THE IMPORTANCE OF INNOVATIVE APPROACHES IN BUILDING MATERIALS MANUFACTURING ENTERPRISES

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Abstract

This article examines why innovative approaches are a decisive factor in the competitiveness, efficiency and sustainability of enterprises that manufacture building materials, with particular reference to the rapidly expanding industry of the Republic of Uzbekistan. The study combines a structured review of the innovation-management and construction-materials literature with secondary analysis of official statistics (National Statistics Committee of Uzbekistan, the Uzsanoatqurilishmateriallari Association, the Ministry of Investment, Industry and Trade) and international benchmarks (McKinsey Global Institute, IEA-based estimates, peer-reviewed materials science). A four-dimensional analytical framework – product, process, organisational and ecological innovation – is used to classify and evaluate innovation options. Uzbekistan's cement output nearly doubled from 11.0 million tonnes in 2021 to 21.5 million tonnes in 2025, and total building-materials output reached 45.7 trillion soums in January–October 2025. Growth, however, has been driven mainly by capacity expansion rather than by productivity or technological upgrading. The evidence indicates that process and ecological innovations – clinker substitution (e.g. limestone calcined clay cement, which cuts

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CO2 by about 40%), waste-heat recovery, alternative fuels and digital process control – offer the largest combined economic and environmental returns. Organisational innovation and human-capital development are the main enabling conditions.

The article links global innovation evidence to the specific growth trajectory of a transition economy and proposes a staged innovation roadmap and policy recommendations for building-materials enterprises.

Keywords: innovation management; building materials industry; cement; Industry 4.0; low-carbon materials; circular economy; competitiveness; Uzbekistan.

1. Introduction

The building materials industry is a foundational sector of every national economy. It supplies cement, concrete, ceramics, glass, gypsum products, insulation and wall materials to housing, infrastructure and industrial construction, and therefore transmits its efficiency – or inefficiency – to the entire investment cycle. At the same time, the sector is among the most resource- and energy-intensive branches of manufacturing. Cement production alone is estimated to account for roughly 5–8% of global anthropogenic CO2 emissions, largely because of the calcination of limestone and the high-temperature combustion required to produce clinker [3; 7].

The wider construction value chain has also been notoriously slow to innovate. The McKinsey Global Institute found that global labour-productivity growth in construction averaged only about 1% per year over two decades, against 2.8% for the world economy and 3.6% for manufacturing [10]. Closing this gap was estimated to be worth about USD 1.6 trillion of additional value added annually. These two facts – a heavy environmental footprint and weak productivity growth – make innovation not an optional strategy but a structural necessity for building-materials enterprises.

The Republic of Uzbekistan provides an instructive case. Since 2017 the state has pursued a deliberate policy of expanding domestic production of construction

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materials, beginning with Presidential Resolution PP-4198 of 20 February 2019 on the radical improvement and comprehensive development of the building-materials industry [14] and a follow-up resolution of May 2019 on accelerating the sector's development [15]. Output has since grown at a remarkable pace: cement production reached 21.5 million tonnes in 2025, produced by 42 plants with a combined capacity of 40.5 million tonnes [12]. A presidential decree that entered into force in December 2025 set an annual output target of 62 trillion soums and an export target of USD 1.5 billion, and earmarked 100 billion soums per year from 2026 for artificial intelligence and digital technologies in the industry [16].

Rapid quantitative growth, however, raises a qualitative question. Capacity expansion based on imported, conventional technology can raise volumes quickly, but it does not by itself secure long-term competitiveness, export readiness or compliance with tightening environmental requirements, such as carbon border adjustment mechanisms in key export markets. The research gap addressed here is the limited body of work that systematically connects international innovation evidence in building materials with the concrete development trajectory of a fast-growing transition economy.

Accordingly, the **aim** of this article is to substantiate the importance of innovative approaches for building-materials manufacturing enterprises and to identify the innovation directions with the greatest economic and environmental impact.

2. Literature Review

2.1 Innovation as a driver of enterprise competitiveness

The modern understanding of innovation originates with Schumpeter, who described economic development as a process of "new combinations": new products, new methods of production, new markets, new sources of supply and new forms of

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organisation [1]. This typology remains the backbone of contemporary measurement. The Oslo Manual of the OECD and Eurostat defines a business innovation as a new or improved product or business process that differs significantly from the firm's previous ones and has been introduced to the market or brought into use [2]. It distinguishes product innovations from business-process innovations, the latter covering production methods, logistics, information systems, organisation and marketing.

Organisational research confirms that innovation is multidimensional. Damanpour's meta-analysis showed that the determinants of innovation – specialisation, managerial attitude toward change, technical knowledge resources, slack resources and external communication – differ in strength across innovation types and organisations [19]. Rogers' diffusion theory adds that adoption depends on an innovation's relative advantage, compatibility, complexity, trialability and observability [6]. These attributes help explain why some technologies spread rapidly in heavy industry while others stall despite clear benefits.

The dynamic-capabilities perspective links innovation to sustained advantage. Teece argues that firms prosper in changing environments when they can sense opportunities, seize them through investment, and reconfigure assets and routines accordingly [5]. For capital-intensive building-materials plants, whose kilns, furnaces and presses have service lives of several decades, the capacity to reconfigure is especially important because technological lock-in is costly.

2.2 Environmental pressure as a trigger of innovation

Porter and van der Linde advanced the hypothesis that well-designed environmental regulation can stimulate innovations that partly or fully offset compliance costs, improving both resource productivity and competitiveness [4]. The building-materials sector is a strong test of this hypothesis. Andrew estimated global

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process emissions from cement at about 1.5 Gt CO2 in 2016–2017, roughly 4% of fossil-fuel emissions, and noted that energy-related emissions could add a further 60%, bringing the industry's total to as much as 8% of global CO2 emissions [3]. Lehne and Preston similarly concluded that deep decarbonisation of cement requires simultaneous progress in energy efficiency, fuel switching, clinker substitution, novel cements and carbon capture [7].

Materials science has produced commercially viable responses. Scrivener, John and Gartner showed that reducing the clinker factor through supplementary cementitious materials is the most realistic short-to-medium-term route to large CO2 reductions [8]. Limestone calcined clay cement (LC3), which combines roughly 50% clinker with calcined clay, limestone and gypsum, achieves mechanical performance equivalent to ordinary Portland cement, better chloride resistance and approximately 40% lower CO2 emissions, at a cost competitive with conventional cement [9]. Habert and colleagues add that the greatest mitigation potential lies across the whole value chain – from clinker and binder to concrete mix design, structural design and end-of-life recycling [18].

2.3 Digitalisation and Industry 4.0

The Industrie 4.0 concept describes cyber-physical production systems in which machines, products and people are connected through sensors, data platforms and automated decision-making [11]. In building-materials plants, typical applications include advanced process control of kilns and mills, predictive maintenance, automated quality control, energy management systems and digital twins of production lines. The McKinsey Global Institute identified digital technology, new materials and advanced automation as three of seven levers that together could raise construction-sector productivity by 50–60% [10].

2.4 Circular economy

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The circular economy reframes waste as a resource. Geissdoerfer et al. define it as a regenerative system in which resource input, waste, emissions and energy leakage are minimised by slowing, closing and narrowing material and energy loops [20]. In building materials this includes co-processing of industrial and municipal waste as alternative fuels, the use of slag, fly ash and recycled aggregates, and the recovery of waste heat for electricity generation.

2.5 Research gap

The literature offers a well-developed theory of innovation and abundant technical evidence on low-carbon and digital solutions. Yet most empirical work concerns mature markets in Europe, North America, China and India. Far fewer studies examine how these innovations should be prioritised in transition economies where the industry is expanding rapidly, capacity is new and institutional support is evolving. This article addresses that gap for Uzbekistan.

3. Materials and Methods

3.1 Research design

The study follows a qualitative-dominant mixed-methods design combining three components: (1) a structured literature review; (2) secondary statistical analysis of the building-materials industry of Uzbekistan; and (3) comparative evaluation of innovation directions using a multi-criteria framework. This design suits the exploratory and explanatory aims of the research, where the purpose is to establish the significance of innovation and to prioritise options rather than to test a single causal hypothesis.

3.2 Literature review procedure

Sources were identified in Scopus, Web of Science, Google Scholar and institutional repositories using combinations of the keywords *innovation*, *building materials*, *cement*, *low-carbon*, *clinker substitution*, *Industry 4.0*, *digitalisation*,

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circular economy and *productivity*. Inclusion criteria were: peer-reviewed articles, foundational monographs, or reports by recognised international organisations; direct relevance to innovation in building-materials manufacturing or the construction value chain; and transparent methodology. Grey literature without identifiable authorship or data was excluded.

3.3 Statistical data

Quantitative data on Uzbekistan were drawn from the National Statistics Committee (stat.uz), the Uzsanoatqurilishmateriallari Association, the Ministry of Investment, Industry and Trade's investment guide, and specialist industry reporting that cites official statistics. The indicators analysed include cement output (2021–2025), ready-mix concrete output, total industry output value, exports, investment projects commissioned and installed capacity. Normative documents – presidential resolutions and decrees on the development of the industry – were analysed through document analysis to identify the policy instruments that support innovation.

Growth dynamics were assessed with standard indicators. The average annual growth rate over a period of *n* years was calculated as the compound annual growth rate:

$$CAGR = (Q_t / Q_0)^{1/n} - 1 \qquad (1)$$

where Q0 and Qt are output in the base and final years. Capacity utilisation was calculated as the ratio of actual annual output to installed annual capacity.

3.4 Analytical framework

Innovation options were classified along four dimensions derived from the Oslo Manual [2] and the environmental-innovation literature [4; 8] (Table 1).

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Table 1. Analytical framework: dimensions of innovation in building-materials enterprises

Dimension	Content in building-materials enterprises	Example solutions
Product innovation	New or substantially improved materials with better performance or lower footprint	Blended and LC3 cements, aerated concrete, composite basalt rebar, energy-efficient glass, dry mixes
Process innovation	New production technologies and methods	Dry-process kilns, vertical roller mills, waste-heat recovery, advanced process control
Organisational innovation	New management practices, business models and cooperation	Lean production, R&D units, university–industry clusters, digital sales channels
Ecological (circular) innovation	Reduced resource use, emissions and waste	Alternative fuels, industrial by-products as raw materials, recycled aggregates, carbon accounting

Each direction was then evaluated qualitatively against four criteria: economic effect (cost and productivity), environmental effect (CO2 and resource use), investment requirement, and implementation readiness under current conditions in Uzbekistan. Ratings (high, medium, low) are based on effect sizes reported in the reviewed literature and on the availability of raw materials, technology and skills in the country.

3.5 Limitations of the method

The study relies on secondary data. Enterprise-level indicators of innovation activity (R&D spending, share of new products in sales, patents) are not published in a consistent form for the Uzbek building-materials industry, so innovation intensity is inferred from production, investment and policy data. The multi-criteria ratings are

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expert-based judgements grounded in the literature, not results of a statistical model. These limitations are revisited in Section 5.

4. Results

4.1 Growth dynamics of the building-materials industry in Uzbekistan

The industry of Uzbekistan has entered a phase of accelerated expansion. Cement, the sector's core product, illustrates the pattern most clearly (Figure 1).

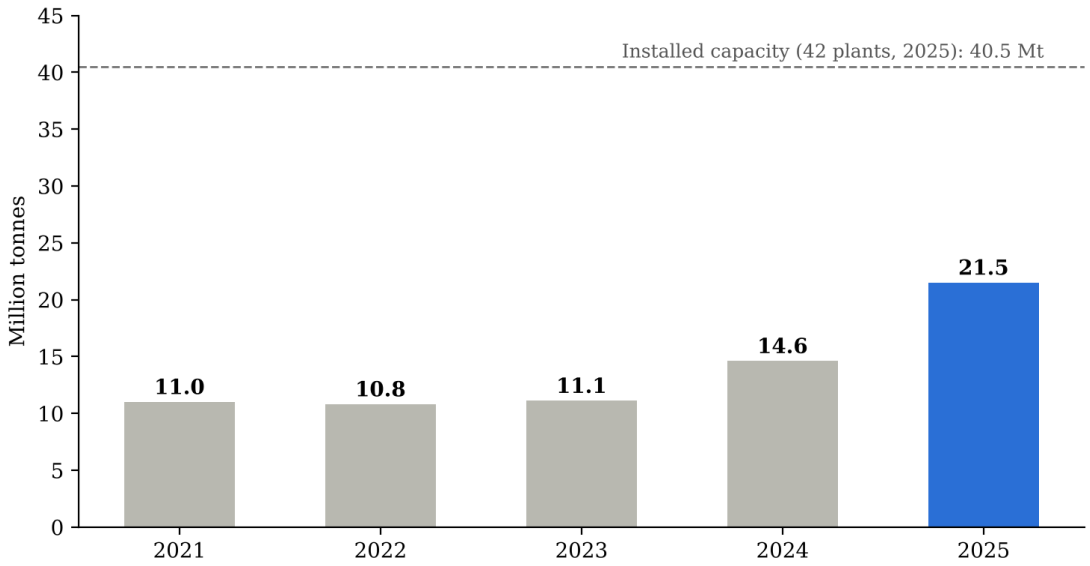


Figure 1. Portland cement output in Uzbekistan, 2021–2025, million tonnes

Sources: CemNet citing the National Statistics Committee (2021–2024) [17]; Ministry of Investment, Industry and Trade (2025 output and capacity) [12].

Cement output was essentially flat in 2021–2023 at about 11 million tonnes, then rose by roughly 31% in 2024 and by a further 47% in 2025. Applying formula (1) to 2021–2025 gives a compound annual growth rate of about 18%. In 2025, however, the 21.5 million tonnes produced represented only about 53% of the 40.5 million tonnes of installed capacity [12], and in 2024 the ratio was near 36% against a capacity of about 40.8 million tonnes [22].

Table 2 summarises the main indicators of the wider industry.

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Table 2. Key indicators of the building-materials industry of Uzbekistan, 2025

Indicator	Value	Source
Industry output, January–October 2025	45.7 trillion soums (113.5% of the prior-year period)	[13]
Expected industry output, full year 2025	52 trillion soums	[21]
Exports, January–September 2025	USD 810.2 million	[21]
Expected investment, 2025	USD 2.4 billion	[21]
New investment projects commissioned, 2025	353 projects worth USD 1.8 billion	[12]
Cement plants / installed capacity	42 plants / 40.5 million t per year	[12]
Ready-mix concrete, January–July 2025	1.95 million t (+27.7% year on year)	[23]
Policy target (decree of December 2025)	Output 62 trillion soums; exports USD 1.5 billion	[16]

Export growth in 2025 came mainly from aluminium building products, ceramics, stone products, glass, cement and binders, particle and MDF boards, and PVC and plastic products [21]. This shows that the product range has started to diversify beyond basic binders toward higher value-added finished materials.

4.2 Policy instruments supporting innovation

Document analysis identified a consistent sequence of state measures. Resolution PP-4198 (February 2019) launched the comprehensive modernisation of the industry [14]. The May 2019 resolution set target parameters to 2025, including a doubling of cement output and multiple-fold growth of aerated concrete blocks (about 7 times) and composite basalt reinforcement (about 3 times), and attracted at least USD 500 million of preferential credit lines for 2019–2021 [15]. It also introduced new university training specialisations in building-materials technology. The

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December 2025 decree added a dedicated annual allocation of 100 billion soums from 2026 for artificial intelligence and digital technologies, a requirement that publicly funded projects use at least 80% domestic materials, and the preparation of an official list of environmentally friendly, resource- and energy-efficient materials [16].

4.3 Comparative evaluation of innovation directions

Applying the framework of Section 3.4 produced the evaluation in Table 3.

Table 3. Evaluation of innovation directions for building-materials enterprises in Uzbekistan

Innovation direction	Dimension	Economic effect	Environmental effect	Invest-ment need	Readiness in Uzbekistan
Clinker substitution (blended cements, LC3)	Product / ecological	High: lower clinker and fuel cost	High: about 40% less CO2 for LC3 [9]	Low–medium	High: large limestone and clay reserves
Advanced process control and energy management	Process / digital	High: fuel and power savings	Medium	Medium	Medium: needs data infrastructure and skills
Waste-heat recovery power generation	Process	High: on-site electricity	Medium	High	Medium
Alternative fuels and co-	Ecological / circular	Medium	Medium–high	Medium	Low–medium: waste

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Innovation direction	Dimension	Economic effect	Environmental effect	Invest-ment need	Readiness in Uzbekistan
processing of waste					collection and regulation
Predictive maintenance and automated quality control	Process / digital	Medium–high: less downtime, stable quality	Low–medium	Medium	Medium
New finished materials (aerated concrete, basalt rebar, energy-efficient glass)	Product	High: import substitution and exports	Medium	Medium–high	High: supported by targets [15]
R&D units and university–industry clusters	Organisational	Medium (long term)	Indirect	Low	Medium: training programmes exist
Carbon accounting and product certification	Organisational / ecological	Medium: export market access	Indirect	Low	Low–medium

Two directions combine high economic and high environmental effects with good readiness: clinker substitution and new finished materials based on local raw materials. Digital process control and waste-heat recovery offer strong returns but

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depend on investment, data infrastructure and skills. Organisational innovations require modest investment but act mainly as enablers of the others.

5. Discussion

5.1 From extensive to intensive growth (RQ1, RQ2)

The results show that the recent expansion of Uzbekistan's building-materials industry has been predominantly extensive. Output growth followed a large wave of capacity commissioning, and capacity utilisation of about 53% in 2025 indicates that physical capacity has run ahead of effective demand and of the industry's ability to sell competitively in export markets. In terms of Schumpeter's typology [1], the industry has so far relied mainly on "new sources of supply" and new plants rather than on new methods of production or new products.

This pattern is typical of the early catch-up phase of transition economies, and it was an appropriate response to the import dependence of the late 2010s. But international evidence suggests that extensive growth has diminishing returns. The persistent productivity gap of the construction value chain documented by the McKinsey Global Institute [10] shows that volume growth without technological upgrading locks enterprises into low margins and high exposure to energy prices. With much of the new capacity based on standard imported equipment, the competitive differentiation of Uzbek producers will increasingly depend on how they operate plants, what products they make and how clean their production is – that is, on innovation.

Low utilisation also changes the economics of innovation. When plants are not capacity-constrained, the payoff from building new lines falls, while the payoff from process innovation that lowers unit cost, and from product innovation that opens new market segments, rises. Underused capacity therefore strengthens rather than weakens the case for an innovation-led strategy.

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5.2 Why process and ecological innovations should come first (RQ3)

The comparative evaluation (Table 3) identifies clinker substitution as the direction with the strongest combined effect. This is consistent with the conclusion of Scrivener et al. that supplementary cementitious materials are the most realistic route to large-scale CO2 reductions in the short to medium term [8], and with the finding that LC3 delivers about 40% lower emissions at equivalent performance and competitive cost [9]. For Uzbekistan the argument is strengthened by local conditions: the country's substantial limestone reserves [12] and widely available clays reduce raw-material risk, and because LC3 can be produced with existing equipment, the investment barrier is low.

The environmental argument has become an economic one. Under the Porter hypothesis [4], environmental constraints stimulate innovations that improve resource productivity. For an industry whose policy target is USD 1.5 billion of exports [16], the carbon intensity of products is becoming a condition of market access, as carbon border adjustment mechanisms in the European Union and carbon-disclosure requirements of international buyers expand. Enterprises that build carbon accounting and low-clinker product lines now will avoid costly retrofits later.

Digital process innovations – advanced process control, energy management and predictive maintenance – form the second priority. Their returns depend on data infrastructure and skills, which explains their medium readiness rating. The dedicated state allocation of 100 billion soums per year for AI and digital technologies [16] can lower this barrier if it is directed to pilot projects with measurable outcomes, such as specific fuel consumption per tonne of clinker or kiln availability, and if results are shared across enterprises to improve the observability of benefits that Rogers identifies as decisive for diffusion [6].

5.3 Organisational innovation as the enabling condition

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Technical innovations do not diffuse automatically. Damanpour's evidence that technical knowledge resources, managerial attitudes toward change and external communication are strong determinants of innovation [19], together with Teece's emphasis on the ability to sense, seize and reconfigure [5], suggests that the binding constraint for many Uzbek enterprises is organisational. Most new plants were built to produce standard products efficiently, not to develop new ones. Few have dedicated R&D or technology units, and cooperation with universities remains at an early stage, even though specialised training programmes were introduced after 2019 [15].

Three organisational innovations appear particularly important: (1) small in-house technology and quality units responsible for mix optimisation, testing and process data analysis; (2) industry–university consortia, for example around the national engineering and polytechnic institutes, for applied research on local raw materials and alternative binders; and (3) shared testing and certification infrastructure that allows smaller producers to prove the performance of new products to designers and public clients.

5.4 Synthesis: a staged innovation roadmap

The findings can be combined into a three-stage roadmap for building-materials enterprises:

1. **Stage 1 (1–2 years): efficiency and quick wins.** Energy audits, energy management systems, optimisation of grinding and kilns, introduction of blended cements within existing standards, basic production data collection.
2. **Stage 2 (2–4 years): product and digital upgrading.** Industrial-scale LC3 and other low-clinker cements, expansion of finished high value-added materials, advanced process control, predictive maintenance, carbon accounting and environmental product declarations.

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3. **Stage 3 (4–7 years): structural transformation.** Waste-heat recovery and alternative-fuel systems, industrial symbiosis with metallurgy and energy (slag, fly ash, waste), digital twins of plants, and preparation for carbon capture where economically justified.

The sequencing reflects the readiness ratings: early stages emphasise low-investment, high-readiness measures that generate cash flow and capabilities for later, capital-intensive stages.

5.5 Comparison with previous studies and limitations

The conclusions agree with international studies that rank clinker reduction and energy efficiency as the most cost-effective decarbonisation levers [7; 8; 18]. They extend that literature by showing that, in a transition economy with new and underused capacity, these levers also serve as the main route from extensive to intensive growth. The study has limitations. It relies on secondary and aggregate data, and the multi-criteria ratings are judgement-based. Future research should collect enterprise-level data – through surveys aligned with the Oslo Manual [2] – on R&D expenditure, the share of new products in sales, energy intensity and CO2 intensity, allowing econometric testing of the link between innovation activity and enterprise performance in Uzbekistan.

6. Conclusion and Recommendations

This study set out to substantiate the importance of innovative approaches for building-materials manufacturing enterprises. Its main conclusions are as follows.

First, innovation is a structural necessity for the sector, not an optional strategy. The industry's heavy environmental footprint – cement alone accounts for an estimated 5–8% of global CO2 emissions – and the long-standing productivity gap of the construction value chain mean that enterprises relying only on volume growth will face rising cost, regulatory and market-access pressures.

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Second, the building-materials industry of Uzbekistan has achieved impressive extensive growth. Cement output nearly doubled from 11.0 to 21.5 million tonnes between 2021 and 2025, and industry output reached 45.7 trillion soums in the first ten months of 2025. Yet utilisation of about 53% of installed cement capacity shows that further gains must come from intensive, innovation-driven development rather than from new capacity.

Third, the innovation directions with the greatest combined economic and environmental effect are clinker substitution (especially LC3 based on local limestone and clay), new high value-added finished materials, digital process control and energy management, and waste-heat recovery. Organisational innovation – technology units, university–industry cooperation and shared testing infrastructure – is the enabling condition for all of them.

On this basis the following recommendations are proposed.

For enterprises:

1. Adopt a formal innovation strategy with measurable indicators: specific energy and fuel consumption per tonne, clinker factor, CO2 intensity, share of new products in sales.
2. Introduce blended and low-clinker cements, beginning with pilot batches of LC3 and certification under applicable standards.
3. Establish in-house technology and quality units, and build production data systems as the basis for advanced process control and predictive maintenance.
4. Implement carbon accounting and environmental product declarations to prepare for export markets with carbon requirements.

For policymakers and industry associations:

1. Direct the annual state allocation for AI and digital technologies to competitive, outcome-based pilot projects whose results are published for the whole industry.

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2. Update technical standards and public procurement rules so that low-clinker and other low-carbon materials, once certified, can be specified in publicly funded projects, linking the 80% local-content rule to performance and environmental criteria.
3. Support industry–university research consortia on local raw materials, alternative binders and industrial by-products, and expand shared testing and certification laboratories.
4. Develop regulation and logistics for collecting industrial and municipal waste as alternative fuels and raw materials.

The practical value of the study lies in its staged roadmap, which allows enterprises to sequence innovation from low-investment efficiency measures to structural transformation. Its theoretical contribution lies in showing that, in a transition economy with new and underused capacity, low-carbon and digital innovations are also the primary mechanism for moving from extensive to intensive growth. Further research based on enterprise-level survey data is needed to quantify these relationships.

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