). Methodological support for assessing the quality of transition stages to European norms and standards in activities of an architectural and construction company. Journal of Strategic Economic Research, № 3, P. 59-79. DOI: 10.30857/2786-5398.2025.3.5 [in English].

Посилання на статтю:

Kubanov R.A. Regulatory and Economic Foundations for Integrating EU Environmental Standards in Architectural and Construction Enterprises / R.A. Kubanov, O.V. Denysiuk, D.A. Makatora // *Економіка: реалії часу*. Науковий журнал. – 2026. – № 1 (83). – С. 87-98. – Режим доступу: <https://economics.net.ua/files/archive/2026/No1/87.pdf>. DOI: 10.15276/ETR.01.2026.10. DOI: 10.5281/zenodo.19642942.

Reference a Journal Article:

Kubanov R.A. Regulatory and Economic Foundations for Integrating EU Environmental Standards in Architectural and Construction Enterprises / R.A. Kubanov, O.V. Denysiuk, D.A. Makatora // *Economics: time realities. Scientific journal*. – 2026. – № 1 (83). – P. 87-98. – Retrieved from: <https://economics.net.ua/files/archive/2026/No1/87.pdf>. DOI: 10.15276/ETR.01.2026.10. DOI: 10.5281/zenodo.19642942.

