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A Review of Using the Green Buildings Strategy to Reduce the Effects of Unplanned Urbanization in Bengaluru

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Abstract: ***Bengaluru (12.9716° N, 77.5946° E), Karnataka, situated at an elevation of 920m from mean sea level is a metropolitan city having a Moderate Climatic condition and also knows as "City of gardens & Lakes". Rapid urbanization in Bengaluru has led to significant environmental problems, including air and water pollution, solid waste, and traffic congestion. Unplanned urbanization has resulted in the scarcity of resources, deforestation, traffic congestion, and pollution of air, water, and soil and waste disposal problems. Bengaluru, encircled by a green belt area, has witnessed a significant increase in land prices, making it unaffordable. Cities are responsible for a large percentage of global energy consumption and greenhouse gas emissions. Water contamination scarcity and urban floods are significant concerns of today in cosmopolitan cities like Bengaluru. Water resource management and flood forecasting systems are crucial for addressing these issues. We have witnessed higher land surface temperatures and Urban heat island effects during both dry and wet seasons in Bengaluru. Sustainable construction, including green buildings, aims to reduce reliance on fossil fuels, minimize negative environmental impacts through encompassing energy efficiency, recycling of waste materials, and renewable resources and improve residents' quality of life. Deploying renewable energy in India aims to advance economic development, improve energy security, and mitigate climate change. The government has implemented policies and programs to attract investments and create job opportunities in the renewable energy sector. However, the adoption of green building practices in India is hindered by a lack of proper policies, incentives, and communication. The impact of urbanization on the environment and public health in Bengaluru is examined in this paper and Green/sustainable construction is suggested as one of solution put forward to mitigate significant impacts of the unplanned urbanization with data collected from secondary sources.***

Keywords: Energy conservation, Green building, Literature review, Storm water management, Urbanization

1. Introduction

Urbanization is the movement of people from rural to urban areas, leading to population growth and urban migration. Bengaluru, the capital of Karnataka, India, has a metro area population of 13,608,000 as per the 2023 census and is among India's fastest-growing cities. The district covers an area of 2196 sq.km, with a population density of 6192 people per sq.km. Urbanization offers opportunities for jobs, education, healthcare, and modern living, but it also harms the environment, particularly water and air quality, impacting public health. To tackle this issue, a stable policy framework, legislation, and increased awareness among Bengaluru's residents about environmental problems are needed for sustainable urban development.

Urbanization leads to economic growth and improved overall well-being. Butunplanned urban growth poses significant environmental challenges, including:

1) Depletion of resources
2) Increased air, water, and soil pollution
3) Global warming
4) Accumulation of solid waste
5) Climate change
6) Scarcity of freshwater and groundwater
7) Deforestation and reduction in agricultural activities
8) Decreased availability of land
9) Flooding
10) Landslides
11) Increased road traffic
12) Growth of slums near water bodies and waste disposal areas, leading to unhealthy living conditions
13) Health issues for residents
14) Scarcity of energy
15) Destruction of habitats

Rapid urbanization and resource overexploitation are causing irreversible harm to the global environment, with consequences for future generations. The concept of sustainable development, particularly through green buildings and energy efficiency, offers a solution to regulate the high consumption of energy and resources in urban areas. Green buildings, as defined by the Indian Green Building Council (IGBC), prioritize water conservation, energy efficiency, waste reduction, and healthier indoor environments. The IGBC envisions India becoming a global leader in sustainable construction by 2025.

Government subsidies, coupled with growing awareness of environmental degradation and climate change, are driving the demand for green buildings. Immediate implementation of sustainable measures in future construction projects is crucial to prevent further environmental pollution. At the 26th UN Climate Change Conference, Indian Prime Minister Narendra Modi announced targets to achieve 500 gigawatts of non-fossil energy capacity, meet 50% of energy needs through renewables, reduce carbon emissions by one billion tonnes, and lower carbon intensity by less than 45% by

2030.These efforts highlight the significance of green and sustainable development.

2. Methodology

A literature review was carried out on urbanisation and its significantenvironmental challenges in present scenario, which was helpful in understanding the importance of practicing green building strategy.

Urbanisation

Bengaluru is the smallest district in terms of area but the largest in terms of population in Karnataka state. It is highly urbanized, with 90.94% of its population residing in urban areas. The rapid growth of Bengaluru has led to a decline in environmental quality. The city, known as the "Land of lakes," has seen a reduction in the number of lakes from 285 to 194 due to unplanned and irresponsible urbanization, resulting in decreased groundwater, loss of native species, and pollution [1].

Urbanization brings challenges such as resource depletion, pollution, and global warming. Urbanization is the migration of people from rural to urban areas, often driven by insufficient infrastructure and resources in rural regions [3]. Poor-quality rural-urban migration leads to urban decay and various social issues. Major environmental problems in the future may arise from existing practices that lack political attention [4]. The compact city concept aims to reduce sprawl, promote equitable growth, and preserve green spaces [5]. Urbanization involves the concentration and centralization of economic activities in central areas, along with dispersal into suburbs. It has a significant impact on the environment, including pollution, waste generation, resource depletion, and social costs related to population growth and poverty [3].

Air pollution in Bengaluru, primarily caused by increasing traffic, non-environmentally friendly fuel sources, and industrial development, negatively affects human health. The city generates significant amounts of solid waste, with roughly 60% being organic waste. Air-related diseases, such as asthma, and waterborne and vector-borne diseases are prevalent. Successive master plans have impacted land use and the green belt.

Proper maintenance and sustainable development are crucial for addressing environmental degradation in urban areas.

Impacts of unplanned urbanization

Bengaluru is facing two critical urban challenges such as water contamination and recurring urban floods. The water quality in agroecosystems along the rural-urban transition zones (RUT) of Bengaluru was evaluated, revealing deterioration and unsuitability for human consumption. Increasing agriculture productions and increasing wastewater effluents associated with increasing population has affected the surface water bodies both in urban and adjoining rural areas of Bengaluru. Studies on collected water samples from various urban areas in Bengaluru is attributed to high degree of anthropogenic interferences such as waste disposal, sewage inflow and agriculture runoff in the rural areas .Utilizing urban surface water without proper treatment and soil management practices can result in soil pollution, increased salinity, and alkalinity, rendering these resources unsuitable for crop cultivation in urban agro-ecosystems [7].

Moreover, urban areas face the recurring challenge of storm flooding due to high-intensity rainfall events and rapid urbanization. The rise in urban population and haphazard infrastructure development contribute to the increased vulnerability to floods. Bengaluru's topography naturally divides the city into major watershed regions, and the Koramangala-Chellagatta Valley stands out as the most frequently flooded area .The significant reasons for flooding in Bengaluru city include population growth and urbanization, climate change causing urban heat islands, high-intensity rainfall, inadequate stormwater drainage, lack of infrastructure planning, encroachment into natural habitats, destruction of natural channel flow, conversion of wetlands into layouts, reduced water body capacity due to untreated sewage, haphazard drainage system development, slum dwellings in low-lying areas, dumping of solid waste, and increased runoff coefficient and reduced groundwater capacity due to urbanization [8].

Urbanization has resulted in rise on surface temperature at Bengaluru urban area. The urban heat island (UHI) effect was observed, with increasing UHI intensity during both dry and wet seasons, highlighting the need to understand the relationships between urbanization, UHI, and vegetation for future planning and mitigation efforts. As cities expand, they also exhibit the urban heat island effect, characterized by higher surface and air temperatures, reduced vegetation, and increased heat storage. Bengaluru's UHI intensity and its relationship with vegetation density and aerosol concentrations have not been extensively studied [9].

Collaboration between environmental managers, city planners, and policymakers is recommended focussing on sustainable construction methods to create and preserve green spaces in rapidly urbanizing cities.

Water crisis

Throughout history, civilizations have flourished around various water bodies such as lakes and rivers, serving as vital sources of livelihood. Though water covers 71.6% of the earth's surface, only 2.5% of the earth's water is fresh water. Lakes, accounting for just 0.007% of the Earth's surface, are particularly scarce. The report predicts that by 2030, India's water demand will be double the supply. Groundwater, which constitutes 40% of the country's water supply, is depleting rapidly, with 54% of India's groundwater sources in decline [10]. Large cities in India, including Mumbai, Jaipur, Bhatinda, Lucknow, Nagpur, and Chennai, are currently experiencing acute water shortages, directly affecting around 100 million people. A WaterAid report from 2018 stated that the demand for water in Indian cities is projected to increase rapidly in the near future due to urban growth.

As the fifth largest metropolitan city in India, Bengaluru relies on its lakes and other surface water bodies for their aesthetic beauty, diverse ecosystems, flood prevention, sediment control, drinking water supply, and groundwater

recharge to maintain a healthy water table. Water pollution, defined as the contamination of water bodies, whether natural or man-made, poses a significant problem. Sources of pollution include improper disposal of plastic waste and discharge of urban and industrial sewage. In the past, Bengaluru had 262 water bodies that served as reservoirs for runoff water, ensuring a reliable water supply for drinking, irrigation, and fishing. However, water pollution originates from sewer lines and industrial waste. The limited capacity of sewage treatment plants has led to only a fraction of generated sewage being treated, while the rest is directly released into water bodies. Moreover, encroachment resulting from urbanization has further degraded and encumbered these water bodies, contributing to their decline [11].

Failure to address this issue could result in a 6% GDP loss for India by 2050. The frequent occurrence of water scarcity in urban areas not only reflects the government's inability to provide safe drinking water but also leads to social conflicts, tensions, and detrimental effects on public health [10]. The findings indicate that a significant portion of India's water supply is contaminated, with up to 70% of water being contaminated according to government data and 80% of surface water being polluted. Groundwater plays a vital role in fulfilling 50% of water needs in urban areas, but its extraction rate is the highest in the world.

Lakes, which play crucial roles in climate change, ecosystems, and human environments to be projected for the upcoming generations. The study suggests the use of satellite-based GPS systems to map lake boundaries, bot-based autonomous cleaning systems monitored through mobile applications, and mobile app-based water level monitoring with a centralized database. Formulation of stringent regulations to stop disposal of untreated sewage/industrial effluent to waterbodies to be made.

Solid waste management

Solid waste management (SWM) poses a significant challenge for urban local bodies in India due to increased municipal solid waste (MSW) generation resulting from urbanization, industrialization, and economic growth. India faces major challenges in waste generation, collection, transportation, treatment, and disposal. The current systems are unable to handle the increasing urban waste, resulting in adverse impacts on the environment and public health [12].

Proper solid waste management in construction sites is vital to prevent environmental degradation. Utilizing green resources in construction can enhance energy efficiency and reduce carbon emissions. However, inadequate disposal of construction materials raises concerns about the effectiveness of existing regulations. Improperly disposed solid waste poses health risks, compromises safety, and contributes to environmental degradation and climate change through gas emissions. Current SWM systems in India remain inefficient, with the informal sector playing a major role in waste extraction.

The composition of MSW in Indian cities typically consists of approximately 41% organic waste, 40% inert waste, and 19% potentially recyclable materials. Projections indicate a significant increase in waste generation, with urban areas expected to reach 0.7 kg per person per day by 2025. The Ministry of Environment and Forests (MoEF) has issued rules to regulate MSW management, emphasizing the responsibilities of municipal authorities in collection, segregation, transportation, processing, and disposal. C&D waste management and utilization have not progressed as planned, with recycling rates remaining low. The need for recycling, reusing, and substituting construction materials has become evident, particularly with issues such as sand mining. The lack of support for effective business models and limited compliance have hindered progress in managing C&D waste, plastic waste, and e-waste.[13].

However, among these challenges lie opportunities for sustainable solid waste management. The priority is to transition from reliance on environmentally harmful waste dumps to efficient waste management systems that retain valuable resources within the economy. Urgent action is required to transition to more sustainable SWM, involving new management systems and facilities. Waste management infrastructure is crucial for sustainable development and must focus on resource extraction through materials, energy, and nutrient recovery. Investing in SWM and developing markets for reusable/recyclable materials are essential for this transition.

Sustainable and economically viable waste management in India requires maximizing resource extraction from waste while ensuring the safe disposal of residual waste. This can be achieved through the development of engineered landfill and waste-to-energy facilities. However, India faces challenges in waste policy, waste technology selection, and the availability of appropriately trained personnel in the waste management sector.

The country's diverse religious groups, cultures, and traditions further complicate achieving sustainable development. India's effective recycling tradition and established networks contribute to resource recovery. However, unhygienic conditions, environmental pollution, and health risks persist due to inefficient waste disposal. Green buildings, renewable energy utilization, and adherence to waste management rules offer solutions to mitigate environmental degradation.

Indoor air quality

People worldwide spend approximately 90% of their time in various indoor environments. While outside air pollutants can infiltrate indoors, indoor contaminants are also generated through activities like heating, cooling, cooking, and emissions from building materials. Since individuals spend a significant portion of their lives indoors, this has a considerable impact on human health and productivity.

Apart from residential settings, significant time is also spent in offices, educational institutes, and various commercial and industrial buildings. Research in North America has indicated that adults spend 87% of their time in buildings, with the remaining time divided between vehicles (6%) and outdoor spaces (7%) [14]. Given the substantial time spent indoors, exposure to indoor air pollutants significantly affects human health and work efficiency.

The energy crisis of the 1970s highlighted the importance of energy efficiency in buildings, resulting in more airtight and insulated structures worldwide. Energy-saving measures led to reduced fresh air circulation in air conditioning systems. Furthermore, improved living standards have led to increased use of synthetic materials and chemicals for indoor construction and decoration. Pesticides, cleaning agents, air fresheners, and cooking emissions are additional sources of indoor air pollution that need to be examined in detail.

IAQ regulations are to be considered and implemented during the design and maintenance phases of building environments incorporating appropriate measures. The assessment demonstrated several advantages of air quality in green buildings compared to conventional buildings. In accordance with ASHRAE regulations, the measurement data indicated satisfactory levels of CO2 and relative humidity.

Carbon foot print

Carbon foot print is a measure of the amount of carbon dioxide and other greenhouse gases released into the atmosphere as a result of the activities of a particular individual, organization, or community. Buildings globally contribute to a substantial portion of greenhouse gas emissions and energy consumption, with the construction sector predicted to generate a significant increase in emissions in the future. The construction industry plays a significant role in increasing carbon emissions, accounting for nearly half of global energy usage and raw material consumption. Globally, in developed and developing countries, buildings contribute to 33% of the greenhouse gas (GHG) emissions and 40% of the global energy consumption which stem from the usage of the equipment, the manufacturing of building materials and transportation [16]. Various construction activities contribute to environmental pollution, including land clearing, equipment emissions, demolition, burning, and chemical usage. Global warming, sea-level rise, ozone depletion, and climate change are undeniable indicators that are closely linked to human activities such as deforestation, fossil energy usage, and construction.

To combat this, it is important to promote awareness of carbon footprints in construction and implement strategies to reduce emissions throughout the entire construction lifecycle, such as alternative additives, improved design, waste recycling, and efficient water and building systems. Researchers worldwide have made efforts to develop standards, techniques, and tools to address greenhouse gas emissions in construction. These include the green building concept, rating systems, and sustainable construction materials.

However, there is a lack of research on the interconnected relationship between drivers linked to low-carbon construction, emphasizing the need for an internationally recognized rating system under the United Nations that measures and quantifies carbon footprints.

Policy interventions focusing on GHG emissions mitigation, including indirect pricing through regulations and direct pricing through carbon taxes and emission trading schemes, are essential to address this issue [15].

Energy crisis

The global reliance on fossil fuels for electricity generation has resulted in significant energy crisis, greenhouse gas emissions. India, in pursuit of its economic development plans, faces a growing energy demand that must be met to improve living standards. However, India's heavy reliance on coal and oil has led to a substantial carbon footprint, contributing 6.65% of global emissions [18]. Urgent action is needed to transition to renewable energy sources and limit climate change's ecological impact, aligning with international agreements like the Paris Agreement. This is demanding the provision of cleaner and more reliable electricity.

The building industry, being the most energy-consuming sector in India, is a focal point for energy conservation efforts. Building design, materials, and techniques in achieving energy efficiency and sustainable development, emphasizing the need for a shift away from traditional materials are required to meet these goals.

The Ministry of Power has formulated the National Electricity Plan (NEP) to ensure efficient and affordable power supply across the country. With approximately 74% of energy demand fulfilled by coal and oil, renewable energy technologies offer a critical solution to achieving sustainable growth with lower emissions. Projections indicate vast solar and wind potentials in India by 2047[17].

In the context of building construction, energy conservation plays a pivotal role in reducing energy use throughout a building's life cycle, including embodied energy and operational efficiency. The building sector holds significant potential for energy savings through proper design, orientation, use of climatic conditions, efficient equipment, renewable energy integration, and optimization of thermal comfort. While energy-saving building designs have gained traction, few studies have focused on their post-construction performance and overall energy-saving effectiveness.

To address the energy crises in the modern world, it is essential to conserve energy in the construction industry through the use of materials and techniques. Various methodologies for improving thermal comfort and reducing energy consumption include solar ventilation, evaporative cooling, rooftop foldable PV modules, radiant cooling, earth-air-pipe system, absorption cooling, natural ventilation enhancement, green roofs, phase change materials, thermal mass, and Trombe.

Renewable energy sources (small hydropower, wind, biomass, WTE, solar) accounted for around 21% of the installed power capacity, with conventional sources contributing 78.791%. Southern states in India have the highest solar irradiance and wind, making them ideal regions for renewable energy generation. The country has emerged as a global leader in renewable energy markets, driven by strong government support and favourable economic conditions. Policies and programs have been designed to attract foreign investments and accelerate growth in the

renewable energy sector. Additionally, the sector is expected to generate a substantial number of domestic jobs [17].

Researches and development in the field of Energy Conservation in Buildings, including climate-responsive buildings, analysis, simulation, modelling, zero energy buildings, and thermal comfort, helping to solve the energy crisis to large extent. India's projected population of 1.4 billion by 2026 further emphasizes the need for sustainable energy practices.

3. Results and Discussions

All the literature referred were pointing towards the requirement to practice green building strategy to improve environment conditions in Bengaluru. It emphasize on increase in green house effect, resource depletion, environmental degradation day by day in our planet. Earth is badly in need of sustainable development by reducing pollution, reducing dependence on natural resources, reducing Global Warming etc. Otherwise almost 200 years, there will be no life on Earth as predicted by Professor Stephen Hawking [22].

India being a developing country, it is quite advanced in this aspect and have a good rank when compared to all other countries. Government of many states in India provides incentives for such kind of constructions. Among the other production and manufacturing sectors, building and construction sectors occupies the first place as the largestcontributor to pollution and natural resource consumption. So, construction industry plays a crucial role in achieving sustainability goals by implementing green building practices and reducing its environmental impact.

Green Buildings

Green buildings, also known as sustainable or eco-friendly buildings, aim to reduce reliance on fossil fuels and minimize negative environmental impacts. Green building technologies and practices can contribute to improving the quality of life for residents and mitigating the environmental and economic challenges associated with rapid urbanization and resource depletion. Government support and increased awareness are essential for promoting sustainable construction practices in India [21]. India, with its rich historical buildings like Hawa Mahal, Gol Gumbaz, Taj Mahal, and Agra Fort, showcases the use of renewable sources and preservation of natural surroundings [20].

The Green Building movement in India has grown significantly since 2003. Green building, is an environmentally responsible and resource-efficient process that encompasses all stages of construction, from siting and design to operation, maintenance, renovation, and demolition. Various design standards and practices worldwide promote green building design. It requires collaboration among the design team, architects, engineers, and clients to achieve not only economic and functional goals but also consider the socio-environmental impact of buildings.

The Indian Green Building Council (IGBC) was established in 2001 under the Confederation of Indian Industry (CII) to promote sustainable built environments and aims to make India a global leader in this domain by 2025.Green buildings prioritize occupant health, safety, comfort, and productivity. They minimize negative environmental impacts and create positive ones by reducing or eliminating greenhouse gas emissions and using environmentally responsible processes and materials [20]

Criteria for green building certification

The Key area of focus in green building certification are;

1) Sustainable sites
2) Water efficiency
3) Energy and atmosphere
4) Material and resources
5) Indoor environmental quality.

Strategies for sustainable sites include,Implementing environmentally friendly transport plans, protecting natural habitats, controlling stormwater, reducing heat island effects, and utilizing renewable energy sources.

Non potable rain water can be safely used for lawn irrigation, toilet flushing and washing cars. In residential buildings, between 50% and 80% of water which falls into the grey water category can be collected for reused for other purpose. Green constructions ensure that water is harvested, used, purified, reused during entire construction period and also minimise water wastage and increasing recycling methods by installing mechanisms throughout the building life cycle.

Passive design strategies like shading and natural ventilation, along with energy-efficient lighting, appliances, and systems, contribute to energy savings. Selecting light colours for roofing and exterior painting helps to reflect heat from Sun as dark colour absorbs heat. Doors and window position and sizes should be designed such that it will allow air flow so that air conditioner is used as less as possible. Effective window placement can provide more natural light and lesser need for electric light during the day. Greenbuilding should also incorporate energy efficient lighting (e.g. LED lights), low energy appliances, high efficiency pumpsand filters. Properly maintaining buildingand associated systems will ensure optimal energy efficiency. Onsite generation of Renewable Energy through Solar power, Wind power, Hydro power can reduce the impact on resources.Substituting renewable energy for conventional energy can substantiallyreduce emissions of GHGs (Green House Gases) and other pollutants [22].

Green building materials and practices promote resource usage efficiency, waste reduction, and the principles of reduce, reuse, and recycle. Reduction in the amount of material going to landfills during the construction phase to be practiced. It generated during construction should be segregated based on its utility and should be sent for recycling. Onsite solutions such as compost bins are provided to reduce waste generated by the occupants going to landfills.

Use of regional materials are encouraged to support the use of indigenous resources, help the local economy, reduce the transportation impacts. Rapidlyrenewable materials that

mature in 10 years or shorter life cycle such as bamboo, wool, cotton insulation, linoleum,wheat board, straw board, cork etc, water efficient materials and durable materials are promoted.
Indoor environmental quality ensures comfort, productivity, and well-being through proper ventilation and air filtration. The materials used in the interior of buildings are also should be eco-friendly with zero VOCs (Volatile Organic Compounds).Other techniques are no smoking, fixing leaks, eliminate aerosols, pet cleaning, planting, car exhaust control etc [22].

Rating framework of green buildings in India
The green/suitable building rating systems followed in India are;

- **IGBC- green new building rating system - India** - regulated by the Indian Green Building Board (IGBC)
- **LEED India** - regulated by the Indian Green Building Board (IGBC**)**
- **GRIHA - Green Rating for Integrated Habitat Assessment** created by TERI (The Energy and Research Institute).
- **SVAGRIHA - Small Versatile Affordable Green Rating for Integrated Habitat Assessment** created by TERI (The Energy and Research Institute).

IGBC green new building rating system -India requires the application of National standards and codes such as the NBC, ECBC, MoEF guidelines, CPCB guidelines, and several others. GRIHA codes and rules have made approach utilized by the Bureau of Energy Efficiency, the Ministry of Non-Conventional Energy Sources, MoEF (Ministry of Environment and Forests), Government of India, also, the Bureau of Indian Standards their core value. GRIHA was created by TERI and has now been further embraced and put to usage by the Ministry of New and Renewable Energy (MoNRE) as the Indian National Rating System for Green Buildings. SVAGRIHA is a latest developed framework particularly for microscopic ventures for example structures with developed area under 2500 m2 [24].

Prominent green building features

- Electric charging provision for battery operated vehicles whereby reducing the pollution from automobile use.
- Sewage Treatment Plant (STP), Rain water harvesting & Storm water Management System for efficient water management.
- Water efficient faucets, fixtures, fittings and urinals minimising the water consumption.
- Water and Energy meters to monitor the consumption and conservation measures for possible savings
- Efficient lighting design for common areas meeting prescribed standards Solar Hot Water System for domestic use.
- Low Volatile Organic Compounds (VOC) adhesives, paints and sealants.
- Improved Indoor Air Quality to enhance the occupant comfort level.
- Maximum use of recycled materials, regionally or locally manufactured materials and reuse of salvaged materials minimising the usage of virgin materials.
- Technology driven analysis for Insulation, Day-lighting & Views from the building, Sun Path, Energy & Lighting and commissioning of all systems.
- Efficient landscaping with drought tolerant species ensuring minimum consumption of water, yet providing an ample green cover.
- HVAC and other equipment which do not use CFC or HCFC based refrigerants.

Certification process of IGBC rating system

1) Online project Registration in www.igbc.in
2) Project team submits Preliminary documentation
3) Review by IGBC 3rd party Assessors
4) Submission of Final documentation by Project team
5) Site visit by IGBC
6) Final review & award of rating
7) Acceptance of rating by Project
8) IGBC presents Plaque & Certificates indicating Certification level

4. Conclusion

Green building is a holistic approach to construction that prioritizes environmental responsibility, resource efficiency, occupant health, and sustainable development. It offers solutions to mitigate climate change, reduce energy consumption, conserve water, promote waste reduction and recycling, and create healthier and more productive spaces. Green buildings, certified by organizations like IGBC, can achieve energy savings of 40-50% and water savings of 20-30% compared to conventional buildings [25].

The Green Building movement in India has gained momentum, and various rating systems and organizations promote sustainable building practices. By adopting green technologies and design strategies, cities can enhance their sustainability and improve the quality of life for their residents. India has a significant potential for extensive construction of green buildings, but obstacles such as the lack of proper policies, incentives, aggressive action, and communication hinder their widespread adoption. Sustainable development, reducing pollution, and minimizing dependence on natural resources are crucial for addressing environmental degradation [27].

Balancing development with environmental protection aligns with the United Nations Sustainable Development Goals (SDGs). Key SDGs pertaining to the construction sector include sustainable cities and communities, clean water and sanitation, and affordable and clean energy [30].

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