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Developing a Sustainable Healthcare Facility: A Case Study of Satellite Centre of a Tertiary Care Hospital in Northern India

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Abstract
The concept of green building has gained global recognition over the years, with various voluntary building rating systems promoting its adoption. It is the practice of creating environmentally responsible and resource-efficient buildings right form siting a design, construction, maintenance, renovation, till its deconstruction. A study was conceived to analyze the measures opted to make one of the satellite centres' of a leading tertiary care hospital in Northern India environmentally sustainable and resource efficient using standards of Green Rating for Integrated Habitat Assessment (GRIHA-2017) and Energy Conservation Building Code (ECBC-2017). The project has area span of 25 acres; having 300 bedded hospital block, residential complex as well as outdoor facility. The outdoor-lighting system were installed with 90W LED fixtures having 100 lumen/Watt luminous efficacy and 100% automatic control. To reduce conventional energy usage hospital and residential complex were well-lit with windows having Window Wall Ratio (WWR) of 26.7. The project has usage of renewable energy more than 5% of the lighting demand than the proposed renewable energy usage of one percent of artificial lighting. The project was found to be fully compliant to all energy conservation criteria and thus, was ranked "outstanding" by GRIHA in the energy conservation category in year 2022. Therefore, to have a green hospital and a sustainable future, constant efforts are needed to be taken up with support and guidance provided by Government of India along with technical aid by agencies like GRIHA, ECBC and so on.

Keywords
Green building, Hospital, renewable, energy conservation, environment, efficiency

INTRODUCTION

Green building is the practice of creating structures that are environmentally responsible and resource-efficient throughout their life cycles, from siting to design, construction, operation, maintenance, renovation, and deconstruction [1]. Also known as sustainable or high-performance buildings, they aim to minimize environmental impact and preserve natural areas, habitats, and biodiversity [2]. Green design principles lead to reduced energy consumption, decreased air and water pollution, minimal water usage, limited waste generation, enhanced user productivity, and improved marketability.

The concept of green building has gained global recognition, with various voluntary building rating systems promoting its adoption. In India, the Green Rating for Integrated Habitat Assessment (GRIHA) was developed to suit the diverse climatic conditions and building types prevalent in the country [3]. GRIHA considers national building codes, energy conservation regulations, and local standards to evaluate the sustainability of structures. The Energy Conservation Building Code (ECBC) is another significant initiative promoting energy efficiency in commercial buildings, with different levels of standards aimed at reducing energy consumption [4].

Healthcare facilities, operating year-round, are major energy consumers due to heating, cooling, lighting, ventilation, and medical processes. Improving hospital design, maximizing natural light and ventilation, using

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energy-efficient appliances, and adopting renewable energy sources are crucial steps toward energy conservation in healthcare settings [5]. Well-designed hospitals not only enhance patient recovery but also positively impact healthcare staff.

METHODOLOGY

A healthcare project initiated in 2013 spans 25 acres and includes a 300-bed hospital block, indoor and residential facilities, guest house, and visitor hostel. The hospital block features an ICU, operating rooms, and ancillary services such as dietetics, manifold, pharmacy, central sterile supply department etc. To evaluate its compliance with green building principles, the project was assessed using the GRIHA rating system, which encompasses 34 criteria; including seven criteria related to energy conservation (Table-1).

Table 1: GRIHA Criteria

S.no	Criterion
1	Site Selection
2	Preserve and protect landscape during construction
3	Soil Conservation (Till post-Construction)
4	Design to include existing Site Features
5	Reduce hard paving on site/and or provide shaded hard paved surfaces
6	Enhance Outdoor-Lighting System Efficiency
7	Plan utilities efficiently and optimize On Site Circulation Efficiency
8	Sanitation/safety facilities for construction workers
9	Reduce air pollution during construction
10	Reduce landscape water requirement
11	Reduce the water use by the building
12	Efficient water use during construction
13	Optimize building design to reduce conventional energy demand
14	Optimize energy performance of building within specified comfort limits
15	Utilization of fly ash in building structure
16	Reduction in embodied energy of Construction materials
17	Use low energy material in interiors
18	Renewable energy utilization
19	Renewable Energy based Hot Water System
20	Waste water treatment
21	Water recycle and reuse (including rainwater)
22	Reduction in waste during construction
23	Efficient waste segregation
24	Storage and Disposal of Wastes
25	Resource recovery from waste
26	Use low -VOC paints/ adhesives/ sealants
27	Minimize ozone depleting substances
28	Ensure water quality
29	Acceptable outdoor and indoor noise level
30	Tobacco and smoke control
31	Provide at least the minimum level of accessibility for persons with disabilities
32	Energy audit and validation
33	Operation & Maintenance
34	Innovation

The steps followed in the assessment compliance were as:

1. Preliminary Assessment:

- Conduct an initial assessment of the hospital's energy consumption patterns, environmental impact, and current building design features.
- Identify areas for potential improvement in energy efficiency, waste management, water conservation, and indoor air quality.

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2. Energy Audit:

- Perform a comprehensive energy audit to evaluate the hospital's energy usage across various systems and operations.
- Analyze energy consumption data to identify opportunities for optimization and reduction of energy consumption.
- Prioritize energy-saving measures based on their potential impact and cost-effectiveness.

3. GRIHA Compliance Assessment:

- Review the Green Rating for Integrated Habitat Assessment (GRIHA) criteria to understand the requirements for achieving compliance.
- Evaluate the hospital's design, construction, and operation against GRIHA parameters related to site planning, water efficiency, energy conservation, material usage, and indoor environmental quality.
- Implement necessary modifications or improvements to ensure alignment with GRIHA standards.

4. ECBC Compliance Assessment:

- Review the Energy Conservation Building Code (ECBC) guidelines to determine the applicable energy performance standards for the hospital.
- Assess the hospital's energy systems, including HVAC, lighting, and equipment, to ensure compliance with ECBC requirements.
- Implement energy-efficient technologies and design strategies to meet or exceed ECBC standards, aiming for significant reductions in energy consumption.

5. Integration of Energy-Efficient Practices:

- Incorporate energy-efficient design principles into the hospital's architecture, such as passive solar design, natural lighting, and ventilation strategies.
- Install energy-efficient lighting fixtures, appliances, and HVAC systems to minimize energy use while maintaining comfort and safety standards.
- Implement renewable energy sources, such as solar panels or wind turbines, to offset energy consumption and reduce reliance on fossil fuels.

6. Monitoring and Continuous Improvement:

- Establish a system for ongoing monitoring and management of energy consumption and environmental performance.
- Regularly track energy usage data and compare it against established benchmarks to identify trends and areas for further improvement.
- Implement continuous improvement measures, such as staff training, operational adjustments, and technology upgrades, to optimize the hospital's sustainability performance over time.

RESULTS

The assessment for compliance was done by GRIHA team in collaboration with the team of hospital engineering wing of the institute. Although, the facility was conceptualized in year 2013, yet measures were opted to take required modifications to upgrade the facility to the standards of GRIHA-2017 and ECBC-2017 to make it more environment friendly and energy efficient. Complying with the standards and to enhance outdoor-lighting system efficiency 90W LED fixtures with luminous efficacy of more than 100 lumen per watt were installed having 100% automatic control. To reduce conventional energy usage the buildings in the project are made well-lit with windows installed, having Window Wall Ratio (WWR) calculated to be 26.78% (Table 2).

Table 2: Window to Wall Ratio (WWR)

Block name	**WWR (%)**
Hospital	30.97
OPD	35.55
Housing Type III	13.14
Housing Type IV	19.23
Housing Type V	13.46
Visitor’s block	32.96
Director’s Bungalow	18.53
Overall WWR of the project	26.78 %

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Double glazed glass unit were used for hospital and residential blocks having U-value of 1.8 and 5.5 W/sq.m K respectively for better thermal performance i.e. the capability of keeping valuable heat in. The glass for residential and hospital blocks complies with Solar Heat Gain Coefficient (SHGC) requirement as per ECBC, thereby limiting the fraction of solar heat admitted through windowpanes, both directly transmitted and absorbed and subsequently released inward. As per GRIHA criterion requirements, the day lighted areas were calculated to be 59.47% thereby making the facility eligible for three points under the criterion (Table-3).

Table 3: Day light Area Coverage

Block name	Percentage of day lit area
Hospital	49%
OPD	56%
Housing Type III	88%
Housing Type IV	94%
Housing Type V	93%
Visitor's block	100%
Director's Bungalow	100%
Total percentage of daylit area	59.47%

Further, to optimize energy performance within specified comfort limits various measures were opted viz. SHGC of fenestration 0.22 for hospital and OPD and 0.37 for residential areas, Variable Frequency Drive (VFD) system to regulate flow of air, insulation, and self-illuminating lights etc. thereby achieving 53.78% decrease in Energy performance index (EPI) from benchmarks of GRIHA. USG Boral Standard gypsum boards were used to promote the use of low energy material in interiors of the building. These boards have high level of durability to suit every kind of climatic conditions along with quick installation for extensive support. The project met the criteria of usage of renewable energy (in the form of solar power system) for more than 5% of the lighting demand than the proposed renewable energy system of 1% or more of artificial lighting (interior & exterior) (Table-4).

Table 4: Compliance to GRIHA Standards

S. no.	Criterion	Intent	Measures taken
NO. 6	Enhance Outdoor-Lighting System Efficiency	Luminous efficacy Automatic control	Outdoor lights installed in the hospital are having efficacy of more than 100lumen/w Automatic lighting control of all external lights
NO 13	Reduce the water use by the building	Reduction of water usage by 25% from base case	Using low flow fixtures to reduce water consumption
NO 14	Optimize building design to reduce conventional energy demand	1.Adoptive appropriate climate responsive building design with the limited wall/window ratio and/or SRR. 2.All the fenestration must meet the SHGC requirement of ECBC-2007. 3. Minimum of 25% of the living area should be day-lighted and adequate level of daylight is provided as prescribed by IS code 3. 50% of living areas to be day-lighted.	1.The buildings in the project are well lit with the windows provided. The window wall ratio of the blocks is 26.78 %. 2.The SHGC of the glass for residential and hospital and OPD blocks are directly meeting the SHGC requirement as per ECBC 3. total day-lighted area 59.47%
NO 17	Optimize energy performance of building within specified comfort limits	1.Compliance with Energy conservation building code-2007 2. Every 10% reduction in EPI upto 50%	The project has used the following parameters in the buildings to make it more efficient and thus, complying with ECBC: - SHGC of fenestration- 0.22 for hospital and OPD and 0.37 for residential. The buildings use VFD system to regulate the flow of air. Chiller details- Water cooled centrifugal type chiller Cooling capacity- 500 TR COP- 6.313 Recommended minimum COP as per ECBC 2007- 6.3 VFD controlled The insulation and ductwork are compliant to ECBC 2007 Condenser location is such that the heat exchange is free from any interference. The project has installed manual control switches for all artificial lighting. Self-illuminating exit signs have been installed in

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S. no.	Criterion	Intent	Measures taken
			the building. All the building artificial lights are LED with luminous efficacy more than 100 lmn/watt The exterior lights are controlled by automatic lighting control systems. Transformer details- Oil filled transformer of 2000 kVA capacity Energy efficiency level- 1 Losses at 50% and 100% load- 5.4 kW and 17 kW Maximum allowed losses as per ECBC 2007- 5.4 kW and 18.4 kW All motors installed are IE2 rated and thus, meet ECBC compliance. Electric meters are installed to monitor building level energy consumption and the readings are monitored by the maintenance team. The project has achieved an average of 53.79% reduction in EPI from the benchmarks of GRIHA.
NO	Use low energy material in interiors	Sub-assembly/internal partitions /paneling /false ceiling /in-built furniture Flooring Door windows	The project has installed false ceiling in the hospital and OPD block. The material used for the false ceiling are USG Boral Standard gypsum boards which are enlisted under GRIHA product catalogue. Furthermore, the buildings don't have paneling, in-built furniture, sub-assembly or internal partitions
NO	Renewable energy utilization	Rated capacity of proposed renewable energy system should be equal to or more than 1% of artificial lighting (interior & exterior) and space conditioning connected loads or its equivalent in the building	The project has proposed renewable energy in the form of solar power system of more than 5% of the lighting demand.
NO	Energy audit and validation		

It is worth mentioning that although the design of the building was conceived way back in the year 2013, still the measures to conserve energy are way ahead thus making it eligible for the category of best green hospital. As the project fulfils all parameters with 100% compliance in all major energy conservation criteria, and hence, was ranked outstanding by GRIHA in the energy conservation category in the year 2022. The institute was also awarded as best hospital in Energy Conservation Awards of 'Commercial Buildings' category by state Government agency in the year 2022.

DISCUSSION

This concept of 'Green construction and green buildings' have many benefits, both tangible and intangible, besides the obvious environmental ones. Since green buildings follow laid down principles of sustainability, the structures are more comfortable and raise the living standards of those using them. As the environment is more people-friendly and comfortable, people become more productive and effective when they work in such green structures, thereby adding to economic gains [6]. Worldwide, there have been wide range of green building initiatives, alongside multiple institutions addressing these climate change and sustainable development programs, all of which affect green building concept [6].

United Nations and many other country level organizations are working unanimously to focus on buildings energy and resource efficiency through developing codes, policies and practices, raising awareness and providing framework for financing. Incorporating resource and energy-efficiency into existing building codes can be used to set separate building performance levels and codes for existing infrastructure (walls, roofing, windows, doors), equipment and lighting, setting annual energy consumption levels and so on. Similarly, rapid construction of healthcare infrastructure has put a great burden on the local and indigenous building material supplies beyond their sustainable capacities so many countries are developing building codes for setting framework for safe and health promoting buildings. Their effectiveness varies based on compliance and enforcement structure [5]. The university of Carnegie has stated the relationship between improved indoor air quality and positive health impacts on illness, including asthma, flu, sick building syndrome, respiratory problems and headaches and improvement levels has been documented to be ranging from 13.5 to 87%. The Sambhavna Trust Clinic, Bhopal established in the year 1996 is a green structure, constructed from local materials, is low-cost and durable. It combines beauty with function while blending-in with the landscape and is passively cooled, day lit, harvests the rainwater and uses solar water heaters[7].

With the increasing awareness about the benefits of 'going green', several green building rating systems have been developed. Nowadays, different building rating systems are being used widely across the world, wherein

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most notable are; Leadership in Energy and Environmental Design or LEED (United States, Canada, China and India), Building Research Establishment Environmental Assessment Methods or BREEAM (UK and Netherlands), Green Star (Australia, New Zealand and South Africa), Comprehensive Assessment System for Building Environmental Efficiency or CASBEE (Japan) and Green Mark Scheme (Singapore) [8]. About 28 hospitals in the United States have Gold and Platinum LEED certifications [9]. In the Indian subcontinent, Green Rating Integrated Habitat Assessment (GRIHA), developed by TERI and the Ministry of New and Renewable Energy, and Leadership in Energy and Environment Design (LEED), operated by the Indian Green Building Council (IGBC) are used widely and has been adopted by the government central public works department. Kohinoor Hospital in Mumbai, a 150-bedded multispecialty hospital became the first hospital in Asia and second in the world to achieve LEED platinum certification under Indian Green Building Council [10]. Similarly, satellite centre was ranked outstanding by GRIHA in the energy conservation category in the year 2022 as it fulfilled all parameters with 100% compliance in all major energy conservation criteria.

CONCLUSIONS

This concept of green building has gained global recognition and healthcare facilities being one of the major energy consumers due to heating, cooling, lighting, ventilation, and medical processes can benefit significantly using the concept of green building and energy conservation. Better hospital design, improved natural light and ventilation usage, energy-efficient appliances, and adopting renewable energy sources are crucial steps toward to meet the objectives. Therefore, to have a green hospital and a sustainable future, constant efforts are needed to be taken up with support and guidance provided of Government of India along with technical aid by agencies viz. GRIHA, ECBC and so on.

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