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Enhancing Quality Infrastructure to Improve Green Material Utilization in the Building Structures

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CHAPTER I

INTRODUCTION

1.1. The Rise of Green Building Material in Construction

Sustainability has become a global concern ever since the UN Conference of Environment Stockholm in 1972, which led to the global commitment to sustainable development in the Rio Earth Summit in 1992. With the worsening climate and growing industrial practices, it's paramount for people to start working together to reverse the impact of past industrial pollution and waste.

Sustainable development is a concept of viewing economic activities not just as simply a profit-based pursuit, but also to maintain the long-term stability of both the environment and society resulting from economic activities especially in extractive and manufacturing industries. After the Rio+20 Summit in 2012, the UN members re-evaluate their commitments on sustainable development as well as addressing concerns among members about the responsibilities and contributions they must make with an added emphasis on green economy, which aims to create a low-carbon and wasteless economy (Council on Foreign Relations, 2012). On the other hand, people around the world are now clearly allowed to find their own approach to sustainable development without needing a rigid guideline and avoiding economies becoming overburdened by sustainable development efforts.

The acceptance of sustainable development as a priority has expanded to all areas of the economy, including the construction sector where a key priority lies in a building plan that doesn't only care about economic gains, but also the social and environmental impact of building in that area as well. For this reason, guidelines and policies started to merge in order to promote sustainable construction based on the commitments from the Rio+20 Summit. Unfortunately, Solaimani and Sedighi (2020) reveals that most academic interests in sustainable construction methods, such as lean construction, are mostly developing only in North America and Europe.

However, Mavi et al. (2021) posits that creating an organized process centered on sustainability would set the baseline for later building projects and techniques, which would need to take into account a model of sustainability in order to achieve sustainable construction. As population and wealth grows, urbanization also rockets especially in economically growing cities which may happen outside the planned city development (Yilmaz and Bakis, 2015). This results in resources and environment being deteriorated in the long-run to erect buildings, with the effects of climate change in forms of extreme weathers becoming a common weather pattern in various parts of the world. Therefore, while academic interests in sustainable construction are still sparse, making sustainable construction more widespread globally remains urgent.

A rising sustainability concept in construction is green building, which is a construction method that emphasizes resource efficiency and effectiveness, such as energy, water, and building materials, in order to minimize waste and greenhouse gas emission and projected to be able to reduce energy usage up to 42%, greenhouse gas emission up to 40%, and operational costs up to 40% compared to conventional construction methods (Jakarta Provincial Government, 2024). This trend began in the 1960s when the concept of ecologically-aware architecture was introduced by Paul Soleri, which entered mainstream thinking during the 1970s energy crisis thus pushing more stakeholders to minimize energy use of a building in the long-run (Ng, 2023). In Hong Kong, China for example, the city's buildings consume 90% of electricity and release 60% of annual greenhouse gas emissions which directs Hong Kong, China to respond with a Climate Action Plan 2030+ setting the goal of 70% carbon reduction by 2030 through the implementation of green building certification that requires developers to fulfill sustainability performance criterias through all the phases of the construction project from planning, building, operating, and maintaining the structure (Ng, 2023). Thus, the Asia Pacific region has begun to enforce strict sustainability requirements that not only applies to economic activities, but also construction activities seen as an integral part of their sustainable development efforts.

Green building practices can be divided into 3 periods: prescriptive period, transition period, and performance period (Pyke, 2020). The initial emphasis on green building was centered on prescriptive guidelines, stressing demanding yet feasible targets in spite of a lack of infrastructure for practical data management. Performance was determined through the use of larger practice sets and going above and above the minimum standards for practices in order to produce observable sustainability advantages. By prioritizing sustainability, ensuring accountability, and preserving valued features in the face of conflicting demands, this method that lasted until the 2010s began to promote more effective buildings. During this period, green building has not been well-standardized and usually left to the control of each developer and policymakers.

Over a decade of implementation, the green construction industry encountered issues such as expensive documentation, complex norms, and conflicting performance metrics. Alongside expanding information sharing technologies and openness demands, innovations surfaced, such as evaluation methods for existing structures and tools to improve operational efficiency. The strategy was still disorganized, though, and there were few links between performance metrics for new and old buildings. The transition period reveals issues relating to unstandardized approaches to green building while starting to expand data sharing among developers and construction businesses.

Finally, with the advent of the performance period in the years after 2020, the green building sector is changing from costly prescriptive documentation to practical operational efficiency data, which is now affordable and available. For example, the zero net energy facilities at the US National Renewable Energy Laboratory site, which incorporate cutting-edge procedures and produce better results for people and the environment, serve as an example of how this transformation reforms construction project success based on measurable performance. In the long run, this period will turn targets from a checklist of recommended courses of action into quantifiable operational outcomes.

1.2. The State of Green Building Material Market

The rising trend of green building practices also spurs the demand for green building material. Based on the research from Greenmatch in 2024, the global market for green building materials is expected to reach (British Pound Sterling) GBP 280.3 billion and that amount is projected to jump to GBP 795.9 billion by 2033, or around 12 percent annual growth (Ukpanah, 2024). While the exact number of each type of green building material has not been properly recorded, Ukpanah (2024) listed some of them that stand out as game changers in the industry. For example, structural insulated panels are seen to cut costs not just from the double role of structural support and insulation, but also reducing the cost of air conditioning.

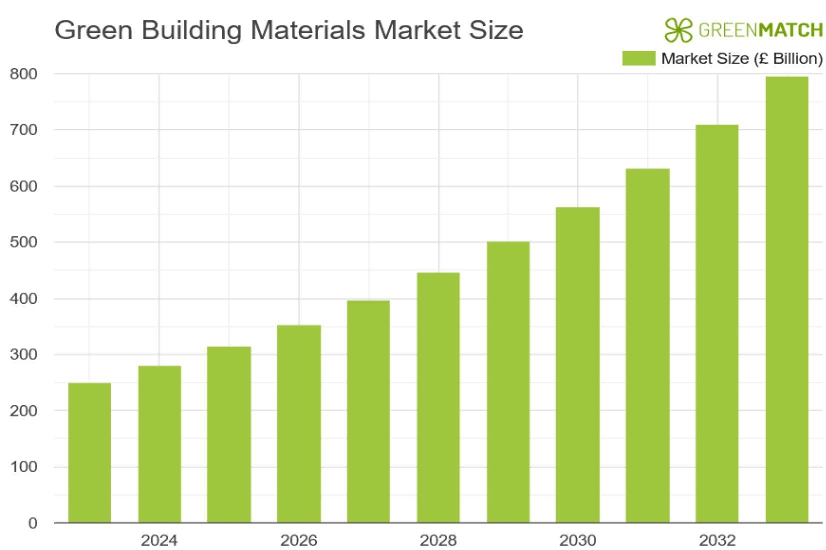

Image 1.1. Global Green Building Materials Market 2023-2033 (in billion GBP or poundsterling) (Ukpanah, 2024)

On the other hand, the supply is at risk to be outpaced by the rising demand in the coming years. WEF (2023) reported that although downstream and customer-face businesses have committed to implementing sustainability measures in their products including exclusively using green materials, many upstream and intermittent players across industries have not committed to the same level, including construction industry. While around 25% of glass manufacturers and 15% of concrete manufacturers have pledged commitment to sustainability efforts, only 2% of construction businesses have done the same (World Economic Forum, 2023). If countermeasures to increase supply are not implemented, the sustainable product demand in the construction sector might collapse.

This establishes the importance for companies to start taking steps to increase the supply of various green building materials to meet the demand of customers. If demands are not met, customers might shift away from green building materials back to conventional materials, which might hamper the sustainability efforts across regions.

1.3. The Green Building Material Trend in Asia-Pacific

The green building material market has grown rapidly in the Asia Pacific region, where it is reported that the revenue has reached GBP 83.4 billion in 2023 and growing at a 12.5% rate (Ukpanah, 2024). A particularly promising example of green building practices is Japan where one of its leading real estate developers, Sekisui House, made sure that 74% of its recently constructed houses achieved net-zero energy status by 2015, underscoring the kingdom of Thailand drive for environmentally friendly building with the goal of zero net energy houses by 2030, illustrating how quickly the economy's construction sector has embraced sustainability (E-Housing, 2024). This shows that green building material can be successful in the Asia Pacific region, but it will require various stakeholders to cooperate in introducing and promoting green building material within conventional supply chains and markets.

For example, China topped the list of buildings certified by the Leadership in Energy and Environmental Design (LEED) program in 2020 for five consecutive years, with over 1100 new LEED certification initiatives, a 50% increase from 2019 (Wu, 2022). Furthermore, Thailand is pumping through their efforts in their Energy Efficiency Plan 2015–2036 where they are targeting to reduce intense energy use in construction by 12%, with 245 certified green buildings in 2021, dominated by office and commercial buildings (Asian Development Bank, 2022), making them a trendsetter in Southeast Asia subregion. On the other hand, companies in Australia have begun to adopt green building materials in their sustainability efforts, such as CEFC who pledges AUD 95 million for the procurement of low carbon concrete in their projects, although stakeholder's resistance to the shift in green material and the lack of suppliers of green material in certain states makes growing green material sector a challenge (CEFC, 2021). These examples have shown development and potential for the green building efforts in Asia Pacific, but there's huge potential to expand the sector which requires cooperation among industry players to achieve their sustainable goals.

The Asia Pacific region is home to some of the largest economies in the world, which will be affected by climate change if people are not shifting towards sustainable practices, especially in the construction sector. However, there are several challenges that the region might face when starting green building projects, namely lack of education and training, lack of familiarity with green building technology, and expensive costs compared to conventional materials (Ayarkwa et al., 2022). Other potential challenges are the resistance to change from developers, lack of clear and detailed building code and regulations, as well as the lack of incentives from policies (Eze, Sofolahan, & Omoboye, 2023). Without close cooperation in the construction industry, any imbalance or one-sided effort by either side will result in minimal growth in the green building material initiatives. Therefore, it is paramount for Asia Pacific to cooperate with the industry not just domestically, but also internationally across the region in order to streamline perception and carve a path to sustainable development.

CHAPTER II

DISCUSSION AND FINDING

2.1 Overview of Green Materials in Construction

Green materials in construction are increasingly recognized as vital components for achieving sustainable development in the built environment. Green building materials are defined as construction inputs that are sourced, produced, and utilized with minimal adverse environmental impact. These materials possess several distinct characteristics: they are sustainable, often made from renewable or recycled resources, require less energy during production, emit fewer or no toxic chemicals, and are durable and recyclable. Common examples include fly ash, construction and demolition waste, biomass ash, recycled glass, and dredging sediments. The use of these materials reflects a commitment to reducing the environmental footprint of construction activities while promoting resource efficiency. Sustainable construction practices, which integrate green materials, aim not only to conserve natural resources but also to create healthier living spaces for occupants through enhanced indoor air quality and thermal comfort.

The benefits of adopting green materials extend across performance, environmental, economic, and social dimensions. From a performance perspective, buildings made with green materials often exhibit greater durability, superior insulation, and improved structural integrity. Environmentally, these materials contribute to lower greenhouse gas emissions, reduced water and energy consumption, and significant waste diversion from landfills. Economically, although the initial cost may sometimes be higher, the long-term operational savings in energy and maintenance costs often outweigh the initial investment. Furthermore, properties built with green materials tend to have higher market value and can attract tax incentives or green building certifications, enhancing their appeal to environmentally conscious investors and tenants. From a health standpoint, green materials ensure better indoor air quality by limiting the release of volatile organic compounds (VOCs) and other pollutants, directly impacting the well-being and productivity of occupants.

The landscape of green building materials is rapidly evolving, driven by innovation, technological advancements, and the tightening of sustainability standards across the construction industry. Emerging trends show a strong shift toward the adoption of bio-based and recycled materials (Cemex Ventures,2023), including but not limited to the following types.

Table 2.1. Types of Green Building Materials

Product	Description	Image
Hempcrete	A lightweight and sustainable construction material made by combining hemp fibers with a lime-based binder. Known for its excellent insulation properties, hempcrete is carbon-negative, meaning it absorbs more carbon dioxide than it emits during production. It is commonly used for walls and floors, providing a breathable structure that is also resistant to fire and pests.	
Bamboo	An engineered material created by laminating bamboo fibers to form strong panels or beams. They are widely used in flooring, wall panels, and even load-bearing structures in modern green construction.	
Mycelium-based bricks	An innovative building material grown from the root structures of fungi, combined with agricultural waste. These bricks are biodegradable, naturally fire-resistant, and provide sufficient strength for certain construction applications.	
Cork	A sustainable material harvested from the bark of cork oak trees without harming the trees themselves. It is lightweight, waterproof, and fire-retardant, making it an ideal choice for insulation, flooring, and wall coverings. Cork also provides excellent acoustic properties, contributing to a quieter indoor environment.	

Recycled plastic bricks	Construction units manufactured by compressing or molding waste plastics. By repurposing non-biodegradable plastic waste into durable bricks, this material not only helps reduce landfill overflow but also provides a lightweight, strong, and cost-effective alternative for walls, pavements, and even small buildings.	
Recycled Glass Concrete	A material produced by substituting traditional aggregates like sand and gravel with crushed recycled glass. This practice not only diverts glass waste from landfills but also gives the concrete a unique aesthetic appeal. It is often used in flooring, countertops, and decorative surfaces, while maintaining structural strength.	
Reclaimed wood	Timber that has been salvaged from old buildings, barns, or ships and repurposed for new construction projects. By giving a second life to aged wood, this practice reduces deforestation and adds a rustic, character-rich element to modern architectural designs. It is often used in flooring, beams, and decorative features	
Precast concrete	Concrete that uses environmentally friendly materials such as construction waste, industrial waste, or recycled materials.	
Terrazzo	Composite material consisting of recycled marble, quartz, glass, or granite chips embedded in a cement or resin binder. Known for its durability and design flexibility, terrazzo is widely used in flooring and wall treatments.	

Moreover, the integration of building-integrated photovoltaics (BIPV) is becoming more widespread, embedding solar energy generation directly into building envelopes to enhance energy efficiency without compromising design aesthetics. Smart materials, such as thermo-responsive insulation that adjusts to temperature changes, are also being explored to improve building adaptability and reduce operational energy consumption. These materials reflect a broader industry shift toward minimizing embodied carbon, promoting circular economy principles, and creating built environments that are not only more sustainable but also healthier and more cost-efficient over the long term (Attune, 2025)

According to Greenmatch data (Ukpanah, 2024), The Green Building Materials Market size is poised to shoot up from GBP 280.38 billion to GBP 795.95 billion by 2033, exhibiting a CAGR of more than 12.4% during the forecast period, between 2023 and 2033. In 2025, the industry revenue of green building materials is estimated at GBP 314.99 billion. The growing environmental pollution and more definite regulation is a significant driver for the green building materials market. As concerns about climate change and environmental degradation increase, there is a stronger push towards sustainable construction practices.

The expansion of the green building materials market is primarily driven by more sophisticated green technology and technical expertise, investments in green buildings, with stricter regulations promoting sustainable building practices followed closely behind (Wang et al., 2020). Advances in construction technologies such as energy-saving systems, smart building innovations, and renewable materials like cross-laminated timber are boosting the efficiency and sustainability of projects. More reliable technology and educated workers mean higher confidence for investors to fund green building projects. These developments, along with supportive policies, are encouraging a transition towards green buildings. Consumers and investors are increasingly seeking environmentally responsible solutions, further accelerating the demand for materials that reduce energy consumption and promote sustainable living (Firoozi, Firoozi, Oyejobi, & Avudaiappan, 2024).

The growth of the green building materials sector is not without its challenges. The fluctuating cost and availability of raw materials could impact market expansion, as many sustainable options require significant upfront investment compared to traditional materials. Economic pressures, including declining disposable incomes in some regions, may also limit the adoption of green practices in residential construction. Additionally, the lack of standardized certifications across industries creates confusion, making it harder for builders and consumers to choose truly sustainable options. Establishing globally recognized standards is crucial to ensuring transparency and fostering greater trust in green building materials.

Despite these hurdles, the future outlook for the green building materials market remains promising. The urgent need to address global carbon emission continues to drive innovation and investment. New materials offering enhanced performance and environmental benefits are attracting broader interest across the construction sector. As sustainable construction becomes a central pillar of international development efforts, green building materials are set to play a pivotal role in shaping the future of the built environment.

2.2 Quality Infrastructure and Standardization Landscape

The increasing urgency to combat climate change and reduce environmental degradation has elevated green building practices from a niche interest to a global imperative. Achieving truly sustainable infrastructure relies heavily on a robust quality infrastructure (QI) ecosystem—comprising standardization, metrology, testing, and certification. This journal examines the role of QI in promoting sustainable buildings, surveys the key international standards and certifications driving green construction, and analyzes regional challenges, with a focus on APEC economies. Quality Infrastructure underpins the credibility and performance of sustainable buildings. Each component of QI plays a critical role:

a. Standards provide consistent frameworks and performance benchmarks. They are crucial in defining what constitutes a "green" or "sustainable" building and guide the design, construction, and operational phases. Also, standards serve as the foundational benchmarks that define the requirements for materials, processes, and performance in green building. They provide uniformity and consistency, facilitating compliance, interoperability, and innovation. International standards such as ISO 14001 (Environmental Management Systems) and ISO 50001 (Energy Management Systems) offer frameworks for organizations to manage environmental responsibilities systematically and improve energy performance, respectively (WBDG, n.d.).

   In the context of green building, standards guide the design, construction, and operation phases, ensuring that sustainability objectives are met. For instance, the ASHRAE Standard 189.1 provides minimum requirements for the design of high-performance green buildings, encompassing aspects like energy efficiency, indoor environmental quality, and site sustainability (Novatr, 2025).

b. Metrology, the science of measurement, underpins the accuracy and reliability of data critical to green building performance. It ensures that measurements related to energy consumption, indoor air quality, water usage, and other environmental parameters are precise and traceable. Accurate measurements are vital for assessing compliance with sustainability standards and for continuous performance monitoring.

c. Metrology enables the quantification of emissions, resource usage, and other environmental impacts, providing the data necessary for informed decision-making and policy development. It supports the validation of building performance claims and the effectiveness of sustainability interventions (NSAI, n.d.).

d. Testing involves the systematic examination of materials, components, and systems to determine their properties and performance under specified conditions. In green building, testing verifies that products and assemblies meet the sustainability criteria outlined in relevant standards.

   For example, testing can assess the thermal performance of insulation materials, the efficiency of HVAC systems, or the durability of sustainable building materials. These evaluations are crucial for ensuring that the selected materials and systems contribute effectively to the building's overall sustainability goals.

e. Certification is the formal attestation that a building, product, or system complies with specific standards or criteria. It provides third-party validation, enhancing credibility and market acceptance. Certification schemes like LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), and CASBEE (Comprehensive Assessment System for Built Environment Efficiency) assess various aspects of building sustainability, including energy efficiency, water conservation, material selection, and indoor environmental quality.

   These certifications not only recognize exemplary sustainable practices but also incentivize continuous improvement and innovation in green building. They serve as tools for benchmarking performance and can influence market dynamics by differentiating certified buildings in the real estate market.

Together, these components drive transparency, foster innovation, and ensure environmental claims are measurable and trustworthy.

2.2.1 Snapshot of Relevant International Standards (ISO, ASTM, LEED, BREEAM, etc.)

Green building standards and certification systems provide essential frameworks for assessing and improving the environmental performance of buildings. Below is a detailed overview of key international standards and certifications, including their focus areas, areas of implementation, and notable examples from APEC economies.

a) ISO Standards

Focus Areas: Environmental management, energy efficiency, and sustainable operations.
Key Standards:

- **ISO 14001**: Establishes the framework for an environmental management system (EMS), enabling organizations to enhance environmental performance through systematic management of environmental responsibilities (ISO, 2015).
- **ISO 50001**: Provides requirements for an energy management system (EnMS), facilitating continual improvement of energy performance (ISO, 2018).

  Implementation in APEC: For example, PT. Waskita Karya in Indonesia has adopted ISO 14001:2015 as part of its integrated management system to improve environmental responsibility across its infrastructure projects (Green Building Council Indonesia, 2022).

b) ASTM Standards

Focus Areas: Testing protocols and data collection to assess sustainability aspects of building materials.
Key Standard:

- **ASTM E2129-24**: Standard practice for collecting data to evaluate the sustainability of building products. It covers materials acquisition, manufacturing impacts, operational emissions, and recyclability (ASTM International, 2024).
- **Implementation in APEC**: ASTM E2129 serves as a technical foundation across APEC economies, particularly in early-stage material vetting for projects aiming for international certifications like LEED or BREEAM (ASTM International, 2022).

c) **LEED (Leadership in Energy and Environmental Design)**

Focus Areas: Energy, water, materials, indoor environmental quality, innovation, and regional priority.

Implementation in APEC:

- **Songdo International Business District (Republic of Korea)**: Contains over 100 LEED-certified buildings, showcasing the largest concentration of green buildings in any single district in Asia (USGBC, 2021)
- **Cebu Exchange (the Philippines)**: Holds multiple certifications including LEED Platinum and EDGE Zero Carbon, recognized as a global benchmark for mixed-use sustainability (Arthaland, 2023)
- **Lè Architecture (Chinese Taipei)**: LEED Gold-certified for its integration of natural ventilation and energy-efficient design (USGBC, 2021).

d) **BREEAM (Building Research Establishment Environmental Assessment Method)**

Focus Areas: Management, health and wellbeing, energy, transport, water, materials, waste, land use, and pollution.

Implementation in APEC: **Marina One (Singapore)**: Dual-certified with both BREEAM and LEED Platinum, combining passive design strategies with high-tech solutions for energy and water efficiency (Green Design Consulting, 2023).

2.2.2 Regional Standards in APEC Economies

a) **Green Mark (Singapore)**: Developed by the Building and Construction Authority (BCA), Green Mark evaluates buildings based on energy and water efficiency, environmental protection, and indoor quality. Projects like Marina One have achieved Green Mark Platinum status (BCA, 2022).

b) **Green Star (Australia)**: Administered by the Green Building Council of Australia, Green Star assesses sustainability in construction and fit-outs. Notable examples include *One Central Park* in Sydney (GBCA, 2022).

c) **BEAM Plus (Hong Kong, China)**: Managed by the Hong Kong Green Building Council, this system assesses site, energy, water, materials, and indoor environmental quality. *The Quayside* in Kowloon East is a prominent BEAM Plus Platinum-certified project (HKGBC, 2022).

2.2.3 Gaps and Challenges in Standard Adoption – A Regional Perspective on APEC Economies

Adopting and implementing green building standards across APEC economies is uneven due to differences in economic development, regulatory frameworks, technical capabilities, and cultural factors.

a) **Financial and Market Barriers**

One of the most common barriers in developing APEC economies is the perception that green buildings are more expensive due to higher initial investment costs, even though they offer long-term benefits (Asia Property Awards, 2023). For example, in the Philippines, green-certified buildings are concentrated in Metro Manila, and adoption in other regions is limited due to a lack of economic incentives and perceived cost burdens (Asia Property Awards, 2023).

b) **Regulatory and Policy Inconsistencies**

Regulatory frameworks for green buildings differ widely across APEC economies. In Indonesia, despite Jakarta's green building regulations, implementation remains inconsistent due to unclear enforcement and limited awareness among stakeholders (Iswanto & Pratama, 2023). In China, fragmented policy enforcement and regional disparities have slowed the uniform adoption of green construction practices (Wang et al., 2023).

c) **Technical and Knowledge Gaps**

There is a shortage of local professionals trained in sustainable building practices across Southeast Asia, making it difficult to implement advanced certification systems like LEED or BREEAM. Moreover, knowledge gaps regarding passive design strategies and sustainable material sourcing persist, especially in secondary cities (ASEAN Centre for Energy, 2022).

d) **Cultural and Perceptual Challenges**

In several APEC member economies, green buildings are perceived as elitist or unnecessary for mass housing. This perception limits demand and discourages widespread application. Public awareness campaigns remain minimal in many regions, particularly in rural or lower-income urban areas (Asia Property Awards, 2023).

e) **Potential Solutions**

To overcome these challenges, various strategic interventions can be recommended:

- **Incentivization**: Government-led tax rebates, soft loans, and green procurement policies can reduce financial burdens and encourage private sector participation (Wang et al., 2023).

- **Policy Harmonization**: Establishing clearer domestic green building frameworks with consistent enforcement across regions is vital.

- **Training & Education**: Domestic programs and partnerships with universities and technical institutes can help bridge knowledge gaps.

- **Traditional Integration**: Promoting passive cooling and vernacular design features that are culturally familiar can reduce costs and increase acceptance (ASEAN Centre for Energy, 2022).

- **Public Outreach**: Awareness campaigns can demystify green buildings and promote their everyday benefits, encouraging wider societal support.

2.3 Policy and Regulatory Environment

The global push toward sustainable construction has been significantly bolstered by government initiatives and regulatory frameworks promoting the adoption of green building materials. Across many economies, policies now mandate energy efficiency standards, provide tax incentives, and establish certification systems aimed at reducing the environmental impact of the construction sector. Green building codes, such as mandatory energy performance benchmarks and material sustainability requirements, are increasingly shaping how projects are designed and executed. Initiatives like the European Union's Green Deal, the U.S. Energy Policy Act, and domestic sustainable development strategies highlight the critical role of policy intervention in accelerating the shift towards greener construction practices. Thailand are also investing in public awareness campaigns, research and development incentives, and subsidies to support businesses transitioning toward eco-friendly materials.

To better understand how regulatory support influences the green building materials market, a comparative analysis across APEC economies namely Australia; China; and Thailand provides valuable insights. Each of this economy demonstrates different levels of policy maturity, market readiness, and strategic emphasis on sustainability.

2.1 Thailand

Bangkok faces severe climate threats, particularly from sea level rise and land subsidence caused by excessive groundwater extraction and heavy construction. Projections warn that much of the city could be submerged by 2030. In response, the city has implemented various adaptive strategies, as follow:

- Since 1983, the Bangkok Metropolitan Administration and the Bangkok Metropolitan Region have collaborated to **construct dikes aimed at preventing tidal and waterway overflow in urban areas.**
- In response to the devastating 2011 floods, the government launched a 500-million-baht infrastructure program, which included the construction **of diversion and drainage tunnels,** a retention pond, and a water expressway to boost the city's flood resilience.
- In 2017, **Chulalongkorn Centenary Park** serves as a crucial piece of green infrastructure, capable of capturing up to one million gallons of water to mitigate urban flood risks.
- In 2019, the **Thammasat Green Roof**, Asia's largest urban rooftop farm—was established. This initiative blends contemporary architecture with traditional farming practices to restore ecological balance. Built on a previously unused rooftop in Bangkok, the facility now functions as a nature-based climate solution, capable of storing 11,718 cubic meters (approximately 3.1 million gallons) of water for crop irrigation. It also enhances biodiversity, provides refuge for wildlife, and contributes to air purification through tree-based oxygen production.

Additionally, Thailand has begun shifting its focus toward sustainability, particularly in the construction sector, marked by the widespread adoption of green building standards. The economy's uses two main certification systems: LEED (an international standard) and TREES (a local adaptation). To boost foreign participation, the Thailand Board of Investment (BOI) offers various incentives for investment in green construction (Lorenz&Partner, 2024).

These efforts highlight how infrastructure and sustainability can be effectively integrated. However, persistent challenges especially groundwater management require ongoing policy enforcement, community collaboration, and long-term resilience planning (Mayors, 2023).

2.2 China

China has positioned green infrastructure as a strategic priority in its broader sustainability agenda. The economy faces severe environmental challenges, including urban flooding, air pollution, and water shortages, which have prompted a domestic pivot toward sustainable urban development. One of the hallmark initiatives is the **Sponge City Program**, launched in 2014, which aims to transform urban areas into ecosystems capable of absorbing, storing, and purifying rainwater. The goal is for 80% of urban areas to reuse at least 70% of rainwater by 2030 (Zevenbergen et al., 2018). This initiative marks a significant shift toward integrating ecological design principles in urban planning.

The Chinese government has backed these efforts with a suite of regulations and technical standards. For example, the Ministry of Housing and Urban-Rural Development has issued guidelines for Sponge City implementation, which include technical specifications for permeable surfaces, green roofs, and constructed wetlands (MOHURD, 2020). Moreover, China has developed domestic green building evaluation standards, such as the **Three-Star Rating System**, and aligns with international systems like LEED and BREEAM in some joint-venture eco-cities.

A prime example of implementation is the **Sino-Singapore Tianjin Eco-city**, a collaborative project between the Chinese and Singaporean governments. Spanning 30 km^2, the city integrates a comprehensive suite of green infrastructure solutions, including waste-to-energy facilities, solar power installations, extensive public transportation, and smart water management systems. It serves as a living laboratory for sustainable urbanism and provides insights into how technical standards and international cooperation can be aligned to create scalable models for future cities (Tan & Wang, 2018).

2.3 Australia

Australia has made notable progress in promoting green infrastructure, especially in the context of climate resilience, water management, and renewable energy. The economy has set ambitious targets, including a 43% reduction in carbon emissions by 2030 and net-zero by 2050. Green infrastructure is viewed as central to achieving these goals. However, implementation has been inconsistent across states and territories due to regulatory fragmentation and procedural delays. In 2023–2024, approvals for renewable and infrastructure projects dropped by 20%, reflecting significant friction in the policy environment (The Australian, 2024).

Australia's green infrastructure development is primarily guided by state-level policies and voluntary certification systems. The **Green Star** rating system, developed by the Green Building Council of Australia (GBCA), is the leading domestic benchmark for evaluating the environmental performance of buildings and precincts. It assesses buildings across multiple categories, including energy, water, materials, and emissions. In addition, the **National Green Infrastructure Network** is working to integrate planning tools across jurisdictions to support biodiversity and ecosystem services.

A significant example is the **Central-West Orana Renewable Energy Zone (REZ)** in New South Wales. This is Australia's first REZ to gain planning approval and aims to add 4.5 GW of network capacity by 2028. It incorporates transmission lines, solar farms, and wind energy projects to feed into the domestic grid. The REZ framework is designed to streamline project approvals and provide regulatory clarity, making it easier for private investors to commit capital. This model of integrated planning and investment signals a promising approach to scaling green infrastructure in Australia (NSW Government, 2023).

2.4 Market Readiness and Adoption Potential

Market readiness for green building varies widely across APEC economies. Developed members like Japan; Republic of Korea; and Singapore have well-established green building regulations and certification programs. Singapore, for instance, aims to green 80% of its building stock by 2030 through the Green Building Masterplan and the Green Mark Scheme (Building and Construction Authority [BCA], 2022).

Republic of Korea mandates zero-energy building (ZEB) standards for all new public buildings from 2023 and private buildings over 1,000 m² from 2025 (Korea Energy Agency, 2023). Meanwhile, developing economies such as Indonesia; the Philippines; and Viet Nam are still in early stages but show growing interest due to rapid urbanization and international support (International Finance Corporation [IFC], 2019). According to IFC (2019), green buildings represent a USD 17.8 trillion investment opportunity in emerging markets in Asia-Pacific by 2030, underscoring significant adoption potential.

a) Existing Barriers (Economic, Regulatory, Technical)

- **Economic Barriers**

  The high upfront cost of green buildings remains a primary deterrent, particularly in emerging economies. Developers often lack access to low-cost green financing, and return on investment is perceived as long-term (Asia Property Awards, 2023).

- **Regulatory Barriers**

  In many APEC economies, the regulatory environment is fragmented or poorly enforced. For instance, while Jakarta has green building mandates, implementation remains weak due to limited institutional capacity and unclear guidelines (Iswanto & Pratama, 2023). In China, regional inconsistency in regulation complicates implementation across provinces (Wang, Li, & Zhang, 2023).

- **Technical Barriers**

  There is a significant skills gap in sustainable design, energy modeling, and certification processes in economies like Indonesia; the Philippines; and Thailand. Moreover, sustainable materials and building technologies are often not readily available or are cost-prohibitive (ASEAN Centre for Energy, 2022).

b) Opportunities for Growth and Policy Support

Green building presents clear opportunities across APEC:

- **Policy Incentives**: Financial incentives, such as tax breaks or fast-track permitting, can help stimulate market adoption. For example, Singapore offers grants under the Green Mark Incentive Scheme (BCA, 2022).
- **Harmonized Codes**: Aligning domestic standards with global certifications like LEED, BREEAM, or EDGE can help attract foreign investment and expertise (APEC, 2015).
- **Workforce Development**: Governments can invest in training programs to develop technical expertise in energy-efficient design and green construction (MDPI, 2023).

c) Role of Public-Private Collaboration and Incentives

- Public-private partnerships (PPPs) are vital in scaling green building practices. Malaysia has shown success with its Large-Scale Solar (LSS) and Net Energy Metering (NEM) programs, which leverage private investment to meet domestic energy efficiency targets (CEO Insights Asia, 2024).
- Singapore's collaboration between the Building and Construction Authority and private developers through the BCA Green Mark Scheme has proven instrumental in mainstreaming green building design (BCA, 2022).
- In emerging economies, PPPs can address both capital and technical limitations by enabling knowledge transfer, co-financing infrastructure, and leveraging regulatory support to de-risk investments.

CHAPTER III
CONCLUSION AND RECOMMENDATIONS

3.1 Key Insights on Materials, Standards, Policies, and Practices:

- **Green Materials**: A wide array of innovative, low-impact materials are emerging (e.g., hempcrete, bamboo, mycelium bricks, self-healing concrete, recycled plastics, reclaimed wood). These offer advantages in durability, emissions reduction, and health impacts.
- **Standards and Certification**: International frameworks such as ISO 14001, ISO 50001, ASTM E2129, LEED, BREEAM, Green Mark (Singapore), Green Star (Australia), and BEAM Plus (Hong Kong, China) guide sustainable construction across design, performance, and lifecycle management.
- **Quality Infrastructure (QI)**: Effective QI systems—encompassing metrology, testing, and certification—are essential to validate green material claims and performance outcomes.
- **Policies and Practices**: Policy leadership varies by economy. Australia; China; and Thailand illustrate different models of regulatory maturity and market incentives supporting green buildings.
- **Challenges**: High initial costs, regulatory fragmentation, limited technical capacity, and cultural resistance are major barriers to widespread adoption, especially in developing APEC economies.

3.2 Preliminary Recommendations

Green Material Prioritization:

- To accelerate the transition towards low-carbon construction, it is essential to prioritize building materials that demonstrate both environmental sustainability and high-performance properties. The following materials represent emerging innovations with strong potential as ush **Self-healing concrete, Recycled plastic bricks, Bamboo and hempcrete, Mycelium-based bricks, and other green materials.**
- Promote localized material sourcing to minimize transportation-related emissions and foster community-based supply chains. Encourage the use of Life-Cycle Assessments (LCA) as a core evaluation method for new materials, focusing on total environmental impact—from extraction and processing to end-of-life reuse or disposal.

Potential International Standards to Be Referred:

- **ISO 14001** – Environmental Management
- **ISO 50001** – Energy Management
- **ASTM E2129** – Sustainability data collection for materials
- **LEED, BREEAM, CASBEE** – Performance-based building certifications
- **Regional standards** like Singapore's Green Mark and Australia's Green Star should be aligned and benchmarked against global best practices.

Capacity-Building Focus Areas:

- **Training programs** on sustainable design, passive cooling techniques, and material innovation.
- **Technical workshops** for professionals (architects, builders, developers) on certification systems (e.g., LEED/BREEAM).
- **University and TVET partnerships** to scale technical expertise.
- **Policy-maker education** to foster coherent domestic
- strategies and enforcement mechanisms.

Strategic Outreach and Market Promotion Pathways:

- **Stakeholder campaigns** to raise awareness among developers, builders, and the public.
- **Pilot projects** in secondary cities to demonstrate benefits and feasibility.
- **Public-private partnerships (PPPs)** to co-finance green construction initiatives.
- **Regional cooperation** within APEC to harmonize standards and knowledge sharing.

3.3 Implications for Main Project and Workshop

How Findings Inform Upcoming Project Stages:

- Provide a foundational **inventory of viable green materials** and **standard frameworks** to support downstream policy and design development.
- Enable **targeted capacity building programs** that match current gaps in skills and technical expertise.

- Support the formulation of **standard harmonization strategies** within APEC for quality assurance and compliance.

Key Topics to Raise in Stakeholder Workshops:

- Barriers and incentives for green material adoption in APEC.
- Experience sharing on implementing **certification and QI systems**.
- Capacity-building opportunities and funding mechanisms.
- Policy alignment and the role of local governments in promoting sustainable practices.
- Strategies to engage private sector stakeholders and scale public-private collaboration.

REFERENCES

Arthaland. (2023). *Cebu Exchange: Sustainability Achievements*. Retrieved from https://arthaland.com/projects/cebu-exchange/

ASTM International. (2022). *ASTM Sustainability Report 2022*. Retrieved from https://www.astm.it/wp-content/uploads/2023/04/ASTM-Sustainability-Report-2022.pdf

Asia Property Awards. (2023). *Proptech paves the way for green building adoption in developing countries*. Retrieved from https://www.asiapropertyawards.com/en/proptech-paves-the-way-for-green-building-adoption-in-developing-countries/

ASEAN Centre for Energy. (2022). *Driving passive cooling implementation through building certification: Challenges and opportunities in the ASEAN region*. Retrieved from https://aseanenergy.org/post/driving-passive-cooling-implementation-through-building-certification-challenges-and-opportunities-in-the-asean-region/

Asian Development Bank. (2022). *Green Infrastructure Investment Opportunities: Thailand 2021 Report*. Asian Development Bank. Retrieved from https://www.adb.org/publications/green-infrastructure-investment-thailand-2021

ASTM International. (2024). *ASTM E2129-24: Standard Practice for Data Collection for Sustainability Assessment*. Retrieved from https://www.astm.org/e2129-24.html

Attune. (2025). Top 7 Green Building Trends Shaping 2025. Retrieved from Attune: https://www.attuneiot.com/resources/green-building-innovations-top-trends-shaping-2025

Ayarkwa, J., Opoku, D., Antwi-Afari, P., Li, R. (2022). Sustainable Building Processes' Challenges and Strategies: The Relative Important Index Approach. *Cleaner Engineering and Technology 7*. DOI:10.1016/j.clet.2022.100455

BCA (Building and Construction Authority). (2022). *Green Mark Certification Scheme*. Retrieved from https://www1.bca.gov.sg/buildsg/sustainability/green-mark-certification-scheme

CEFC. (2021). *Australian Buildings and Infrastructure: Opportunities For Cutting Embodied Carbon*. CEFC. Retrieved from https://www.cefc.com.au/insights/market-reports/australian-buildings-and-infrastructure-opportunities-for-cutting-embodied-carbon/

Council on Foreign Relations. (2012, July 5). *Examining Rio+20's Outcome*. Council on Foreign Relations. Retrieved from https://www.cfr.org/expert-roundup/examining-rio20s-outcome

E-Housing. (2024, September 18). *Sustainable Architecture in Tokyo: Exploring Green Building Innovations*. E-Housing. Retrieved from https://e-housing.jp/post/sustainable-architecture-in-tokyo-exploring-green-building-innovations

Eze, E., Sofolahan, O., & Omoboye, O. (2023). Assessment of Barriers to the Adoption of Sustainable Building Materials (SBM) in the Construction Industry of a Developing Country. *Frontiers in Engineering and Built Environment 3*(3): 153-166. DOI:10.1108/FEBE-07-2022-0029

Firoozi, A. A., Firoozi, A. A., Oyejobi, D., & Avudaiappan, S. (2024). Emerging trends in sustainable building materials: Technological innovations, enhanced performance, and future directions. Elsevier, https://doi.org/10.1016/j.rineng.2024.103521.

GBCA (Green Building Council of Australia). (2022). *Green Star Projects*. Retrieved from https://new.gbca.org.au/green-star/

Green Building Council Indonesia. (2022). *Green Building in Indonesia*. Retrieved from https://gbcindonesia.org/

Green Design Consulting. (2023). *Green Building Progress in the Asia-Pacific Region*. Retrieved from https://www.greendesignconsulting.com/single-post/green-building-progress-in-the-asia-pacific-region

HKGBC (Hong Kong Green Building Council). (2022). *BEAM Plus Directory*. Retrieved from https://www.hkgbc.org.hk/eng/beam-plus/beam-plus-assessment.htm

ISO. (2015). *ISO 14001: Environmental Management Systems – Requirements with Guidance for Use*. International Organization for Standardization.

ISO. (2018). *ISO 50001: Energy Management Systems – Requirements with Guidance for Use*. International Organization for Standardization.

Jakarta Provincial Government. (2024). *Kebijakan Bangunan Hijau*. Jakarta Provincial Government. Retrieved from https://www.jakarta.go.id/kebijakan-bangunan-hijau

Lorenz & Partner. (2024). NL208 Green Building in Thailand. Retrieved from Lorenz and Partners, Legal, Tax, and Business Consultant: https://www.lorenz-partners.com/newsletter-no-208/

Mavi, R., Gengatharen, D., Mavi, N., Hughes, R., Campbell, A., & Yates, R. (2021). Sustainability in Construction Projects: A Systematic Literature Review. *Sustainability*, *13*(4): 1932. DOI:10.3390/su13041932

Ministry of Housing and Urban-Rural Development (MOHURD). (2020). *Technical Guidelines for Sponge Cities Construction*. Beijing: MOHURD Press.

Mayors, T. G. (2023, June 12). Global Covenat of Mayors for Climate and Energy. Retrieved from Indonesia Best Practices, Thailand Green Infrastructure for Climate Change: https://www.asean-mayors.eu/portfolio/bangkok-thailand-green-infrastructure-for-climate-resiliency/#:~:text=The%20establishment%20of%20Chulalongkorn%20Centenary%20Park%20in%202017,Asia%20Urban%20Rooftop%20Farm%20was%20established%20in%202019

National Institute of Building Sciences. (n.d.). *Green Building Standards and Certification Systems*. Whole Building Design Guide. Retrieved from

National Standards Authority of Ireland (NSAI). (n.d.). *Sustainability - What does it mean to metrology?* Retrieved from https://www.nsai.ie/about/news/sustainability-what-does-it-mean-to-metrology/

Ng, J. (2023, March 23). *Green Buildings in Hong Kong: How Effective Are They?* Earth.Org. Retrieved from https://earth.org/green-buildings-in-hong-kong-how-effective-are-they/

Novatr. (2025). *Green Building Standards and Certifications Systems 2025*. Retrieved from https://www.novatr.com/blog/green-building-standards-and-certifications

Pyke, C. (2020, April 28). *Moving the Goalposts: The History of Green Building and Performance*. GRESB. Retrieved from https://www.gresb.com/nl-en/moving-the-goalposts-the-history-of-green-building-and-performance/

Iswanto, D., & Pratama, Y. H. (2023). *Exploring the Barriers to Green Building Implementation in Jakarta*. Journal of Civil Engineering Forum, 9(1), 74–84. https://journal.ugm.ac.id/v3/JCEF/article/view/7150

Solaimani, S. & Sedighi, M. (2020). Toward a Holistic View on Lean Sustainable Construction: A Literature Review. *Journal of Cleaner Production 248*. DOI:10.1016/j.jclepro.2019.119213

USGBC (U.S. Green Building Council). (2021). *LEED Project Directory*. Retrieved from https://www.usgbc.org/projects

Ukpanah, I. (2024, September 5). *Top 15 Sustainable Materials for Green Building in 2025*. Greenmatch. Retrieved from https://www.greenmatch.co.uk/blog/green-building-materials

Ventures, C. (2023, November 13). Top 10 sustainable building materials for eco-friendly construction. Retrieved from CEMEX Ventures: https://www.cemexventures.com/sustainable-building-materials/#:~:text=These%20are%20the%20best%20sustainable,Arqlite

Wang, Y., Li, Y., & Zhang, C. (2023). *Challenges in implementing green building policies in China: A regional perspective*. Journal of Asian Architecture and Building Engineering, 22(1), 34–45. https://www.tandfonline.com/doi/full/10.1080/13467581.2023.2280697

World Economic Forum. (2023). *Winning in Green Markets: Scaling Products for a Net Zero World*. World Economic Forum. Retrieved from https://www.weforum.org/publications/winning-in-green-markets-scaling-products-for-a-net-zero-world/

Wu, Y. (2022, November 18). *China's Green Building Materials Sector: Policies and Investment Opportunities*. China Briefing. Retrieved from https://www.china-briefing.com/news/chinas-green-building-materials-sector-policies-and-investment-opportunities/

Yilmaz, M. & Bakis, A. (2015). Sustainability in Construction Sector. *Procedia - Social and Behavioral Sciences 195*: 2253-2262. DOI:10.1016/j.sbspro.2015.06.312.