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ROLE OF GREEN BUILDINGS IN THE SUSTAINABLE DEVELOPMENT OF TIER-II CITIES IN INDIA

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SUMMARY

Green building technologies (GBTs) have advanced significantly, as a result of the advantages to society, economy, and environment. It might lead to more environmentally friendly growth, considering climate change. The primary goal of GBTs is to utilize water, energy, and other resources sparingly in a balanced manner. Green buildings (GBs) have advantages in terms of reduced energy use and emissions, low operating and maintenance costs, improved productivity, and health. To determine the future course for sustainable green building technologies, a critical analysis of current residential projects in the field is mandatory. Conducting research that pertain to sustainable construction practices minimizing natural resources, are reasonably priced, are planned and built with the possibility of future growth. This article looks at how green building construction is going on, based on case study and offers suggestions for more research and development that will be required for residential projects leading to a sustainable future.

Key words: *sustainable cities, green Buildings, environmentally friendly, high-performance buildings, environmental protection.*

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INTRODUCTION

To lead a sustainable life is already a known fact and green buildings (GBs) play a leading role in fulfilling it. The GB idea would also enhance our lifestyle and environmental conditions by requiring that available resources be used sparingly and in a desired manner. Because GBs use less energy, water, and land, they help to maintain a healthy ecosystem. The Life Cycle Assessment (LCA), efficient site and structure design, efficient materials, improved indoor air quality, energy efficiency, water efficiency, and waste reduction are the seven primary components of green building, site to planning, building, running, upkeep, renovating, and dismantling. "Green building are the structures involving nature friendly construction processes, they are resource-efficient right through a building's life cycle, including site to design, construction, operation, maintenance, renewal, and deconstruction," states the Environmental Protection Agency (EPA). Such traditional buildings are designed by GBs with consideration for economy, usefulness, durability, and comfort. A "sustainable or high-performance building" is another term for a green building (GB). The configuration of GBs uplifts the lifestyle and reduces the environmental pollution by efficacious use of available resources, leading to improvement in health productivity. The consumption of renewable energy resources and technologies have provided GBs a sustainable option. [1] GB minimizes carbon footprints and detrimental gas emissions, promotes greater planting and greenery, recycles, and reuses sustainable materials, enhances occupant health, and is environmentally friendly. To get the most out of GBs, rating systems like Green Rated Integrated Habitat Assessment (GRIHA), Indian Green Building Council (IGBC) are always being improved and expanded upon. The ontogenesis of green buildings includes technical, managerial and behavioural skills. The burgeoning population and pollution level requires improvement in terms of educating and executing the GBs concept. The juxtaposition of GBs and conventional buildings ensures benefits like 20–30% water savings and 40–50% energy savings [2]. Even the indoor air quality is about 8% superior. It safeguards our ecosystem and biodiversity as well. Figure 1 illustrates the effects of GB.

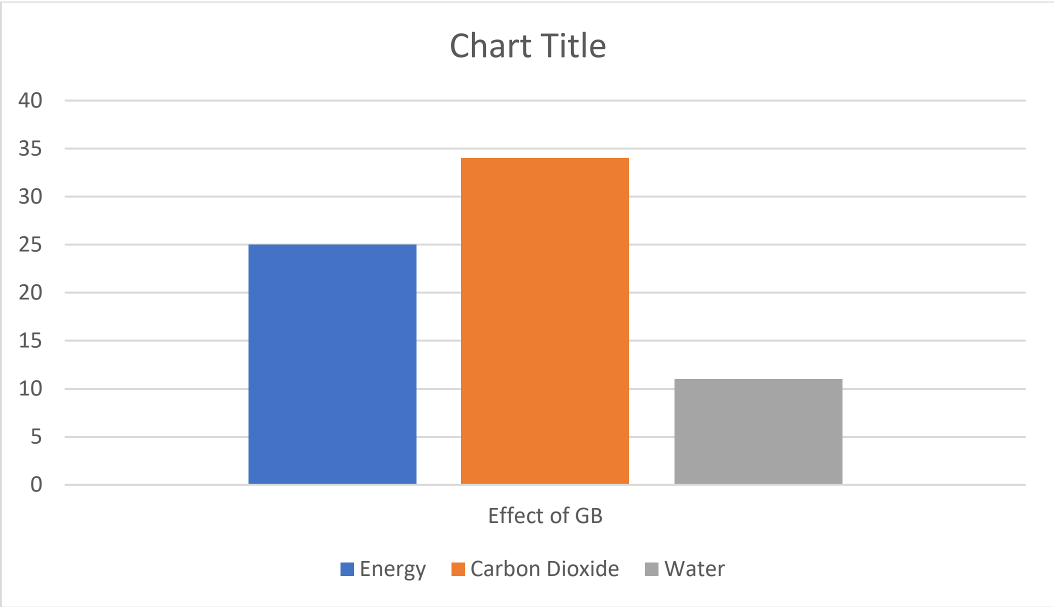

Figure 1. Effect of GB on various parameters and remaining 30% others.

LITERATURE REVIEW

Achieving sustainability through building energy efficiency helps minimize CO2 emissions and air pollution problems. The aid of solar energy for heating applications will attenuate the dismissive environmental effects correlated with the use of electricity [3]. The rapid ascent in required energy leading to higher per capita energy desolation involving factors like industrialization, urbanization, and social and cultural advancement. Study emphasized the connection between daily energy use and environmental fluctuations. The environmental parameters include CO_2, temperature, PM 2.5, and particulate matter (PM). This research can help lower energy needs in green technologies by proactively regulating environmental conditions [4].

A study on the effects of smart sensing networks for lighting, air conditioning, and ventilation was carried out. In this article, environmental system modelling was examined. In practical construction applications, it may regulate the energy and cost of a building's operation as well as the benefits of regulated ventilation and indoor air quality. Thus, intelligent integration with intelligent technology would save expenses and energy needs while simultaneously enhancing comfort levels faster. In a similar vein, carried out research on GB design, which is centred on the Internet of Things and 5G network and has energy efficiency as its primary influence. Next, seek to employ renewable technology to increase energy efficiency [5]. Four Colombian cities were the subjects of studies, which examined the ideas of sustainable building (SB) and energy efficiency (EE). To improve energy efficiency, numerous research has been carried out to examine HVAC (heating, ventilation, and air conditioning) systems. The study concluded that reducing the waste, reusing resources, and recycling had the biggest effects, followed by energy efficiency, water conservation, and humane adaptation. Energy generation is integrated into a building's operational performance using Building Integrated Photovoltaics (BIPV). [6] The BIPV concept can cover between 6 and 22% of the total power demand, suggested a time-of-use grid penalty cost model [8]. On the integration of artificial intelligence for the communication system in green hospitals in one study, IOT was used to manage the medical equipment so that it could be operated remotely and handled through the system. Thus, remote device monitoring and cloud applications were made possible with the aid of technological integration with green hospitals [9]. Investigated Net Zero Energy Buildings (NZEB) that were connected to the solar grid. The author suggested using a multi-objective approach and consumer-centric buildings to maintain net zero annual electricity use. For grid-tied PV-NZEB systems that generate electricity from renewable sources, NZEB achieves efficient load scheduling [7].

The major obstructions include cost, knowledge and involvement of stakeholders. Motivation, practice, attitude, values, and culture are other approaches. To overcome the barriers in developing sustainable development in Malaysia were studied. As was evident, the weather and human conduct had a greater influence on the first two components than the third [10] shows the attitude and actions of the industry with reference to GB practices, introduce Energy, the present work posits that overcoming the obstacles associated with meso- and micro-level research requires significant effort. To get beyond policy-level obstacles, they have proposed reforming general public subsidies, maintained native subsidy programs, and taken the building industry into account for the national Emission Trading Scheme, among other measures [11].

According to the Brundtland Report, "Our Common Future," sustainable development is "to maintain our economic, environmental, and social needs, allowing now and future generations too to use them." [12] discusses the performance of sustainable buildings that are made from industry waste and repurposed materials. According to research conducted safety concerns ranked as the most crucial factor considered when assessing the social sustainability of residential buildings. An attempt to conserve natural resources and lessen carbon emissions is made in the research article, which focuses on the efficient use of natural resources [13]. Recommendations for planting trees and developing green roofs to maintain the overall temperature and provisions for better air quality, conducted a study on the sustainability metrics for gauging GB manufactured in Malaysia [14]. The findings indicated that the most important factors in the Green Building Index (GBI) was Indoor Environmental Quality (IEQ), emphasize waste avoidance while building GB, and they provide several definitions for GB [15]. Waste minimization performance is compared between China and the US for LEED certification. The study also highlights the necessity of implementing a GB rating system at the conclusion assessed a range of options for converting the current residential structure into NZEB for various climatic circumstances. To do this, they considered three main factors: economic, energetic, and thermal comfort. TRNSYS and MOBO were employed to optimize the building. Additionally solar energy is incorporated into NZEB to achieve energy efficiency. Sustainable buildings reduce their carbon imprint on the environment by utilizing a range of energy-related strategies and practices. Environmentally friendly building materials in the NZEB reduces overall costs, minimizes environmental effect, and offers the opportunity to feed excess energy back into the grid [16].

Using both active and passive solar electricity is emphasized by NZEB. Solar energy is the most advantageous renewable energy source, and green buildings prioritize sustainability and green energy. This has been the subject of numerous studies, and study is still ongoing. They concluded that high efficiency and higher power production are largely dependent on the following factors: ambient temperature, shadowing impact, PV direction, and PV slope. Solar tube technology is the most significant building technology in Saudi Arabia [17]. GBs use a dual energy supply system. To meet the NZEB target for hybrid energy, high-rise buildings and warehouses have made use of solar and wind power.

The enhancement of GB development can be achieved by means of government efforts and private enterprises, states that incentives for green practices will come from appropriate government policies and long-term economic benefits. For instance, in the study conducted by [18], which examined the reasons behind the significant differences in the green transition between Singapore, a leader in the field, and Delhi, which is still in the early stages, government policies were found to be supportive of green practices in Singapore, but lacking in coherence and intensity, which only moderately supports green buildings (GBs) [19]. Similarly adopting changes in government policies and using different strategies would benefit GBs, stakeholders pursuing the reduction of carbon emissions. The Knowledge, Attitude, and Practice (KAP) levels in New Zealand were reinforced with practical consequences to support GB design requirements and certifications. Furthermore, in rapidly urbanizing nations like China, where urbanization is increasing quickly (47% in 2008 to 50% in 2012 and 74% in 2050), numerous obstacles must be overcome to achieve the goal. There are six main paradigms for GB adaptation [20]. These paradigms include drivers, barriers, risks, benefits, Critical Sources Factors (CSFs), and Planning and Development Authority (PDAs). It also looks at how adopting appropriate green retrofit policies can have a positive effect on the uptake of green retrofit technologies [21].

Indoor Quality and Occupant Health

Further studies were carried out to corelate rate of ventilation and health of the building occupants. The results demonstrated that low ventilation rates, feelings of poor air quality, and high CO_2 concentrations are associated with disease symptoms [22]. According to research studies, almost all the offices under investigation are not able to qualify the standards for a healthy indoor air quality. A survey conducted in 30 offices across 9 cities in India by the Green Business Certification Incorporated (GBCI) organization evaluated the offices based on their indoor environmental quality, daylight, excess to external landscape, thermal comfort, and soundscapes [23].

GB Model and Design

A building's choice of building materials is a crucial part of the construction process because it can impact the project's cost and quality. Similar research is being done on GBs to find less expensive, more sustainable materials that still meet today's comfort requirements. The usage of Green Mark (GM) as an assessment criterion for a genuine, actual building located in Singapore was emphasized [24]. This article used a hybrid model that included DAMP. Numerous studies conducted have revealed a lack of content and a study gap on design techniques, indicating that it is challenging to determine the energy staging evaluation of designs, such as building scale and size [25]. As a result, through this work, we create design methodologies that, when combined with Building Information Modelling (BIM) tools, facilitate the identification of energy staging during the early stages of a project and establish a correlation between energy performance and mass buildings. The floor height, window area ratio, long side to short side ratio, and envelope area ratio are the main variables used in this study [26]. These variables, when changed, demonstrated how design approaches affected performance. The climate where the net energy zero building is to be built will determine its viability. Therefore, it is important to handle this aspect carefully. As a result, this study also examines the 34 net energy zero buildings that exist worldwide, with a particular emphasis on their essential characteristics for hot, humid regions [27]. The study's conclusions demonstrate the widespread use of natural ventilation, daylighting technologies, and passive architecture. A smaller percentage of cases have an annual energy use of less than 100 kWh, and some even produce more energy than they need. The subject of this study is green office buildings, or GOBs [28].

The study examines the project's design, development and evaluates the two contractual strategies—the design-build and design-bid-build processes—to determine which is superior. Three distinct perspectives are used to assess the data from two case studies in Italy and two in Spain: time, cost, and sustainability level. Additionally, this article elucidates the beneficial correlation between process integration and advancements in GB design [29].

Conventional buildings and those with ratings of 1, 2, and 3 stars were chosen for a survey to assess the level of scent pleasure in the air. In contrast to conventional buildings, buildings scored three stars using the grey technique exhibit a good level of Odor [30]. Out of the three types of buildings, the three-star building type had the highest satisfaction level about fresh air. According to the overall analysis, three-star buildings are ranked highest, followed by one-star and regular structures in second place, and two-star buildings in bottom place. To reduce air and surface temperature, investigation was done on green facades employing canopy evapotranspiration and shading [31].

The findings indicate that moisture transmission in walls composed of insulated planks with connectors reduces the walls' thermic characteristics by 6–8%. The outcomes of this study can be integrated with an additional model to investigate low-carbon energy technologies in the Russian region concentrated on how environmental regulations affect building enterprises' choices about environmentally friendly techniques [32]. The best policies for the formation of a GB alliance will be taxes, subsidies, and carbon trading which were evaluated and gave a thorough explanation of Chinese policy for energy saving in GBs as well as information on policy development and efficacy. In the future, building typology will be a more crucial consideration when working on newly created structures to get the greatest design concepts [33]. In this research, causes of uncertainty related to the comfort criterion, and analysis methodology choices are examined. It concludes that residents of green rated buildings use 8% less energy. Green roofs can help cut down on greenhouse gas emissions. The elements influencing green roofs served as the basis for the investigation. To provide a future roadmap, they considered the plant factor for green roofs, as well as the needs for water, sunlight, and resistance to dryness and cold. The residential projects can be evaluated based on the guidelines of Green Rated Integrated Habitat Assessment (GRIHA) to make stakeholders aware about the present status and motivating them to overcome the shortcomings so as to achieve green star ratings [34].

METHODOLOGY

In the present study analysis of several residential projects of Tier-II cities in India has been done, as to promote green buildings and construction, it is necessary to enhance knowledge among the stakeholders. The residential projects have been evaluated based on the 34 criteria of Green Rated Integrated Habitat Assessment (GRIHA) which is a national agency for rating the projects. The present 5 projects which were studied were traditional and hence it has been evaluated that how close they were to achieve at least 1 star rating as per GRIHA.

Case Study from India

In the present research, case study of 5 residential projects of different locations in Bhopal and Indore were chosen to study their different construction phases and evaluate them on the basis of 34 criteria specified by GRIHA. This evaluation will determine the extent to which this project falls short of achieving a 1- to 5-star rating stipulated by GRIHA. Additionally, it will identify which mandatory or partially mandatory criteria are overlooked by conventional residential projects. The major aim is to find out the status of present residential projects of Tier-II cities and to improve their performance along with the shortcomings. The case study focuses on the selection of the first site Sagar Green Hills (SGH) project, situated on Kolar Road in Bhopal, featuring luxurious 3, 4, and 5 BHK flats equipped with modern amenities including rainwater harvesting, swimming pools, jogging tracks, a club house, Jain temple, and landscaped gardens. The second site selected is residential project Sage Golden Spring (SGS) which is located on Ayodhya Bypass Road, Bhopal and comprises of 3, 4 and 5 BHK Bungalows, 2 and 3 BHK luxurious flats. The third site selected is residential project Milestone which is in Hoshangabad comprising of 3, 4 and 5 BHK Bungalows 2 and 3 BHK luxurious flats. The fourth site selected is project Suncity which is in Katara Hills Bhopal comprising of 3 and 4 BHK Duplexes. The site Prime Square located in Balyakhedi Indore is residential project having luxurious flats shown in Figure 2-6.

Figure 2. Project I SGH

Figure 3. Project II SGS

Figure 4. Project III milestone

Figure 5. Project IV Suncity

Figure 6. Project V Prime Square (Indore)

The comparative analysis of marks gained by all the residential projects has been shown in form of Table 1.

Table 1. Marked gained by projects as per 34 criteria of GRIHA (Total 100 marks)

Details of Criteria			**P1 (SGH)**	**P2 (Milestone)**	**P3 (SGS)**	**P4 (Suncity)**	**P5 Prime Square**
	Clause	**Points**	**Achieved points**				
1. Selecting the site	Partly Mandatory	1	1	1	1	1	1
2. Landscape protection during construction/compensatory depository forestation.	Partly Mandatory	5	3	2	4	4	2
3. Conserving soil (post construction)	-	2	2	2	2	1	0
4. Designing while including existing site features	-	4	1	1	2	1	1
5. Reduction in hard pavements on site	Partly Mandatory	2	1	1	1	1	2
6. Uplifting external lighting system efficiency		3	1	1	1	1	0
7. Sustainable planning of utilities and optimizing on-site circulation efficiency		3	2	1	2	2	1
8. Providing basic sanitation/safety facilities to the construction workers	Mandatory	2	2	2	1	1	1
9. Minimizing air pollution while constructing	Mandatory	2	1	1	1	1	2
10. Reducing the water requirements of landscape		3	1	1	1	1	1
11. Minimizing the use of water in building		2	1	1	1	1	2
12. Utilizing water efficiently during construction		1	1	1	1	1	1
13. Designing building to reduce demand of non-renewable energy	Mandatory	8	3	3	3	3	2
14. Utilizing the building energy performance under specified limits of comfort	Partly Mandatory	16	4	4	4	4	2
15. Consumption of fly-ash in building structure		6	4	4	5	4	4
16. Ways of reducing construction time by utilizing technologies like pre-cast construction, RMC etc.)		4	1	1	2	1	2
17. Using material having lower energy in interior of buildings		4	2	3	2	2	2
18. Utilizing renewable energy in construction	Partly Mandatory	5	0	1	0	0	0
19. using hot- water system based on renewable energy		3	0	1	0	0	0
20. Arrangements of treating waste water		2	1	2	1	1	0
21. Recycling & reusing water (even rainwater)		5	2	3	1	0	0
22. Ways of minimizing construction waste		1	1	1	1	1	1
23. Segregating the construction waste		1	0	0	0	0	1
24. Storing and disposing construction wastes		1	1	1	1	1	1
25. Ways of recovering resources from waste		2	0	0	0	0	0
26. Using paints and products having low VOC		3	2	2	2	2	3
27. Minimizing substances causing ozone depletion	Mandatory	1	0	0	0	0	0
28. Ways of maintaining water quality	Mandatory	2	1	1	1	1	2
29. Maintaining noise in interior and exterior		2	0	0	0	0	0
30. Neglecting use of Tobacco and smoke	Mandatory	1	0	0	1	1	1
31. Providing accessibility for persons with disability		1	0	0	1	1	0
32. Conducting audit of energy, waste and water.	Mandatory	-	-	-	-	-	-
33. Protocols for Operating and maintaining electrical and mechanical equipment's	Mandatory	2	0	0	0	0	0
34. Adopting innovative methods (beyond 100)		4	0	0	0	0	0
TOTAL		104	39	42	43	38	35

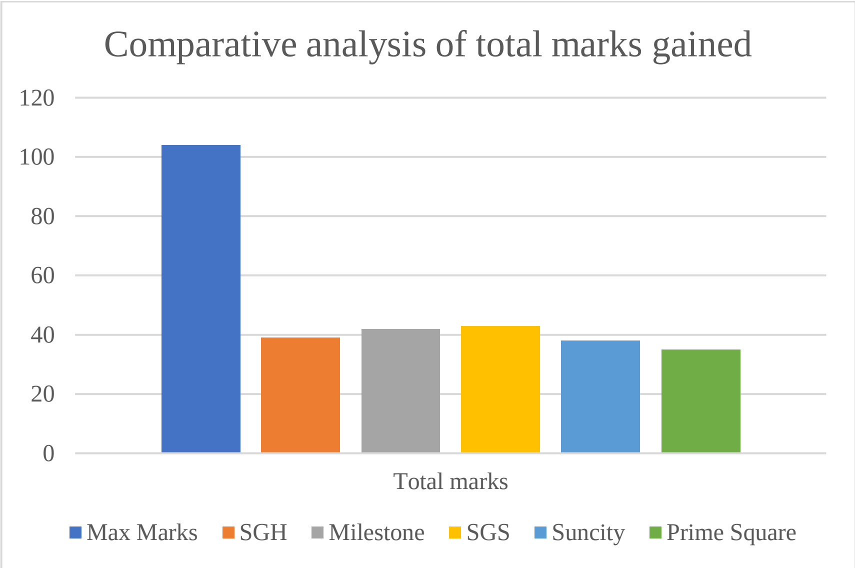

Figure 7. Marks gained by projects as per GRIHA guidelines

The specified rating system as per GRIHA has been shown below in Table 2 which clearly indicates that none of the traditional project is liable to be rated. Marks awarded to projects according to GRIHA guidelines shown in Figure 7.

Table 2. Evaluation system of GRIHA

S. No.	Points scored	Rating
1	50-60	One star
2	61-70	Two stars
3	71-80	Three stars
4	81-90	Four stars
5	91-100	Five stars

RESULTS AND CONCLUSION

In this study we have tried to identify the initiatives taken by the conventional residential projects of Bhopal and Indore which are Tier-II cities of India and evaluated their scores as per the guidelines of GRIHA. Following are the results obtained from the intensive evaluation of 5 residential projects. The shortcomings of the mandatory criterion have been discussed along with suitable suggestions to overcome them.

- In the residential projects, special provisions are not made by the developers for preventing air pollution. As per the mandatory criterion 9, for reducing air pollution on site, the wheels of the heavy vehicles entering and leaving the site must be cleaned. The loading and unloading of the construction materials shall be done after sprinkling water on site. This practice is not being followed by any of the projects.

- As per the mandatory criterion 13, for reducing conventional energy demand, the building surfaces which receives maximum exposure of Sun shall be shaded by external devices. Also, the orientation of buildings should be such that the total daylighted area is more than 25% of the total living area. This provision was not being followed.

- Marks under criterion 14 can be fetched by concerned projects if they follow the norms of Energy Conservation Building Code (ECBC) and National Building Code (NBC) Govt. of India.

- To achieve marks under criterion 18 and 20, renewable energy resources like solar panels can be installed over the buildings and a suitable water treatment plant can be installed for treating the generated waste water.

- As per the mandatory criterion 27, halon free fire suppressing arrangements can be provided in the multi storey buildings. Also, CFC free equipment's can be used for refrigeration and air conditioning. The selected projects were falling short of fulfilling this condition.

- As per the mandatory criterion 28, they shall ensure that whether groundwater or municipal water being used on site is as per the IS 10500. Also, the water quality details from various sources before and after treatment shall be notified. No such water quality testing reports were available on the selected projects.

- As per the mandatory criterion 30, they shall ensure prohibition for the use of tobacco and smoking. For educating all, proper sign boards for prohibiting smoking must be installed on the suitable locations which was missing on all project sites.

- As per the mandatory criterion 32, the builders and developers shall ensure Energy audit along with water and solid waste audit within 2 years of full occupancy. But audits were not conducted for the selected projects.

- As per the mandatory criterion 33, smart water meters shall be available at main supply points so that the building consumptions can be noticed and checked. This arrangement is initially costly but shall be adopted by all the projects.

- Under the Criterion 34, none of the projects have done innovative work in the project hence no marks have been scored.

DECLARATIONS

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Availability of Data and Materials - this manuscript does not report data generation or analysis.

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