Analyzing and Comparing Building Energy Rating Systems in Indian Context

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***Abstract*— This exploration paper aims to present a relative analysis of three prominent structure energy standing systems LEED, GRIHA, and IGBC in an Indian climatic environment. It'll estimate the strength, effectiveness, limitation to make a combined frame which will misbehave all the stylish practices from each standing system to achieve maximum effectiveness in Indian climatic condition. The crucial focus areas include energy effectiveness, water conservation, material selection, inner environmental quality, and rigidity to indigenous climatic conditions. The Primary ideal is to dissect lapping parameters and vital gaps to make a unified frame to the environment which will maximize sustainability while icing mortal comfort and health. Through literature study review and relative analysis. The study combines stylish strategies from each system. The performing frame offers a more effective and practical instrument India and will reduce the no. of instrument as this instrument will accompli all their morals and regulation which will make a long- term socio- profitable benefit for engineers, inventors and policy makers.**

Index Terms- GRIHA, LEED, IGBC, Energy Rating System, health rating system, sustainable construction, sustainable architecture

I. INTRODUCTION

India's Urbanization and new Energy demands requires and demands for sustainable building practices. To address these challenges, various green building rating systems have been developed to assess and enhance the environmental performance of buildings. There are three prominent energy rating systems which are recognized, practiced and recognized in India they are (LEED-India), (GRIHA) and (IGBC) rating system.

LEED-India, adapted from the U.S. Green Building Council's LEED system, emphasizes sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality. LEED has widely been used my multinational builders and corporation and in private sectors because it aims for global sustainability benchmarks In contrast, GRIHA, developed by The Energy and Resources Institute (TERI) and endorsed by the Ministry of New and Renewable Energy, is tailored to India's diverse climates and socio-economic conditions. It offers a framework focusing on energy and water efficiency, waste management, and occupant health and well-being.

The Confederation of Indian Industry created the IGBC rating system, which offers standards for a range of building types, such as commercial, industrial, and residential buildings. It addresses green features under categories such as site selection, water and energy efficiency, material conservation, and innovation.

Comparative analyses of these rating systems reveal differences in criteria weightage, certification processes, and applicability to various building types. For instance, while LEED-India is performance-oriented with a global perspective, GRIHA is more prescriptive, focusing on local contexts and affordability. IGBC, meanwhile, offers flexibility and is often preferred for its simplicity and industry-driven approach. The purpose of this study is to evaluate the efficacy, adaptability, and influence of the LEED-India, GRIHA, and IGBC rating systems in advancing sustainable building practices in India. Stakeholders can make well-informed decisions to create environmentally conscious and energy-efficient buildings by being aware of their advantages and disadvantages.

II. LITERATURE STUDY

A. GRIHA:(Green Rating for Integrated Habitat Assessment)

GRIHA, which stands for Green Rating for Integrated Habitat Assessment, is India's official framework aimed at promoting sustainable construction practices. Developed by TERI and approved by the MNRE in 2007, it was created to minimize the environmental impact of buildings throughout their construction and operational phases. Using sustainable materials, managing waste effectively, conserving water and energy, and improving occupant comfort these are the factors which are all priorities for GRIHA. it follows and aligns with national standards and regulation such as ECBC and NBC and also is tailored and made for to cater to India's diverse climatic conditions and regions. it gives a robust foundation for reducing carbon footprint and promoting energy anr resource efficiency in built environments aligning with global sustainability objectives.

1. Criterion

1.1. Sustainable Site Planning: This category highlights the significance of creating and organizing areas that align with the natural environment. The approach aims to protect biodiversity by integrating natural elements into the design and adhering to local regulations. To mitigate the Urban Heat Island Effect (UHIE), it encourages the use of greenery, reflective surfaces, and green roofing. (GRIHA, 2019)

1.2. Construction Management: This category seeks to conduct construction activities with minimal environmental impact. It encompasses a range of measures to control dust, noise, and water pollution at the site, and also involves effective management of construction waste. Additionally, topsoil is preserved in these guidelines to allow for its reuse in landscaping. To decrease the ecological footprint, the utilization of treated water is also regulated during construction activities. (GRIHA, 2019)

1.3. Energy Optimization- The criteria focuses on use of lower energy through parameters such as improved building insulation, efficient appliances, and design approaches that enhance natural light and airflow the goal is to ultimately reduce the reliance on fossil fuels and also to promote use of renewable energy such as solar panels To promote climate-friendly design, materials and substances with low environmental impact, including those free from ozone-depleting chemicals, are selected.

1.4. Occupant comfort- Buildings should cater to the needs of their occupants, in addition to being eco-friendly. This aspect concentrates on creating spaces that are both comfortable and healthy. Ample natural lighting, paired with effective artificial lighting, enhances productivity and well-being. Good thermal insulation and soundproofing create a pleasant environment for living or working, while maintaining excellent indoor air quality through proper ventilation and low-emission materials safeguards health. (GRIHA, 2019)

1.5. Water Management- This category ensures the use of water which is to use a conservative and efficient manner. It suggests use of low flow fixtures which reduces consumption and promotes practices like water recycling through effective treatment systems. Water harvesting for Irrigation purposes non-potable use reduces the burden on ground water level and use of water which is provided from municipal corporation The emphasis on delivering clean and safe water emphasizes the value of both conservation and quality in sustainable water policies. (GRIHA, 2019)

1.6. Solid Waste Management- For promotion of a sustainable lifestyle, it requires efficient and effective trash management to ensure it this criterion promotes use of recycling where it is possible separation of garbage at the initial or source level and turning organic waste into energy or compost. To reduce the impact on environment it can be done by encouraging waste-to-resource technology and reducing dependency on landfills. For long term sustainability, post construction projects are encouraged implement waste management systems that are mandatory for the occupants to follow. (GRIHA, 2019)

1.7. *Sustainable Building materials*-The selected approach significantly influences the environmental consequences of the project. It encourages the adoption of sustainable alternatives and practices, including the use of recycled materials or materials with low embodied energy. Options such as fly ash bricks and bamboo are favored instead of those that require more resources. The choice of materials is crucial as it considers life cycle assessment to analyze their long-term consequences. The aim is to decrease dependence on non-renewable resources. (GRIHA, 2019)

1.8. *Life Cycle Costing*- Another aspect of sustainability is the assessment of long-term financial consequences. In addition to the upfront construction expenses, life cycle costing involves examining the costs associated with building maintenance and operation. adoption of this method makes sure that the decision which are made ring the design phase, like incorporating energy-efficient technologies, are anticipated to result in savings throughout the building's life. This creates an overall positive picture for both the parties the developer and residents by incorporating both environmental responsibility with financial feasibility.

1.9. *Socio-Economic* Strategies-Sustainability is more than just environmental issues; it also involves human aspects. The main goal is to create a positive social impact by ensuring construction workers have safe working conditions and access to vital resources such as clean drinking water and basic sanitation facilities. It promotes accessibility for individuals with disabilities through the implementation of universal design principles, fostering a more inclusive and environmentally conscious space. Furthermore, it safeguards the welfare of service workers and the interests of stakeholders. (GRIHA, 2019)

1.10. *Performance Metering and Monitoring*- This parameter ensures proper oversight of systems to guarantee that buildings operate as intended. It monitors the ongoing observation of energy as well as water usage which is also supported by smart meters that improve efficiency . Procedure ensures that all systems function and works properly such as lighting and HVAC. Proper long-term maintenance is practiced for achieving long term sustainability goals for the building. (GRIHA, 2019)

1.11. *Innovation*- This category encompasses innovative ideas, solutions, and technologies that are distinctive and exceed existing standards and regulations. Some examples of these technologies include net positive energy systems, advanced water recycling methods, and real-time air quality monitoring tools. These innovations reflect creativity and progress, encouraging stakeholders to adopt unique strategies that improve resource efficiency, occupant health, and environmental outcomes. Such innovations and initiatives motivate stakeholders to implement pioneering green practices while demonstrating that these technologies can be applied effectively in real-world situations and scaled according to specific needs. (GRIHA, 2019)

This is a Table showcasing all Section and Criterion:

Manual Volume	Section	Criterion No.	Criterion Name	Maximum Points	Appraisal Type
I.	Introduction, Process, Criteria (Intent, Appraisal, Compliance)				
II.	1. Sustainable Site Planning	1	Green Infrastructure	5	Partly Mandatory
		2	Low Impact Design Strategies	5	Optional
		3	Design to Mitigate UHIE	2	Optional
	2. Construction Management	4	Air and Soil Pollution Control	1	Partly Mandatory
		5	Topsoil Preservation	1	Optional
		6	Construction Management Practices	2	Partly Mandatory
	3. Energy Optimization	7	Energy Optimization	12	Partly Mandatory
		8	Renewable Energy Utilization	5	Partly Mandatory
IV.	5. Water Management	13	Water Demand Reduction	4	Partly Mandatory
		14	Wastewater Treatment	2	Optional
		15	Rainwater Management	5	Optional
		16	Water Quality and Self-Sufficiency	5	Partly Mandatory
	6. Solid Waste Management	17	Waste Management – Post Occupancy	4	Partly Mandatory
		18	Organic Waste Treatment	2	Optional
V.	7. Sustainable Building Materials	19	Utilization of Alternative Materials in Building	5	Optional
		20	Reduction in Global Warming Potential through Life Cycle Assessment	5	Optional
		21	Alternative Materials for External Site Development	2	Optional
	8. Life Cycle Costing	22	Life Cycle Cost Analysis	5	Optional
VI.	9. Socio-Economic Strategies	23	Safety and Sanitation for Construction Workers	1	Partly Mandatory
		24	Universal Accessibility	2	Optional
		25	Dedicated Facilities for Service Staff	2	Optional
		26	Positive Social Impact	3	Partly Mandatory
	10. Performance Metering and Monitoring	27	Project Commissioning	0	Mandatory
		28	Smart Metering and Monitoring	7	Partly Mandatory
		29	Operation and Maintenance Protocol	0	Mandatory
			Total Points	**100**	
	11. Innovation	30	Innovation	5	Optional

This chart depicts the distribution of criteria in terms of percentage-

2. Rating System

GRIHA has a 100-point percentile-based rating system. On the submission of the required documents and upon final assessment and evaluation, the project is awarded/denied points for all the applicable appraisals. Total applicable points become the denominator while points which are not applicable (as confirmed through documentation assessment) to the project are deducted from both denominator and numerator. Points awarded represent the numerator. Points awarded under the innovation section are added only in the numerator which make them the bonus points. (GRIHA, 2019)

Percentile Threshold	Achievable Star Rating
25–40	□
41–55	□□
56–70	□□□
71–85	□□□□
86 and more	□□□□□

3. Rating Process

Structures in this stage of design are authorized for certification under the GRIHA rating system. Industrial buildings that are used as manufacturing units and warehouses are excluded from the rating system; however, office buildings in the industrial complexes, which are essentially habitable spaces, are eligible for certification. (GRIHA, 2019).

B. IGBC (Green New Buildings Rating System) Introduction

The IGBC Green New Buildings Rating System, established by the Indian Green Building Council (IGBC) and founded by the Confederation of Indian Industry (CII), aims to promote and address environmentally responsible building and construction methods. It has transformed the construction industry by advocating for eco-friendly and sustainable solutions, contributing to the development and certification of millions of square meters of green spaces. This framework, which encompasses all aspects such as energy efficiency, waste management, and water conservation, has enhanced both economic and environmental performance by assisting builders and designers.

1. IGBC Criteria's

(IGBC Green New Buildings Rating System, 2016)

IGBC Green New Buildings Rating System Checklist		Points Available	
		Owner-occupied Buildings	Tenant-occupied Buildings
Modules		**100**	**100**
Sustainable Architecture and Design		**5**	**5**
SA Credit 1	Integrated Design Approach	1	1
SA Credit 2	Site Preservation	2	2
SA Credit 3	Passive Architecture	2	2
Site Selection and Planning		**14**	**14**
SSP Mandatory Requirement 1	Local Building Regulations	Required	Required
SSP Mandatory Requirement 2	Soil Erosion Control	Required	Required
SSP Credit 1	Basic Amenities	1	1
SSP Credit 2	Proximity to Public Transport	1	1
SSP Credit 3	Low-emitting Vehicles	1	1
SSP Credit 4	Natural Topography or Vegetation	2	2
SSP Credit 5	Preservation or Transplantation of Trees	1	1
SSP Credit 6	Heat Island Reduction, Non-roof	2	2
SSP Credit 7	Heat Island Reduction, Roof	2	2
SSP Credit 8	Outdoor Light Pollution Reduction	1	1
SSP Credit 9	Universal Design	1	1
SSP Credit 10	Basic Facilities for Construction Workforce	1	1
SSP Credit 11	Green Building Guidelines	1	1
Water Conservation		**18**	**19**
WC Mandatory Requirement 1	Rainwater Harvesting, Roof & Non-roof	Required	Required
WC Mandatory Requirement 2	Water Efficient Plumbing Fixtures	Required	Required
WC Credit 1	Landscape Design	2	2
WC Credit 2	Management of Irrigation Systems	1	1
WC Credit 3	Rainwater Harvesting, Roof & Non-roof	4	4
WC Credit 4	Water Efficient Plumbing Fixtures	5	5
WC Credit 5	Wastewater Treatment and Reuse	5	5
WC Credit 6	Water Metering	1	2

(IGBC Green New Buildings Rating System, 2016)

Modules		Points Available	
		Owner-occupied Buildings	Tenant-occupied Buildings
Energy Efficiency		**28**	**30**
EE Mandatory Requirement 1	Ozone Depleting Substances	Required	Required
EE Mandatory Requirement 2	Minimum Energy Efficiency	Required	Required
EE Mandatory Requirement 3	Commissioning Plan for Building Equipment & Systems	Required	Required
EE Credit 1	Eco-friendly Refrigerants	1	1
EE Credit 2	Enhanced Energy Efficiency	15	15
EE Credit 3	On-site Renewable Energy	6	8
EE Credit 4	Off-site Renewable Energy	2	2
EE Credit 5	Commissioning, Post-installation of Equipment & Systems	2	2
EE Credit 6	Energy Metering and Management	2	2
Building Materials and Resources		**16**	**16**
BMR Mandatory Requirement 1	Segregation of Waste, Post-occupancy	Required	Required
BMR Credit 1	Sustainable Building Materials	8	8
BMR Credit 2	Organic Waste Management, Post-occupancy	2	2
BMR Credit 3	Handling of Waste Materials, During Construction	1	1
BMR Credit 4	Use of Certified Green Building Materials, Products & Equipment	5	5
Indoor Environmental Quality		**12**	**9**
IEQ Mandatory Requirement 1	Minimum Fresh Air Ventilation	Required	Required
IEQ Mandatory Requirement 2	Tobacco Smoke Control	Required	Required
IEQ Credit 1	CO_2 Monitoring	1	1
IEQ Credit 2	Daylighting	2	2
IEQ Credit 3	Outdoor Views	1	1

(IGBC Green New Buildings Rating System, 2016)

Modules		Points Available	
		Owner-occupied Buildings	Tenant-occupied Buildings
IEQ Credit 4	Minimise Indoor and Outdoor Pollutants	1	1
IEQ Credit 5	Low-emitting Materials	3	3
IEQ Credit 6	Occupant Well-being Facilities	1	-
IEQ Credit 7	Indoor Air Quality Testing, After Construction and Before Occupancy	2	-
IEQ Credit 8	Indoor Air Quality Management, During Construction	1	1
Innovation and Development		**7**	**7**
ID Credit 1	Innovation in Design Process	4	4
ID Credit 2	Optimisation in Structural Design	1	1
ID Credit 3	Waste Water Reuse, During Construction	1	1
ID Credit 4	IGBC Accredited Professional	1	1

2. Rating System-

Certification Level	Owner-occupied Buildings	Tenant-occupied Buildings	Recognition
Certified	40 - 49	40 - 49	Best Practices
Silver	50 - 59	50 - 59	Outstanding Performance
Gold	60 - 74	60 - 74	National Excellence
Platinum	75 -100	75 - 100	Global Leadership

(IGBC Green New Buildings Rating System, 2016)

C. LEED (Leadership in energy and environment design)

1. Introduction

Leadership in energy and environment design that promotes sustainable building practices is recognized as global certification system developed by the U.S. Green building council (USGBC). LEED has developed a framework that can be used for designing, constructing, and operating buildings that prioritize energy efficiency, resource conservation, and occupant well-being. It aims at reducing environmental impact while enhancing the functionality and liveability of spaces by addressing key aspects such as site selection, water efficiency, energy performance, materials selection and indoor environmental quality. It encourages continuous improvement and innovation in sustainable design as it is adaptable to various building types and offers multiple certification levels.

2. LEED CRITERIA'S

Here are comprehensive charts for the Healthcare Building Typology organized by each credit category from LEED BD+C, detailing every credit along with its corresponding points. Note- The chart only mentions the credits for healthcare building typology and for BD+C.

2.1. Integrative Process (IP)

Credit	Points	Description
Integrative Project Planning	Required	Emphasizes early-stage interdisciplinary collaboration and health mission integration
Integrative Process	1	Encourages system synergies for energy, water, and resource conservation through pre-design analyses.

(LEED v4 for BUILDING DESIGN AND CONSTRUCTION, 2019)

2.2. Location & Transportation (LT)

Credit	Points Description	Description
Outdoor Water Use Reduction	Required	Reduces irrigation needs through efficient landscaping.
Indoor Water Use Reduction	Required	Lowers potable water use for indoor plumbing fixtures.
Building-Level Water Metering	Required	Tracks whole-building water usage for monitoring purposes.
Outdoor Water Use Reduction	2	Further reduces irrigation demands using drought-resistant plants or captured rainwater.
Cooling Tower Water Use	2	Enhances cooling tower efficiency and minimizes potable water use.
Water Metering	1	Sub-meters water systems to monitor and optimize use.

(LEED v4 for BUILDING DESIGN AND CONSTRUCTION, 2019)

Credit	Points	Description
LEED for Neighborhood Development	5-9	Encourages locating within certified sustainable neighborhoods.
Sensitive Land Protection	1	Avoids development on environmentally sensitive lands.
High-Priority Site	1-2	Promotes development in urban, brownfield, or high-priority areas.
Surrounding Density & Diverse Uses	1	Develops in dense areas or near diverse land uses to reduce vehicle miles traveled.
Access to Quality Transit	1-2	Ensures proximity to robust transit options to decrease reliance on cars.
Bicycle Facilities	1	Encourages bicycle use through storage, showers, and proximity to networks.
Reduced Parking Footprint	1	Reduces parking to decrease environmental impacts of parking lots.
Green Vehicles	1	Promotes low-emission vehicles through preferred parking and EV charging stations.

(LEED v4 for BUILDING DESIGN AND CONSTRUCTION, 2019)

2.3. Sustainable Sites (SS)

Credit	Points	Description
Construction Activity Pollution Prevention	Required	Mandates sedimentation and erosion control during construction.
Environmental Site Assessment	Required	Identifies and remediates contaminated sites.
Site Assessment	1	Surveys site conditions (topography, hydrology, vegetation, etc.) to guide design.
Protect or Restore Habitat	1	Preserves or restores greenfield areas or provides financial support for habitat restoration.
Open Space	1	Creates accessible outdoor spaces for recreation and biodiversity.
Rainwater Management	1–2	Manages onsite runoff for specified rainfall events.

(LEED v4 for BUILDING DESIGN AND CONSTRUCTION, 2019)

2.4. Energy & Atmosphere (EA)

Credit	Points	Description
Fundamental Commissioning	Required	Ensure design and construction meet energy-related requirements.
Minimum Energy Performance	Required	Achieves baseline energy efficiency through building systems
Building-Level Energy Metering	Required	Monitors energy use with metering systems.
Enhanced Commissioning	6	Optimizes energy system operations through advanced commissioning.
Optimize Energy Performance	18	Incentivizes significant reductions in energy use.
Demand Response	2	Promotes grid demand management through system flexibility.
Renewable Energy Production	3	Encourages onsite renewable energy installations.
Green Power and Carbon Offsets	2	Supports renewable energy certificates or carbon offset purchases.

(LEED v4 for BUILDING DESIGN AND CONSTRUCTION, 2019)

2.5. Materials & Resources (MR)

Credit	Points	Description
Storage & Collection of Recyclables	Required	Ensures access to recycling facilities for waste diversion.
Construction Waste Management Plan	Required	Manages construction waste for recycling and reduction.
Mercury Source Reduction	Required	Reduces use of mercury in lamps and medical equipment.
Life-Cycle Impact Reduction	5	Evaluates material choices for sustainability through life-cycle assessments.
Product Disclosure: Environmental Product Declarations	2	Promotes use of products with transparency in environmental impact.
Material Ingredients	2	Encourages use of materials with safer chemical compositions.
Design for Flexibility	1	Promotes adaptability in healthcare facilities to future needs.

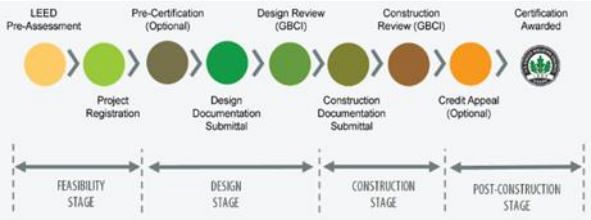
(LEED v4 for BUILDING DESIGN AND CONSTRUCTION, 2019)

2.6. Indoor Environmental Quality (EQ)

Credit	Points	Description
Minimum Indoor Air Quality	Required	Ensures basic air quality through ventilation and controls.
Environmental Tobacco Smoke Control	Required	Prohibits smoking to protect indoor air quality.
Enhanced Indoor Air Quality	2	Adds strategies for improved air quality.
Low-Emitting Materials	3	Uses products with low VOC emissions.
Construction IAQ Management Plan	1	Protects indoor air quality during construction
Indoor Air Quality Assessment	2	Tests air quality post-construction to ensure compliance.
Thermal Comfort	1	Enhances occupant comfort through improved temperature controls.
Daylighting and Views	1–2	Increases daylight access and connection to the outdoors.
Acoustic Performance	1	Optimizes spaces for reduced noise and better acoustics.

(LEED v4 for BUILDING DESIGN AND CONSTRUCTION, 2019)

3. Registration Process



(LEED v4 for BUILDING DESIGN AND CONSTRUCTION, 2019)

4. Rating System

Certification Level	Points Required	Performance Criteria
Certified	40–49	Basic achievement of sustainability measures across all credit categories.
Silver	50–59	Enhanced strategies for energy, water efficiency, and material optimization.
Gold	60–79	Significant improvements in energy performance, indoor environmental quality, and use of renewable energy.
Platinum	80+	Demonstrates leadership in sustainability with outstanding performance in all criteria.

(LEED v4 for BUILDING DESIGN AND CONSTRUCTION, 2019)

III. COMPARITIVE ANALYSIS

Sr. No.	Category	IGBC	LEED	GRIHA
1	Management / Sustainable Site / Site & Project Management / Site Aspect			
A	Site selection / Brownfield redevelopment / Reuse of land / Reclaimed land / contaminated land / sustainable construction	✓	✓	✓
B		✓	✓	✓
C		✓	✓	✓
D	Hard Landscaping / Boundary protection / Landscaping / Environmental mgmt. / Microclimatic control / Health & safety practices	✓	✓	✓
E	Responsible construction practices / Maintainability / Commissioning / Building Tuning / Operation & Maintenance	✓	✓	✓
2				
A		✓	✓	✓
B	Optimize energy performance / Cold storage / Lab systems / Natural ventilation / Energy features / HVAC / Equipment / Lighting	✓	✓	✓
C	Renewable energy / Green power / Renewable energy system	✓	✓	✓
3	WATER EFFICIENCY			
A	Water consumption / Water monitoring / Water meter / Water usage monitoring	✓	✓	✓
B	Water use reduction / Landscaping / Water efficiency in fittings, cooling, irrigation systems	✓	✓	✓
C	Innovative wastewater technologies / Stormwater mgmt. / Water recycling	✓	✓	✓
4	MATERIALS			
A	Building reuse / Façade reuse / Structural reuse	✗	✓	✗
B	Recycling / Resource reuse / Sustainable timber / Recycled content / Waste mgmt.	✓	✓	✓
C	Local or Regional Materials	✓	✓	✗

5	INDOOR ENVIRONMENTAL QUALITY / HEALTH & WELL-BEING			
A	IAQ performance / IAQ in wet areas / IAQ mgmt. in parking & public transport interchanges	✓	✓	✓
B	ETS control / Low-emitting materials / CO2 & VOC monitoring / Hazardous materials control	✓	✓	✓
C	Thermal comfort / Reduced heat island effect / RETV / Thermal insulation	✓	✓	✗
D	Ventilation rates / Naturally ventilated design / AC systems / Localized ventilation	✓	✓	✓
e	Daylighting & views / Electric lighting levels / Interior lighting	✓	✓	✓
f	Safety & Security	✓	✓	✓
6	TRANSPORTATION			
A	Public transport access / Commuting / Local transport	✓	✓	✓
B	Cyclist facilities	✓	✓	✓
C	Travel plan / Fuel efficiency / Green transport	✓	✓	✗
D	Car park minimization	✓	✓	✓
E	Pedestrian routes / Local transport	✓	✗	✓
F	Proximity to amenities	✓	✗	✗
7	POLLUTION			
a	Light pollution reduction	✓	✓	✓
b	Ozone protection / CFC reduction / Refrigerant GWP / CO2 emission reduction	✓	✓	✓
c	No emissions	✓	✗	✓

IV. CASE STUDY: A BENCHMARK FOR SUSTAINABLE ARCHITECTURE

1. INTRODUCTION:

The Crystal, which was initially constructed as the Siemens headquarters and is currently functioning as the City Hall of London, showcases an innovative method for sustainable design. This structure incorporates bioclimatic techniques and state-of-the-art technologies, establishing it as a standard for energy-efficient buildings.
The Crystal has achieved LEED Platinum and BREEAM Outstanding certifications, showcasing its outstanding environmental performance. LEED measures sustainability through energy and water efficiency, materials, and indoor environmental quality, while BREEAM focuses on innovation, resource management, and environmental effects.

These esteemed certifications emphasize The Crystal's position as a leader in integrating sustainability into urban development (Michael Osei Kwakye, 2023).

2. METHODOLOGY:

This study employs a case study approach to assess Crystal's sustainable strategies concerning its local climate. The main methods consist of:

- Literature Review: Grasping the concepts of sustainability and bioclimatic architecture.
- On-Site Observations: Gathering data on energy consumption, ventilation, and material effectiveness
- Digital simulations: Making use of modelling technologies to assess natural ventilation, thermal comfort, and energy economy.
- Physical Models: Building scaled prototypes to study the dynamics of heat and airflow in various settings.
- Critical Analysis: Assessing how well the building performs considering international sustainability norms.

3. CONTEXT: LOCAL CLIMATIC CONDITIONS:

Situated in London, Crystal is created to adapt to the city's temperate maritime climate marked by mild summers, cool winters, and regular precipitation. Important climatic factors include:

- Moderate Solar Radiation: Enhanced shading and daylighting systems guarantee thermal comfort while minimizing the need for artificial lighting.
- High Humidity and Rainfall: Rainwater harvesting systems reduce water waste and minimize dependence on outside water sources.
- Cool Temperatures: Efficient heating systems, geothermal energy, and proper insulation provide the necessary thermal comfort during the winter months.
- Variable Wind Speeds: The design incorporates cross-ventilation to improve indoor air quality and reduce the reliance on mechanical cooling.

4. DESIGN ASPECTS TO ENSURE SUSTAINABILITY

Crystal has several eco-friendly design elements that adhere to bioclimatic principles, including:

- Energy Systems: Make use of the steady temperatures of the Earth to effectively control heating and cooling. Help the facility achieve its net-zero energy goals by producing renewable energy on-site.
- Water Management: Gathers and repurposes rainwater for irrigation and sanitation purposes. Treats wastewater for non-potable uses, lowering environmental footprint.
- Ventilation And Thermal Comfort: Well-positioned openings enable cross-ventilation, lessening the reliance on air conditioning. Reduces heat transfer while allowing natural light to enter.
- Material Selection: Implement low-emissivity materials to enhance thermal and acoustic comfort. Use locally sourced and recyclable materials to limit embodied energy.
- The comparative evaluation reveals that GRIHA, LEED, and IGBC offer distinct advantages based on contextual adaptability, performance evaluation, and implementation simplicity.
- GRIHA aligns closely with Indian climatic zones and building codes, making it ideal for projects focused on passive design strategies, resource conservation, and socio-economic inclusivity.
- LEED focuses on performance-based assessment through commissioning, energy modeling, and real-time monitoring, enhancing post-occupancy operational efficiency.
- IGBC provides practical flexibility with simplified documentation and broad applicability, supporting ease of adoption in commercial and industrial developments.
- All three systems converge on core sustainability themes such as energy efficiency, water conservation, material optimization, waste management, and indoor environmental quality.
- There is a need for advancement in water metering, promoted by LEED and GRIHA, which will benefit post-occupancy performance validation and efficient building management.
- Sustainable material selection, including local sourcing, low-VOC products, and recyclable materials, plays a critical role in reducing embodied energy and enhancing indoor air quality.
- Passive design strategies, although central to GRIHA, are underutilized in other systems, representing a missed opportunity for climate-responsive architecture.
- GRIHA's inclusion of socio-economic criteria—such as worker welfare, accessibility, and health standards—extends the scope of sustainability beyond environmental factors.
- Life cycle costing, encouraged in GRIHA and supported in LEED, ensures long-term economic viability by balancing initial costs with operational savings.
- Credits in innovation of advance technologies and encouragement by increasing in credits for advancement will improve sustainable design practices
- There is a union of overlapping factors across rating framework which will collaborate a singular framework streamlining parameters and certification.

CONCLUSION

This research provides a detailed comparative evaluation of three major building energy rating systems—LEED, GRIHA, and IGBC—specifically in the Indian context. Each system is crucial in advancing sustainable development by focusing on key aspects such as energy efficiency, water conservation, material usage, indoor environmental quality, and responsiveness to climate. LEED is known for global recognition and where performance-based framework is needed. GRIHA is adapted and best suited for Indian standards and regional climatic condition and caters socio economic factors. Conversely, IGBC presents flexibility and simplicity, making it easily accessible for professionals in the industry. The conclusion indicates that GRIHA is suitable for local regional climatic condition and adaptability and inclusive growth, LEED is suited best for international recognition, innovation and international standards. IGBC takes a practical approach and serves as a practical option because of its widespread implementation. Integrated framework that combines the advantages of all three systems could significantly improve sustainability results in India's built environment, promoting environmental stewardship, economic viability, and human welfare.

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