GREEN BUILDING CONSTRUCTION IN THE MODERN WORLD: A CRITICAL REVIEW

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ABSTRACT

Over the past few decades, researchers are focusing on a long-term living solution comprehending the planning, design, construction, and operation of buildings considering several important, fundamental elements such as energy consumption, water consumption, interior environmental quality, material sections, and the structure's influence on the environment. The notion of eco-structuring improves the long-term viability of a building but eventually underscores the concept of "Green Building" in the construction industry. The prime purpose of this study is to augment the factors that accord significantly to the sustainability and environmental friendliness of green building construction. It is discernible that a poorly maintained building has an influence on the users' quality of life and productivity along with the environment. Maintenance also contributes to long-term sustainability by reducing noxious emissions and conserving energy and resources, which is becoming more widely recognized in the built environment and structures. Again, considering from the viewpoint of a life cycle, building materials should originate from a sustainable source to decrease the environmental impact of construction. As a result, purchasing products from a local source is recommended since it benefits local businesses and reduces transportation-related greenhouse gas emissions. Extensive research on green building technology and implementation, smart building management, and user interface design should be taken into account while navigating a sustainable way of life while protecting the environment. A holistic assessment of Indoor Environmental Quality (IEQ) and its effects on the occupants of the green building is performed here in this study. Another aim of this study is to offer an understanding of current rating systems such as LEED, which were established to assess building performance using a variety of features and indicators. According to the findings, extra credits should be given to these existing rating systems to account for the influence of design and architecture in the performance assessment of green buildings, which would make not only the structures but also the architecture of these buildings green.

Keywords: *Green building; Sustainability; Indoor Air Quality; Environmental conservation; Renewable energy*

1. INTRODUCTION

Buildings and building activities contribute to 40% of CO_2 emissions, making them one of the major contributors to global warming. We are now coping with a variety of environmental challenges, including the threat of climate change, natural resource depletion, growing air and water pollution, and rising solid waste levels. These occurrences are rapidly becoming a major source of worry when evaluating real estate assets and a key motivation in decision-making. Green construction has become a hot topic in the real estate industry. Sustainable development is progressing with the ongoing construction of green buildings all over the world. Green building performs as the natural element in the process of creating structures that are environmentally responsible, sustainable, and resource-

efficient for living or other uses. This entails conserving energy, water, and other natural resources, as well as protecting human health and boosting staff productivity by reducing waste, pollution, and environmental harm. The notion of "eco-structuring" enhances long-term viability. Green building reduces energy use by 30-50%, CO_2 emissions by 35%, waste generation by 70%, and water usage by 40%, all of which contribute to enhancing the environment (Kamal & Gani, 2016).

In their study, Manoj Katiyar et al. inferred the relevance of spatial design and rating systems used in green building construction, which may solve difficulties with newly developed green buildings and also design the stringent use of rating systems (Katiyar et al., 2021). Nitish Kumar Sharma has spent a lot of time researching the usage of sustainable materials and reuse/refurbishment in green building construction (Sharma, 2020). The construction stage of a building project is a vital link that takes the most time, needs the most modern technology, and has the most influence on the quality level of the green building over its whole life cycle. Jun Zhou conducted a thorough investigation on the relationship between construction management and green building efficiency (Zhou, 2020). Kirstie O'Neill and David Gibbs wrote some case studies on approaches to green buildings in the UK and Germany that covered sustainability elements (O'Neill & Gibbs, 2018). Since the benefit of BIM has become widely recognized in the architectural and construction sectors, up-to-date synthesis of the link between BIM and green buildings is urgently needed. Yongkui Li et al. offer a study on the integration of BIM technology with green building construction., (Lu et al., 2017). Human action and thinking are used to save the environment. Retrofitting technology is unique in its ability to make a building more environmentally friendly and sustainable. F.A.Mohd-Rahim et al. address the research of this field in depth., (Mohd-Rahim et al., 2017).

2. GREEN BUILDING & ITS CONSTRUCTION

Green building is defined as the planning, design, construction, and operation of structures that take into account a few basic, fundamental factors such as energy consumption, water use, interior environmental quality, material sections, and the structure's impact on its surroundings (Green Building in the United Kingdom - Wikipedia, n.d.). There are certain objectives and goals to achieve through green building construction, which are discussed herein brief. A green building maximizes the use of natural resources and reduces energy consumption to operate and employs highly skilled workers. The three R's - reducing, reusing, and recycling - are emphasized in green building. Green buildings place a greater emphasis on natural lighting, climate management, and efficient design to decrease their carbon footprint and operating costs. Improved product design, resource reuse, and recycling are all part of the green building idea.

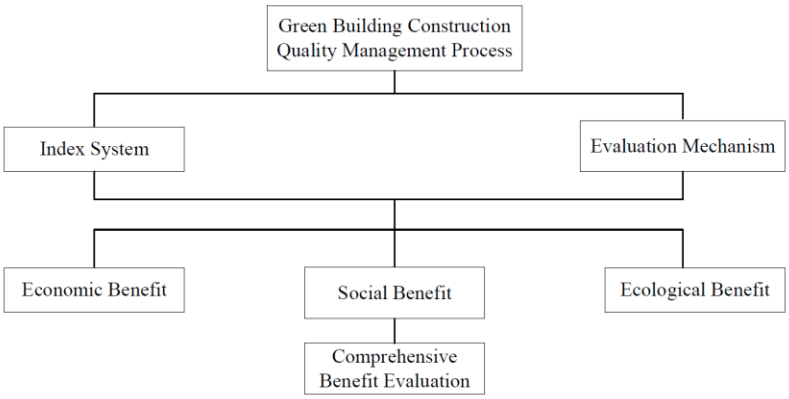

Figure 1: A comprehensive assessment of the quality management of green building construction

The operation process in the green building construction process must perform a quality value analysis, identify quality management activities, distinguish operation activities that can add value from those that are unnecessary and wasteful, and then implement green building construction quality

management. In the above figure 1, the process of the comprehensive inspection of green building construction quality management is shown (Zhou, 2020).

3. GREEN BUILDING MATERIALS

Construction is undoubtedly one of the most resource-intensive sectors on the planet. Concerns regarding the effects of conventional building materials on human and environmental health are emerging. It is clear that actions are needed to make the built environment and construction activities more sustainable (Barrett et al., 1999). Kein et al. (1999) and Ding (2008) describe the building industry as uncaring and profit-motivated, and the members as destroyers of the environment rather than its protectors (Yin et al., 2018). After the combustion of fossil fuels, cement manufacture is the second-largest source of anthropogenic greenhouse gas emissions. Cement kilns, which emit more than 25 tons of nitrogen oxides per year, have been recognized as stationary sources of nitrogen oxides. Although cement accounts for just around 15% of the final concrete mix, additional embodied energy is derived from the transportation and extraction of aggregates, as well as the fabrication of steel in the case of reinforced concrete. The manufacturing of iron and steel accounts for roughly 4% of worldwide energy use. Iron, steel, and non-ferrous metals, as well as other construction materials like cement, glass, lime, and bricks, account for 20% of yearly dioxin and furan emissions. This does not include emissions from the manufacture and use of PVC and other chlorinated chemicals used as paints, sealants, plastics, and wood preservatives, for which particular numbers are not yet available. Road transport infrastructure, particularly asphalt paving, adds another 1% of yearly dioxin emissions. The burning of municipal trash accounts for the majority of dioxin emissions (69%) (Petkar, 2016). Table 1 stated below provides a list of some popular green building Materials along with their uses, economic & environmental benefits (8 Green Building Materials in New Construction | Dumpsters.Com, n.d.).

Table 1: List of Some Green Building Materials and Usage & Benefits

Material	Uses in building	Economic benefit	Environmental benefit
Bamboo	Flooring Fences Cabinetry	Durable for being resistant to mold, mildew, insects	Renewable No fertilizers or pesticides required performs as a carbon sink
Natural Stone	From countertops/fireplaces indoors to fencing/retaining walls outdoor	The durability makes it cost-effective over the long term	Nontoxic Promotes healthy indoor air low embodied energy
Cellulose Insulation	Standard insulating material for frames and Triple-glazed windows	Reduces drafts Reduces Air leaks Reduces heat entering through windows	Recycled Energy efficient Nontoxic
Paper Insulation	Different insulation purposes	Made from recycled newspaper and cardboard	Insect-resistant Fire retardant

Material	Uses in building	Economic benefit	Environmental benefit
Cork	Flooring	Harvesting of cork does not harm trees and the bark from each tree can be stripped up to 20 times during its life cycle	Highly renewable Hypoallergenic Fluid resistant Fire retardant
Sheep's wool	Insulation Soundproofing	Less energy is required to manufacture Cheap	Eco-friendly Energy-efficient
Certified Lumber	Framing Decking Flooring Cabinetry	Often costs no more than alternatives	Renewable Reusable
Steel studs	Commercial structures	Less material is needed for structural integrity Cheaper than wood Fewer repairs	Recyclable Low site waste
Perforated Metal	Sunshades Building facades Railing systems Garage screening Decorative cladding	Lasts for generations Decreases cooling and lighting requirements	Up to 100% recyclable Indefinitely renewable Reduces building energy needs
Living Plants	Roofs/walls covered with vegetation	Natural Insulation Counteracts sick building syndromes	Improves air quality Energy efficient
Solar Tiles	Protects a building Absorbs energy from the Sun and stores it	Reduces energy costs over the long term Financial incentives (e.g., Tax credits)	Emissions-free Clean energy

4. USE OF RENEWABLE ENERGY

As the construction materials of green buildings are covered in the 'Green Building Materials' section, so in this section, the energy production and usage will be discussed in brief. Renewable energy techniques and strategies that can be used in a building are as follows [(NRDC, n.d.); (Karadağ, 2021)]:

- **Geothermal Heat Pumps:** Geothermal technology is a new take on a recognizable process—the coils at the back of your fridge are a mini heat pump, removing heat from the interior to keep foods fresh and cool.
- **Small Wind Systems:** Depending on the electricity needs, wind speeds, and zoning rules in a specific area, a wind turbine may reduce your reliance on the electrical grid.
- **Renewable Energy:** Advocating for renewables, or using them in the home, can accelerate the transition toward a clean energy future.
- **Solar Power:** At a smaller scale such as shown in figure 2, we can harness the sun's rays to power the whole house—whether through PV cell panels or passive solar home design.

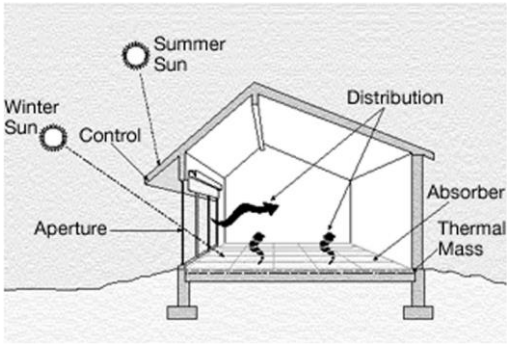

Figure 2: Passive solar heat gain process

The benefits of this renewable energy sources in our environment are huge, some key aspects to be noted down as:

- **Less global warming:** Even when including "life cycle" emissions of clean energy (i.e., the emissions from each stage of a technology's life—manufacturing, installation, operation, decommissioning), the global warming emissions associated with renewable energy are minimal.
- **Improved public health:** Geothermal and biomass systems emit some air pollutants, though total air emissions are generally much lower than those of coal- and natural gas-fired power plants.
- **Inexhaustible energy:** Strong winds, sunny skies, abundant plant matter, heat from the earth, and fast-moving water can each provide a vast and constantly replenished supply of energy.
- **Jobs and other economic benefits:** Compared with fossil fuel technologies, which are typically mechanized and capital intensive, the renewable energy industry is more labor-intensive.
- **Stable energy prices:** Renewable energy is providing affordable electricity across the world right now, and can help stabilize energy prices in the future.

5. OPERATIONS & MAINTENANCE

For green buildings, there is a requirement for long-term upkeep. Maintenance helps sustainability by keeping noxious emissions to a bare minimum and decreasing energy and resource consumption. Green building maintenance influences not only operating costs but also social and environmental factors (Zainol et al., 2014). The green building operations include various types of sustainability features to be named as Indoor Air Quality performance, Energy Conservation, Water Management, Waste Reduction and Management. Here we will discuss this in brief [(2019 Global Status Report for Buildings and Construction | World Green Building Council, n.d.); (U.S. Green Building Council Announces Top 10 Countries and Regions for LEED Green Building | U.S. Green Building Council, n.d.); (34 Main Pros & Cons Of Green Building - E&C, n.d.)]:

5.1 Indoor Air Quality Performance

- Ascertain that all building exhaust systems receive preventative maintenance from the building maintenance personnel (restrooms, garage exhaust fans, etc.).
- Adjust occupancy-based systems such as HVAC and ventilation to the building's actual occupancy times or utilize occupancy-based controls.

5.2 Energy Conservation

- To guarantee energy efficiency, comfort, operation, and productivity, use the ENERGY STAR Portfolio Manager opens in a new window, which has exact criteria for HVAC operations.
- Adjust occupancy-based systems such as HVAC and ventilation to the building's actual occupancy times or utilize occupancy-based controls.

- Replace outdated fluorescent lighting with more energy-efficient options like T8/T5 or compact fluorescent bulbs.

5.3 Water Management

- Water systems should be sub-metered to identify future possibilities for improvement.
- Provide tenants with training on how to utilize water-saving fixtures.
- Provide instruction on how to properly maintain waterless urinals.
- Individual treatment of greywater and usage of potable water

5.4 Waste Reduction & Management

- Water systems should be sub-metered to identify future possibilities for improvement.
- Provide tenants with training on how to utilize water-saving fixtures.
- Provide instruction on how to properly maintain waterless urinals.
- Individual treatment of greywater and usage of potable water

6. GREEN BUILDING RATING SYSTEMS

There has been a growing understanding of the importance of sustainability in the built environment and structures. As a result of all of this, modern rating systems have been developed to assess the performance of buildings based on a variety of variables and metrics. Among these are energy efficiency, water efficiency, environmentally friendly materials, and products, enhanced indoor air quality (IAQ), and improved operation and maintenance (O&M) procedures.

Table 2: Weightages for Different Domains in Different Rating Systems (Katiyar et al., 2021)

System	Weightage (%)						
	Site	Energy	Water	Materials	IAQ	O&M	Others
BREEAM	15	25	5	10	15	15	15
CASBEE	15	20	2	13	15	15	15
Green Globes	11.5	36	10	10	20	-	12.5
LEED	20	25	7	19	22	-	7
GRIHA	21	32	16	18	3	2	8

7. OVERALL CONDITION OF GREEN BUILDING CONSTRUCTION

7.1 Green Building Construction in The United Kingdom

In Hertfordshire, for example, the Beaufort Court is a zero-emission building built on the site of a former Ovaltine egg farm. With a total yearly capacity of 3,200 kilowatt-hours, it boasts its 225-kilowatt wind turbine and solar array. One Angel Square in Manchester has one of the highest BREEAM scores of any structure on the planet. This structure makes use of natural resources by exploiting passive solar gain for heating and natural ventilation through its double-skin façade (Green Building in the United Kingdom - Wikipedia, n.d.).

Figure 3: One Angel Square, Manchester, England (One Angel Square - Wikipedia, n.d.)

7.2 Green Building Construction in Bangladesh

Bangladesh is developing a green building grading system for the region. The first proposed grading method aimed to satisfy the UN's Millennium Development Goals (MDGs) target, as the council for the first time endorsed green building certificates. In 2011, the Ministry of Public Works and the World Bank started collaborating on energy and water efficiency, as well as carbon reductions through Green Building Certifications (BGBC) (Green Building in Bangladesh - Wikipedia, n.d.).

Figure 4: Grameenphone Corporate Head Quarter, Dhaka, Bangladesh (Grameenphone Corporate Head Quarter (GPHouse), n.d.)

7.3 Green Building Construction in The United States

An example of a structure that should be specified here is as follows: The Wayne Lyman Morse United States Courthouse is a federal courthouse in Eugene, Oregon. It is part of the Ninth Judicial Circuit, which serves the District of Oregon, and was finished in 2006. The courthouse is named for former the United States Senator Wayne Morse, who represented Oregon in the Senate for 24 years. The courthouse is the first new federal courthouse to get LEED Gold certification (Wayne Lyman Morse United States Courthouse - Wikipedia, n.d.).

Figure 5: Wayne Lyman Morse United States Courthouse, Eugene, Oregon, United States

The rating systems are also leaving a great impact on the construction of green buildings with more care and sustainability features in the current world. One of the highly remarked rating systems is LEED Certification developed by the United States Green Building Council (USGBC). The list ranks countries and regions in terms of cumulative LEED-certified gross square meters as of December 31, 2018 (U.S. Green Building Council Announces Top 10 Countries and Regions for LEED Green Building | U.S. Green Building Council, n.d.).

Table 3: List of Countries/Regions for Most Cumulative LEED Certified Gross Square Meters Usage

Ranking	Country/Region	Number of Projects	Gross Square Meters (in millions)
1	Mainland China	1,494	68.83
2	Canada	3,254	46.81
3	India	899	24.81
4	Brazil	531	16.74
5	Republic of Korea	143	12.15
6	Turkey	337	10.90
7	Germany	327	8.47
8	Mexico	370	8.41
9	China, Taiwan	144	7.30
10	Spain	299	5.81

8. LIMITATIONS & CHALLENGES OF GREEN BUILDING CONSTRUCTION

There is no unmixed good on earth. So does for this, the green building construction industry could face some serious limitations in some certain fields. Environmentally-friendly construction materials are in scarce supply. It may be difficult to keep up with the upkeep of a structure that has been built from renewable energy sources such as solar panels, wind turbines, and hydropower. Moreover, the initial start-up cost is so high, the modern and inventive technology that may be used for the construction could be a major issue to resolve for the developing countries which are not so very well equipped or technologically advanced. The funding for this kind of project could be a mammoth task for the developing countries (34 Main Pros & Cons Of Green Building - E&C, n.d.).

Despite the limitations discussed briefly above, there are also some challenges to be met before the green building construction project breaks ground. Some to be named as (Kamal & Gani, 2016):

- Excessive National and Urban Population: Present and Future
- High-priced, high-quality eco-friendly materials.
- Imbalance in Urbanization (Regional/Spatial)
- Access to land and houses is unequal.
- Financial Resource Constraints in Cities: The Government's Low-Per-Capita Investments

9. FUTURE OF GREEN BUILDING CONSTRUCTION

Increasing demand for constructions with low greenhouse gas emissions is propelling the green building materials industry forward. Furthermore, the lower operating and maintenance costs associated with the construction of new green buildings, as a result of lower energy usage, are driving up demand for these materials. The worldwide green building materials market reached a value of US$ 299 billion in 2020, according to the publisher's newest study, "Green Building Materials

Market: Global Industry Trends, Share, Size, Growth, Opportunity, and Forecast 2021-2026" (Global Green Building Materials Market (2021 to 2026) -, n.d.).

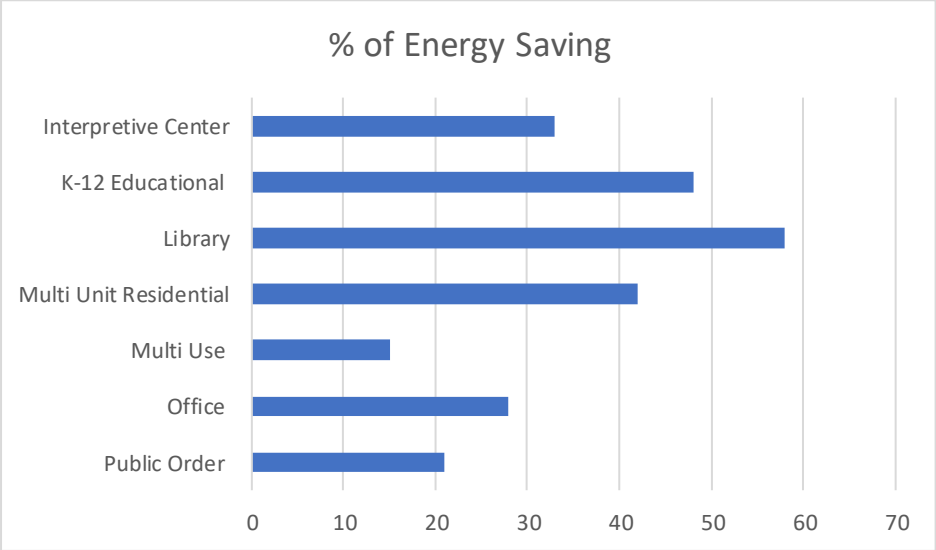

Figure 6: Energy Savings from LEED Certified Buildings (Zuo & Zhao, 2014)

10. CONCLUSIONS & RECOMMENDATIONS

The construction of green buildings and the development of their characteristics are quickly increasing all over the world. When evaluating green building development and monitoring, there are a few things to keep in mind. External variables include regulatory policies, rating and certification systems, and economic advantages, to mention a few. Internal aspects such as the development and implementation of green building technologies, smart building management, and user interaction design should also be considered. Green building development is advancing at a rapid rate all around the world. However, by focusing solely on green features and design, a gap remains between the inhabitants' wishes/comfort and the green building's long-term sustainability characteristics. There should be a thorough case study and consideration of the residents' opinions. The green building construction business in western nations such as the United States, the United Kingdom, and Germany, which has been addressed here, is already mature. However, in eastern nations such as Japan, China, and Bangladesh, the green building sector is still in its infancy and relies solely on government support. However, entrepreneurship or privatization in the green building construction sector is a key element in revolutionizing the industry's sustainability. Though green building construction is still in its infancy, builders should rigorously adhere to the rules and approved rating systems, which should be reviewed frequently. The discussed leading rating systems like LEED, BREEAM is to be used for monitoring because these rating systems have already been developed. The rest of the systems need to be improved in every aspect. The recommendation of this paper deduces some key points about green building construction such as:

- User-driven ideas and implementations of design in green buildings
- Provision of training and education about green building construction in the private sector
- Raising the local awareness about green building construction and conservation of nature to meet the challenge of global climate change

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