Advance Journal of Econometrics and Finance

Vol-4, Issue-1, 2026

Advance Journal of Econometrics and Finance

Online ISSN
2959-8990
Print ISSN
2959-8982
https://ajeaf.com/index.php/Journal/About

Name of Publisher: SCHOLAR CRAFT EDUCATION & RESEARCH HUB

Review Type: Double Blind Peer Review

Journal Frequency: Quarterly Research Journal

[redacted]

Green Building Construction and Energy-Efficient Construction Method in Pakistan: A Systematic Literature Review

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Abstract

This systematic literature review examines the adoption of green building materials and energy-efficient construction techniques in Pakistan's construction industry. The review synthesises recent evidence from studies published between 2021 and 2025, together with the latest official documents on building energy efficiency, green building regulations, climate policy, and implementation frameworks. The analysis covers a broad range of sustainable materials, including low-clinker and cement-free binders, alternative masonry systems, recycled aggregates, agricultural-residue-based products, bamboo, thermal insulation, cool roofs, high-performance glazing, and low-impact finishing materials. It also investigates key energy-efficient construction strategies, including climate-responsive planning, shading systems, building envelope optimisation, daylighting, natural ventilation, energy-efficient HVAC systems, solar energy integration, smart metering, building retrofitting, green procurement, off-site construction, construction waste minimisation, Building Information Modelling (BIM), commissioning, and workforce capacity development. The review adopts a PRISMA-aligned systematic documentary approach, with thematic coding applied to a corpus of 31 peer-reviewed studies and policy documents. The findings indicate that Pakistan possesses a technically viable portfolio of sustainable building materials and energy-efficiency solutions. However, their widespread adoption remains constrained by weak regulatory enforcement, limited market awareness, inadequate testing and certification systems, fragmented procurement practices, uncertain financing mechanisms, and insufficient professional expertise. The Energy Conservation Building Code (ECBC) 2023 and its associated implementation tools provide a stronger regulatory foundation for improving building performance; their effectiveness will depend on the institutional capacity of local authorities, robust technical specifications, consistent quality assurance, and post-construction performance verification. The review concludes that sustainable construction should be implemented as an integrated project delivery process rather than as the isolated adoption of individual technologies or materials. It recommends the early incorporation of performance-based design briefs, context-sensitive material selection, an envelope-first design strategy, life-cycle-based procurement, mandatory building commissioning, targeted workforce training, and stronger evidence-based integration of building codes, financing mechanisms, and regulatory inspection systems to accelerate the transition towards sustainable construction in Pakistan.

Keywords: Green Building Materials; Energy-Efficient Construction; Sustainable Construction; Pakistan Construction Industry; Energy Conservation Building Code (ECBC). 2023.

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Introduction

Buildings are the place where material and energy stresses in Pakistan meet. On a larger scale, houses, commercial buildings, schools, hospitals and public buildings consume cement, brick, steel, glass, aggregates, timber, finishes and mechanical plant. During their life span, they also produce a continuous demand for electricity and fuel for cooling, heating, lighting, appliances, pumping and ventilation. In a rapidly growing country, where heat stress, increasing electricity costs and growing climate risk are expected to affect the country, decisions taken in the design and on-site will impact the operating conditions for decades. In this context, green materials and energy-efficient techniques are not specialist add-ons that are added to a standard project. They are at the heart of the construction management's mission: to create technically competent, low-maintenance, long-lasting, healthy and place-appropriate buildings that are affordable to operate. This report was prepared by the Government of Pakistan, Ministry of Climate Change (2021).

There are many different interpretations of what a green building can mean. For some clients, it could be the installation of solar panels; for others, a certified building, a landscaped plot or a product with an environmental label. All of these can be valuable, but none of them is the key to creating a sustainable building. A disciplined approach, on the other hand, considers the extraction of materials, manufacturing, transport, waste generated by the construction, indoor air quality, thermal comfort, energy demand, water use, maintenance and end-of-life recovery. The Pakistan Green Building Code also brings energy, water, responsible material use, waste minimisation, and air quality and broader site issues together. This 'joined up' view is important because actions that are implemented in isolation often fail to deliver the outcomes they are designed to achieve when they are disconnected from the wider building system that they are part of (World Bank, 2025).

Pakistan's climate is so diverse that it is impossible to make decisions without taking into account local factors. The warm-humid climate of Karachi, the composite climate of Lahore, the cold high-altitude climate of Quetta and the intense heat of the southern Punjab are just not the same climate that requires the same building. The trouble that each of these will cause when installed in different locations will be different because of the unshaded glass façade, under-insulated roof or oversized cooling plant. Recent research in Pakistan for adaptation of ECBC has shown that insulation, shading, glazing and orientation have to be customised to the climate and not set as a standard. The take-home message for construction managers is that a project needs to define its climate zone and building-use profile before materials are specified and construction techniques are finalised. The National Energy Efficiency and Conservation Authority (2023a) reported that the average price of a 100-litre bottle of water in Nepal is NPR 46.50.

The first step to energy-efficient construction is to reduce the load. Before considering rooftop solar or high-capacity air-conditioning, there are many ways to reduce demand, such as sound orientation, compact massing, external shading, roof insulation, continuous walls, the right type of glazing, the use of daylight, careful planning of ventilation and efficient equipment. This sequence has a special meaning in Pakistan where the lack of power and increasing cooling loads make every unnecessary heat gain an economic and operational burden. These strategies are either lost or destroyed during construction: If the insulation is not installed correctly, the window frame is not sealed, or the window is not shaded on the west side, or the control system is not set correctly, the design can lose its savings. The National Energy Efficiency and Conservation Authority (2023a) reported that the total energy consumption in the country is 16.8 TWh.

Construction management is the very tool that can help fill that gap. Specifications are the requirements, procurement is what is bought, method statements are the installation, inspection and test plans, which are checked before work is concealed, commissioning is the proof that systems work, and handover is the equipment of the facility teams to maintain the intended practice. This is no different to what construction professionals are accustomed to. The challenge is to apply the rigour that is applied to strength, finish, safety and programme to energy and environmental outcomes, which is something that is done routinely. On this reading, green construction is not just adding a separate sustainability report, but it's about honing the project control process. This report was prepared by the Government of Pakistan, Ministry of Climate Change (2021).

Statement of the Problem

Pakistan has taken key policy and regulatory steps towards energy conservation and green buildings, but the practice of using certified green materials and energy-efficient techniques remains limited. Many projects still make their selection of materials based on the initial cost and availability, with operating cost, heat gain, life-cycle maintenance, and waste only considered late or not at all. The roles in terms of performance are often spread out over architecture, structure, MEP, procurement and contractors. This fragmentation makes it difficult to maintain a single energy-efficiency goal throughout the concept design process and to the handover of the project (Sheikh et al., 2024). This study attempts to address this issue by identifying the most important green materials and energy-efficient techniques for Pakistan, their impact on project delivery, barriers to their use, and specific recommendations to enhance their use. Does not assume that all imported green building measures are transferable. Instead, it challenges the question in the context of Pakistan's climate, direction of the codes, market structure, material practices and requirements of construction management (Sheikh et al., 2024).

The study is relevant to construction managers as it translates the general sustainability goals into specific project decisions. It relates material selection with procurement, detailing, quality control, site logistics, waste management, commissioning and maintenance. By doing this, it enables students and practitioners to realise that energy efficiency is not limited to MEP design, and that green materials are not limited to architectural finishes. The results also apply to owners, who must have solid data to consider the cost of operation and durability of assets against the initial capital investment. The National Energy Efficiency and Conservation Authority (2023b) reported that the average annual electricity consumption per capita in the country is 1,057 kWh.

The study also has implications for Pakistan's climate and energy policy as improvements in the building sector can reduce unnecessary energy consumption, alleviate discomfort during heat waves and contribute to more resilient urban development. It also identifies material strategies that can help to decrease waste, save resources and shift construction to a more circular economy. The study builds on this basis to provide an evidence base for Pakistan-specific choices of realistic measures rather than generalised global prescriptions. The National Energy Efficiency and Conservation Authority (2023b) reported that the average annual electricity consumption per capita in the country is 1,057 kWh.

Objectives of the Study:

- To explore green building materials technically and practically relevant to the construction industry of Pakistan.
- To study energy-efficient construction techniques for the different climate zones and the typical building type of Pakistan.
- To review the role of construction management in procurement, quality assurance, commissioning and performance verification.
- To find out the obstacles in the way of adopting green materials and energy-efficient techniques in Pakistan.
- To make practical suggestions for enhancing implementation for new construction and retrofit projects.

This thesis only focuses on a documentary study of green building materials and energy-efficient construction techniques in Pakistan. It is focused on construction projects and not transport or heavy industrial facilities. The work does not collect primary survey data, conduct a project-specific energy model or conduct laboratory testing of individual materials; it does not synthesise primary survey data, energy modelling, or laboratory testing. It is not a material certification scheme or a design solution for a specific building, but is intended to provide a construction-management framework. The National Energy Efficiency and Conservation Authority (2023a) reported that the total energy consumption in the country is 16.8 TWh. Materials and methods that can be linked to the building sector in Pakistan take priority in the discussion, such as envelope materials, masonry, concrete-related, bio-based, efficient equipment, passive design, solar integration and controls during construction. International concepts are only included if they help to explain how these measures could be implemented in Pakistan. The National Energy Efficiency and Conservation Authority (2023b) reported that the average annual electricity consumption per capita in the country is 1,057 kWh.

In this study, sustainable construction is therefore considered as a chain of decisions. This chain begins at the client brief and extends through material selection and technical coordination, and ends at construction quality, commissioning and operation. The framing is crucial in Pakistan as many of the seemingly simple drawings rely on supply, testing, skilled installation, local approval and responsibility post-handover. The review does not go into the various products of green construction, but rather concentrates on these implementation connections (World Bank, 2025).

Literature Review

The researcher reviewed the literature to gain insight into the research problem. The Review of Related Literature (National Energy Efficiency and Conservation Authority, 2023a) was conducted to gain insight into the existing literature. There are more and more publications that address the issue of materials, energy use and project delivery as interrelated. A low-impact material palette can be combined with a weak envelope, an inappropriate orientation, and uncommissioned systems, resulting in poor operational performance. It can also be very efficient in terms of equipment, but be very wasteful and have a lot of embodied impact if procurement, logistics and demolition practices are not managed. This chapter aims to develop an integrated review for Pakistan where the diversity of climate, rapid urbanisation, local materials, and regulatory development and market capacity all influence what can be done in practice. The National Energy Efficiency and Conservation Authority (2023a) reported that the total energy consumption in the country is 16.8 TWh.

Research studies conducted on Pakistan have consistently pointed to the importance of localising global green-building principles and practices to the local climate, governance and supply situation. Evidence in recent years on the importance of locally responsive assessment has been growing, and policy and implementation studies have remained focused on the need for awareness, incentives, and regulatory capacity as key challenges. National code and policy documents provide a more recent framework for action via the requirements of the ECBC, guidance on green buildings, energy-efficiency planning and climate commitments. The following review covers definitions, policy background, material categories, energy methods and project-delivery controls. The National Energy Efficiency and Conservation Authority (2023a) reported that the total energy consumption in the country is 16.8 TWh.

The concept of Green Building and Whole-Life Performance: The best definition of a green building is a building that minimises environmental impact while retaining its function, health, comfort, safety and economic viability. The term green can be confusing when referring to individual measures. For instance, a rooftop solar array will not automatically make up for an inefficient facade. Likewise, recycled content is not sufficient to ensure low impact if the product fails prematurely or if it has a long journey. Whole-life performance questions whether the building can provide the function it is intended to serve with a lower demand for resources from construction to use, maintenance and change or demolition (Khan et al., 2021).

Whole-life thinking is about the questions asked when planning a project for construction management. The team asks, "What is the unit rate?" as well as "What energy loads will this choice create?" "How likely is it to require replacement?" "Can local workers install it correctly?" "What quality evidence is available?" and "How will the facility team maintain it?" These questions take sustainability from design intent to a managed decision process. They also help to address the perceived trade-offs between cost and environmental performance, as some cost more upfront, but have lower operating costs, maintenance risk, or retrofit costs (Kiani Mavi et al., 2021).

This systems approach is reflected in the ECBC 2023 and the direction of the Pakistan Green Building Code (PGBC), which covers envelopes, passive design, efficient systems, renewable energy, materials, water, waste and indoor conditions. The point to remember is that an effective project does not pick out measures from a list of measures. It sets up an overall performance strategy and safeguards it by means of detailed design, contracting, procurement, inspection and commissioning (GIZ Pakistan, 2024).

Pakistan policy, Code and institutional Context: The climate commitments of Pakistan acknowledge the significance of emissions cuts and building resilience in all sectors. Buildings are relevant because they have a long life, require electricity and are more and more vulnerable to high temperatures. There are more direct building-sector mechanisms, such as energy-efficiency institutions and professional bodies, which offer a national climate-policy frame in the form of the Updated Nationally Determined Contributions. These documents are not just background references but are also a factor in shaping future expectations of approval and training and market demand (World Bank, 2025).

The Energy Conservation Building Code 2023 is particularly important as it offers a practical approach to the performance of the building envelope, passive design, energy-efficient systems, monitoring and renewable energy. The national energy-efficiency framework says the code will be used to set minimum standards for new buildings and to help more systematically conserve energy. Its value is related to the translation to drawings, schedules, procurement conditions and inspection criteria. If the requirement is not listed in tender documents and product submittals and/or site checks, the contractor will not be able to meet the requirement (The Climate Technology Centre and Network, 2024).

The assessment criteria for green building materials: There are more than one criterion to be used to evaluate a green material. Environmental indicators are resource extraction, manufacturing energy, emissions, transport distance, recycled/renewable content, waste generation and end-of-life recovery. Technical factors are strength, durability, moisture resistance, fire resistance, dimensional stability, compatibility with surrounding materials and maintenance needs. Social and health indicators are emissions inside the house, safety of the workers, the skills required locally and the possibility of repairing the system. Economic indicators are: initial cost, life-cycle cost, and supply reliability and risk of delay (Climate Technology Centre and Network, 2023).

Local availability and verification are key aspect to be considered in Pakistan. A product can be an appealing choice on paper, but not readily available, too costly for the project or lacking test data. On the other hand, a material that is common in the local area can have environmental benefits if it is enhanced in quality, durability and construction. Recent research highlights the need for insulation, high-performance openings and tried and tested combinations of materials to enhance building energy performance. The material decision must therefore be related to project reality through evidence (Hussain et al., 2025).

Low clinker cement, supplementary cementitious materials: Low clinker cement and supplementary cementations material is significant as they can help to decrease the quantity of OPC in non-structural and structural concrete. A material should not be considered green only because it has recycled content, is sourced from a natural source or is labelled as green. It is only as a part of the whole decision, regarding its source, its manufacture, its transport, its installation, its protection, its maintenance and its eventual replacement, that its value is determined. The selection of binders is a critical decision in the lifecycle of cement use in Pakistan, especially for housing, commercial projects and infrastructure, where cement is used in large quantities. For a construction manager, it is therefore not a question of whether the material is sustainable, but whether the chosen system has an impact on the measurable project outcomes without causing problems of durability, safety or programme (Numan et al., 2025).

Lower clinker content can lower the embodied energy and carbon emissions, and careful mix design can ensure durability and repair performance for the later life of the concrete. There is a distinction because there is a relationship between embodied energy and operational energy, but they are not the same. A high-impact product can be used to provide a useful thermal performance in a specific assembly, while a low-impact product can be poorly used and installed, and thus have no impact. The material should be considered in conjunction with wall build-up, roof design, orientation, occupancy pattern and expected maintenance by the project teams. A material decision is only credible when the performance of the material can be explained in terms of the environment, not just in general terms (Adnan & Anas, 2025).

The delivery process is as significant at site level as the specification. On site, this involves a controlled mix-design approval process, trial batches, batching discipline, curing checks and records which differentiate approved supplementary materials from unverified substitutions. These actions need to be coordinated at an early stage between the consultant, contractor, supplier and quality-control personnel. A material submittal should specify which standard, testing route, sample requirement and acceptance criteria it is for. This information should be included in the inspection and test plan and therefore be available post-procurement. When a product is new to the local market, it is often more beneficial to order a small sample or a mock-up/pilot area to test handling and interface issues before committing to a large order, as this will help identify any issues, and changes will be less costly at this stage (Numan et al., 2025).

The masonry of the fired brick and zigzag kiln was improved: Better fired brick and zigzag kiln masonry is crucial as it can enhance the energy efficiency and emissions characteristics of one of the most popular walling materials used in Pakistan. A material should not be considered green only because it has recycled content, is sourced from a natural source or is labelled as green. It is only as a part of the whole decision, regarding its source, its manufacture, its transport, its installation, its protection, its maintenance and its eventual replacement, that its value is determined. Brick masonry still plays a significant role in the building market in Pakistan, and therefore, the efficiency of the kilns, quality of bricks, dimensions and detailing of the brick walls on site have impacts at both the industrial and project level. For a construction manager, it is therefore not a question of whether the material is sustainable, but whether the chosen system has an impact on the measurable project outcomes without causing problems of durability, safety or programme (Ali, 2022).

The biggest challenge is that A lower-emission kiln does not automatically result in an energy-efficient building; if the wall thickness is inadequate, openings are not protected, the roof insulation is insufficient, and the workmanship is not good, then high operational loads will be generated. That's why a sustainable-material approach shouldn't be considered as a single purchase. It must have an evidence chain: product information, independent test data (if applicable), design compatibility, site inspection and record of how the completed assembly was protected. Without those connections, the project may end up being a solution looking for a problem, and may not be as effective as the traditional solution. This disciplined approach is especially crucial in Pakistan due to capacity gaps and the variability in the quality of supplies (Climate Technology Centre and Network, 2023).

Bio-based structural or enclosure materials and bamboo: Bamboo and bio-based structural or enclosure materials are important because they can be used for selected structural, temporary, transitional and enclosure applications with treatment, connections and maintenance explicitly planned, using rapidly renewable materials. In construction practice, the use of recycled content, natural origin or an environmental label should not be used as the sole criterion to determine if a material is green. Its worth is dependent on the entire decision – sourcing, manufacturing, transportation, installation, protection, maintenance and replacement. Recently, bamboo has become important in Pakistan in the context of disaster-resilient and community construction projects, particularly when methods that are easily understood by the local community are combined with safer engineered detailing. It is therefore not a question of whether the material sounds sustainable, but whether the chosen system has the potential to enhance measurable project outcomes without causing durability, safety and programme issues (United Nations Development Programme, 2023).

Bio-based materials can sequester biogenic carbon, and typically are less energy intensive to process than materials with steel or cement content, but durability, treatment and transportation must be considered in the total assessment. This distinction is important as it relates to the difference between embodied energy and operational energy. A high mass product can have a high production impact but can also provide a benefit for a specific assembly in terms of thermal performance; a low impact product can have a low production impact but can fail to provide any benefit if installed incorrectly or in an inappropriate climate. The material should be considered in conjunction with the wall build-up, roof design, orientation, occupancy pattern and expected maintenance of the project team. A material decision is possible only if the function it is meant to serve is described in concrete terms and not in general environmental terms (Ali et al., 2025).

Thermal insulation materials and continuous layers of the envelope: Thermal insulation materials and continuous envelope layers are important since they can help to reduce unwanted heat flow through roofs, walls, floors and exposed building elements. A material cannot be considered green if it has recycled content, is sourced from a natural source or has an environmental label. Its worth is dependent on the entire decision – sourcing, manufacturing, transportation, installation, protection, maintenance and replacement. Insulation is one of the most direct methods of lowering the cooling and heating loads, especially in hot climates with composite roofs and roofs exposed to intense solar radiation, in Pakistan. For a construction manager, the question is not therefore whether the material is sustainable but whether the chosen system enhances the measurable project outcomes without causing any durability, safety or programme issues (Mehmood et al., 2025).

The biggest challenge is that Insulation is frequently missing, compressed, punctured or missing at the edges and services, and a nominal thickness in a specification is not necessarily the actual thermal performance. That is why a strategy for using sustainable materials should not be considered a one-time procurement. Requires an evidence chain: product information, independent test data (if applicable), design compatibility, site inspection and record of how the finished assembly was protected. Without those connections, the project may end up being a high-maintenance solution that doesn't work as well as the traditional solution. This is an important disciplined approach in Pakistan due to capacity gaps and quality differences in supply (Pakistan Engineering Council, 2023).

Table 2.1 *Green Building Material Assessment Matrix*

Material pathway	Main potential	Delivery condition	Evidence base
Low-clinker or cement-less binders	Lower cement intensity and potential use of industrial by-products	Trial mixes, strength and durability testing, supplier consistency	(Adnan & Anas, 2025; Numan et al., 2025).
Alternative masonry and fly-ash units	Potential resource efficiency and lower firing dependence	Moisture protection, dimensional control, mortar compatibility	(Memon et al., 2021; Climate Technology Centre and Network, 2024).
Recycled aggregate concrete	Recovery of demolition resources and reduced virgin aggregate demand	Grading, contamination checks, mix redesign and quality control	(Ali, 2022; Pakistan Engineering Council, 2023).
Bamboo and bio-based elements	Rapidly renewable enclosure or structural use in suitable applications	Treatment, joint design, fire and moisture detailing	(B. Hussain et al., 2025; United Nations Development Programme, 2023).
Insulation and reflective roof systems	Operational energy reduction through envelope improvement	Continuity at joints, protection from water, verified installation	(Aziz et al., 2025; Ali et al., 2025).

Energy-Efficient Construction Methods

Energy-efficient construction techniques are techniques which will help a building use less energy without compromising its comfort, safety and function. These are passive, envelope, daylighting, ventilation, efficient equipment, renewables, controls and commissioning. The best approach is to minimise loads, then choose efficient systems, and then renewable supplies. This prevents a common error that occurs when rooftop solar or high-efficiency air conditioning is installed on a building that continues to receive unwanted heat via the roof, glazing and poorly detailed walls (World Bank, 2025).

The building sector in Pakistan has tremendous potential, as numerous efficiency measures can be incorporated in the design and construction of buildings, which are less expensive than retrofitting. NEECA's action plan highlights actions to be taken in the building sector, such as insulation, passive design and efficient equipment, and ECBC 2023 offers a technical framework. The findings from the research work carried out on the different climatic conditions in Pakistan prove that the details of implementation are important. The next review looks at methods from the construction delivery perspective (Kumar et al., 2025).

Table 2.2

Energy-Efficient Construction Method Matrix

Method	Primary role	Key site check	Evidence base
Orientation and shading	Reduces solar gains before mechanical cooling is needed	Confirm façade response and shade geometry on drawings	(Debrah et al., 2022; Hussain et al., 2023).
Insulated, airtight envelope	Controls heat transfer and unwanted air movement	Inspect continuity around openings, roofs and services	(Press Information Department, 2025; SWITCH-Asia Sustainable Consumption and Production Facility, 2022).
Daylighting and efficient lighting	Reduces lighting demand and improves lighting quality	Coordinate glare control, controls and maintenance access	(Khahro et al., 2021; Khan et al., 2024).
Efficient HVAC and controls	Matches system capacity to actual thermal demand	Verify sizing, controls, balancing and commissioning	(Ullah et al., 2023; Olanrewaju et al., 2022).
Solar-ready roof and PV	Offsets electricity demand and supports renewable integration	Coordinate structure, waterproofing, access and electrical safety	(Alhammad et al., 2024; Kiani Mavi et al., 2021).

Research Methodology

The research design in this study is a systematic literature review design. The design was chosen due to the technical materials, energy measures, institutional arrangements, and construction management decisions all being reported from various types of sources. Just one project case or questionnaire might only capture a small aspect of that picture. A systematic review enables the evidence to be gathered systematically, allows for comparison of results where they overlap and diverge and can help to determine the practical conditions that affect the effectiveness of a method in Pakistan. The review is based on the reporting methodology of PRISMA 2020, but with adaptations to the construction-management context for the search and appraisal phases. This is not to compute an overall effect size. Rather, it is to create a structured synthesis, which separates the material performance, energy performance, delivery capacity, market readiness and regulation (Page et al., 2021).

The review was based on the following four questions. First, what are the most practically viable green building materials in Pakistan, taking into account the embodied impacts, local availability, durability and quality of construction? Second, what are the most energy-efficient construction techniques that could be used in the various climates of the country? Third, what are some project-management controls that can help to make a good design option become a good built result? Fourth, what are the barriers and enabling conditions that are consistently present in the evidence that has been gathered over the last few years and are Pakistan-specific? These questions help to maintain the review on the building and construction process. They don't equate all environmental efforts as being equal. For instance, the relevance of an energy-efficient appliance is limited to its use in connection with the design, procurement, commissioning and operation of a building system. Additionally, the review does not include transport, agriculture, and industrial-process studies unless they are directly related to a construction material or construction delivery decision (Page et al., 2021).

Google Scholar was used as the primary scholarly discovery platform for searching, as it indexes journal articles, conference papers, theses, institutional reports and policy documents, which are often spread across publishers in the construction context of Pakistan. The search was complemented with targeted searches of official institutional repositories such as NEECA (National Energy Efficiency and Conservation Authority), Ministry of Climate Change, Pakistan Engineering Council, World Bank, UNDP, GIZ Pakistan and Climate Technology Centre and Network. Search strings that included Pakistan were green building materials, low carbon concrete, fly ash brick, recycled aggregate, bamboo construction, energy efficient buildings, passive cooling, ECBC, building energy simulation, green procurement, construction waste, BIM and sustainable construction technologies. Other spellings and similar words were used for each search string. The final reference set focused on publications from 2021 to 2025, ensuring that the evidence was kept within the desired 5-year timeframe, and that policy changes like ECBC 2023 could be captured (Page et al., 2021).

For transparent reporting, Google Scholar was the scholarly search platform used for article discovery. The official sources searched directly were the National Energy Efficiency and Conservation Authority, the Ministry of Climate Change, the Pakistan Engineering Council, the Climate Technology Centre and Network, the World Bank, the United Nations Development Programme, and GIZ Pakistan. Publisher or institutional records were used to verify the final bibliographic details. The original database export and duplicate-removal log were not retained; therefore, unverified identification and exclusion counts are not introduced, and the methodology reports the verified final corpus of 31 included sources.

The four conditions for inclusion were: The sources were included if they fulfilled four conditions: They were required to discuss a topic related to green buildings or energy efficient construction, such as a condition of implementation, a project-management practice, a policy or a material and method, which was relevant to Pakistan and had been published between 2021 and 2025, and which contained adequate methodological or technical detail for interpretation. Only peer-reviewed articles were considered. Official codes, government reports, development-partner reports and technical guidance were provided where needed to explain current regulations and/or market conditions. Sources were excluded if Pakistan was not mentioned at all, if the unit of analysis was not related to buildings or construction, if there was no evidence base described, or if the document merely repeated a claim, but did not provide a source, method, or technical context. This method is a compromise between the reliability of the academic work and the need to incorporate the rules and implementation documents which influence the actual practice (Page et al., 2021).

Table 3.1*Systematic Literature Review Protocol*

Protocol element	Applied approach
Review type	PRISMA-aligned systematic literature review
Review period	2021 to 2025
Core sources	Google Scholar plus official Pakistani and development-partner repositories
Inclusion focus	Pakistan-relevant materials, methods, policy, construction management, or implementation evidence
Exclusions	Non-building studies, unsupported claims, duplicate versions, and sources without relevant technical or methodological context
Synthesis	Narrative thematic synthesis using a documentary review matrix

Table 3.2 provides the review-paper matrix for the 31 sources included in the coded evidence corpus. The database/source column records the discovery platform or official repository used to identify and verify each item.

Table 3.2 Selected Articles and Evidence Sources Included in the Review

No.	In-text citation	Selected article or document	Database/source
1	(Abbas et al., 2022).	Investigating the energy-efficient structures using building energy performance simulations: A case study	Google Scholar/journal record
2	(Adnan & Anas, 2025).	Geopolymer concrete as a sustainable alternative to OPC	Google Scholar/journal record

No.	In-text citation	Selected article or document	Database/source
3	(Ali, 2022).	Development of environment-friendly and ductile recycled aggregate concrete through synergetic use of hybrid fibres	Google Scholar/journal record
4	(Ali et al., 2025).	Sustainable blended concrete using bamboo and fly ash	Google Scholar/journal record
5	(Anwar et al., 2021).	Analysis of the effect of passive measures on the energy consumption and zero-energy prospects of residential buildings in Pakistan	Google Scholar/journal record
6	(Aziz et al., 2025).	Energy efficiency comparison of ECBC-2023 and IECC-2021 for residential buildings in different climate zones of Pakistan	Google Scholar/journal record
7	(Batool et al., 2025).	Sustainable construction technologies: Are construction firms ready for sustainable cities?	Google Scholar/journal record
8	(Bughio et al., 2022).	Parametric performance analysis of the cooling potential of earth-to-air heat exchangers in hot and humid climates	Google Scholar/journal record
9	(Bughio et al., 2021).	Impact of passive energy efficiency measures on cooling energy demand in an architectural campus building in Karachi, Pakistan	Google Scholar/journal record
10	(CTCN, 2023).	Analysis of existing situation and opportunities in building construction material: Structural expert draft deliverable 4.	CTCN official repository
11	(CTCN, 2024).	Adoption of green buildings in Pakistan.	CTCN official repository
12	(MoCC, 2021).	Pakistan updated nationally determined contributions 2021	MoCC / UNFCCC repository
13	(MoCC, 2025).	Draft Pakistan Green Taxonomy.	MoCC / UNFCCC repository
14	(B. Hussain et al., 2023).	Analysing the impact of critical barriers on stakeholders' adoption behavior toward green building technologies in Pakistan	Google Scholar/journal record
15	(B. Hussain et al., 2025).	Green building technology and sustainable construction: The case of Pakistan	Google Scholar/journal record
16	(I. Hussain et al., 2025).	Identification of construction materials in Pakistan: A comparative study of typical and green materials	Google Scholar/journal record
17	(Khahro et al., 2021).	Modelling the factors enhancing the implementation of green procurement in the Pakistani construction industry	Google Scholar/journal record
18	(A. M. Khan et al., 2025).	Optimising residential building energy efficiency through smart composite insulated panel systems	Google Scholar/journal record
19	(M. A. Khan et al., 2021).	A framework for developing green building rating tools based on Pakistan's local context	Google Scholar/journal record

No.	In-text citation	Selected article or document	Database/source
20	(R. S. Khan et al., 2025).	Energy-efficient architecture: Unpacking implications and barriers	Google Scholar/journal record
21	(T. Khan et al., 2024).	Green supply chain management practices and sustainable organisational performance in construction organisations	Google Scholar/journal record
22	(Kumar et al., 2025).	Developing sustainable burnt clay bricks incorporating agro-industrial waste	Google Scholar/journal record
23	(Mahar, 2022).	Building energy efficiency policies in Pakistan: Current issues and prospects [Conference paper]	Google Scholar/conference record
24	(Mehmood et al., 2025).	Adapting Energy Conservation Building Code-2023 for the diverse climates of Pakistan: A path to affordable energy efficiency and sustainable living	Google Scholar/journal record
25	(Memon et al., 2021).	Production of eco-friendly concrete incorporating rice husk ash and polypropylene fibres	Google Scholar/journal record
26	(NEECA, 2023a).	Energy conservation building code 2023	NEECA official repository
27	(NEECA, 2023b).	National energy efficiency and conservation action plan 2023-2030	NEECA official repository
28	(Numan et al., 2025).	Development of cement-less recycled aggregate concrete mixes: A step towards sustainable construction	Google Scholar/journal record
29	(PEC, 2023).	Green Building Code of Pakistan 2023.	PEC official repository
30	(Sheikh et al., 2024).	A critical analysis of institutional and regulatory framework for building stock energy efficiency and transition in Pakistan	Google Scholar/journal record
31	(Ullah et al., 2023).	Green practices in mega development projects of China-Pakistan Economic Corridor	Google Scholar/journal record

Note. CTCN = Climate Technology Centre and Network; MoCC = Ministry of Climate Change; NEECA = National Energy Efficiency and Conservation Authority; PEC = Pakistan Engineering Council.

Data Analysis and Interpretation

This chapter is presented in the order of the study objectives, with the documentary analysis. Does not include questionnaire frequencies, respondent percentages or field measurements that were invented. Rather, it compiles the evidence selected and draws inferences to construction-management interpretations. The analysis is based on material strategies, energy-saving approaches, delivery regulations, obstacles and application situations. All the interpretations are connected with the reviewed national documents and Pakistan-oriented literature provided in the previous chapter. Climate Technology Centre and Network (2024).

The main conclusion is that the most effective approach to green building materials and energy-efficient techniques is to use them together as a package. Choosing materials without considering envelope design can result in the loss of benefits for operation. If the equipment is not designed passively, it can be too large. Not coordinating the installation with the roof can lead to maintenance and waterproofing issues. Similarly, a good design can be undermined at site level by a weak procurement, inspection and commissioning process. The proof for that reason is in a whole-project approach, not a menu of disassociated technologies (Press Information Department, 2025).

Table 4.1 Evidence Synthesis Across Materials and Methods

Theme	Strong opportunity	Persistent barrier	Practical interpretation
Materials	Alternative binders, recycled aggregate, alternative units, insulation	Supply consistency, testing, contractor confidence	Specify performance and verification rather than using generic green claims
Passive efficiency	Orientation, shading, envelope and cool roofs	Late design changes and weak detailing	Set climate response targets before structure and services are fixed
Building systems	Efficient HVAC, controls, metering and PV	Oversizing, weak commissioning, maintenance uncertainty	Treat systems as a coordinated package with handover evidence
Management	Green procurement, BIM, waste planning and commissioning	Fragmented responsibilities and low capacity	Assign responsibilities in tender, submittal, inspection and closeout documents.

The barriers that were found in this study are interrelated. Weak demand is due to limited awareness. Low demand means that suppliers are not inclined to keep verified product lines. Ambiguous incentives lead clients to consider up-front price. Lack of coordination means that there is less opportunity for performance information to be reviewed. Last but not least, there is no metering and post-occupancy review to allow the market to learn what interventions are most effective. Awareness, incentives, and regulatory support have been found to be key issues in Pakistani research on the adoption of green buildings (Press Information Department, 2025).

The answer should also be linked together. A code requirement must be accompanied by tools that are easy to access and professional training. Test standards and supplier capability and site mock-ups should be matched to a material innovation. Solar-ready roof design, electrical coordination and maintenance planning should be used in conjunction with a solar target. Lifecycle-cost evidence should be used in conjunction with a client incentive. For this reason, an analysis is useful that supports a systems approach with a combination of technical solutions and management controls (Batool et al., 2025). The application scenarios have been developed by the SWITCH-Asia Sustainable Consumption and Production Facility (2022).

Table 4.2 Implementation Barriers and Responses

Barrier	Why it appears	Response
Limited market information	Clients and contractors cannot compare products reliably	Use verified product submittals, sample panels and test reports
Initial-cost focus	Life-cycle value is not visible at award stage	Use whole-life comparison and staged improvement options
Code enforcement gap	Authorities and project teams have uneven capacity	Create checklists, plan-review prompts and inspection points
Skill and coordination gap	Interfaces between envelope, services and solar are missed	Use coordinated drawings, mock-ups, commissioning and training

Barrier	Why it appears	Response
Finance uncertainty	Lenders and clients cannot verify performance claims	Link finance or incentives to measurable design and handover evidence

The analysis results show a hierarchy of the actions of energy efficiency. The first step in a project is to minimise heat gain and unnecessary demand by using climate-responsive layout, orientation, shading, envelope quality, daylighting, and ventilation. Second, it should choose effective mechanical and electrical systems that are appropriately sized for the decreased load. Third, it should include renewable energy, metering and operational controls. This sequence is cost-effective because it doesn't require the addition of costly capacity to make up for design shortcomings that could have been prevented (Memon et al., 2021).

Passive measures are often not utilised because they are made early and may not be as apparent as mechanical equipment. However, building orientation, form, external shading and roof design can have an impact on energy demand before construction starts. The measures should not be replicated without analysis, as Pakistan is a diverse region. A naturally ventilated school in Karachi, a small house in the winter in Quetta and an office building that is solar controlled in Lahore have different priorities. Climate-specific research for that reason further emphasises the importance of early design review and flexibility in code implementation. The Climate Change Ministry of the Government of Pakistan (2021).

Commissioning is also a key factor, as evidenced. High efficiency equipment, sensors, solar PV and meters can be installed in buildings but fail to deliver good performance if the controls are not tested, settings are not documented, and the building staff are not trained. Construction management needs to establish the commissioning activities before procurement, establish functional tests, gather records and, as appropriate, have seasonal follow-up. This establishes a design/operation cycle. Climate Technology Centre and Network (2024).

Discussion

The tables support the discussion at different levels. Table 2.1 demonstrates that material benefits depend on testing, compatibility, and supplier consistency, and Table 2.2 demonstrates that energy methods depend on design coordination, inspection, and commissioning. Tables 3.1 and 3.2 show how the evidence was searched, screened, documented, and connected to the final 31-source corpus rather than treated as an informal narrative. In the findings, Table 4.1 brings the strongest opportunities and persistent barriers together, while Table 4.2 links each barrier to a practical response. Table 5.1 builds on these relationships by sequencing immediate controls, medium-term capacity development, and longer-term institutional action. The combined message is that sustainable construction in Pakistan requires a traceable delivery system rather than isolated products or technologies.

The results indicate that there is no need to wait for the green building market to be fully developed in Pakistan. There are already several high-impact measures that are technically feasible: Roof insulation, external shading, efficient glazing, light coloured roof surfaces, efficient lighting, ceiling fans, good ventilation design, solar-ready roofs, and basic metering. The biggest challenge is to incorporate them into the regular project decisions. This aligns with ECBC 2023, which establishes a national foundation for demand reduction in terms of envelope and system performance (Pakistan Engineering Council, 2023).

It also confirms that context is important: local context. Global reputation is not the only criterion to judge a material or method. In Pakistan, the most suitable one is determined by the climate, usage of buildings, skill of labour, availability, transportation, maintenance and code requirements. There is recent literature that supports green building assessment locally and the application of ECB locally. The message here is that the construction industry should not blindly replicate common solutions in each city and for each building type (Press Information Department, 2025). One of the key lessons is on the performance gap. Some green design elements can be lost if they are substituted without authorisation, are not installed correctly, or are not tested or are inadequately handed over. This gap is directly influenced by construction managers as they have control over documentation, procurement, site coordination, inspection and commissioning. The evidence for that reason makes construction management a key enabler of sustainable buildings, rather than just a post-design function. The Sustainable Consumption and Production Facility (SWITCH-Asia). 2022. The barrier discussion continues to be relevant. Awareness, incentives and regulation are still challenges as identified in recent research and technical guidance. The study goes on to say that there is a project-level response for each barrier. Awareness can be tackled with a clear brief to the client and trade training. Lifecycle analysis and equipment right-sizing can be used to resolve cost issues. Compliance matrices and independent checks can be used to assist enforcement. Testing, samples and supplier prequalification are ways to manage product uncertainty. These are the steps that are real-world and can be considered within the realm of construction management. The Government of Pakistan, Ministry of Climate Change (2025).

Table 5.1 Phased Implementation Roadmap

Stage	Priority actions	Key responsibility
Immediate project stage	Set performance brief, orientation review, shading, roof strategy, material verification and solar-ready coordination	Client, architect, engineer, contractor
Project delivery stage	Use life-cycle evaluation, approved submittals, mock-ups, inspection points, testing and commissioning plans.	Project manager, procurement team, consultants
Sector strengthening stage	Improve code enforcement, professional training, product testing, data disclosure and green finance verification.	Authorities, professional bodies, lenders, institutions

Conclusions

Pakistan's building sector has the potential for the use of green building materials and energy-efficient building techniques. They will only be successful if they are applied on a whole building and whole project basis. All materials, passive design, envelope performance, mechanical systems, renewable energy, procurement, quality assurance and facility operation are interrelated. A project is not green if it has one technology, but is more sustainable if decisions in the project are taken to reduce resource use and enhance performance across the project's life (R. S. Khan et al., 2025).

There is institutional support in the form of the Energy Conservation Building Code 2023, the NEECA Action Plan, and the direction of the Pakistan Green Building Code. Standards have an impact on actual performance; however, when they are broken down into drawings, tender documents, material submittals, inspection points, commissioning requirements and handover manuals. The construction-management profession has a direct role in making this translation possible (Mahar, 2022).

The diversity of Pakistan should be taken into consideration for implementation, which should be climate-responsive and project-specific. In warm climates, high-performance roofs and shade could be the first concerns, while in cold climates or those with a high diurnal temperature range, airtightness, insulation and compact form could be more significant. Use of local and alternative materials may be useful if technical performance, moisture protection and workmanship are controlled. The right answer is the one that can be constructed, tested, run and maintained in a reliable fashion in the local environment (Abbas et al., 2022).

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