Macrothink Institute™

Environmental Management and Sustainable Development
ISSN 2164-7682
2022, Vol. 11, No. 4

Green Building Best Practices in Achieving Energy and Environmental Sustainability

Noraina Mazuin Sapuan

Universiti Malaysia Pahang Al-Sultan Abdullah, Pahang, Malaysia

E-mail: noraina@ump.edu.my

Nazatul Faizah Haron

Faculty of Business & Management, School of Management Sciences

Universiti Sultan Zainal Abidin, Terengganu, Malaysia

E-mail: nazatulfaizah@unisza.edu.my

Vikniswari Vija Kumaran

Faculty of Business and Finance, Universiti Tunku Abdul Rahman, Perak, Malaysia

E-mail: vikniswarivk@utar.edu.my

Nur Surayya Saudi

Faculty of Defence Study and Management

National Defence University of Malaysia, Malaysia

E-mail: nursurayya@upnm.edu.my

Abdul Rahim Ridzuan (Corresponding author)

Faculty of Business and Management, Universiti Teknologi MARA, Malaysia

Institute for Big Data Analytics and Artificial Intelligence (IBDAAI)

Universiti Teknologi MARA, Malaysia

Centre for Economic Development and Policy, Universiti Malaysia Sabah, Malaysia

Institute for Research on Socio Economic Policy, Universiti Teknologi MARA, Malaysia

Accounting Research Institute (ARI), Universiti Teknologi MARA, Malaysia

E-mail: Rahim670@uitm.edu.my

Macrothink Institute™

Environmental Management and Sustainable Development
ISSN 2164-7682
2022, Vol. 11, No. 4

Received: June 9, 2022 Accepted: August 7, 2022 Published: November 18, 2022

doi:10.5296/emsd.v11i4.21052 URL: https://doi.org/10.5296/emsd.v11i4.21052

Abstract

In the construction and building industry, sustainable development is becoming a powerful force for economic, social, and environmental gains with fewer negative consequences for the environment. It is essential to establish green and sustainable practices in the building and construction industry in order to improve energy efficiency, particularly by utilising the newest green technologies. As a result, the study's objectives are to first investigate the most relevant practices to be used for green building employment; second, evaluate the benefits produced by the execution of green building; and third, analyse the best practices of green building characteristics. The findings of this study showed that green buildings developed using energy-efficient systems and implementing sustainable practices can reduce energy consumption, as well as lower the cost of operating and maintaining these buildings in the long term. Meanwhile, the government's role is essential to attracting more participants in implementing sustainable practices in the construction and building sector, especially through more stringent regulations and appealing incentives.

Keywords: Sustainability, Energy efficiency, Green building, Best practices

1. Introduction

The building sector has been criticised for consuming a significant amount of primary energy and natural resources. In 2018, commercial and residential buildings contributed to 36% of total energy usage and 39% of energy production, while the production of building materials and products such as steel, cement, and glass accounted for 11% of process-related CO_2 emissions (International Energy Agency, IEA, 2020). More seriously, the CO_2 emissions released from construction materials are higher than those from other types of manufacturing and transportation sectors (Sharma, 2018). Climate change primarily results from elevated emissions of CO2 and other greenhouse gases [Pujiati, et. (2023a); Majekodunmi, et al. (2023a); Shaari et al. (2022a); Shaari, et al. (2021); Mohamed Yusoff, et al. (2023); Ridzuan,et al. (2022a); Ridzuan, et al. (2020a); Ridzuan et al. (2019); Md Razak, et al. (2017); Zainal, et al. (2020)]. A relentless annual growth in CO2 emissions further worsens the challenges of climate change and global warming [Majekodunmi, et al. (2023b); Pujiati, et al. (2023b); Shaari, et al. (2022b); Handayani,, et al. (2022); Ridzuan, et al. (2022b); Borhan,, et al. (2021); Ridzuan, et al. (2020b)]. Hence, the concept of green building was developed to reduce negative environmental consequences. According to WGBC (2018), a green building is a structure that minimises or eliminates negative impacts on our climate and natural environment through its design, construction, and operation.

As the global population is expected to continue rising to more than 9.8 billion by 2050, natural resource consumption likewise upsurges, as does demand for new products and services, putting further strain on the existing resources (United Nations, 2017). This leads to a gradual rise in the yearly global average temperature [Shaari, et al. (2023); Voumik, et al. (2023a); Voumik, et al. (2023b); Hendrawaty, et al. (2022); Kumaran, et al. (2020); Ridzuan, et al. (2021a); Ridzuan et al. (2021b)]. Hence, it is important to optimise the use of resources that maximise their net value while avoiding 'upstream' pollution and, at the same time, conserving these resources.

Green buildings often use fewer resources and provide better indoor air quality and higher comfort levels to their inhabitants than non-green buildings (Darko, Zhang, and Chan 2017). While most green building research focuses solely on environmental sustainability, the idea of green building is congruent with the triple bottom line (i.e., environmental, economic, and social elements) of sustainable development. (Zuo and Zhao, 2014). To decrease the undesirable impacts on the usage of resources, green buildings' execution is apt to integrate procedures from the beginning to the end of the building's life cycle (Environmental Protection Agency, EPA, 2009). In numerous projects, green building has successfully reduced energy consumption, CO_2 emissions, improved water management, and sustained the materials' life circulation through better site progress, building, procedure, maintenance, elimination, and recycling of materials (Kreuger et al., 2019; Patnaik et al., 2015; Wang et al., 2014). Green buildings generally go above the building code standards, which include elements such as passive solar heating and cooling design, efficient heating, ventilation, and air conditioning (HVAC), energy-saving lighting, and first-rate window glazing (Wells et al., 2018; Darko et al., 2017; Udawatta et al., 2015; Garde et al., 2014; Li et al., 2013).

Despite the yearly growth in green certification acceptance and the square foot covered by the construction sector, the overall number of floors remains unchanged compared with the total square foot of this industry (Zhang et al., 2019). This is partly due to many obstacles to promoting green construction, such as a lack of awareness among customers and designers, as well as higher costs for purchasing sustainable materials and products that are unbearable to contractors and subcontractors (Ahn et al., 2013).

Thus, the objectives of this study are: first, to investigate the most pertinent procedures to be implemented for green building employment; second, to examine the benefits generated from green building execution; and third, to explore the best practices of green building features.

The organisation of this paper is divided into a few sections. The First Section is the introduction, followed by Section Two on the green building rating system and net zero buildings. Chapter Three discusses the benefits of green building development; Chapter Four on green building best practices; and finally, Chapter Five concludes the study.

2. Green Building Rating System and Net Zero Buildings

2.1 Green Building Rating System

Green building rating instruments are used for assessing and recognising buildings that meet certain environmental standards. Rating systems are often used to recognise and reward companies and organisations that develop and operate green buildings. Also, rating systems encourage and motivate these organisations by attracting incentives to drive sustainability in the building and construction sectors.

The building industry employs a Green Building Rating System (GBRS) to assess, improve, and/or promote the sustainability of buildings (Zhang et al., 2019). Essentially, the rating system assesses several factors, including a building's operational performance, environmental impact, and environmental impact measurement, as well as objectively evaluates and judges the development of a structure (Awadh, 2017).

The green rating has been identified as one of the most important external drivers for developing green buildings, and it has received much attention in the literature. Most green construction decisions and activities in buildings are centred on financial returns. So, only if stakeholders are financially feasible can developers adopt green solutions. Moreover, there is no requirement for individuals to comply with a green building assessment system for the sake of green practices (Darko et al., 2017; Udawatta et al., 2015).

Green building assessment tools use numerous techniques appropriate for early preparation and design, construction, operation, maintenance, restoration, and demolition stages (Awadh, 2017; Zhang et al., 2019). Different building models, such as homes, commercial buildings, or even entire neighbourhoods, use distinct tools and rating approaches depending on the building types. The World Green Building Council (World GBC, 2021) has recognised various measurements and tools used by all the members best suited to the particular market, especially in over seventy countries that recognise green building councils.

According to Zhang et al. (2019), green buildings in the United States, United Kingdom, and Japan have reached an advanced implementation degree. These nations have developed and enhanced green buildings' legal and regulatory frameworks. In fact, their laws, rules, departmental codes, and regional regulations are interdependent and complement each other. A solid and comprehensive legal structure is a crucial assurance and the basis for high-quality green building development.

The earliest certification scheme for green buildings was the Building Research Establishment Environmental Assessment Methodology (BREEAM) in the UK in 1990. Since its introduction, this certificate has been carried out in 89 countries, accumulating 594,011 certification programmes (BREEAM, 2021). Meanwhile, Leadership in Energy and Environmental Design (LEED) was released in 1998 by the US Green Building Council (USGBC). LEED was the most popular and widely used green building rating system in 167 countries in 2018 (Zhang et al., 2019). Earning a LEED certification comes with a bunch of advantages, including providing third-party validation of a company's capacity to build a sustainable project. Not only does the certification process guide the use of indoor and outdoor materials, but it also helps to lower operating costs by promoting the use of less expensive and renewable energy sources (WBDG, 2019). Other major GBRS include the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan and the Green Star system in Australia (CASBEE, 2021). In 2009, the German Green Building Council and the German government collaborated to develop a building evaluation system in Germany known as Deutsche Gesellschaftfür Nachhaltiges Bauen (DGNB), possibly the most sophisticated building evaluation system in the world (Vyas and Jha, 2018).

2.2 Net Zero Buildings

Domestic energy usage has become a global trend in reducing energy demand for fuel-based energy through renewable energy. Energy-saving methods were developed, and they have drawn the attention of numerous researchers and practitioners in implementing energy efficiency practices in the building sector, especially in implementing net-zero energy buildings (NZEB). According to Wells et al. (2018), NZEB is a building with certain features that equal energy generation to use and considers reducing energy demands and energy expenses that equal zero or net-zero greenhouse gas (GHG) emissions.

NZEB is also defined as a building that consumes the same or less energy than it produces each year. It is critical to initiate a time-period review for NZEB annually (Wells et al., 2018). The biggest amount of energy required for heating is in the winter due to lower solar gains, and it might be offset near the end of the year as renewable energy will be produced during the summer (Abu Grain & Alibaba, 2017).

Furthermore, passive methods serve as a crucial element in pursuing zero energy building design goals (Li et al., 2013). It directly impacts thermal balance and lighting loads, which impact the building's electromechanical systems. This result shows a significant indirect decrease in energy usage for heat control, lighting, and ventilation, which is well balanced by renewable energy systems (Garde et al., 2014).

According to Albatayneh (2021), optimising various design variables such as flat roof construction, natural ventilation rate, and window shading control schedule can help reduce energy consumed for heating and cooling loads. The ‘nearly zero' quantity of energy required should be provided to a ‘very substantial extent by renewable energy sources on-site or nearby.

Furthermore, Hu and Qiu (2019) discovered that energy savings are highly dependent on mechanical system advancement by improving mechanical units’ efficiency or lowering the unit utility cost. Magrini et al. (2020) further explained the possibilities of improving the NZEBs by converting to Positive Energy Buildings (PEBs) with the aim of meticulously improving the design and sizing of the building ecosystem and the plant system by generating electricity from renewable sources that are more sustainable for maintaining the cost in the future.

3. The Benefits of Green Building Development

Green buildings provide incremental benefits such as lesser operating costs, improved health and productivity, and constructive environmental externalities (Kats, 2003), consistent with the finding from Zhang (2017), who highlighted five types of incremental advantages connected with green buildings: decreased operating costs, greater comfort, health, and productivity, enhanced corporate reputation, higher market value, and positive environmental externalities.

There is no conclusive answer to whether developing and operating green buildings is more expensive than the traditional operating cost approach. While some researchers claim that green building is more expensive (Chan et al., 2009; Shi et al., 2013), other data suggest that green building may contribute little or no additional expense to the non-green method (Matthiessen & Morris, 2004). This is consistent with the finding from Kats et al. (2003) that the majority of the additional cost of green buildings is not in ‘hard costs' (i.e., installation expenses for green parts and materials), but rather in ‘soft costs' (i.e., extra-time expenses for design, planning, and construction).

Moreover, applying an energy and water efficiency system helps reduce the energy and water used for construction activities. The development of the recycling system and the design and reuse of materials can help reduce waste costs. Even though highly efficient resources may be somewhat expensive, they save money over the building's long lifespan (Zhang et al., 2017).

For construction to be as efficient as possible, green buildings, particularly LEED-certified ones, will utilise energy-saving measures. Building techniques can considerably cut energy costs when combined with environmentally friendly measures. According to the USGBC (2021), the cost of maintaining LEED buildings has fallen by approximately 20% over normal business buildings. Green building retrofits usually decrease operating expenses by around 10% over a year. Meanwhile, data from the European Commission (2015) showed that global energy efficiency measures could save an estimated €280 to €410 billion in savings in energy spending. Furthermore, green building can create millions of new jobs and contribute to a higher GDP for the country. Green construction in the USA generated $167.4 billion in GDP from 2011 to 2014 (World GBC, 2021). The green construction sector in Canada produced a GDP of $23.45 billion in 2014 and accounted for about 300,000 full-time jobs (Canada Green Building Council, 2016).

The purpose of green building is not limited to decreasing environmental and economic consequences, but also to improving human health and wellbeing (World GBC, 2021). According to Park and Yoon (2011), indoor air quality improves due to low CO_2 concentrations and contaminants, as well as high ventilation rates by up to 8%. Moreover, appropriate sound insulation might be utilised to improve focus, particularly in school and residential buildings. This is consistent with MacNaughton et al.’s (2016) finding that improvements to the built environment, including ventilation, lighting, and materials, have resulted in improved indoor environmental quality (IEQ) in green buildings. These facts serve to make our living and working environments healthier and more comfortable (Al-Sulaili, 2018). A recent study by Xue et al. (2019) discovered that biophilia design could play an important role in helping green building rating tools (GBRTs) address human health and wellbeing by restoring and strengthening the relationship between man and nature.

4. Green Building Best Practices

A green building uses technology, building materials, and design techniques that lower threats to the environment and public health. Improved site selection, building design, material selection, construction, maintenance, elimination, and possible reuse are employed to achieve this. The main consequences include less site disruption, less use of fossil fuels, less water consumption, and fewer pollutants discharged throughout the building's construction, occupation, and disposal.

4.1 Sustainable Building Design

Throughout the building's life cycle, sustainable building design seeks to minimise resource depletion, including that of energy, water, land, and raw materials, as well as to prevent environmental damage brought on by facilities and infrastructure. The most ecologically friendly architecture may produce settings that are liveable, cosy, secure, and useful.

The Whole Building Design Guide is one of the newest approaches to sustainable building design, It draws on the collective knowledge of all stakeholders throughout the project's life cycle, from determining the need for a building to planning, design, construction, building occupancy, and operations. This design incorporated two elements, which are an integrated design approach and an integrated team process. The "integrated" design approach departed from the traditional planning and design process, which depends on the knowledge of experts who pursue their individual specialisations in a manner that is relatively secluded from one another. To evaluate the design for cost, quality-of-life, future flexibility, efficiency, overall environmental impact, productivity, creativity, and how the occupants will be enlivened, an integrated team process entails the design team and all affected stakeholders working together throughout the project phases (Whole Building Design Guide, 2014).

The first step in creating a green building is choosing an appropriate location, as this decision may have both direct and indirect effects on many environmental factors, including security, accessibility, and energy usage. By leveraging natural site factors like breeze, sunlight, shade, and topography, cautious planning minimises stormwater flow, eliminates erosion risks, maximises open space, and maintains existing ecosystems.

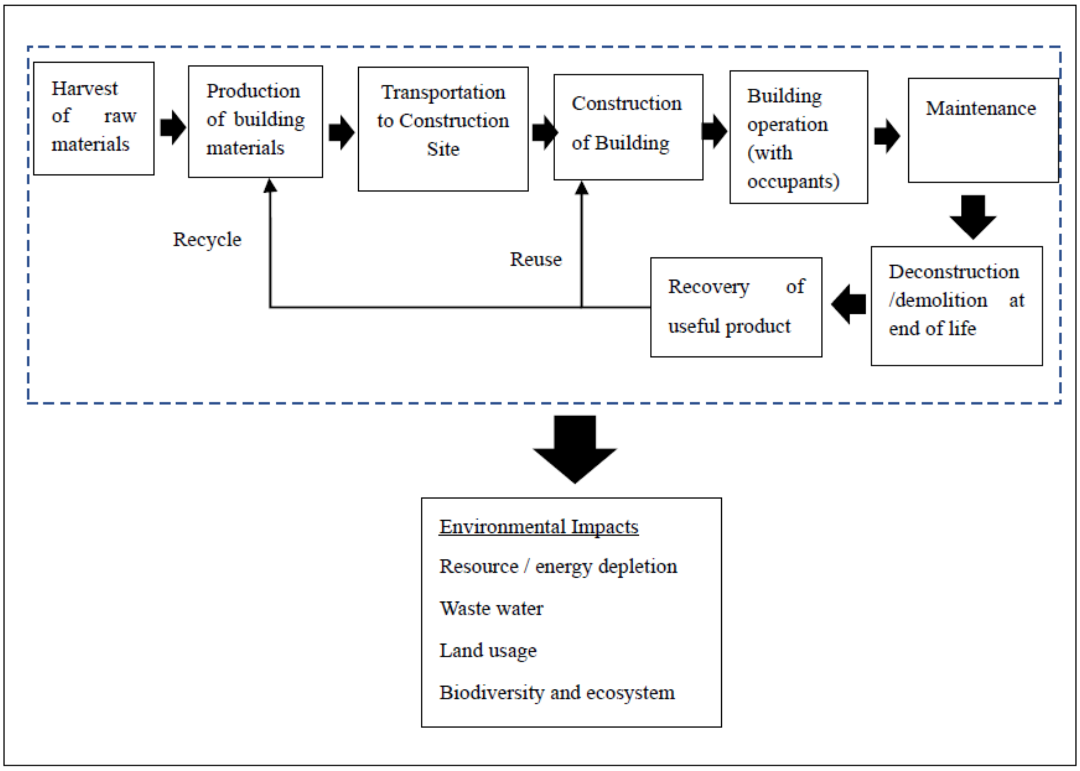

Figure 1. Building Life Cycle and Environmental Impact

According to Figure 1, energy consumption for green buildings should be minimal overall over their lifespan. This comprises three types of energy: 1) the embodied energy related to the procurement, processing, production, and transportation of building materials during the construction phase; 2) the energy used to operate the building; and 3) demolition energy related to the removal, destruction, and recycling of building materials (Akadiri et al., 2012). This implies a green building must be able to minimise inputs from nature (such as energy, water, materials, and land) while also reducing outputs or loadings from nature (such as waste and pollution). This means a green building must have minimal energy demands and environmental impacts throughout its life-cycle.

4.2 Green Building Facilities

Green buildings are intended to produce a comfortable, productive, and healthy working environment. To provide a healthier indoor environment, greater comfort and welfare of the occupants, increased productivity, and improved marketability of the building, indoor air quality, thermal comfort, and lighting comfort are given special consideration throughout the design and construction of the building. Among the indoor and outdoor facilities available in green buildings are the following:

i) Orientation and Shape of the Building

The new sustainable building's design and construction must take into account the building's orientation and shape. Regarding optimal building, orienting its position and shape should strategically maximise the exposure to natural elements, mainly the sun and wind. Exposing most of the building to the sun can enhance the entry of high-quality daylight that contributes to natural ventilation that provides adequate fresh and cool air, especially in summer (Mohanty, 2012). It also contributes to passive solar heating when heating is required. This can reduce the dependency on the HVAC system. All of these have the potential to provide greater comfort while using less energy. Moreover, the orientation of the building towards good wind energy can contribute to the utilisation of wind turbines for power generation (Albatayneh, 2021).

ii) Building Envelope

The heat flow over the building operation is determined by the heat transfer across the building envelope, which comprises the roof, walls, windows, floor, and internal walls. The green building design needs to optimise the power generated from the sun. The glass façade allows natural daylight to be enjoyed for as long as possible without the sun's heat impacting the indoor temperature. The majority of green buildings now being built have a special double-skin glass façade that enables for passive solar energy collection in the winter and temperature management in the summer. It allows warmed air between its inner and outer skins to rise up and out and close in the winter, permitting the façade to form an isolated blanket around the building, enhancing its energy efficiency (3D Reid, 2013). To reduce electricity usage, HVAC systems utilised in a building should be used effectively and only when necessary.

iii) Solar Panel

Solar systems have the ability to capture solar radiation and convert it into heat and electricity. Some green buildings not only have solar panels on their roofs, but they also have solar panels covering the outside walls of the building. It contributes to using less gas or electricity. Even though such systems need more money to install, they save money on energy bills and aid in lowering greenhouse gas emissions from non-renewable energy sources like fossil fuels (Mohanty, 2012).

iv) Cool Roof

The effect of a roof on saving energy is often being overlooked. A sustainable green building technique called a cool roof tries to reflect heat and sunlight away from the structure. By lowering heat absorption and thermal emittance, it makes a substantial contribution to keeping rooms at a consistent temperature in buildings. Simply said, they reflect more of the sun's rays than conventional single roofs and keep air from escaping through a building’s roof, whether it be warm or cool.

The majority of solar radiation is reflected away by cool roofs, which are typically constructed with specific tiles and reflective coatings that absorb less heat. In the summer, cool roofs may easily lower temperatures by more than 50 degrees Celsius, which also lowers the need for power. Moreover, there is significant evidence that cool roofs have a more effective cooling impact than green roofs (He et al., 2020).

v) Efficient Lighting System

The lighting system’s design plays a significant role in raising the standard of the indoor environment. Natural light is preferable to artificial light for the human eye, but excessive outdoor light causes glare. In order to meet the demands of the occupants, green buildings enable the regulation of the amount and intensity of natural light that enters the space (Mohanty, 2012).

Even when artificial lighting is utilised, the right colour execution of the light is carried out to enhance occupant productivity. Currently, some of the green buildings utilise LED illumination systems that continuously monitor occupancy, movement, luminosity, humidity, and temperature, thereby allowing the structure to autonomously change energy consumption to enhance efficiency (Deloitte, 2015). When motion, temperature infrared, or daylight sensors are triggered, the low-energy LEDs turn on. LEDs conserve electricity since they provide 300 Lux instead of the typical 500 Lux. As a result, instead of the typical 8 Wats/m2, 3.9 Wats/m2 are used (Jalia et al., 2018). In some green buildings, LEDs are powered by a digital ceiling consisting of sensor-connected computer connections that anticipate the lighting requirements of the people rather than operate at a steady speed. Compared to normal lighting, the architects are projected to save up to 80% of their energy usage (BREEAM, 2016).

vi) Internet of Things (IoT) and Artificial Intelligent (AI)

The Internet of Things (IoT) is also important in achieving environmental sustainability. Sensor systems make it easier to keep an eye on energy consumption and water usage; then, proper action can be taken based on the monitoring data, especially to achieve long-term sustainability. On the other hand, AI systems can control everything in a facility, including air irrigation and HVAC, to save energy and promote clean operations.

Currently, in a well-known building, i.e., The Edge, Amsterdam, the IoT is part of the digital infrastructure connecting every technological system in the building. The system is operated by a single network linked to the lighting system, the building's HVAC system, the elevator, and other digitalisation-related systems. The system also managed the management facilities, such as computers, printers, and other office equipment, making it easier for the management to handle day-to-day operations more efficiently and systematically (Deloitte, 2015).

In The Edge, every occupant can use a smartphone app that connects them to their building. This software can assist occupants in interacting with the building through various functions available in the app to instruct a variety of tasks, such as reporting maintenance concerns to the technical staff or finding vacant workstations or parking spots (CDBB, 2018; Jalia et al., 2018).

viii) Green Landscaping

Green structures too consider acceptable landscaping techniques like choosing the right plants, managing the water on the property responsibly, and choosing the right building materials for the development of the landscape in a way that complements natural ecosystems.

An easy and inexpensive method to increase a building's energy efficiency and raise the appeal and value of a property is through strategic landscape design. This green landscape can enhance the surrounding region, minimise excessive building heat gain through thoughtful landscape design, and foster a natural and healthy environment (Mohd Hussain et al., 2014). For example, certain plants can be strategically placed to protect the building from the sun's rays and heat, reducing glare and temperature, and providing comfort inside and outside the building. Additionally, the choice and positioning of trees and groundcovers contributes to protection and a reduction in ambient air temperature, which creates an ideal microclimate and reduces the need for air conditioning by 5-20%. (Mohanty, 2014).

4.3 Water and Waste Management

A key feature of a green building is managing water and waste from construction until demolition. Green buildings reduce their water demand and wastewater and solid waste generation using a strategy similar to that outlined for reducing energy demand.

The well-known 3R principles of waste reduction, reuse, and recycling underpin the entire practice of solid waste management. Water-efficient fixtures, rainwater harvesting, and greywater recycling systems for toilet flushing and irrigation work together to reduce water usage. The design also incorporated rainwater harvesting and greywater recycling techniques to reduce water usage, enhancing water efficiency (3D Reid, 2013).

4.4 Alternative Building Materials

Material selection is critical for creating a safe, non-toxic indoor setting, where it should be based on natural-made materials. Paints that are founded on organic compounds and materials with low chemical emissions are among the important resources in developing a green building (Khoshnava et al., 2020).

These resources are constructed based on sustainable techniques throughout their life cycle and reusable practices. The materials usage is able to reduce environmental consequences such as global warming, resource depletion, and toxicity across the building's entire life cycle (WBDG, 2018). Moreover, environmentally preferred materials should reduce negative effects on human health, enhance worker safety, lower liability, and lower disposal costs (Darko et al., 2017; Kibert, 2016).

Green construction regulations establish a wide range of "substitute" materials that can replace conventional materials. The potential of non-toxic materials in substitution of conventional counterparts to improve indoor air quality, occupational health, and production conditions has zero impact on people's lives (Krueger et al. 2019). For instance, latex, eco flooring, water-based paints, and more non-toxic materials have been developed to substitute conventional high volatile organic compound (VOC) paints to improve indoor air quality (Koshnava et al. 2020).

Furthermore, the bio-based materials are organic, and plant-based resources such as wood, bamboo, straw, and wool are considered renewable resources as they can be reused, recycled, easily regrown and have good abilities as a hygroscopic agent, which leads to energy savings (Romano 2019). However, there is a possibility of resource depletion if we depend on this resource, especially for long- life-cycle growth (Kreuger et al., 2019; Wang et al., 2014).

Meanwhile, recycled, reused, and reconstructed goods can minimise extraction burdens, avert trash from landfills, save energy processing, and recover residual value for items at the end of their lives (Chen et al., 2001; Beullens, 2004). Few studies have compared the thermal and sound insulation properties of various natural and synthetic insulation materials, such as recycled polyester fibres and waste wool (Patnaik et al., 2015), conventional insulating materials such as polystyrene, rock and glass wool, and kenaf, as well as recycled PET fibres (Intini & Kuhtz, 2011), textile waste, stubble fibres, and sunflower stalk (Binici et al., 2014).

5. Conclusion

The development of green buildings has increased tremendously in developed nations. However, the demand for green construction and green buildings is still lacking in other countries, especially when the success criteria for implementing green buildings depend on the ongoing development of new technologies, integral management of building operations, consistent certification system standards, and appropriate policy adjustments.

Nevertheless, the implementation of green buildings has several advantages, including environmental, economic, and social benefits. A reduction in energy consumption is one of the most significant environmental advantages. Green buildings are built using highly efficient systems and sustainable practices to enhance efficiency and save costs. One of the most important aims of green construction is water conservation. This improvement in water efficiency can lower the amount of water required for building operations.

Furthermore, this environmentally friendly structure is equipped with energy-efficient heating, ventilation, and air-conditioning systems. Allowing fresh air in and eliminating items that generate hazardous emissions ensures optimal indoor air quality. Additionally, adequate sound insulation is employed to improve focus, particularly in residential structures. All of these facts will contribute to a healthier and more pleasant living and working environment.

Hence, to attract more demand for green buildings, governments can also play a significant role, especially by enforcing green building regulations and giving more incentives to industrial players and owners. They participate in developing and implementing green practices in every type of building, such as residential, commercial, or industrial buildings.

Acknowledgement

This research paper is funded by Strategic Research Partnership Grant -100-RMC/5/3/SRP INT (010/2022), provided by Universiti Teknologi MARA, Malaysia

References

Abu Grain, M. Y., & Alibaba, H. Z. (2017). Optimising Existing Multistory Building Designs towards Net-Zero Energy. *Sustainability, 9*, 399. https://doi.org/10.3390/su9030399

Ahn, Y. H., Pearce, A. R., Wang, Y., & Wang, G. (2013). Drivers and barriers of sustainable design and construction: The perception of green building experience. *International Journal of Sustainable Building Technology and Urban Development*, *4*(1), 35e45. https://doi.org/10.1080/2093761X.2012.759887

Akadiri, P. O., Chinyio, E. A. & Olomolaiye, P. O. (2012). Design of A Sustainable Building: A Conceptual Framework for Implementing Sustainability in the Building Sector. *Buildings, 2*, 126-152. https://doi.org/10.3390/buildings2020126

Albatayneh, A. (2021). Optimisation of building envelope parameters in a semi-arid and warm Mediterranean climate zone. *Energy Reports*, *7*, 2081-2093. https://doi.org/10.1016/j.egyr.2021.04.011

Al-Sulaili, A. D., Al-Matrouk, M. F., & Al-Baghli, R. A. (2020). Environmental and economic benefits of applying green building concepts in Kuwait. *Environment, Development and Sustainability, 22*, 3371-3387. https://doi.org/10.1007/s10668-019-00352-1

Awadh, O. (2017). Sustainability and Green Building Rating Systems: LEED, BREEAM, GSAS and Estidama critical analysis. *Journal of Building Engineering, 11*, 25-29. https://doi.org/10.1016/j.jobe.2017.03.010

Beullens, P. (2004). Reverse logistics in effective recovery of products from waste materials. *Reviews in Environmental Science & BioTechnology, 3*, 283-306. http://doi.10.1007/s11157-004-2332-3

Binici, H., Eken, M. Dolaz, M. Aksogan, O. & Kara, M. (2014). An environment-friendly thermal insulation material from sunflower stalk, textile waste and stubble fibers. *Construction and Building Materials, 51*, 24-33. https://doi.org/10.1016/j.conbuildmat.2013.10.038

Borhan, H., Ridzuan, A. R., Mat Saat, R., Subramaniam, G., & Mohd Amin, S. (2021). Modelling the environmental kuznets curve of water pollution impact on economic growth in developing country. *International Energy Economics and Policy, 11*(5), 545-552. https://doi.org/10.32479/ijeep.11571

BREEAM. (2021). *Building Research Establishment Environmental Assessment Methodology (BREEAM)*. [Online] Available: http://www.breeam.com.world

BREEM. (2013). *One Angle Square*. [Online] Available: https://www.breeam.com/case-studies/offices/one-angel-square-co-operative-group-hq-manchester/

BREEM. (2016). *The Edge.* [Online] Available: https://www.breeam.com/case-studies/offices/the-edge-amsterdam

Canada Green Building Council. (2016). *New CaGBC market impact report demonstrates green buildings are an engine of economic growth in Canada*. [Online] Available: https://www.cagbc.org/News/EN/2016/20160210_News_Release.aspx

CASBEE. (2021). *Comprehensive Assessment System for Built Environment Efficiency (CASBEE), 2016*. [Online] Available: http://www.ibec.or.jp/CASBEE/english

CDBB. (2018). *The Edge Amsterdam - showcasing an exemplary IoT building.* [Online] Available: https://www.cdbb.cam.ac.uk/news/2018CaseTheEdge

Chan, E. H., Qian, Q. K., & Lam, P. T. (2009). The market for green building in developed Asian cities the perspectives of building designers. *Energy Policy, 37*(8), 3061-3070. https://doi.org/10.1016/j.enpol.2009.03.057

Chen, T. Y., Burnett, J., & Chau, C. K. (2001). Analysis of embodied energy use in the residential building of Hong Kong. *Energy, 26*(4), 323-340. https://doi.org/10.1016/S0360-5442(01)00006-8

Darko, A., Zhang, C., & Chan, A. (2017). Drivers for green building: A review of empirical studies. *Habitat International, 60*, 34-49. https://doi.org/10.1016/j.habitatint.2016.12.007

Deloitte. (2015). *The edge of tomorrow.* [Online] Available: https://www2.deloitte.com/ru/en/pages/about-deloitte/articles/gx-the-edge-of-tomorrow.html

EPA. (2009). *Buildings and their Impact on the Environment: A Statistical Summary. 2009.* [Online] Available: https://archive.epa.gov/greenbuilding/web/pdf/gbstats.pdf

Garde, F., Lenoir, A., Scognamiglio, A., Aelenei, D., Waldren, D., & Rostvik, H. N. (2014). Design of Net Zero Energy Buildings: Feedback from international projects. *Energy Procedia, 61*, 995-998. https://doi.org/10.1016/j.egypro.2014.11.1011

Handayani, B. D., Yanto, H., Pujiati, A., Ridzuan, A. R., Keshminder, J. S., & Shaari, M. S. (2022). The implication of energy consumption, corruption, and foreign investment for sustainability of income distribution in Indonesia. *Sustainability, 14,* 15915. https://doi.org/10.3390/su142315915

He, C., Zhao J., Zhang Y., He L., Yao Y., Ma, W., & Kinney P. L. (2020). Cool Roof and Green Roof Adoption in a Metropolitan Area: Climate Impacts during Summer and Winter. *Environmental Science & Technology, 54*(17), 10831-10839. https://doi.org/10.1021/acs.est.0c03536

Hendrawaty, E., Shaari, M. S., Dwi Kesemuah, F. S., & Ridzuan, A. R. (2022). Economic growth, financial development, energy consumption and life expectancy: Fresh evidence from ASEAN countries. *International Journal of Energy Economics and Policy, 12*(2), 444-448. https://doi.org/10.32479/ijeep.12670

Hu, M., & Qiu Y. (2019) A comparison of building energy codes and policies in the USA, Germany, and China: progress toward the net-zero building goal in three countries. *Clean Technologies and Environmental Policy, 21*, 291-305. https://doi.org/10.1007/s10098-018-1636-x

IEA. (2020). *Energy Technology Perspectives 2020.* [Online] Available: https://www.iea.org/reports/energy-technology-perspectives-2020

Intini, F., & Kuhtz, S. (2011). Recycling in buildings: An LCA case study of a thermal insulation panel made of polyester fiber, recycled from post-consumer PET bottles. *The International Journal of Life Cycle Assessment, 16*(4), 306-315. https://doi.org/10.1007/s11367-011-0267-9

Jalia, A., Bakker, R., & Ramage, M. (2018). *The Edge, Amsterdam: Showcasing an exemplary IoT building*. Centre for Digital Built Britain. [Online] Available: https://www.cdbb.cam.ac.uk/system/files/documents/TheEdge_Paper_LOW1.pdf.

Kats, G. (2003). *The Costs and Financial Benefits of Green Buildings*. USA for Massachusetts Technology Collaborative. Washington, DC.

Khoshnava S. M., Rostami, R., Mohamad, Zin R., Štreimikienė, D., Mardani, A., & Ismail, M. (2020). The Role of Green Building Materials in Reducing Environmental and Human Health Impacts. *International Journal of Environmental Research and Public Health, 17*(7), 2589. https://doi.org/10.3390/ijerph17072589

Kibert, C. J. (2016). *Sustainable Construction: Green Building Design and Delivery*. John Wiley & Son, New Jersey, USA.

Krueger, K., Stoker A., & Gaustad, G. (2019). “Alternative” materials in the green building and construction sector: examples, barriers, and environmental analysis. *Smart and Sustainable Built Environment*. https://doi.org/10.1108/SASBE-09-2018-0045

Kumaran, V. V., Ridzuan, A. R., Khan, F. U., Abdullah, H., & Mohamad, Z. Z. (2020). An empirical analysis of factors affecting on renewable energy consumption in selected ASEAN countries: Does quality of governance matters? *International Journal of Energy Economics and Policy, 10*(2), 1-9. https://doi.org/10.32479/ijeep.8142

Li, D. H. W., Yang, L., & Lam, J. C. (2013). Zero energy buildings and sustainable development implications − a review. *Energy, 54*(2013), 1-10. https://doi.org/10.1016/j.energy.2013.01.070

MacNaughton, P., Spengler, J., Vallarino, J., Santanam, S., Satish, U., & Allen, J. (2016). Environmental perceptions and health before and after relocation to a green building. *Building and Environment, 104*, 138-144. https://doi.org/10.1016/j.buildenv.2016.05.011

Magrini, A., Lentini, G., Cuman, S., Bodrato, A., & Marenco, L. (2020). From nearly zero energy buildings (NZEB) to positive energy buildings (PEB): The next challenge - The most recent European trends with some notes on the energy analysis of a forerunner PEB example. *Developments in the Built Environment, 3*, 1000192. https://doi.org/10.1016/j.dibe.2020.100019

Majekodunmi, T. B., Shaari, M. S., Abidin, N. Z., & Ridzuan, A. R. (2023a). Green technology, exports and CO2 emissions in Malaysia. *Heliyon, 9*, e18625. https://doi.org/10.1016/j.heliyon.2023.e18625

Majekodunmi, T. V., Shaari, M. S., Zainal, N. F., Harun, N. H., Ridzuan, A. R., Abidin, N. Z., Abd Rahman, N. (2023b). Gas consumption as a key for low carbon state and its impact on economic growth in Malaysia: ARDL approach. *International Journal of Energy Economics and Policy, 13*(3), 469-477. https://doi.org/10.32479/ijeep.14134

Matthiessen, L. F., & Morris, P. (2004). *Costing green: a comprehensive cost database and budgeting methodology*. [Online] Available: https://www.usgbc.org/resources/costing-green-comprehensive-cost-database-and-budgeting-methodology

Md Razak, M. I., Ridzuan, A. R., Mohd Masdek, N. R., Mohd Rasid, M. R., & Talib, A. H. (2017). Determinants of environmental quality in selected Asia Pacific countries based on panel estimation. *Advanced Science Letters, 23*(9), 9215-9219. https://doi.org/10.1166/asl.2017.10057

Mohamed Yusoff, N. Y., Ridzuan, A. R., Soseco, T., Whajoedi, Narmaditya, B. S., & Ann, L. C. (2023). Comprehensive outlook on macroeconomic determinants for renewable energy in Malaysia. *Sustainability, 15*, 3891. https://doi.org/10.3390/su15053891

Mohd Hussain, M. R., Nizarudin, N. D., & Tukiman, I. (2014). Landscape Design as Part of Green and Sustainable Building Design. *Advanced Materials Research, 935*, 277-280. https://doi.org/10.4028/www.scientific.net/AMR.935.277

Park, J. S., & Yoon, C. H. (2011). The effects of outdoor air supply rate on work performance during 8-h work period. *Indoor Air, 21*(4), 284-290. https://doi.org/10.1111/j.1600-0668.2010.00700.x

Patnaik, A., Mvubu, M., Muniyasamy, S., Botha, A., & Anandjiwala, R. (2015). Thermal and sound insulation materials from waste wool and recycled polyester fibers and their biodegradation studies. *Energy and Buildings, 92*. https://doi.org/10.1016/j.enbuild.2015.01.056

PLP Architecture. (2016). *The Edge*. [Online] Available: https://www.archdaily.com/785967/the-edge-plp-architecture

Pujiati, A., Feronica, S. M. F., & Ridzuan, A. R. (2023b). Measurement of the role of innovation in increasing performance index: Empirical study in developed and non-developed countries. *International Business and Accounting Research Journal, 7*(1), 18-36.

Pujiati, A., Handayani, B. D., Yanto, H., Ridzuan, A. R., Borhan, H., & Shaari, M. S. (2023a). The detrimental effects of dirty energy, foreign investment and corruption, on environmental quality: New evidence from Indonesia. *Frontier in Environmental Science, 10,* 1074172. https://doi.org/10.3389/fenvs.2022.1074172

Ridzuan, A. R., Fianto, B. A., Esquivias, M. A., Kumaran, V. V., Shaari, M. S., & Albani, A. (2022b). Do financial development and trade liberalization influence environmental quality in Indonesia? Evidence-based on ARDL model. *International Journal of Energy Economics and Policy, 12*(5), 342-351. https://doi.org/10.32479/ijeep.13494

Ridzuan, A. R., Kumaran, V. V., Fianto, B. A., Shaari, M. S., Esquivias, M. A., & Albani, A. (2022a). Reinvestigating the presence of environmental kuznets curve in Malaysia: The role of foreign direct investment. *International Journal of Energy Economics and Policy, 12*(5), 217-225. https://doi.org/10.32479/ijeep.13461

Ridzuan, A. R., Md Razak, M. I., Albani, A., Murshidi, M. H., & Abdul Latiff, A. R. (2020a). The impact of energy consumption based on fossil fuel and hydroelectricity towards pollution in Malaysia, Indonesia and Thailand. *International Journal of Energy Economics and Policy, 10*(1), 215-227. https://doi.org/10.32479/ijeep.8140

Ridzuan, A. R., Md Razak, M. I., Kamaludin, M., Haron, N. F., & Ismail, N. A. (2020b). Macroeconomic indicators for electrical consumption demand model in Malaysia, *International Journal of Energy Economics and Policy, 10*(1), 16-22. https://doi.org/10.32479/ijeep.8139

Ridzuan, A. R., Sapuan, N. M., Abdul Rahman, N. H, Borhan, H., & Othman, A. (2019). The impact of corruption on environmental quality in the developing countries of ASEAN-3 countries. *International Journal of Energy Economics and Policy, 9*(6), 469-478. https://doi.org/10.32479/ijeep.8135

Ridzuan, A. R., Shaari, M. S., Rosli, A.,Md Jamil, A. R., Siswantini, Lestari., A., & Zakaria, S. (2021b). The nexus between economic growth and natural resource abundance in selected ASEAN countries before pandemic Covid-19. *International Journal of Energy Economics, and Policy, 11*(2), 281-292. https://doi.org/10.32479/ijeep.10615

Ridzuan. A. R., Zakaria, S., Fianto, B., Mohamed Yusoff, N. Y., Che Sulaiman, N. F., Md Razak, M. I., Siswantini, & Lestari., A. (2021a). Nexus between financial development and income inequality before Pandemic Covid-19: Does financial kuznets curve exist in Malaysia, Indonesia, Thailand and Philippines? *International Journal of Energy Economics, and Policy, 11*(2), 260-271. https://doi.org/10.32479/ijeep.10616

Romano, A., Bras, A., Grammatikos, S., Shaw, A., & Riley, M. (2019). Dynamic behaviour of bio-based and recycled materials for indoor environmental comfort. *Construction and Building Materials, 211*, 730-743. https://doi.org/10.1016/j.conbuildmat.2019.02.126

Shaari, M. S., Esquivias, M. A., Ridzuan, A. R., Zainal, N. F., & Sugiharti, L. (2022b). The impact of corruption and environmental degradation on foreign direct investment: New evidence from the ASEAN+3 countries. *Cogent Economics & Finance, 10*(1), 2124734. https://doi.org/10.1080/23322039.2022.2124734

Shaari, M. S., Lee, W. C., Ridzuan, A. R., Lau, E., & Masnan, F. (2022a). The impacts of energy consumption by sector and foreign direct investment on CO2 emissions in Malaysia. *Sustainability, 14*, 16028. https://doi.org/10.3390/su142316028

Shaari, M. S., Masnan, F., Abd Rani, N. J., Zainal Abidin, Z., Ridzuan, A. R., & Othman, N. (2023). The grim cost of economic growth and environmental degradation: A comprehensive panel ardl study of public debt in the ASEAN-5 countries. *Sustainability, 15*(10756), 1-15. https://doi.org/10.3390/su151410756

Shaari, M. S., Zainol Abidin, M., Ridzuan, A. R., & Meo, M. S. (2021). The impacts of rural population growth, energy use and economic growth on CO2 Emissions. *International Journal of Energy Economics and Policy, 11*(5), 553-561. https://doi.org/10.32479/ijeep.11566

Sharma, M. (2018). Development of a 'Green building sustainability model' for Green buildings in India. *Journal of Cleaner Production, 190*, 538-551. https://doi.org/10.1016/j.jclepro.2018.04.154

Shi, Q., Zuo, J., Huang, R., Huang, J., & Pullen, S. (2013). Identifying the critical factors for green construction an empirical study in China. *Habitat International, 40*, 1-8. https://doi.org/10.1016/j.habitatint.2013.01.003

Three D Reid (3D Reid). (2013). *One Angel Square*. [Online] Available: https://www.archdaily.com/337430/1-angel-square-3d-reid

Udawatta, N., Zuo, J., Chiveralls, K., & Zillante, G. (2015). Attitudinal and behavioural approaches to improving waste management on construction projects in Australia: Benefits and limitations. *International Journal of Construction Management, 15*(2), 137-147. https://doi.org/10.1080/15623599.2015.1033815

United Nation. (2017). *World Population Prospects: The 2017 Revision.* World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. [Online] Available: https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html

USGBC. (2021). *Leadership in Energy and Environmental Design (LEED) V4.* [Online]

Available: http://www.usgbc.org/leed

Voumik, L. C., Islam, M. A., Ray, S., Mohamed Yusoff, N. Y., & Ridzuan, A. R. (2023b). CO2 emissions from renewable and non-renewable electricity generation sources in the G7 countries: Static and dynamic panel assessment. *Energies*, *16*, 1044. https://doi.org/10.3390/en16031044

Voumik, L. C., Rahman, M. H., Nafi, S. M., Hossain, M. A., Ridzuan, A. R., & Mohamed Yusoff, N. Y. (2023a). Modelling a sustainable, non-renewable, and renewable energy based on the EKC hypothesis for Africa's most popular tourist destination. *Sustainability, 15*, 4029. https://doi.org/10.3390/su15054029

Vyas, G. S., & Jha, K. N. (2018). What does it cost to convert a non-rated building into a green building? *Sustainable Cities and Society, 36*, 107-115. https://doi.org/10.1016/j.scs.2017.09.023

Wang, L., Toppinen, A., &Juslin, H. (2014). Use of Wood in Green Building: A Study of Expert Perspectives from the UK. *Journal of Cleaner Production, 65*, 350-361. https://doi.org/10.1016/j.jclepro.2013.08.023

WBDG. (2018). *Sustainability.* Whole Building Design Guide Sustainable Committee. [Online] Available: https://www.wbdg.org/design-objectives/sustainable

WBDG. (2019). *Green Building Standards and Certification Systems.* [Online] Available: https://www.wbdg.org/resources/green-building-standards-and-certification-systems

Wells, L., Rismanchi, B., & Aye, L. (2018). A review of Net Zero Energy Buildings with reflections on the Australian context. *Energy and Buildings, 158*, 616-628. https://doi.org/10.1016/j.enbuild.2017.10.055

World GBC. (2021). *About Green Building Council.* [Online] Available: http://www.worldgbc.org/index.php?cID=220

Xue, F., Siu, S., Lau, Y., Gouc, Z., Song, Y., & Jiang, B. (2019). Incorporating biophilia into green building rating tools for promoting health and wellbeing. *Environmental Impact Assessment Review, 76*, 98-112. https://doi.org/10.1016/j.eiar.2019.02.004

Zainal, N. I. H. N., Ridzuan, A. R., & Ab Rahman, Z. (2020). The Driving Prospects of Sustainable Environment in Malaysia. *International Journal of Academic Research in Economics and Managment and Sciences, 9*(1), 66-77. https://doi.org/10.6007/IJAREMS/v9-i1/7317

Zhang, L., Wu, J., & Liu, H. (2017). Turning green into gold: A review on the economics of green buildings. *Journal of Cleaner Production, 172*, 2234-2245. https://doi.org/10.1016/j.jclep ro.2017.11.188

Zhang, Y., Wang, H., Gao, W., Wang F., Zhou, N., Kammen, D. M., & Ying, X. (2019). A Survey of the Status and Challenges of Green Building Development in Various Countries. *Sustainability, 11*, 5385. https://doi.org/10.3390/su11195385

Zuo, J., & Zhao, Z. (2014). Green building research current status and future agenda: a review. *Renewable & Sustainable Energy Review, 30*, 271-281. https://doi.org/10.1016/j.rser.2013.10.021