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Current Challenges and Future Prospects of Green Construction in Malaysia

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ABSTRACT: Malaysia's rapid urbanization, driven by a growing population and increasing industrial and infrastructural demands, significantly impacted the environment. The construction sector, a key contributor to economic growth, simultaneously became a major source of environmental degradation due to high resource consumption and waste generation. In response to these challenges, the integration of green materials and sustainable technologies emerged as a viable solution to minimize the negative environmental footprint of construction activities. This paper provides a comprehensive overview of the current state of green materials in Malaysia, including bamboo, organic waste, recycled concrete aggregate, and plastic waste, highlighting their benefits and limitations. Additionally, sustainable construction technologies such as solar energy, hydropower, biogas systems, green roofing, and rainwater harvesting are examined for their potential role in enhancing environmental sustainability. The study further evaluates existing government policies and regulations governing green construction in Malaysia, identifying key challenges such as ineffective waste management, regulatory enforcement gaps, and illegal dumping. Comparisons with international best practices, including those from Japan and Hong Kong, offer insights into potential improvements for Malaysia's regulatory framework and implementation strategies. The paper also discusses the prospects of green materials and sustainable construction technologies, outlining potential solutions to enhance their adoption. By addressing both the challenges and opportunities within the sector, this review aims to contribute to the advancement of sustainable construction practices in Malaysia, ultimately fostering a eco-friendlier and more resilient built environment.

KEYWORDS: Construction; policies; management; green; sustainable; challenges; Malaysia

1. Introduction

The construction sector has played a pivotal role not only in the economy of individual nations but also in the global economy. It has been described as a dynamic sector that involves both forward and backward linkages with other industries [1]. Additionally, the construction sector is vital for providing the socio-economic infrastructure necessary for industrial development, as well as key facilities such as commercial and residential areas, highways, dams, playgrounds, stadiums, healthcare units, ports, railways, airports, communication systems, power generation and supply stations. Such infrastructure in developing countries not only provides economic benefits but also helps to elevate living standards within communities [2]. The construction sector supports local economies by utilizing locally sourced materials and labour for infrastructure projects, thereby creating employment and improving economic efficiency. This is especially relevant in Malaysia, where the construction sector has been a crucial part of the nation's economic growth. From 1991 to 2010, the sector contributed an average of 4.09% to Malaysia's Gross Domestic Product (GDP), with a minimum of 3% and a maximum of 5.7%. During this same period, the average growth rate of the construction sector was 4.74%, with fluctuations ranging from -23% to 21% in the two decades leading up to Vision 2020. The sector's contribution to employment was also noteworthy, averaging 8.56% of the total workforce, with a range between 7.2% and 9.5% [3].

However, this rapid expansion has not been without its challenges. The construction sector now faces increasing issues related to environmental degradation, resource depletion, and high energy consumption, some of which not only harm the environment but also pose serious health risks to the population [4, 5]. As noted by Ikau et al., the construction industry is responsible for one of the largest streams of waste generation in Malaysia [6]. This may be since many contractors do not practice resource reduction, material separation, recycling, or the reuse of construction materials at their sites. Additionally, they often fail to properly dispose of waste, with much of it ending up in landfills [7]. The type and quantity of waste produced varies depending on the stage of construction, the nature of the work, and the practices followed on-site [8].

These challenges have underscored the urgent need for more eco-friendly practices within the construction industry to safeguard Malaysia's environment. The use of green materials, designed to be more sustainable, energy-efficient, and environmentally friendly than traditional materials, has emerged as a viable solution. Malaysia has also begun incorporating green technologies that significantly reduce reliance on conventional methods, benefiting the environment while simultaneously promoting economic growth. This paper aims to explore the environmental challenges in Malaysia's construction industry and evaluate the role of green materials and technologies in promoting sustainable development.

2. Current State of Construction Management Practices and Legislative Policies

In Malaysia, construction projects were required to comply with a range of government policies established by various regulatory bodies, depending on the context. Agencies such as the Natural Resources and Environment Board Sarawak (NREB), the Department of Environment (DOE), the Department of Irrigation and Drainage (DID), and the Occupational Safety and Health Administration (OSHA) set out specific regulations and standards that all construction projects had to follow to ensure sustainable practices and mitigate environmental impacts. One key requirement was that an Environmental Impact Assessment (EIA) be conducted before the initiation of any construction project if it was classified under the categories listed in the First Schedule of the Natural Resources and Environment (Prescribed Activities) Order, 1994.

The process of obtaining environmental clearance in Malaysia consisted of three important stages. First, the site's suitability for construction was assessed. Projects categorized as prescribed underwent rigorous EIA approval. Second, projects had to comply with air and water pollution control standards, which involved securing written approvals for air emissions and submitting notifications for the management of sewage, industrial effluents, and leachates. The final step involved applying for the necessary licenses from DOE state offices for any activities related to the transportation of prescribed materials, treatment and disposal of scheduled waste, and other environmentally sensitive operations before construction could begin. Additionally, the Environmental Quality Act of 1974, enforced by the DOE, provided the legal framework for environmental management practices in Malaysia's construction sector, ensuring that all projects met the required environmental standards [9].

However, despite these policies and regulations, the management of construction waste in Malaysia faced significant issues, one of the most pressing being illegal dumping. A recent survey conducted by the Johor Solid Waste Management and Public Cleansing Corporation (SWCorp) highlighted a troubling trend: the number of illegal dumping sites in the region had been steadily increasing each year since 2017. Approximately 90% of these sites were used by waste disposal contractors, construction firms, and recycling companies seeking to avoid the costs associated with proper waste disposal [9]. A study by Aja and Al-Kayiem on waste management practices in Malaysia found that many landfill sites were poorly maintained, posing serious risks to the environment [10]. Illegal dumping led to various environmental problems, including land degradation, contamination of groundwater and surface water due to leachate, soil deterioration, and depletion of natural resources. These ongoing issues not only endangered ecosystems but also posted significant risks to human health and well-being [11].

Upon further inspection of the effects of Malaysia's construction waste and its policies, several issues were observed. Authorities such as the Ministry of Housing and Local Government administered the Solid Waste and Public Cleansing Management Act 2007 (Act 672), which regulated controlled solid waste and public cleansing to ensure proper sanitation under housing and local government oversight. While the act covered waste management within housing schemes and local government areas, its focus was primarily on preventing waste from causing unsanitary conditions. Although construction waste was included in the act as controlled solid waste, its overall approach to managing construction waste remained limited compared to the comprehensive strategies outlined in the waste management hierarchy [12].

The Ministry of Natural Resources and Environment enforced the Environmental Quality Act 1974 (Act 127), which aimed to prevent, reduce, and control pollution while improving

Malaysia's environmental quality. This act addressed various types of waste, including liquid, solid, gaseous, and radioactive waste—whether normal or scheduled. However, its focus was on waste that caused pollution once deposited, lacking continuous management measures [12]. Lastly, the Construction Industry Development Board (CIDB), operating under the Pembinaan Malaysia Act 1994 (Act 520), addressed enforcement regarding construction waste, though the act did not fully align with the principles of the waste management hierarchy [12].

These examples illustrated the lack of effective monitoring and enforcement, which often allowed businesses to breach regulations without facing penalties. Furthermore, limited transparency and public involvement in environmental decision-making resulted in conflicting interests and insufficient environmental protection. The lack of enforcement was also evident in a case study of the city of Ipoh, where the estimated amount of construction waste disposed of was assessed separately for legal and illegal dumpsites. According to the survey, approximately nine tonnes of construction waste were disposed of at the legal dumpsites, while a significantly higher amount (12,351 tonnes) were disposed of at illegal dumpsites [13].

3. Potential Solution and Environmental Systems of Other Country

For Malaysia to achieve a more sustainable environment, it should look to developed nations like Japan and Hong Kong for guidance on managing construction waste. Japan set a strong example with its Recycling Law established in 1991, which empowered officials to select recyclable materials and promote their reuse. The Japanese approach included mandatory Waste Management Reports for construction projects, specific waste management clauses in contracts, sorting obligations under the Construction Recycle Act, and established standards for recycled construction waste. Similarly, Hong Kong effectively managed construction waste through its Construction Waste Disposal Charging Scheme (CWDCS), introduced in 2005. This scheme led to a 65% reduction in landfill waste, demonstrating its success in improving waste management and environmental conditions [12].

In Hong Kong, environmental legislation was highly specialized, with ordinances addressing specific waste categories. This specificity ensured clearer boundaries and more effective implementation for each type of waste. In contrast, Malaysia's environmental acts were drafted more generally, resulting in overlapping clauses across various regulations issued by different government and private bodies. While both Malaysia and Hong Kong utilized similar methods for managing construction and demolition (C&D) waste, such as recycling and landfilling, Hong Kong's construction stakeholders were notably more engaged in recycling programs due to the enforcement of the CWDCS. Despite government efforts to promote recycling, Malaysia's initiatives did not garner as much attention. Critical practices in Hong Kong, such as on-site and off-site sorting, were key to successful recycling and waste reuse. Although Malaysia implemented sorting programs, their effectiveness remained unclear. To improve waste management, Malaysia should enhance both on-site and off-site C&D waste sorting practices, which would help reduce costs and extend the lifespan of landfills [14].

An efficient waste classification method was the foundation and precondition for successful waste management. For example, classification systems were developed to assist in data collection, supervision, and monitoring, thereby informing appropriate management guidelines. This approach produced optimistic outcomes when conducted in China, the EU, Japan, and the USA, where major contributions to C&D waste were observed. Additionally, incorporating more prefabrication concepts into building design could help contractors substantially minimize the generation of C&D waste. It also aided in significantly reducing truck activities, which, in turn, accelerated construction practices [10].

4. Green Materials Utilised in Malaysian Construction Activities

To minimize the environmental impact of buildings throughout their life cycle, Green Building (GB) has emerged as a modern construction approach. It promotes the use of eco-friendly materials, the adoption of resource-saving techniques and waste reduction measures, and the enhancement of indoor environmental quality, among other sustainable practices [15]. The first step in incorporating such construction approaches is the selection of green materials, as construction materials play a vital role in building projects. Their chemical, physical, and mechanical properties, when combined with appropriate design, determine the structural strength and stability of a building. Proper material selection ensures the longevity and functionality of construction projects [16]. The definition of green materials is constantly evolving, depending on regional, functional, temporal, and other multi-dimensional contexts. A green material can be defined as one that maximizes efficiency with minimal resource use, aligns with natural ecosystem processes, reduces dependence on additional energy and materials, and supports the transition toward a service-based economy [17].

4.1.Palm oil organic waste.

Palm oil industry is one of the major agro-industries in counties like Malaysia, this industry produces a large amount of waste in the forms of empty fruit brunches, fibres, and kennel (Table 1). As vast amount of waste produced from this industry, the by-products then have been used as fuel to heat up boilers to generate electricity at temperatures of about 800-1000°C where the ash produced from the process has been known as palm oil fuel ash [18]. Muthusamy et al. (2015) has found that the replacement of palm oil fuel ash in concrete from 10% to 30% resulted in strength higher than control [19]. However, it reaches the maximum compressive strength at the replacement of 20%. The improvement in modulus of elasticity has also been observed at 20% replacement of palm oil fuel ash in concrete [19]. This is due to the densification of the internal structure of concrete through filling effect of the fine ash and the pozzolanic reaction that improved the bond between hydrated cement matrix and aggregate improved the concrete performance [18]. Palm oil fiber has also been found as an additive material in concrete, it can improve concrete cracking resistance [20]. A high tensile strength and high content of lignin make palm oil fiber is suitable as reinforcement in concrete. It enhances the mechanical properties such as fatigue and tensile stress as well as cracking also. The mechanism involved is by transferring stress from matrix to the fibber through interfacial shear. The percentage of palm oil fiber that is suitable to be used in concrete is from 0.2% to 0.6%, beyond this fraction will reduce the compressive and flexural strength [20].

4.2.Risk husk ash.

Rice Husk Ash (RHA) is a by-product derived from the incineration of rice paddy husks. When added to cement, risk husk ash improves its consistency, setting time, and strength properties. Research has shown that replacing Ordinary Portland Cement (OPC) with RHA can enhance both compressive and flexural strength, with an optimal replacement level typically around

10%. At this level, risk husk ash provides a beneficial balance, improving concrete's overall performance. In addition to enhancing strength, risk husk ash also decreases the density of concrete compared to conventional mixtures. This reduction in density is accompanied by improved resistance to tensile loading, which contributes to the overall durability of the concrete. The addition of risk husk ash not only extends the setting time of cement but also positively affects its normal consistency. Therefore, while RHA can significantly improve concrete's properties, its most effective use is typically at lower replacement levels to achieve optimal performance and balance in the final product [18].

4.3. Recycled concrete aggregate.

Repurposing concrete from demolished structures reduces the demand for virgin aggregates, conserving natural resources and decreasing the environmental impact of mining and transportation. This process also helps minimize landfill waste, as concrete that would otherwise be discarded is reused in new construction. Economically, recycled concrete can be more cost-effective than natural aggregates due to lower transportation and disposal costs. Its performance, when properly processed, can be comparable to conventional concrete, making it suitable for a range of applications, from road bases to structural concrete [21]. However, recycled concrete aggregate are currently only implemented in road construction such as pavement and driveways in Malaysia.

Recycling concrete waste into recycled concrete aggregate involves crushing concrete lumps into smaller particles to create an alternative, eco-friendly aggregate. However, recycled concrete aggregate often exhibits lower quality compared to natural aggregates due to the presence of adhered mortar, which is porous and contains microcracks. This results in recycled concrete aggregate having lower density, higher water absorption, and reduced mechanical strength. The interfacial transition zone between recycled concrete aggregate and cement paste can be weak, leading to lower overall concrete strength. Consequently, concrete made with high percentages of recycled concrete aggregate often demonstrates decreased compressive strength due to the inferior quality of recycled concrete aggregate and its impact on the hydration process and interfacial bond [21].

Despite this a lot of researches has been done to improve the limitations of recycled concrete aggregate such as the usage acid immersion to clean recycled concrete aggregate effectively removes loose adhered mortar showing improved density, water absorption, and mechanical strength, indicating that acid treatment effectively enhances recycled concrete aggregate physical properties by removing weak , thermal treatment with heating RCA at 800°C makes it comparable to traditional river-dredged aggregates [21], adjusting the water-to-cement ratio and increasing cement content improves recycled concrete aggregate concrete strength while lowering this ratio also enhances freezing and thawing resistance, making it comparable to concrete with natural aggregates incorporating pozzolanic materials like pulverized fly ash, ground granulated blast-furnace slag, and silica fume can boost the strength and durability of recycled concrete aggregate concrete [22].

4.4.Bamboo.

Bamboo has recently emerged as a prominent structural material, offering several significant advantages over traditional materials. Where it is used as structural frameworks, scaffolding or even bio composites in various construction projects. Bamboo is a popular green material as it is highly sustainable. As one of the fastest-growing plants, bamboo can reach harvestable size in just 3–6 years, growing three times faster than many other species. It is also beneficial for Malaysia as Malaysia has a lot of bamboo forests which belong to the sympodial bamboo category. It is reckoned that in Peninsular Malaysia there are around 59 bamboo species which originates from 7 genera, i.e., *Bambusa*, *Dendrocalamus*, *Dinochloa*, *Gigantochloa*, *Racemobamboos*, *Schizostachyum* and *Thyrsostachys* [23]. Secondly, bamboo is environmentally friendly due to its strong carbon sequestration capabilities. It can absorb up to 12 tons of CO_2 per hectare and produces nearly 35% more oxygen than an equivalent area of trees, making it beneficial for climate change mitigation [24]. Thirdly, bamboo is economically advantageous. It is less expensive than conventional construction materials like steel, largely because it requires less energy to harvest and transport. This results in lower manufacturing costs [25]. Lastly, bamboo boasts high tensile strength, with a tensile strength of approximately 193 MPa, comparable to the 159 MPa tensile strength of mild steel. This high strength-to-weight ratio allows bamboo to serve as a resilient material capable of withstanding high-speed winds and seismic forces [9].

4.5. Plastic waste.

The amount of solid waste being produced is rising with the current wave of urban and industrial growth, along with the challenge of managing it in landfills. In Malaysia, plastic waste claims around a tenth of the total waste, due to its widespread use in manufacturing, packaging, medical, and industrial sectors. Plastic contains harmful compounds that can cause significant environmental damage if not managed properly [26]. Therefore, repurposing plastic waste for construction provides both a sustainable waste management solution and supports eco-friendly building practices. Plastic waste can be converted into lightweight, durable construction materials such as roofing tiles, pavement blocks, and wall panels, offering alternatives to traditional materials like bricks, concrete, and wood. These plastic-based materials have a lower carbon footprint and are more environmentally friendly. Additionally, using plastic waste reduces the need for new raw materials, conserving natural resources and cutting energy consumption [26].

In Malaysia, various initiatives aim to promote the use of plastic waste in construction. Government policies and regulations encourage sustainable practices, including the recycling of materials. One notable project, the Eco Block initiative, seeks to convert plastic waste into interlocking blocks for building purposes. These blocks, made from a blend of plastic waste and cement, have been tested for strength and durability, offering a cost-effective and environmentally friendly alternative to traditional construction materials. This approach not only helps manage plastic waste but also conserves landfill space and reduces the energy required to produce new plastics [9, 26].

Plastic waste is being used to produce red bricks by replacing some of the sand with plastic pellets. Since sand and cement are the primary raw materials for concrete bricks, substituting sand with plastic helps reduce the weight of the bricks and lowers the overall sand consumption. This substitution process, which involves various mixing methods, has been shown to enhance the strength and reduce the heat conductivity of the bricks, making them excellent for construction. Additionally, plastic waste can replace aggregates in road construction, enhancing the load-bearing capacity and overall performance of roads by improving their structural integrity and tensile strength. Utilizing recycled plastics in construction is an effective green strategy that minimizes landfill waste, reduces environmental contamination, and lowers construction costs [26].

Table 1. Organic waste that potential for construction green material

Organic Waste Type	Description	Benefits	Challenges
Palm Oil Organic Waste	By-products from the palm oil industry (empty fruit bunches, fibres, kernels) are used as fuel to generate electricity and as additives in concrete.	- Palm oil fuel ash (POFA) improves concrete strength (optimal at 20% replacement). - Palm oil fibre enhances mechanical properties and cracking resistance.	- Excessive replacement (beyond 0.6% for fibre) reduces compressive and flexural strength. - Ash production requires high-temperature combustion (800-1000°C).
Rice Husk Ash (RHA)	By-product from rice husk incineration, used in cement to improve its properties.	- Enhances compressive and flexural strength (optimal at 10% replacement). - Reduces concrete density and improves tensile resistance. - Extends cement setting time and improves consistency.	- Higher replacement levels may negatively impact concrete performance. - Proper processing is needed to maximize benefits.
Recycled Concrete Aggregate (RCA)	Crushed concrete from demolished structures used as an alternative to natural aggregates.	- Reduces demand for virgin aggregates, conserving resources. - Lowers landfill waste and transportation costs. - Can be used in pavement and driveways.	- Lower density, higher water absorption, and weaker mechanical properties due to adhered mortar. - Reduced compressive strength compared to natural aggregates. - Requires treatments (acid immersion, thermal heating, or pozzolanic materials) to improve quality.
Bamboo	Fast-growing, sustainable material used in construction for frameworks, scaffolding, and bio composites.	- Highly sustainable (harvestable in 3-6 years). - Strong carbon sequestration, absorbing up to 12 tons of CO_2 per hectare. - High tensile strength (~193 MPa, comparable to mild steel). - Cost-effective compared to traditional materials.	- Requires proper treatment for durability and resistance to pests and moisture. - Structural application still under research for wider implementation.
Plastic Waste	Repurposed plastic waste used in construction materials like tiles, blocks, and road aggregates.	- Reduces landfill waste and environmental contamination. - Lightweight and durable construction material. - Plastic-based bricks and Eco Blocks offer sustainable alternatives. - Improves road durability by enhancing tensile strength.	- Requires proper processing to ensure durability and strength. - Some plastics contain harmful compounds requiring careful handling. - Large-scale implementation still limit

5. Green Material and Their Challenges

Implementing green building materials in Malaysia faces several challenges such as that some green material has higher cost compared to traditional materials, specifically in higher upfront costs. Additionally, the limited availability of these materials poses a challenge as most of them need to be imported, which can increase their cost and complicate their procurement. Another major difficulty is the shortage of skilled workers knowledgeable in green building techniques, making it challenging to integrate these materials into construction projects. Lastly, regulatory barriers also impede progress, as existing building codes and regulations may not be well-suited to accommodate green building materials, complicating the approval process for such projects [9]. Green materials and technologies along with their respective challenges are summarized in Table 2.

Table 2. Green materials and technologies along with their respective challenges.

Green Material/Technology	Advantages	Challenges
Bamboo, Organic Waste, Recycled Concrete Aggregate, Plastic Waste	Sustainable, reduces waste, promotes circular economy	Higher upfront costs, limited availability (requires imports), lack of skilled workers, regulatory barriers
Solar Technology	Renewable, cost-effective in the long run, reduces CO_2 emissions, low noise pollution, job creation, scalability	High initial installation cost, intermittent energy production (weather-dependent), efficiency issues (dust, shading), spatial limitations in urban areas
Hydropower Technology	Stable, clean, and reliable energy, suitable for Malaysia's river-rich geography, supports flood control and irrigation	Environmental and social impact (ecosystem disruption, displacement of communities), high initial investment for dam construction
Biogas Technology	Converts organic waste into renewable energy, reduces landfill waste, provides high-quality fertilizer, supports palm oil industry	High setup cost, dependency on consistent feedstock quality, periodic maintenance challenges
Green Roof System	Reduces urban heat island effect, improves thermal comfort, enhances stormwater management, improves air quality and biodiversity	High installation and maintenance cost, requires suitable plant selection for Malaysia's climate, potential drainage and water logging issues
Rainwater Harvesting System (RWHS)	Reduces water consumption, helps prevent flash floods and soil erosion, provides alternative water source	High initial installation cost, requires regular maintenance, water quality affected by pollutants, seasonal variations impact reliability

5.1.Solar technology.

According to a study comparing the annual cost of SWHs and EWHs over time, installing SWHs is more cost-effective because utilising EWHs will result in a higher electricity bill due to growing families and potential rises in electricity rates [27]. SWHs can prevent around 1583 kg of CO_2 emissions annually per unit installed [28]. Therefore, it results in clean and renewable electrical power for the communities. According to the financial evaluation, SWHs can save up to RM 708.30 in energy costs per year per household [28]. Additionally, there is no noise pollution generated during operation as the solar energy [29]. When opposed to using fossil fuels to produce electricity, one of the main drawbacks of using solar energy is that it is heavily reliant on meteorological conditions. This makes solar energy volatile and unpredictable, which significantly limits and complicates power production [30]. Solar technology in Malaysia has seen significant advancement in recent years, driven by the country's abundant sunlight with a monthly solar radiation around 400–600 MJ/m^2 [31]. Solar technology involves the use of semi-conductor devices called Photovoltaic (PV) cells, which convert sunlight energy directly to electrical energy [32]. Solar technology provides a clean and renewable source that reduces the reliance on fossil fuels and lowers greenhouse gas emissions. The long-term cost of using solar energy is also lower for electrical bills compared to traditional electrical generation methods [31].

Solar technology also creates job opportunities in the installation, maintenance, and manufacturing sectors, contributing to economic growth. The scalability of the technology allows for both large-scale solar farms and small, residential installations, making it adaptable to various needs and settings [33]. The Malaysian Government has also provided initiatives and incentives, such as the Feed-in Tariff (FiT) and Net Energy Metering (NEM) schemes, have been implemented to support the growth of solar energy, reflecting a strong commitment to increasing solar energy capacity and overcoming financial barriers [34]. There are challenges with solar technology such as the initial installation cost of solar PV systems can be high, which may be a barrier for widespread adoption despite falling prices over recent years [35]. Solar energy production is also intermittent, as it relies on sunlight, which can be inconsistent during cloudy days or at night [35]. The efficiency of solar panels can be affected by factors such as dust accumulation, animal faeces and the angle of installation hindering the absorption of solar energy [36]. Solar technology also faces spatial challenges, particularly in densely populated cities or high-rise buildings, available roof space may be limited, making installation difficult [35].

5.2. Hydropower technology.

Hydropower involves capturing the kinetic energy of river water through dams, which then drives turbines connected to generators to produce power. Which is great for a fossil fuel-dependent country such as Malaysia it is more efficient in power generation and has the advantage of generating a stable, clean, and reliable source of electricity [37]. It is more advantageous for Malaysia as it has 200 rivers, in which most of them has origins in mountainous regions, with weathers that expect regular rainfall up to 5080 mm for West Malaysia and 3850 mm for East Malaysia. These criteria all contribute to the potential construction and efficiency of a dam [38]. For example, Malaysia has 2 large-scale hydroelectric projects, such as the Bakun and Murum dams, that generates a substantial amount of power where these projects also offer ancillary benefits, such as improved water management for irrigation and flood control [38]. Hydropower still has its major flaws, especially large dams, which can have significant environmental and social impacts such as the flooding of vast areas, disruption of local ecosystems such as downstream organisms, and displace local communities. For instance, the Bakun Dam's construction led to the displacement of Indigenous communities and significant ecological changes in the region [39]. Furthermore, the high initial investment required for dam construction and infrastructure can be a financial burden, despite the long-term benefits [40].

5.3. Biogas technology.

Biogas technology is the usage of organic waste and converting it to renewable energy. An abundance of organic waste in Malaysia from agricultural activities such as palm oil plantations, food processing industry, and livestock operations provides a huge potential in dealing with both the increasing national dependency of fossil due and increasing requirement for energy due to the population growth [41]. Biogas technology involves anaerobic digestion, where organic waste is broken down by microorganisms in the absence of oxygen to produce biogas, primarily composed of methane. This biogas then can be used for generating electricity, heat, or as a substitute for natural gas in various applications, while the remaining digestate serves as a high-quality fertilizer [42]. The usage of biogas technology can significantly reduce the volume of organic waste sent to landfills, which alleviates pressure on waste management systems and minimizes methane emissions from waste decomposition. It would be suitable for palm oil mills, which are all over Malaysia which helps in managing this waste effectively while generating a renewable energy source. The digestate produced can then be used in the agricultural sector, which benefits soil quality. The high initial capital investment for setting up biogas facilities can be a barrier, particularly for small and medium-sized enterprises [41]. The efficiency of biogas production is highly dependent on the consistency and quality of the feedstock, resulting in periodic maintenance [43] that adds to cost and difficulty to travel to such areas.

5.4. Green roof system.

Green roof technology involves installing a layer of vegetation on building rooftops. In Malaysia, where urbanization and climate resilience are increasingly important, green roofs offer a viable solution to improve environmental and building performance. The technology typically comprises a series of layers, including a waterproof membrane, a drainage system, a growing medium, and vegetation. Plants on green roofs can undergo evapotranspiration, which helps to reduce the heat island effect by increasing humidity and cooling the air. This effect lowers energy costs for air conditioning and reduces air pollution. Additionally, green roof systems enhance internal thermal comfort by absorbing and reflecting solar radiation, thus decreasing the amount of heat radiated from buildings [44]. Additionally, green roofs can manage stormwater more effectively by absorbing rainwater and reducing runoff, which mitigates flooding risks in urban areas prone to heavy rainfall. They also offer improved air quality by filtering pollutants and providing green space, which supports biodiversity and enhances urban aesthetics. Like other technologies, implementing green roof system requires high initial cost of installation, where the maintenance requirements are also a concern, as green roofs necessitate regular care to ensure plant health and system functionality, which can involve additional costs and expertise. Moreover, the selection of appropriate plant species that can thrive in Malaysia’s hot and humid climate is critical. Failure to choose suitable plants can result in poor performance and increased maintenance will be caused by issues such as drainage issues, water logging issues, unfit plant species for Malaysia’s climate [45].

5.5. Rainwater harvesting system (RWHS).

Due to issues such as growing population growth water shortages has been occurring due to freshwater consumptions and simply more people using water in Malaysia. The Malaysian weather where frequent and heavy rainwater harvesting allows for the use of rainwater harvesting technology which involves the collection and storage of rainwater that can be used for irrigation, flushing toilets, and even potable water offering a promising solution for enhancing water sustainability. The system typically includes catchment areas such as roofs, gutters, downpipes, storage tanks, and filtration units. Rainwater harvesting system can also reduce the effect of rainwater on soil systems, especially in urban areas would help decrease flash floods and even reduce occurrence of soil erosion [46]. Despite its advantages, rainwater harvesting has some drawbacks. Like other energy technologies the initial cost of installing rainwater collection and filtration systems can be high, which may deter some homeowners or businesses. Maintenance is another concern, as the systems require regular cleaning and inspection to ensure the quality of the collected water and the efficiency of the filters. Moreover, the quality of rainwater can be affected by atmospheric pollutants. Seasonal variations in rainfall can also affect the reliability of rainwater supply, making it less predictable during extended dry periods [47].

6. Conclusion

Malaysia has environmental issues that is caused by the mishandling due to rapid urbanization and population growth. Especially in the construction industry, which is important in supporting the country's expansion socially, economically, and human capacity wise. Therefore, the by-product of environmental impact that potentially can have a long-term human and environment health of Malaysia must be discussed, examined and evaluated. This study has outlined that Malaysia do have a standard framework in the handling of waste management, the demonstration of the usage of green materials and green technology as Malaysia has enormous potential in accessing such natural renewable energy due to its geolocation and weather. If the issues such as stricter enforcement on environmental law on business, the outlook of learning from countries with more complete than incorporating it in a way that suits the country, Malaysia has a bright outlook in creating a thriving country that is more responsible environmentally, higher quality of life for its people, while not limiting its growing economy.

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Author Contribution

Wil Son Sam, Audrey Primus, Daniela Sentiveanu: drafting of the manuscript, writing and revision, conceptualization, data analysis; Surya Dewi Puspitasari, Md Abu Hanifa Jannat, Jayapadma Mudalige Miyuru Uthpala Jayapadma: methodology and interpretation of the results; Yuangga Rizky Illahi, Muhamad Diki Permana, Amit Kumar Maharjan, Rabin Maharjan, Jovale Vincent Tongco: research design, data collection, interpretation, writing and revision.

Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Dehdasht, G.; Ferwati, M. S.; Abidin, N. Z.; Oyedeji, M. O. (2021). Trends of construction industry in Malaysia and its emerging challenges. *Journal of Financial Management of Property and Construction*, *27*, 161–178. https://doi.org/10.1108/jfmpc-08-2020-0054.

[2] Snieska, V.; Simkunaite, I. (2009). Socio-Economic Impact of Infrastructure Investments. *Engineering Economics*, *63*(3).

[3] Khan, R. A.; Liew, M. S.; Ghazali, Z. B. (2014). Malaysian construction sector and Malaysia vision 2020: Developed nation status. *Procedia - Social and Behavioral Sciences*, *109*, 507–513. https://doi.org/10.1016/j.sbspro.2013.12.498.

[4] Chuan, G. K. (1982). Environmental impact of economic development in peninsular malaysia: A review. *Applied Geography*, *2*(1), 3–16. https://doi.org/10.1016/0143-6228(82)90014-5.

[5] Asnor, A.S.; Al-Mohammad, M.S.; Wan Ahmad, S.; Almutairi, S.; Rahman, R.A. (2022). Challenges for Implementing Environmental Management Plans in Construction Projects: The Case of Malaysia. *Sustainability*, *14*, 6231. https://doi.org/10.3390/su14106231.

[6] Ikau, R.; Joseph, C.; Tawie, R. (2016). Factors influencing waste generation in the construction industry in Malaysia. *Procedia - Social and Behavioral Sciences*, *234*, 11–18. https://doi.org/10.1016/j.sbspro.2016.10.213.

[7] Begum, R. A.; Siwar, C.; Pereira, J. J.; Jaafar, A. H. (2009). Attitude and behavioral factors in waste management in the construction industry of Malaysia. *Resources, Conservation and Recycling*, *53*(6), 321–328. https://doi.org/10.1016/j.resconrec.2009.01.005.

[8] Nagapan, S.; Rahman, I. A.; Asmi, A.; Adnan, N. F. (2013). Study of site's construction waste in Batu Pahat, Johor. *Procedia Engineering*, *53*, 99–103. https://doi.org/10.1016/j.proeng.2013.02.015.

[9] Chong, J. H.; Liu, M. S.; Hernandes, E.; Albescu, M. (2023). Implementation of green materials in construction management system in Malaysia. *Civil and Sustainable Urban Engineering*, *3*(1), 51–69. https://doi.org/10.53623/csue.v3i1.212.

[10] Umar, U. A.; Shafiq, N.; Malakahmad, A.; Nuruddin, M. F.; Khamidi, M. F. (2016). A review on adoption of novel techniques in construction waste management and policy. *Journal of Material Cycles and Waste Management*, *19*(4), 1361–1373. https://doi.org/10.1007/s10163-016-0534-8.

[11] Rahim, M. H. I. A.; Kasim, N.; Mohamed, I.; Zainal, R.; Sarpin, N.; Saikah, M. (2017). Construction waste generation in Malaysia construction industry: illegal dumping activities. *IOP Conference Series: Materials Science and Engineering*, *271*, 012040. https://doi.org/10.1088/1757-899x/271/1/012040.

[12] Nagapan, S.; Rahman, I. A.; Asmi, A. (2012, April). Construction waste management: Malaysian perspective. *International Conference on Civil and Environmental Engineering for Sustainability*, Thistle Hotel, Johor Bahru, Malaysia, 229–309.

[13] Mahayuddin, S. A.; Pereira, J. J.; Badaruzzaman, W. H. W.; Mokhtar, M. B. (2008). Construction waste management in a developing country: case study of Ipoh, Malaysia. *Waste Management and the Environment IV*. https://doi.org/10.2495/wm080491.

[14] Wahi, N.; Joseph, C.; Tawie, R.; Ikau, R. (2016). Critical review on construction waste control practices: Legislative and waste management perspective. *Procedia - Social and Behavioral Sciences*, *224*, 276–283. https://doi.org/10.1016/j.sbspro.2016.05.460.

[15] Sharma, N. (2020). Sustainable building material for green building construction, conservation and refurbishing. *MATTER: International Journal of Science and Technology*, *29*, 5343–5350.

[16] Kanniyapan, G.; Nesan, L. J.; Mohammad, I. S.; Keat, T. S.; Ponniah, V. (2019). Selection criteria of building material for optimising maintainability. *Construction and Building Materials*, *221*, 651–660. https://doi.org/10.1016/j.conbuildmat.2019.06.108.

[17] Aghdam, K. A.; Rad, A. F.; Shakeri, H.; Sardroud, and J. M. (2018). Approaching green buildings using eco-efficient construction materials: A review of the state-of-the-art. *Journal of Construction Engineering and Project Management*, *8*, 1–23. https://doi.org/10.6106/JCEPM.2018.8.3.001.
[18] Tambichik, M. A.; Mohamad, N.; Samad, A. A. A.; Bosro, M. Z. M.; Iman, M. A. (2018). Utilization of construction and agricultural waste in Malaysia for development of Green Concrete: A Review. *IOP Conference Series: Earth and Environmental Science*, *140*, 012134. https://doi.org/10.1088/1755-1315/140/1/012134.
[19] Muthusamy, K.; Zamri, N.; Zubir, M.A.; Kusbiantoro, A.; Ahmad, S.W. (2015). Effect of mixing ingredient on compressive strength of oil palm shell lightweight aggregate concrete containing palm oil fuel ash. *Procedia Engineering*, *125*, 804–810. https://doi.org/10.1016/j.proeng.2015.11.142.
[20] Dawood, E.; Ramli, M. (2009, August). Study the effects of using palm fiber on the properties of high strength flowable mortar.
[21] Ismail, S.; Ramli, M. (2013). Engineering properties of treated recycled concrete aggregate (RCA) for structural applications. *Construction and Building Materials*, *44*, 464–476. https://doi.org/10.1016/j.conbuildmat.2013.03.014.
[22] Safiuddin, Md.; Alengaram, U.J.; Rahman, Md. M.; Salam, Md. A.; Jumaat, Mohd. Z. (2013). Use of recycled concrete aggregate in concrete: A review. *Journal of Civil Engineering and Management*, *19*(6), 796–810. https://doi.org/10.3846/13923730.2013.799093.
[23] Yusof, N.M.; Hua, L.S.; Tahir, P.M.; James, R.M.S.; Al-Edrus, S.S.O.; Dahali, R.; Roseley, A.S.M.; Fatriasari, W.; Kristak, L.; Lubis, M.A.R.; et al. (2023). Effects of Boric Acid Pretreatment on the Properties of Four Selected Malaysian Bamboo Strips. *Forests*, *14*, 196. https://doi.org/10.3390/f14020196.
[24] He, H.; Zheng, X.; Wang, Y.; Wang, W.; Li, M.; Wang, S.; Wang, J.; Wang, C.; Zhan, H. (2022). Effects of Climate Change and Environmental Factors on Bamboo (*Ferrocalamus strictus*), a PSESP Unique to China. *Forests*, *13*, 2108. https://doi.org/10.3390/f13122108.
[25] Goh, Y.; Yap, S. P.; Tong, T. Y. (2020). Bamboo: The emerging renewable material for sustainable construction. *Encyclopedia of Renewable and Sustainable Materials*, 365–376. https://doi.org/10.1016/b978-0-12-803581-8.10748-9.
[26] Lau, Y. Y.; Talukdar, G.; Hasti Widyasamratri, Wang, J.; El-shaammari, M. (2023). Utilization of Green Materials and Technology for Sustainable Construction in Malaysia. *Tropical Environment Biology and Technology*, *1*(1), 47–66. https://doi.org/10.53623/tebt.v1i1.238.
[27] Ali, B.; Sopian, K.; Al Ghoul, M.; Othman, M. Y.; Zaharim, A.; Razali, A. M. (2009). Economics of domestic solar hot water heating systems in Malaysia. *European Journal of Scientific Research*, *26*(1), 20–28.
[28] Bashir, M.J.K.; Jing, O.L.; Sethupathi, S.; Aun, N.C. (2015). Evaluation of energy cost saving and pollutants emission reduction for solar water heater development in Malaysia. Springer: Singapore. https://doi.org/10.1007/978-981-287-505-1_25.
[29] Vunnam, S.; VanithaSri, M.; Alla, R. (2023). An outline of solar photovoltaic systems impact on environment. *Bulletin of Electrical Engineering and Informatics*, 12(5), 2635–2642. https://doi.org/10.11591/eei.v12i5.5584.
[30] Breeze, P. (2016). An Introduction to solar power. In *Solar Power Generation* (pp. 1–8). Elsevier. https://doi.org/10.1016/B978-0-12-804004-1.00001-4.
[31] Mekhilef, S.; Safari, A.; Mustaffa, W. E. S.; Saidur, R.; Omar, R.; Younis, M. A. A. (2012). Solar energy in Malaysia: Current state and prospects. *Renewable and Sustainable Energy Reviews*, *16*(1), 386–396. https://doi.org/10.1016/j.rser.2011.08.003.
[32] Ab Kadir, M. Z. A.; Rafeeu, Y.; Adam, N. M. (2010). Prospective scenarios for the full solar energy development in Malaysia. *Renewable and Sustainable Energy Reviews*, *14*(9), 3023–3031. https://doi.org/10.1016/j.rser.2010.07.062.

[33] Chua, S. C.; Oh, T. H. (2012). Solar energy outlook in Malaysia. *Renewable and Sustainable Energy Reviews*, *16*(1), 564–574. https://doi.org/10.1016/j.rser.2011.08.022.
[34] Razali, A. H.; Abdullah, M. P.; Hassan, M. Y.; Hussin, F. (2019). Comparison of new and previous Net Energy Metering (NEM) scheme in Malaysia. *ELEKTRIKA- Journal of Electrical Engineering*, *18*(1), 36–42. https://doi.org/10.11113/elektrika.v18n1.141.
[35] Hayat, M. B.; Ali, D.; Monyake, K. C.; Alagha, L.; Ahmed, N. (2018). Solar energy-A look into power generation, challenges, and a solar-powered future. *International Journal of Energy Research*, *43*(3), 1049–1067. https://doi.org/10.1002/er.4252.
[36] Gupta, V.; Sharma, M.; Pachauri, R. K.; Dinesh Babu, K. N. (2019). Comprehensive review on effect of dust on solar photovoltaic system and mitigation techniques. *Solar Energy*, *191*, 596–622. https://doi.org/10.1016/j.solener.2019.08.079.
[37] Hossain, M.; Huda, A. S. N.; Mekhilef, S.; Seyedmahmoudian, M.; Horan, B.; Stojcevski, A.; Ahmed, M. (2018). A state-of-the-art review of hydropower in Malaysia as renewable energy: Current status and future prospects. *Energy Strategy Reviews*, *22*, 426–437. https://doi.org/10.1016/j.esr.2018.11.001.
[38] Yah, N. F.; Oumer, A. N.; Idris, M. S. (2017). Small scale hydro-power as a source of renewable energy in Malaysia: A review. *Renewable and Sustainable Energy Reviews*, *72*, 228–239. https://doi.org/10.1016/j.rser.2017.01.068.
[39] Ahsan, R.; & Bin Haji Ahmad, M. H. (2016). Development, displacement and resettlement a challenge for social sustainability: A study on mega development project (Bakun Dam) in Sarawak. *International Journal of Advances in Agricultural and Environmental Engineering*, *3*(1). https://doi.org/10.15242/ijaaee.er0116020.
[40] Keong, C. Y. (2005). Dam-Induced Development and Environmental and Social Sustainability: The Bakun Industrialization Strategy Revisited. *Journal of Economic Issues*, *39*(1), 123–150. https://doi.org/10.1080/00213624.2005.11506783.
[41] Chien Bong, C. P.; Ho, W. S.; Hashim, H.; Lim, J. S.; Ho, C. S.; Peng Tan, W. S.; Lee, C. T. (2017). Review on the renewable energy and solid waste management policies towards biogas development in Malaysia. *Renewable and Sustainable Energy Reviews*, *70*, 988–998. https://doi.org/10.1016/j.rser.2016.12.004.
[42] Hosseini, S. E.; Wahid, M. A. (2013). Feasibility study of biogas production and utilization as a source of renewable energy in Malaysia. *Renewable and Sustainable Energy Reviews*, *19*, 454–462. https://doi.org/10.1016/j.rser.2012.11.008.
[43] Aziz, N. I. H. A.; Hanafiah, M. M.; Gheewala, S. H. (2019). A review on life cycle assessment of biogas production: Challenges and future perspectives in Malaysia. *Biomass and Bioenergy*, *122*, 361–374. https://doi.org/10.1016/j.biombioe.2019.01.047.
[44] Siew, Chin; Sakundarini. (2019). Designing a guideline for green roof system in Malaysia. *Journal CleanWAS*, *3*(2), 05-10. https://doi.org/10.26480/jcleanwas.02.2019.05.10.
[45] Ismail, Z.; Aziz, H. A.; Nasir, N. M.; Mohd, T. (2012). Obstacles to adopt green roof in Malaysia. 357–361. https://doi.org/10.1109/CHUSER.2012.6504339.
[46] Hafizi Md Lani, N.; Yusop, Z.; Syafiuddin, A. (2018). A review of rainwater harvesting in Malaysia: Prospects and challenges. *Water*, *10*(4), 506. https://doi.org/10.3390/w10040506.
[47] Lee, K. E.; Mokhtar, M.; Mohd Hanafiah, M.; Abdul Halim, A.; Badusah, J. (2016). Rainwater harvesting as an alternative water resource in Malaysia: potential, policies and development. *Journal of Cleaner Production*, *126*, 218–222. https://doi.org/10.1016/j.jclepro.2016.03.060.