

ASSESSMENT OF LOW-CARBON STRATEGY IN THE LATVIAN CONSTRUCTION SECTOR

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Received 07.03.2026; accepted 01.05.2026

Abstract. The construction sector is a major contributor to greenhouse gas emissions and resource consumption, making its decarbonisation essential for achieving climate neutrality. In Latvia, although national policies are aligned with the European Green Deal, the implementation of low-carbon strategies remains limited due to the absence of a structured evaluation framework. This study develops a multi-criteria assessment framework that integrates environmental, economic, and governance dimensions to evaluate low-carbon strategies in the Latvian construction sector. The analysis is based on secondary data, comparative evaluation, and a semi-quantitative scoring approach. Three strategies are examined: deep energy renovation, industrial prefabrication and modular construction, and circular construction. The findings indicate that deep renovation has the highest potential for reducing operational emissions, while prefabrication is effective in addressing embodied carbon and improving construction efficiency. Circular construction contributes to resource efficiency but remains dependent on market conditions and regulatory development. The study provides a structured decision-making framework and policy insights to support the transition toward sustainable construction in Latvia.

Keywords: *Low-carbon construction, embodied carbon, deep renovation, modular construction, circular economy, Latvia.*

INTRODUCTION

The construction sector is one of the most resource-intensive and environmentally impactful industries worldwide, accounting for a significant share of energy consumption, natural resource use, and greenhouse gas (GHG) emissions (European Commission, 2020). Within the European Union (EU), buildings are responsible for approximately 36 % of energy-related carbon dioxide emissions and generate more than one-third of total waste (Eurostat, 2023). These figures highlight the critical role of the built environment in achieving climate neutrality.

As a member of the EU, Latvia aligns its climate and energy objectives with the European Green Deal and the “Fit for 55” framework through the National Energy and Climate Plan (2021–2030) (Ministry of Economics, 2020). The plan emphasises improving energy efficiency, increasing the use of renewable energy,

and promoting circular economy principles in the construction sector. However, despite this policy alignment, the implementation of low-carbon strategies in Latvia remains limited due to structural and institutional challenges.

A significant proportion of Latvia's residential buildings were constructed before 1990 and are characterised by poor thermal performance (CSB, 2024). As a result, these buildings require high energy input for heating and operation, leading to elevated operational emissions. While operational emissions remain dominant, increasing attention is being directed toward embodied carbon associated with construction materials and processes. Studies indicate that embodied emissions can account for up to 40–50 % of total lifecycle emissions in modern buildings, particularly as operational efficiency improves (Pomponi & Moncaster, 2017; Röck et al., 2020).

The transition toward low-carbon construction is further constrained by limited adoption of life cycle assessment (LCA), insufficient digitalisation, and continued reliance on carbon-intensive materials (Ministry of Economics, 2020). Similar challenges have been identified in Central and Eastern Europe, where financing constraints and fragmented ownership structures hinder large-scale renovation initiatives (Urge-Vorsatz et al., 2013).

Given these challenges, there is a need for a structured and systematic approach to evaluate low-carbon strategies in the Latvian construction sector. This study develops a multi-criteria assessment framework that integrates environmental, economic, and governance dimensions to evaluate the feasibility and impact of selected strategies.

By applying this framework to key strategies: deep energy renovation, industrial prefabrication and modular construction, and circular construction, the study aims to provide practical insights for policymakers and industry stakeholders to support the transition toward a low-carbon built environment.

This study aims to develop and apply a structured multi-criteria framework to assess the effectiveness and feasibility of key low-carbon strategies in the Latvian construction sector. In this context, the research seeks to determine how different approaches, such as deep energy renovation, prefabrication and modular construction, and circular construction, compare in terms of environmental impact, economic feasibility, and governance alignment.

It is assumed that deep energy renovation provides the most significant environmental benefits in Latvia, while prefabrication and circular construction offer complementary advantages but face relatively greater implementation constraints, particularly in economic and institutional dimensions.

The relevance of this study is underscored by the growing urgency to achieve climate neutrality within the EU and Latvia's commitment to the European Green Deal, alongside the significant environmental impact of the construction sector and the current lack of structured evaluation frameworks to support informed decision-making in this field.

1. RESEARCH METHODOLOGY

This study adopts a qualitative research approach supported by a structured multi-criteria evaluation framework to assess low-carbon strategies in the Latvian construction sector. The methodology combines secondary data analysis with comparative evaluation, allowing different strategies to be examined across environmental, economic, and governance dimensions in a consistent manner.

The research is carried out in three stages.

- A review of academic literature, European Union policy documents, and national reports is conducted to establish the theoretical background of low-carbon construction. Particular attention is given to concepts such as life cycle assessment (LCA), operational and embodied carbon, and circular economy principles.
- Three strategies are selected for detailed analysis: deep energy renovation of existing buildings, industrial prefabrication and modular construction, and circular construction focusing on construction and demolition waste management. These strategies are chosen based on their relevance to the Latvian context, their presence in policy frameworks, and their representation in existing research.
- The selected strategies are evaluated using a multi-criteria framework. The evaluation considers environmental performance, economic feasibility, and governance alignment. Environmental performance refers to the potential for reducing emissions and improving energy efficiency, while economic feasibility relates to investment requirements and long-term cost implications. Governance alignment reflects the extent to which each strategy is supported by existing policies, regulatory frameworks, and institutional capacity.

To ensure transparency in the evaluation, each strategy is assessed using a five-point scale ranging from very low to very high performance. This scoring approach allows qualitative observations from secondary data to be translated into a structured comparison. The resulting scores are used to develop a comparative evaluation matrix, which highlights the relative strengths and limitations of each strategy across the three dimensions.

The study focuses on the period between 2015 and 2025, corresponding to the implementation of Latvia's National Energy and Climate Plan and recent European climate policies. The geographical scope is limited to Latvia, although insights from other European contexts are considered where relevant.

The analysis is based entirely on secondary data, including European Union reports, national policy documents, statistical databases such as Eurostat and the Central Statistical Bureau of Latvia, and peer-reviewed academic literature. While this approach enables a broad and policy-relevant assessment, it also introduces certain limitations. In particular, the availability of consistent data on embodied carbon is limited, and the absence of primary data restricts the inclusion of stakeholder perspectives.

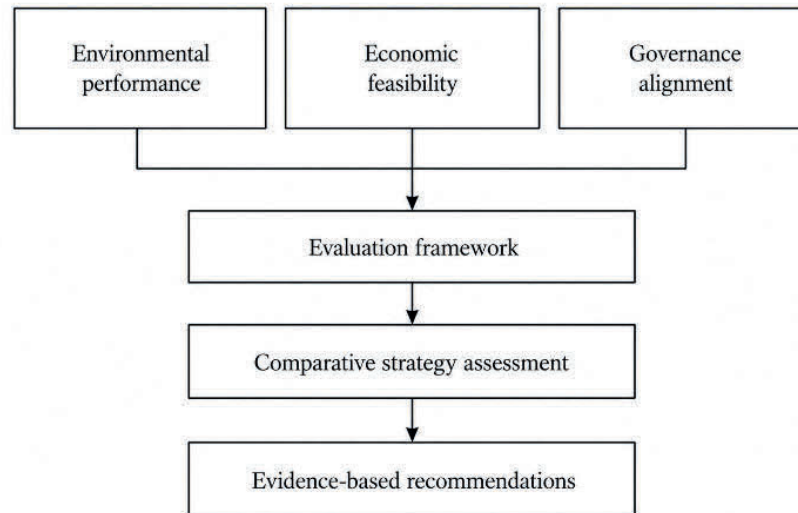


Fig. 1. Multi-criteria evaluation framework for low-carbon strategies.

Figure 1 presents a conceptual multi-criteria evaluation framework that structures the assessment of low-carbon strategies through the integration of environmental, economic, and governance dimensions. It reflects a systems-based approach, where each dimension captures a distinct but interrelated aspect of sustainability. The environmental dimension focuses on the capacity of each strategy to reduce both operational and embodied carbon emissions, improve energy efficiency, and optimise resource use across the building lifecycle. The economic dimension evaluates not only initial investment requirements but also lifecycle cost efficiency, payback periods, and broader economic implications such as productivity gains and market viability. The governance dimension captures the institutional and regulatory context, including policy alignment, availability of incentives, administrative capacity, and the degree of stakeholder coordination required for implementation.

The framework assumes that these dimensions are not independent but interact dynamically. For instance, strong governance support can mitigate economic barriers through subsidies or regulatory facilitation, while economically viable solutions are more likely to achieve widespread adoption and thus deliver greater environmental benefits. Conversely, weak institutional support or market conditions may limit the practical implementation of environmentally effective strategies. The use of a standardized scoring scale enables qualitative information derived from secondary sources to be translated into comparable metrics, facilitating a transparent and systematic comparison across strategies. As such, the framework serves not only as an analytical tool but also as a decision-support mechanism, allowing policymakers and stakeholders to identify trade-offs, prioritise interventions, and design integrated pathways toward low-carbon development in the construction sector.

2. RESULTS AND DISCUSSION

The evaluation of low-carbon strategies in the Latvian construction sector indicates that each approach contributes differently to emission reduction and sustainability objectives. The application of the multi-criteria framework enables a structured comparison across environmental, economic, and governance dimensions, while also highlighting practical challenges that affect implementation.

2.1. Deep Energy Renovation of Existing Buildings

Deep energy renovation emerges as the most effective strategy for reducing operational emissions in Latvia, primarily due to the characteristics of the existing building stock. A significant proportion of residential buildings were constructed before 1990 and exhibit poor thermal performance, resulting in high energy consumption for heating and operation (CSB, 2024; European Commission, 2022).

Evidence from European policy reports indicates that deep renovation can achieve energy savings of approximately 40–60 %, depending on building type and the depth of intervention (European Commission, 2020; BPIE, 2011). These reductions translate directly into substantial decreases in operational carbon emissions. Typical measures include improving insulation, upgrading heating systems, and integrating energy-efficient technologies.

Despite this potential, the rate of renovation remains relatively low. High upfront investment costs and administrative barriers continue to limit large-scale implementation (Ministry of Economics, 2020). From an economic perspective, deep renovation involves significant initial investment; however, lifecycle savings from reduced energy consumption can offset these costs over time. In terms of governance, Latvia benefits from alignment with European climate policies, although coordination challenges between stakeholders and institutional complexity continue to affect implementation.

2.2. Industrial Prefabrication and Modular Construction

Industrial prefabrication and modular construction provide an alternative approach focused on improving construction efficiency and reducing embodied carbon. Prefabrication involves the off-site production of building components, allowing for greater precision, reduced material waste, and shorter construction timelines.

Research indicates that prefabrication improves material efficiency and reduces construction waste through controlled production processes (Akanbi et al., 2019). In addition, the use of low-carbon materials such as timber can significantly reduce lifecycle emissions compared to conventional materials such as concrete and steel, while also providing carbon storage benefits (Röck et al., 2020). This is particularly important given that embodied carbon can account for up to 40–50 % of total lifecycle emissions in modern buildings (Pomponi & Moncaster, 2017; Röck et al., 2020).

From an economic perspective, prefabrication can improve productivity by reducing construction time and labour requirements, which may lead to cost efficiencies in large-scale projects. However, its adoption in Latvia remains limited due to insufficient industrial capacity, a lack of standardised design practices, and challenges in integrating digital technologies.

From a governance perspective, although European policies promote innovative and sustainable construction practices, existing regulatory frameworks and procurement systems are not fully adapted to modular construction methods. As a result, wider adoption requires both technological advancement and regulatory adjustments.

2.3. Circular Construction and Waste Management

Circular construction focuses on improving resource efficiency through waste reduction, reuse, and recycling of materials. This approach is particularly relevant in Latvia, where construction and demolition waste is increasing, and sustainable material management is becoming more important.

Within the EU, recovery rates for construction and demolition waste often exceed 70 %, reflecting significant potential for material reuse and recycling (Eurostat, 2023). Practices such as recycling materials, reusing building components, and designing for disassembly can reduce resource consumption and environmental impact.

Despite these advantages, the implementation of circular construction in Latvia remains constrained. Recycling infrastructure is still developing, and there is limited standardisation in material recovery processes. In addition, market demand for secondary materials remains relatively low, reducing incentives for adopting circular practices.

From an economic perspective, circular construction can reduce material costs over time and create opportunities in the recycling and waste management industries. However, these benefits depend on the development of supporting infrastructure and effective market mechanisms. Governance plays a critical role in enabling this transition, as policy interventions and regulatory frameworks are required to support adoption and ensure consistency.

2.4. Comparative Evaluation of Strategies

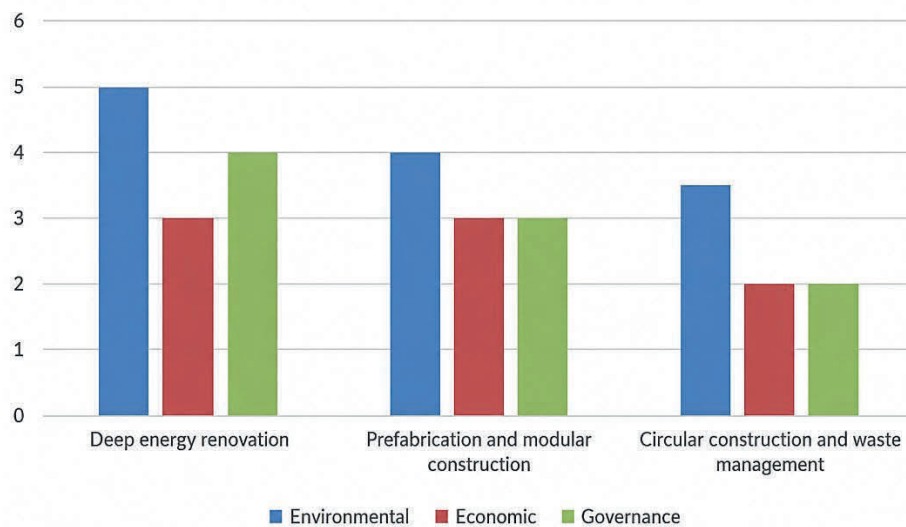
The comparative evaluation highlights that each strategy contributes to decarbonisation at different stages of the building lifecycle. Deep energy renovation primarily addresses operational emissions, while prefabrication focuses on embodied carbon reduction and construction efficiency. Circular construction complements these strategies by enhancing resource efficiency and reducing waste.

The results are presented as a comparative scoring matrix in Table 1, illustrating the relative performance of each strategy across environmental, economic, and governance dimensions.

Table 1. Comparative Evaluation of Low-Carbon Strategies

Strategy	Environmental (1–5)	Economic (1–5)	Governance (1–5)	Justification
Deep energy renovation	5	3	4	High operational emission reduction potential; strong policy support; high upfront cost
Prefabrication and modular construction	4	3	3	Improves material efficiency and reduces embodied carbon; moderate adoption and regulatory alignment
Circular construction	3	2	2	Enhances resource efficiency; constrained by infrastructure and market limitations

The results indicate that deep energy renovation performs strongly in terms of environmental impact and governance alignment, although economic constraints remain significant. Prefabrication demonstrates a more balanced profile across all dimensions, reflecting moderate benefits and moderate implementation challenges. Circular construction, while important for long-term sustainability, currently faces limitations related to infrastructure, market readiness, and policy support.

**Fig. 2.** Visual representation of comparative evaluation of low-carbon strategies.

These findings suggest that no single strategy is sufficient to achieve comprehensive decarbonisation. Instead, an integrated approach is required, combining multiple strategies to address both operational and embodied emissions while improving resource efficiency across the construction lifecycle.

While the comparative evaluation provides a structured assessment of the selected strategies, the results should be interpreted with caution. The analysis is based on secondary data and generalised performance ranges, which may not fully capture project-specific variations or local implementation conditions. In addition, limitations in the availability of consistent data on embodied carbon introduce a degree of uncertainty in the comparative assessment.

CONCLUSIONS

This study assessed the applicability of low-carbon strategies in the Latvian construction sector using a structured multi-criteria evaluation framework. By examining deep energy renovation, prefabrication and modular construction, and circular construction across environmental, economic, and governance dimensions, the study provides a comparative understanding of their relative performance.

The findings indicate that deep energy renovation offers the most significant potential for reducing operational emissions, particularly in the context of Latvia's ageing building stock. However, its implementation remains constrained by high upfront investment costs and administrative barriers. Prefabrication and modular construction demonstrate a more balanced performance, contributing to improved construction efficiency and reduced embodied carbon, although their adoption is limited by industrial capacity and regulatory readiness. Circular construction supports long-term resource efficiency and waste reduction, but is currently restricted by underdeveloped infrastructure and limited market demand for secondary materials.

The comparative assessment highlights that no single strategy is sufficient to achieve comprehensive decarbonisation. Instead, a coordinated approach is required, combining renovation efforts with material-efficient construction practices and circular economy principles to address both operational and embodied emissions across the building lifecycle.

From a policy perspective, the findings emphasise the need for integrated measures across financial, regulatory, and institutional domains. Strengthening financial support for renovation, adapting regulatory frameworks to facilitate innovative construction methods, and improving infrastructure for material recovery are key priorities for advancing low-carbon construction in Latvia.

This study contributes to the literature by providing a structured and context-specific evaluation of low-carbon strategies using a transparent comparative framework. However, the analysis is limited by its reliance on secondary data and the use of generalised performance ranges, which may not fully capture project-level variations. Future research could address these limitations by incorporating empirical data, refining evaluation criteria, and exploring the application of more advanced decision-support methods.

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