REGULATORY AND INSTITUTIONAL DRIVERS OF GREEN CEMENT ADOPTION IN INDONESIA

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Abstract

The transition toward low-carbon construction materials is essential for achieving decarbonization target, yet adoption of green cement remains limited in many developing countries. This study aims to examine how regulatory and institutional misalignment affects the adoption of green cement in Indonesia's construction sector. Using a mixed-method approach combining eight in-depth stakeholder interviews, a perception survey of 51 respondents, and regulatory document analysis, the research identifies key structural and institutional barriers influencing adoption. The findings reveal strong coercive pressures on cement producers to decarbonize, contrasted by the absence of mandatory requirements, technical guidelines, and procurement incentives for cement consumers, such as contractors and public project owners. Despite high stakeholder awareness and conditional readiness to adopt green cement, limited trialability, performance validation, and policy alignment constrain diffusion. To address these gaps, the study proposes four integrated interventions: a structured national pilot program, a green public procurement framework, national technical guidelines for green cement application, and ecosystem-wide capacity-building initiatives. The study contributes to sustainability transition and policy adoption literature by highlighting regulatory asymmetry as a central constraint and offers policy-relevant recommendations for accelerating low-carbon construction materials in Indonesia and comparable emerging economies.

Keywords: *green cement, low-carbon construction, policy alignment, institutional theory, diffusion of innovation*

Introduction

The cement industry is one of the most carbon-intensive industrial sectors worldwide, contributing approximately 6–10% of global anthropogenic CO_2 emissions due to both calcination processes and energy consumption (Imbabi et al., 2012; Naqi & Jang, 2019) In response to increasing climate change concerns, governments have strengthened regulatory frameworks to reduce emissions from cement production and promote the use of low-carbon construction materials. In Indonesia, this policy direction is reflected in several national regulations, including Presidential Regulation No. 98/2021 on Carbon Economic Value and Government Regulation No. 20/2020 mandating Continuous Emission Monitoring Systems, which together impose strong decarbonization obligations on cement producers.

These regulatory pressures have encouraged technological innovation within the Indonesian cement industry. Producers have developed various forms of green cement, particularly blended cements that incorporate supplementary cementitious materials such as fly ash, slag, calcined clay, and silica fume. Previous studies

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indicate that such products can reduce CO_2 emissions by approximately 13–22% compared to conventional Ordinary Portland Cement, depending on material composition and production processes (Kanagaraj et al., 2023; Olsson et al., 2024). From a technological perspective, green cement is therefore increasingly viable and available in the Indonesian market.

Despite this supply-side readiness, the adoption of green cement in Indonesia's construction sector remains limited. Public and private construction projects continue to rely predominantly on conventional cement, indicating a persistent gap between technological availability and market uptake. This situation suggests that technological feasibility alone is insufficient to drive adoption and that regulatory and institutional factors play a critical role in shaping adoption outcomes.

Existing policy and innovation studies emphasize that adoption is strongly influenced by the alignment of regulatory instruments, institutional incentives, and actor expectations. Policy adoption is an iterative and negotiated process rather than a purely top–down mechanism, and misalignment between policy objectives and implementation instruments often leads to weak or fragmented outcomes (Colebatch et al., 2010; Howlett et al., 2025). In the Indonesian cement sector, cement producers are subject to binding environmental regulations, while contractors, developers, and public procurement agencies face no equivalent obligations or incentives to adopt low-carbon materials. This regulatory asymmetry creates a structural barrier that constrains the diffusion of green cement.

From an innovation perspective, diffusion depends on factors such as compatibility with existing construction practices, opportunities for trialability, and observability of performance outcomes (Rogers, 1995). In risk-averse construction systems, the absence of pilot projects, standardized application guidelines, and validated performance evidence can significantly delay adoption. Institutional theory further highlights the role of coercive, normative, and mimetic pressures in shaping organizational behavior. While coercive pressures on Indonesian cement producers are strong, normative and mimetic pressures on material users remain weak, limiting demand-side momentum for green cement adoption.

Although prior studies have examined green cement technologies and broader sustainability transitions, empirical research has largely focused on technological performance, life-cycle impacts, and production-side innovation. Recent studies identify technical uncertainties and the lack of standardized application guidelines as key barriers to adoption (Akter & Hawas, 2025), while others highlight those national strategies for decarbonizing cement, such as carbon capture or clinker substitution, vary significantly depending on local regulatory and economic contexts (Guo et al., 2024). Research in emerging economies further emphasizes the importance of frugal and cost-efficient innovation to improve affordability and feasibility of low-carbon materials (Ebolor et al., 2022).

However, despite these contributions, limited empirical research has examined how regulatory asymmetry and institutional misalignment between supply-side cement producers and consumers jointly constrain green cement adoption in developing countries, particularly Indonesia. Existing studies give comparatively less attention to demand-side governance mechanisms, procurement structures, and institutional pressures that shape adoption decisions at the project level. This study addresses this gap by integrating policy adoption theory, diffusion of innovation theory, and institutional theory to analyze the regulatory and

institutional barriers affecting green cement adoption in Indonesia and to propose evidence-based mechanisms for accelerating diffusion.

Accordingly, this study aims to analyze how regulatory and institutional misalignment influences the adoption of green cement in Indonesia's construction sector and to identify evidence-based mechanisms for accelerating its adoption. Using a mixed-method approach that combines stakeholder interviews, perception surveys, and regulatory analysis, the study provides empirically grounded insights and proposes policy-relevant solutions to support Indonesia's transition toward sustainable construction materials.

Research Methodology

This study employs a mixed-method research design to examine regulatory, institutional, and innovation-related factors influencing the adoption of green cement in Indonesia's construction sector. A mixed-method approach is appropriate for sustainability transition and policy research, where complex governance dynamics require both qualitative depth and quantitative support to capture institutional processes, stakeholder perceptions, and regulatory contexts (Creswell & Plano Clark, 2018). By integrating qualitative interviews, a perception-based survey, and secondary regulatory analysis, the study enables methodological triangulation and strengthens the robustness of findings.

Data Collection Methods

1. Primary Data

Primary data were obtained through two complementary methods.

a. In-Depth Interviews (IDI)

Eight in-depth interviews were conducted with key stakeholders representing different roles within the green cement ecosystem, including government regulators, cement producers, contractors or developers, professional associations, and academic experts. Informants were selected using purposive sampling to ensure that participants possessed direct experience and institutional knowledge relevant to policy adoption, innovation diffusion, and regulatory implementation.

The sample size for interviews is consistent with qualitative and policy-oriented research, which prioritizes analytical depth and thematic saturation over statistical representativeness. Methodological studies indicate that thematic saturation in focused qualitative research is commonly achieved within 6–12 interviews when the research scope is clearly defined and participants share comparable levels of expertise (Guest et al., 2006; Creswell & Poth, 2018). Accordingly, eight interviews were sufficient to capture recurring themes related to regulatory asymmetry, institutional pressures, and adoption barriers.

Purpose of this in-depth interview is to explore stakeholder perspectives on policy adoption and diffusion barriers, to uncover institutional, technical, and regulatory challenges and to form the qualitative foundation for triangulation with survey findings

Interviews were conducted either face-to-face or via online platforms, lasted approximately 45–60 minutes, and were audio-recorded with the consent of participants. All interviews were transcribed verbatim prior to analysis.

b. Perception Survey

An online survey (Google Forms) was administered using quota purposive sampling, targeting 30–50 respondents across stakeholder groups: Government/ regulators; Cement producers, Contractors/ developers; Professional associations Academics/ researchers.

The instrument contained Likert-scale (1–5) statements covering: Policy and regulatory coherence; Innovation attributes (performance,

compatibility, trialability); and Institutional pressures (regulatory, normative, mimetic).

The survey also included open-ended questions on perceived barriers, policy support needs and Pilot project recommendations.

A total of 51 valid responses were collected. For exploratory and explanatory mixed-method research, such sample sizes are considered appropriate for descriptive analysis and triangulation rather than statistical inference or population generalization (Creswell & Plano Clark, 2018). The survey was designed to complement qualitative findings by identifying perception trends across stakeholder groups and enhancing analytical robustness through integration with interview results.

Purpose of this survey is to quantify perceptions related to policy gaps and innovation attributes; to complement qualitative findings with measurable trends and to enhance validation and robustness via mixed-method triangulation.

2. Secondary Data

Secondary data were collected from national regulations, ministerial decrees, Indonesian National Standards (SNI), sustainability reports from major cement producers, and peer-reviewed academic literature related to green cement, life-cycle assessment, and sustainable construction policy. These sources provided contextual grounding, supported validation of primary data findings, and enabled cross-verification of regulatory and institutional patterns.

Ethical Considerations

Ethical considerations were observed throughout the research process. All interview participants were informed of the study objectives and provided informed consent prior to participation. Participant identities were anonymized, and all data were treated confidentially and used exclusively for academic research purposes.

Data Analysis Method

1. Qualitative Data Analysis

Interview transcripts and document reviews were analyzed through thematic analysis, using the following steps:

a. Familiarization, reading transcripts and notes
b. Coding, identifying key statements and grouping them into sub-themes
c. Theme development, clustering codes under theoretical categories: Policy adoption; Diffusion of innovation; Institutional pressures.
d. Interpretation, synthesizing themes to understand regulatory and institutional barriers

Coding was performed manually using Excel/NVivo. Patterns were compared across stakeholder groups to identify alignment and divergence.

2. Quantitative Data Analysis

Survey results were analyzed using descriptive statistics, including: Frequency distribution; Mean and standard deviation and Cross-tabulation of stakeholder differences. Open-ended responses were qualitatively coded to triangulate quantitative findings. Because the goal was thematic triangulation, not statistical inference, the sample size was appropriate for mixed-method synthesis.

To illustrate numerical analysis, Equation (1) presents the average response formula used:

$$C_i = \frac{\sum_{n=1}^{N_i} X_n}{N_i} \tag{1}$$

where:

C_i = average response score of groups i
X_n = response value of respondent n
N_i = total respondents in group i

3. Validity, Reliability, and Triangulation

To enhance validity and reliability, the study employed methodological triangulation by

integrating multiple data sources and methods, including interviews, surveys, and secondary data analysis (Denzin, 1978). Findings from different sources were systematically compared to reinforce interpretations and reduce single-source bias. The use of theory-driven coding further strengthened analytical consistency and reliability across qualitative and quantitative components.

Result

This section presents the empirical findings derived from the perception survey (N = 51), in-depth interviews (N = 8), and secondary regulatory analysis. Results are summarized to highlight key patterns across policy adoption, innovation attributes, institutional pressures, and readiness to adopt green cement in Indonesia.

Respondent Demographics

A total of 51 survey participants and eight interview informants contributed to this study, representing cement producers, contractors, regulators, associations, and academia. Table 1 summarizes the survey respondent profile.

Table 1. Respondent Profile (N = 51)

Variable	Category	n	%
Organization type	Academia/Research	4	8
	Association	1	2
	Cement Industry	25	49
	Contractor/Developer	13	25
	Government/Regulator	8	16
Years of experience	<3 years	11	22
	3–5 years	13	25
	6–10 years	4	8
	>10 years	23	45
Familiarity with green cement (1–5)	Mean (SD)	4.27	—
Experience in green/low-carbon material projects	Yes	33	65
	No	18	35

The demographic distribution reflects a balanced ecosystem representation, with nearly half from the cement industry (supply side) and the rest from contractors, regulators, and academic actors (demand and institutional sides). The high familiarity score (M = 4.27) indicates that respondents possess adequate knowledge to assess green cement adoption challenges.

Interview participants consisted of senior technical staff, policy experts, association representatives, and engineers involved in major infrastructure projects. Combined, the demographic profile establishes a strong foundation for credible triangulation.

Quantitative Findings

1. Policy Adoption and Regulatory Coherence

Survey items related to policy adoption reveal mixed perceptions (Table 2).

Table 2. Descriptive Statistics – Policy Adoption (N = 51)

Code	Survey Item	Mean	SD
PA1	National emission-reduction policies are clearly communicated	3.88	0.91
PA2	Alignment across production and consumption regulations	**3.37**	0.98
PA3	My organization understands decarbonization targets	**4.27**	0.83
PA4	Government provides sufficient technical guidance	3.53	0.92
PA5	Industry/academia input is considered in policymaking	4.12	0.79

Survey results indicate that stakeholders possess strong awareness of national decarbonization objectives and emission-reduction targets. However, perceptions of regulatory alignment between cement production policies and construction-sector consumption remain comparatively weak (Table 2). This finding suggests that while climate policy signals are well communicated at the national level, their translation into coherent implementation instruments across the construction value chain remains limited.

2. Innovation Attributes

Table 3 shows the descriptive statistics for innovation attribute.

Table 3. Descriptive Statistics – Innovation Attributes

Code	Survey Item	Mean	SD
IN1	Green cement performance comparable to OPC	3.76	0.97
IN2	Regulatory alignment supports innovation compatibility	**3.24**	0.86
IN3	Organization understands government climate targets	4.33	0.91
IN4	Government provides adequate technical support	3.61	0.92
IN5	Industry input considered in policymaking	4.06	0.88

Responses related to innovation attributes reveal generally positive perceptions of green cement performance compared to conventional Ordinary Portland Cement. Nonetheless, compatibility with existing procurement procedures and construction workflows is perceived as limited (Table 3). This indicates that technical feasibility alone does not guarantee adoption when operational practices, specifications, and approval processes remain oriented toward conventional materials.

3. Institutional Pressures

Table 4 shows the descriptive statistics for institutional pressures.

Table 4. Descriptive Statistics – Institutional Pressures

Code	Survey Item	Mean	SD
IP1	Compliance with environmental regulations	**4.47**	0.61
IP2	Professional associations encourage sustainable materials	4.00	0.82
IP3	Peer/industry pressure to adopt sustainable practices	3.57	0.85
IP4	Certification influences material choices	4.00	0.92
IP5	Lack of regulations hinders green cement adoption	3.69	1.03

Institutional pressure analysis shows an uneven distribution of influence across the construction ecosystem (Table 4). Coercive pressures related to environmental regulation are strongest, particularly for cement producers, while mimetic pressures—such as peer adoption and industry benchmarking—are relatively weaker. Normative pressures from professional associations and certification systems are present but insufficient to drive widespread behavioral change among contractors and project owners.

4. Readiness and Intention to Adopt

Table 5 shows the descriptive statistics for readiness and intention.

Table 5. Descriptive Statistics – Readiness & Intention

Code	Survey Item	Mean	SD
RI1	Ready to adopt if guidelines exist	**4.39**	0.70
RI2	Willing even at higher cost if preferred in procurement	3.98	0.91
RI3	Training would increase adoption likelihood	4.31	0.91

Despite the constraints identified above, respondents demonstrate a high level of conditional readiness to adopt green cement (Table 5). Willingness increases significantly when technical guidelines, training programs, and procurement preferences are available. This finding suggests that resistance to adoption is not ideological but structural, shaped by the absence of enabling mechanisms rather than lack of interest or awareness.

Qualitative Findings

Qualitative analysis of interview data reinforces the survey findings and identifies four dominant themes. First, interviewees consistently highlight regulatory gaps, noting that while producers are bound by decarbonization mandates, contractors and procurement agencies face no mandatory requirements to use low-carbon cement. Second, respondents report persistent performance uncertainty at the operational level, particularly related to mix design, curing behavior, and long-term durability, which is exacerbated by the absence of standardized guidelines. Third, institutional pressures on the demand side are described as weak, with limited incentives or sanctions influencing material choice. Finally, stakeholders express strong willingness to adopt green cement if supported by pilot projects, technical validation, and clearer policy direction.

Table 6. Thematic Analysis Summary

Theme	*Key Subthemes*	*Summary*
Policy Adoption	Regulatory gaps, misalignment	Supply-side mandates strong; demand-side obligations absent
Diffusion of Innovation	Awareness, performance uncertainty, compatibility	Technical performance accepted but not well understood operationally
Institutional Pressures	Coercive, normative, mimetic	Strong for producers; weak for contractors and regulators
Readiness	Conditional willingness	Guidelines, pilots, and procurement incentives needed

Regulatory Gap Evaluation

Secondary data confirms a clear asymmetry that is shown in Table 7.

Table 7. Regulatory Gap Evaluation

Regulation on Supply Side (Cement Producers)	Regulation on Demand Side (Cement Consumer)
Cement producers are bound by decarbonization and CO_2 emission control policies, thereby continuously undertaking strategic initiatives to produce environmentally friendly cement products. Key regulations include: 1. Peraturan Presiden No. 98/2021: Presidential Regulation No. 98/2021 on the Implementation of Carbon Economic Value (CEV) to achieve the Nationally Determined Contribution (NDC) targets and control greenhouse gas emissions. 2. Peraturan Pemerintah No. 20 tahun 2020 Pasal 101-108 mandating cement plants to install Continuous Emission Monitoring Systems (CEMS) to encourage innovation toward producing green, environmentally friendly cement. 3. Peraturan Menteri Perindustrian Nomor 12/M-ind/Per/1/2012 on the Roadmap for CO_2 Emission Reduction in the Indonesian Cement Industry, updated in the Decarbonization Roadmap 2025 (not yet ratified). 4. Peraturan Menteri Perindustrian No 26 Tahun 2024 on the Mandatory Implementation of Indonesian National Standards (SNI) for certain cements: SNI 0302:2014 (Portland Pozzoland Cement); SNI 8912:2020 (Hydraulic Cement); SNI 7064:2022 (Composite Cement); SNI 8363:2023 (Portland Slag Cement); SNI 3758:2024 (Masonry Cement); and SNI 9353:2025 (Mandatory Low-Carbon Cement). 5. Permen LHK No. 19 Tahun 2021 Pasal 13 concerning the utilization of non-hazardous industrial waste as a substitute for raw materials in the cement industry.	There are no binding regulations requiring the use of environmentally friendly cement (low-carbon cement). Furthermore, there is no explicit national policy mandating consumers—including contractors, consultants, and developers, both public and private—to adopt low-carbon cement in their projects. Current provisions include: 1. Peraturan Menteri PUPR No 9 Tahun 2021, on Sustainable Construction Guidelines, which does not mandate the use of environmentally friendly cement. 2. Peraturan Menteri PUPR No 21 Tahun 2021 on Green Building Performance Assessment, which does not specify the use of environmentally friendly cement. 3. Spesifikasi Umum Bina Marga 2018 which still requires the use of OPC (Ordinary Portland Cement). While environmentally friendly cement is recommended (such as Portland Pozzoland), it remains conditional upon supervisory approval.

This imbalance constitutes a market failure, where innovation exists but is not absorbed.

Triangulation of Evidence

Triangulation across survey, interviews, and secondary analysis reveals:

1. Regulatory Misalignment Is the Central Barrier
   a. Lowest survey score: PA2 = 3.37
   b. Interviews repeatedly cited "no mandatory rules"
   c. Secondary data confirm zero demand-side mandates
2. Awareness Gaps Persist
   a. High familiarity but moderate performance confidence
   b. Contractors least informed
3. Performance Concerns Are Informational, stakeholders need validated pilot data
4. Institutional Pressures Are Uneven, strong for producers, minimal for users
5. Readiness Is High but Conditional, shown in score RI1 = 4.39; RI3 = 4.31

Table 8. Synthesized Key Findings

No.	Key Insight
1	**Regulatory misalignment is the most critical barrier** preventing green cement adoption.
2	**Stakeholder readiness is high**, but adoption is conditional on technical and regulatory guidance.
3	**Awareness gaps persist**, especially at the operational level (contractors, procurement officers).
4	**Institutional pressures remain insufficient** on the demand side to create meaningful adoption pull.
5	**Pilot projects are the strongest enabler** for building trust, legitimacy, and performance confidence.
6	**Cost sensitivity and absence of incentives** remain major deterrents to adoption.
7	**Cross-stakeholder coordination is weak**, leading to fragmented actions and inconsistent policy direction.

Discussion

This study demonstrates that the limited adoption of green cement in Indonesia is driven primarily by regulatory and institutional misalignment rather than technological constraints. Although stakeholders exhibit high awareness of national decarbonization goals and conditional readiness to adopt green cement, the absence of demand-side regulatory instruments, procurement incentives, and technical guidance significantly constrains diffusion. These findings indicate that supply-side innovation alone is insufficient to trigger widespread adoption without complementary governance mechanisms.

Regulatory asymmetry between producers and users emerges as the central structural barrier. While cement producers operate under binding environmental regulations, contractors, developers, and procurement agencies face no equivalent obligations or incentives to use low-carbon materials. This misalignment reflects broader challenges in policy adoption, where objectives are not supported by coherent implementation instruments across actors (Colebatch et al., 2010; Howlett et al., 2025). In contrast, international experience shows that demand-side policies—such as green public procurement and mandatory material specifications—play a decisive role in accelerating low-carbon material adoption by institutionalizing demand.

From an innovation diffusion perspective, adoption constraints are linked to limited trialability, observability, and compatibility with existing construction practices. Although green cement performance is generally perceived as comparable to conventional cement, uncertainty persists due to the lack of standardized technical guidelines and validated pilot projects. This aligns with prior studies identifying technical uncertainty and lack of standards as key barriers (Akter & Hawas, 2025). The findings further suggest that these uncertainties are institutional rather than technological, arising from insufficient mechanisms for experimentation and learning.

Institutional pressures influencing adoption are uneven across the construction ecosystem. Strong coercive pressures apply to cement producers, whereas normative and mimetic pressures on contractors and project owners remain weak. Similar patterns have been observed in other emerging economies, where adoption of low-carbon materials depends on coordinated institutional signals and cost-sensitive implementation strategies (Ebolor et al., 2022). These results underscore the need for integrated policy interventions that combine regulatory alignment, pilot-based validation, and procurement reform.

Overall, the findings highlight that accelerating green cement adoption in Indonesia requires coordinated action across regulatory, institutional, and technical domains. Structured pilot projects and demand-side procurement mechanisms are essential to reduce perceived risk, strengthen legitimacy, and translate national decarbonization commitments into practical adoption pathways. From a sustainability transition perspective, green cement can scale beyond niche applications only when supported by aligned regime-level structures.

Conclusions

This study set out to examine the regulatory and institutional factors influencing the adoption of green cement in Indonesia's construction sector and to identify mechanisms that can accelerate its adoption. The conclusion address these objectives based on empirical findings from interviews, survey data, and regulatory analysis.

First, regarding the influence of regulatory and institutional conditions, the study finds that green cement adoption in Indonesia is constrained primarily by regulatory asymmetry between supply-side and demand-side actors.

Cement producers are subject to mandatory decarbonization policies and emission controls, while contractors, developers, and public procurement bodies face no binding requirements to use low-carbon cement. This imbalance results in limited demand-side adoption despite the availability of compliant green cement products. Institutional pressures are also uneven: coercive pressure is strong for producers but weak for material users, with limited normative and mimetic forces encouraging adoption at the project level.

Second, concerning mechanisms to accelerate adoption, the findings indicate that stakeholders are willing to adopt green cement when enabling conditions are present. Empirical evidence shows that adoption readiness increases significantly when technical application guidelines are available, performance has been validated through pilot projects, and procurement frameworks provide preference or incentives for low-carbon materials. The absence of these mechanisms currently reinforces risk-averse behavior among contractors and project owners.

Overall, the study concludes that accelerating green cement adoption in Indonesia requires targeted interventions that directly address the identified regulatory and institutional barriers. Aligning supply-side regulations with demand-side regulations (e.g. procurement policies), supporting structured pilot projects to reduce performance uncertainty, and strengthening institutional guidance.

In conclusion, the adoption of green cement in Indonesia is not limited by technology, but by governance and institutional factors. Implementing coordinated regulatory, technical, and capacity-building interventions is essential to activate market demand, strengthen legitimacy, and advance the country's transition toward low-carbon construction.

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