



Comparing Residential Buildings at IIT Kanpur using GRIHA Ratings

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Abstract: India's construction sector has witnessed significant growth in recent decades, with building sector becoming one of the largest contributors to energy consumption and greenhouse gas emissions. This rapid growth has significant environmental impacts highlighting the urgent need for adopting sustainable building practices. Rating systems such as GRIHA provide a systematic framework to assess building performance and identify opportunities for enhancing environmental performance. This paper focuses on assessing the sustainability ratings of the Faculty Apartment, a residential building comprising four blocks [A, B, C and D] at IIT Kanpur, using GRIHA Guidelines. The methodology involved on-site visits, a discussion with the Senior Assistant Engineer [Civil] IWD, IIT Kanpur, and surveys of ten residents of the apartment to gather the current performance data. Based on these insights, retrofitting strategies were proposed to enhance energy efficiency, reduce operational costs, and minimize environmental impacts. The findings show that initial ratings for Block A and B were 36.5% [1 GRIHA star] and for Block C and D were 47% [2 GRIHA star]. After suggested retrofitting, the ratings will improve significantly, with Blocks A and B reaching 63.5% and Block C and D 68% [3 GRIHA stars for all blocks], respectively. A direct comparison of sustainability scores before and after retrofitting highlights the improvements, demonstrating how such interventions can strengthen green ratings while promoting environmental sustainability. The study emphasizes that retrofitting reduces costs and environmental impacts while supporting IIT Kanpur's goal of achieving net-zero carbon emissions by 2030 and aligning with India's broader 2070 net-zero commitment.

Keywords: Green Buildings; Sustainable Design; Resource Conservation; GRIHA.

1 Introduction

India's construction and urban development sectors are experiencing remarkable growth, driven by population expansion, economic progress, and rapid urban migration. While this growth is essential to meet the rising demands for infrastructure and housing, it also places immense pressure on critical natural resources such as energy, water, land, and raw materials.

The building sector is one of the largest energy consumers, contributing significantly to greenhouse gas emissions both during construction [embodied carbon] and operation [lighting, HVAC, appliances]. It accounts for approximately 37% of the country's total annual primary energy [1]; one-fifth of total CO₂ emissions and consumes around 33% of national electricity [2]; In 2021, India's total emissions reached around 3.4 GtCO₂e excluding LULUCF [AR6, 2024]. Our building materials sector is highly resource- and energy-intensive, consuming 60 Mt of cement and 14 Mt of steel in 2020, with steel demand projected to rise from 111 Mt to 489 Mt, brick production to 750 billion–1 trillion/year, and cement output to 1,000–2,000 Mt by 2050, driving significant CO₂ emissions [3].

These numbers highlight the urgent need to adopt sustainable and environmentally responsible building practices that minimize the ecological footprint of construction while enhancing climate resilience and human well-being. The integration of green building strategies presents a practical solution, enabling the creation of infrastructure that is both functional and environmentally sustainable. Green buildings, also known as sustainable or high-performance buildings, involve the design, construction, and operation of structures in ways that are environmentally responsible and resource-efficient throughout their entire life cycle.

Green buildings offer a wide range of environmental, economic, and social benefits. Environmentally, they conserve natural resources, improve air and water quality, and reduce waste and pollution. Economically, they lower operational costs through improved efficiency, promote sustainable materials, and enhance long-term value. Socially, they improve occupant health, comfort, and productivity, while easing the burden on local infrastructure and contributing to a higher quality of life. These benefits underscore the importance of integrating green practices into both new developments and retrofitting existing structures.

To promote such practices, the Government of India and related agencies have introduced frameworks like the Green Rating for Integrated Habitat Assessment [GRIHA] and the Energy Conservation Building Code [ECBC]. GRIHA, developed by The Energy and Resources Institute [TERI] and endorsed by the Ministry of New and Renewable Energy [MNRE], provides a comprehensive rating system for assessing environmental performance, focusing on passive design, resource efficiency, and eco-friendly materials [4].

Similarly, the ECBC, formulated by the Bureau of Energy Efficiency [BEE], sets minimum energy performance standards for new commercial buildings and major retrofits [5]. Together, these frameworks establish benchmarks for energy efficiency, water conservation, material optimization, and environmental responsibility. By encouraging performance-based design, they aim to reduce the environmental impact

of the built environment and support the development of climate-resilient infrastructure.

Although several studies exist on topics such as the comparison of various green building rating systems or the assessment of commercial and institutional buildings in India using GRIHA and related frameworks, residential buildings, which constitute a significant part of the built environment have received comparatively less attention. Moreover, the existing studies usually evaluate single projects in isolation, without undertaking comparative analyses of different blocks or buildings within the same campus context.

This study involves a comparative assessment of different blocks of the Faculty Apartment at IIT Kanpur using GRIHA framework. This has two primary objectives: first, to compare the current sustainability ratings of the selected blocks and second, to propose retrofitting strategies for improving their environment performance. The buildings are re-evaluated under the GRIHA framework after applying retrofitting measures, enabling a direct comparison between the initial and post-retrofit ratings. This approach not only emphasizes the role of retrofitting in advancing sustainability but also underscores its wider benefits for residents and the environment.

2 Literature Review

2.1 Green Building Rating Systems

Globally, the movement toward sustainable construction has been shaped by various rating systems and performance standards aimed at minimizing the environmental footprint of buildings. Prominent among them is LEED, which stands for Leadership in Energy & Environmental Design and is developed by the U.S. Green Building Council [USGBC]. It addresses energy and water use, materials selection, waste management and indoor environmental quality through a set of credit categories. LEED is globally recognized as a symbol of sustainability and is supported by a community of people and organizations working to promote greener construction [6]. Another widely known framework is BREEAM [Building Research Establishment Environmental Assessment Method] from the UK. It provides a holistic sustainability assessment across multiple categories and validating this performance through third party certification [7]. While India has adopted its own indigenous frameworks like GRIHA, IGBC and ECBC.

IGBC- Indian Green Building Council is a part of Confederation of Indian Industry [CII]. It was formed in 2001 with a vision, "To enable a sustainable built environment for all and facilitate India to be one of the global leaders in the sustainable built environment by 2025" [8]. IGBC certification for residential societies offers several significant benefits including 20-30% reduction in energy cost, 30-50% reduction in water requirement and improved health & wellbeing of the occupants. The validity of

the IGBC Green Residential Societies rating is 3 years from the date of the issuance of the certificate [9].

The Energy Conservation Building Code [ECBC] sets minimum energy performance standards for commercial buildings. The ECBC includes energy performance standards for several critical building systems, with a focus on improving the overall energy efficiency of the building. Key systems addressed under ECBC include the Building Envelope, Heating, Ventilation, and Air Conditioning [HVAC], Lighting, Service Water Heating, and Electric Power and Distribution [10]. Among Indian rating systems, GRIHA provides a comprehensive framework for assessing building sustainability and is discussed in detail in the following section.

2.2 The GRIHA Framework

Green Rating for Integrated Habitat Assessment- GRIHA is India's national green building rating system, initiated by The Energy and Resources Institute [TERI] and supported by the Ministry of New and Renewable Energy [MNRE], Government of India. The system helps us to assess how environment friendly a building is by awarding points to various categories. The main goal is to reduce the use of resources, manage waste better, and encourage the use of renewable energy so that we can build more sustainable future.

GRIHA was designed specifically to evaluate non-air-conditioned and partially air-conditioned buildings. It is applicable to commercial, institutional, and residential projects in India, with a strong emphasis on national environmental priorities, regional climatic conditions, and the promotion of locally appropriate solutions. [11]. Projects with built up area more than 2,500 m² [excluding basements, parking areas and typical buildings] are eligible for certification under GRIHA Version 2019. The certification process begins with the eligibility check of the built-up area; next the project team registers the building with TERI and submits preliminary project details. During the design phase, sustainable features like energy efficiency, water conservation, and waste management are integrated into the building design. Once the design is finalized, TERI conducts a comprehensive assessment of the building based on the established GRIHA v.2019 criteria.

Finally, based on the assessment outcomes, the project is awarded a GRIHA rating ranging from 1 to 5 stars, indicating its level of sustainability [12].

Table 1: GRIHA rating Threshold

| GRIHA V 2019 Ratings Threshold | GRIHA Ratings |
|---|----------------------|
| 25-40 | 1 star |
| 41-55 | 2 stars |
| 56-70 | 3 stars |
| 71-85 | 4 stars |

[Data: <https://www.grihindia.org/>]

This study uses the GRIHA V 2019 Self-evaluation checklist for the assessment of the blocks of the Faculty Apartment. The checklist assigns points on various criteria including sustainable site planning, construction management, energy optimization, occupant comfort, water management, solid waste management, sustainable building materials, life cycle costing, socio economic strategies, performance metering and monitoring which sum up to 100. Additional 5 points are awarded for innovation [13]. The distribution of points across these criteria is presented below:

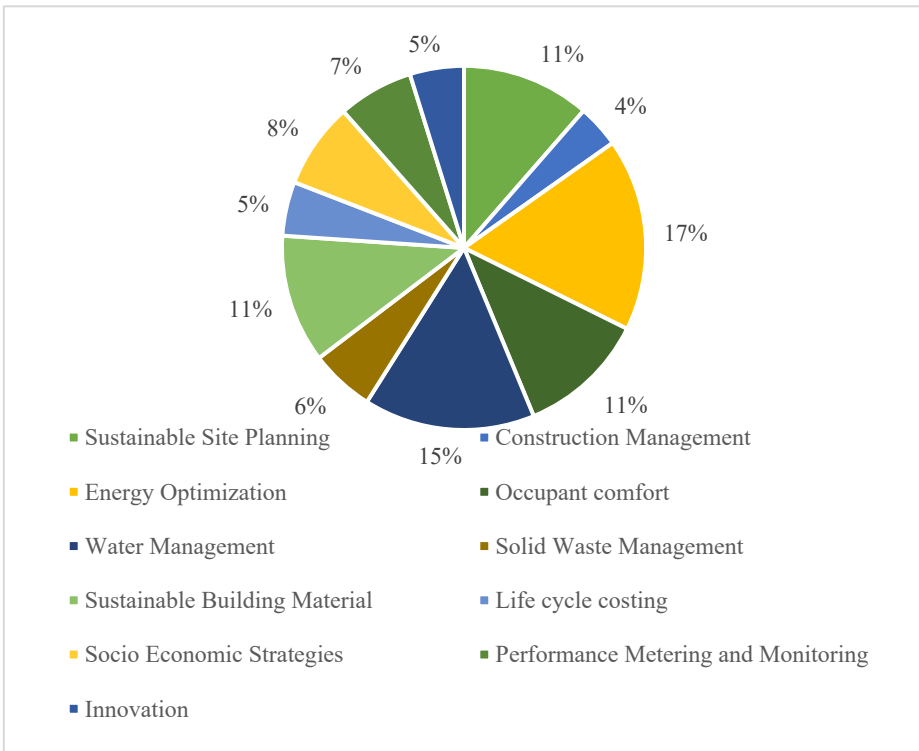


Fig.1.GRIHA Rating system

[Data: GRIHA V 2019 Self-evaluation checklist][13]

2.3 Green Buildings in Academic Campuses

The Academic campuses are increasingly recognized as an ideal setting for implementing and evaluating green building practices. These campuses offer a controlled environment where innovative technologies in energy efficiency, water conservation, and sustainable materials can be applied and monitored over time. To understand how these green building principles are applied in the real world, several

case studies of buildings within academic campuses have been reviewed. These examples show the range of sustainable strategies implemented and their outcomes.

Case Study 1: IIT Dharwad, is committed to achieving a net-zero campus in water, energy, and waste by 2030. It has earned a 5-star GRIHA rating for the Large Development Master Plan in 2022. IIT Dharwad can harvest 327 million liters of rainwater annually, exceeding its future demand of 248 million liters for a population of 10000. Water-saving fixtures enhance efficiency. Solar passive architecture, Effective insulation, strategic glazing, shading devices, and sustainable materials are used for minimizing energy consumption. A 1.25 MW rooftop solar PV system is proposed to meet annual energy needs. The institute manages waste through an on-site phytoremediation STP, source-level segregation using color-coded bins, and proposed biogas and composting systems. This case shows how GRIHA can effectively guide sustainable planning and development at the campus scale [14].

Case study 2: Centre for Environmental Science and Engineering, IIT Kanpur. It has GRIHA provisional rating of 5 star with a score of 93/100. The building integrates multiple green design strategies and is fully compliant with the Energy Conservation Building Code [ECBC]. Annual energy savings of ₹18.5 lakhs is estimated, the energy demand is managed through sun-path-based orientation, optimized openings with shading, insulated cavity walls, double glazing, and shaded roofs. Passive measures like Earth Air Tunnel and thermal storage further minimize cooling needs. Renewable energy sources, including solar PV panels, meet 30% of internal lighting demand, while solar systems supply hot water and outdoor lighting. Water-efficient fixtures have reduced the demand, and a dedicated STP ensures greywater is reuse for horticulture. The CESE building demonstrates how integrating sustainable practices can deliver long-term environmental benefit and cost savings on academic campuses [15].

Case study 3: Western Side Teaching Block Complex, NIT Karnataka, Surathkal. It has a GRIHA provisional rating of 4 Star. This project achieved a 60.93% reduction in energy consumption compared to GRIHA benchmarks, with an Energy Performance Index [EPI] of 15.81 kWh/m²/annum. A 30 kWp solar PV system is installed which generates 32,712 kWh annually, meeting nearly 59% of internal lighting demand. Water conservation measures reduced landscape water demand by 33.6% with the use of native species and sprinkler system, and building water demand by 50.6% using efficient fixtures. Sustainable building materials were prioritized with 30% replacement of cement with GGBS in structural concrete, PPC with 30% fly ash were used in plaster and mortar and low-energy flooring, ceiling, and paneling used. This case shows how integrating renewable energy, water efficiency, and eco-friendly materials can significantly reduce environmental impact while complying with GRIHA standards [GRIHA Case studies].

Case study 4: Sabarmati Hostel, IIT Madras have a GRIHA provisional rating of 4 star. This project achieved 80.1% reduction in energy use compared to GRIHA benchmarks, with an EPI of 19.9 kWh/m²/annum. A 360 kWp solar PV system is installed to supports

renewable energy generation. Sustainable site planning included pre-monsoon excavation, planting 100+ trees, and shading 50% of hardscape. Water demand was reduced by 61.4% with the help of efficient fixtures and a 4 MLD SBR-based STP. Waste is managed using multi coloured bins for each floor, and STP sludge is reused as landscape manure. Fly-ash bricks and low-energy finishes further lowers the embodied energy [GRIHA- Case study].

Case Study 5: H1-Type Residential Building, IIT Bombay, has a GRIHA provisional rating of 3 star. The building achieved 34.3% reduction in energy use compared to GRIHA benchmarks, with an EPI of 65.7 kWh/m²/year. A 11.34 kWp solar PV system is installed to supports renewable energy generation. Sustainable planning preserved topsoil, planted native trees, and maximized cross-ventilation. Water demand has been reduced by 68% in landscaping with drip irrigation and 54% in building use through efficient fixtures. Daylighting covers 49% of spaces, while timer-controlled exterior lighting adds efficiency. Sustainable Building materials were prioritized with the use of PPC with high fly ash content. It helped lowering embodied energy by 84.68%. Multi-colored bins and a designated collection area ensure proper segregation of dry and wet waste. This case reinforces GRIHA's role in enabling resource-efficient campus buildings [GRIHA Case study].

While these case studies demonstrate the effectiveness of the GRIHA framework in evaluating academic campuses and highlight their environmental benefits, but most of these assessments are limited to single buildings or large institutional projects. Comparative evaluations of multiple residential blocks within the same campus remain scarce. Moreover, the majority of studies emphasize on current performance ratings without exploring how buildings can be further improved through targeted interventions. To address this gap, the present study assesses the sustainability ratings of different residential blocks of the Faculty Apartments at IIT Kanpur and proposes retrofitting strategies aimed at enhancing their performance. The ratings are then re-evaluated post-retrofitting to demonstrate the potential improvements in environmental responsibility.

3 Methodology

3.1 Study Area

This study presents case study of Faculty Apartment building located on the IIT Kanpur campus. This residential building is primarily designed to accommodate faculty members and their families. It comprises four tower blocks: Block A, Block B, Block C and Block D. Block A and B were constructed in 2013 while Block C and D in 2015-16. Each block consists of six floors with each floor having four flats, totalling 24 flats in each block. Dedicated shaded stilt parking space is provided for each block. Each flat included three balconies to enhance the natural ventilation. The complex is surrounded by ample green cover.

Additionally, children's parks have been developed within the vicinity. The total plinth area of each block is around 12362.00 m², the super built-up area per flat being 257.55 m² and the area each flat occupies is 181.86 m².

3.2 Data Collection

Data for the assessment was collected through on-site visit to all four blocks of Faculty Apartment, IIT Kanpur. During these visits the key focus was to know about the presence of solar panels, naturally ventilated corridors, daylight integration in corridors and stairs, water consumption for landscape, presence of mature trees, species of trees replanted, building orientation and about any other sustainability practices adopted on site. Additionally, the ongoing renovation work provided an opportunity to observe the paints and adhesives used in the flats, offering additional information on the materials used in the building.

Additionally, informal interviews were conducted with ten residents to know about the current energy and water usage among them. The questionnaire primarily focuses on:

- The site planning and management practices adopted.
- Energy Efficiency- % of LED lighting system used, about renewable energy sources and appliances [BEE 3+ star], building envelop.
- Water Efficiency- about plumbing fixtures and flush system used, average water consumption in lpcd, water metering system, is wastewater reused.
- Waste Management Practices- waste being segregated and collected separately, collection of hazardous and E- waste.
- Natural ventilation and Indoor air quality.
- Awareness among residents and their perception on green buildings and sustainable development.

Moreover, discussions with Assistant Engineer [Civil], from the Institute Work Department [IWD], IIT Kanpur, provided insights into the materials used and construction practices adopted on site. He also mentioned that a rainwater harvesting system has been installed, and the rooftop pipes are connected to soak pits.

3.3 GRIHA Scoring Approach

The environmental performance of the Faculty Apartment blocks has been assessed using the GRIHA V 2019 self-evaluation checklist. This subsection explains the scoring approach adopted to evaluate the buildings against GRIHA criteria.

1. Sustainable site planning: Maximum points under this category are twelve and seven have been awarded initially considering no. the of mature trees present but mostly have been replanted. The average distance of more than 5 basic amenities from the main

entrance of the project is less than GRIHA base case including, health centre, school, grocery store, pharmacy shop park.

The low impact design strategies adopted include, Passive: - Improved ventilation by 3 balconies in each flat, open corridors and circular courtyard, Daylight have been integrated with providing adequate window to wall ratio; Active: - Energy efficient lighting system have been used, use of sewage treatment plant and rain water harvesting system.

2. Construction Management: 1.5 marks have been awarded out of 4 in this category as no significant measures were adopted to minimize the air and soil pollution during construction. But the topsoil is fertile mostly or it can be made fertile through organic means.

3. Energy optimization: Exterior lighting fixtures appear to be LED-based; however, detailed specifications confirming combined luminous efficacy ≥ 80 lm/W are not currently available. The survey depicts most of the houses uses 100% LED-based lights and BEE 3+ star rated appliances. Solar panels are not installed in block A and B, but in block C and D 80.08 kWp solar panels have been installed a renewable energy source. Smart Grid-Urban field pilot has been used in block C.

4. Occupant Comfort: Daylight autonomy requirement is met for regularly occupied area; acoustic comfort requirements are also met for all regularly occupied spaces in the building. Low VOC paints and adhesives have been used but there is no provision for continuous monitoring of the indoor air quality

5. Water Management: Residential GRIHA base case is 135 l/c/d, our calculation estimates around 150-170 l/c/d for the residents. It does not depict reduction from the GRIHA base case. Rainwater harvesting system have been implemented but segregation of greywater and black water is not present. The WPI calculated here is 1.365 KL/m² /year which is more than the GRIHA benchmark i.e. 1.35 kL/m² /year.

6. Solid Waste Management: I.I.T. Kanpur have tie ups with localized vendors for better waste management. Kitchen and Solid waste go to Agnys waste management, chemical waste to Ramky Environment Engineers Ltd., BHOOMI project for Bio composting of horticulture and Organic waste into manure.

7. Sustainable Building Materials and other parameters: PPC was used in the construction process which have around 25-35% fly ash content. For super structure PPC lowers the global warming potential [GWP] by 15-25%, Clay bricks increases the GWP, RCC structural frame neutral.

For the interior low VOC paints and adhesives have been used, reducing the GWP, LED lights reduce the GWP. For block A and B mosaic flooring have been used which increases the GWP and for block C and D tile flooring is used lowering GWP.

Dedicated resting rooms are not present for the service staff at the premises. The points allotted to each subcategory for each block have been presented in tabular format in the result and discussion section.

3.4 Comparative Analysis Approach

The comparative analysis was conducted to evaluate the environmental performance of the four Faculty Apartment blocks at IIT Kanpur. Blocks A and B, were constructed in 2013 with same materials and design. These are assigned same GRIHA ratings, while Blocks C and D, were built in 2015–16 with similar design and construction materials, these have received same ratings. Hence, the comparison focuses on two groups of blocks: [A and B] and [C and D]. Each group is assessed using total and category-wise GRIHA scores, including Energy, Water, Materials, Waste, and Indoor Environment, with the help of the observations from on-site visits, resident surveys, and discussions with the assistant engineer. Scores and observations are depicted in tabular format to show clear comparison between the two groups. This approach also informed the prioritization of retrofitting strategies for the most critical gaps. Actual scores and detailed results are presented in the Results section

3.5 Study Limitations

The study has certain limitations which should be noted. The survey data from the residents may be subjected to personal bias or inaccuracies. Observations made during the site visit were limited to accessible areas and the information obtained from the discussion with the assistant engineer, may not cover all aspects of building performance. Additionally, the analysis lacks long-term post-occupancy performance data, which could provide deeper insights into energy and water efficiency trends. The analysis. Certain assumptions were made during the GRIHA scoring process where complete information was not available. Future studies could integrate IoT-based metering and digital monitoring systems to enable real-time data collection and improve the accuracy of performance evaluation. Despite these constraints, the adopted methodology provides a reliable basis for comparative assessment.

4 Results and Findings

4.1 Initial GRIHA Ratings

In the above section, “3.3 GRIHA Rating Approach,” the scores for individual criteria have been calculated based on the existing conditions using the GRIHA Version 2019 Self-Evaluation Checklist. The assessment reflects the initial ratings of the Faculty Apartment complex at IIT Kanpur prior to retrofitting, providing a baseline for evaluating the building’s sustainability performance and identifying areas for improvement.

Table 2 presents the distribution of points across various GRIHA rating criteria for Block A & B and Block C & D. These represent the initial ratings before the implementation of any retrofitting measures.

Table 2: Initial GRIHA score distribution

| Parameters | Max Points | Block A and B [Points Awarded] | Block C and D [Points Awarded] |
|---|------------|--------------------------------|--------------------------------|
| 1. Sustainable Site Planning | 12 | 7 | 7 |
| 2. Construction Management | 4 | 1.5 | 1.5 |
| 3. Energy Optimization | 18 | 1 | 6 |
| 4. Occupant Comfort | 12 | 9.5 | 9.5 |
| 5. Water Management | 16 | 3.5 | 3.5 |
| 6. Solid Waste Management | 6 | 5 | 5 |
| 7. Sustainable Building Materials | 12 | 4 | 5.5 |
| 8. Life cycle costing and Socio-Economic Strategies | 13 | 4 | 5 |
| 9. Performance Metering and Monitoring | 7 | 1 | 4 |

[Data based on GRIHA V 2019 Self-evaluation checklist]

The initial ratings for block A and B were calculated by summing up the score of individual criteria, which comes out to be 36.5%, GRIHA provisional rating of 1 star. For block C and D, it comes to be 47%, with a GRIHA provisional rating of 2 star.

Table 3: Initial GRIHA ratings

| | | | |
|----------------------|-------|-------------|----|
| Block A and B | 36.5% | [25 – 40] % | ★ |
| Block C and D | 47% | [41 – 55] % | ★★ |

[Data based on GRIHA Rating Threshold]

4.2 Comparative Assessment of Blocks A & B and C & D

Blocks A & B and Blocks C & D were evaluated comparatively to understand how design and construction practices have influenced their sustainability performance. Block C & D achieved comparatively higher ratings [GRIHA provisional rating - 2 star] majorly due to better performance under criteria of Energy Optimization, Sustainable Building Materials and Performance Metering and Monitoring.

While no solar panels are installed on Blocks A & B, Blocks C & D are equipped with 80.08 kWp solar PV systems, which significantly improves their energy optimization score. Additionally, Smart Grid-Urban field pilot has been used in block C. Construction materials also contributed to score variation: mosaic flooring in Blocks A and B led to a higher Global Warming Potential [GWP], whereas tile flooring in Blocks C and D resulted in a comparatively lower GWP and improved sustainability performance.

Blocks A & B lagged behind in the categories, reflecting differences in construction timelines and the incorporation of improved sustainability measures in the later-built blocks.

4.3 Proposed Retrofitting Strategies

This part of the paper explains the retrofitting measures that are proposed to be adopted to improve the GRIHA rating and overall sustainability of the building.

1. Energy Efficiency Measures:

- i. Solar Panels: Installation of 80.08 kWp Solar panels in block A and B. Using PVWatts Calculator [NREL] with suitable input parameters for the location of faculty apartment, IIT Kanpur the estimated annual energy generation is approximately 120,120 kWh per year, taking the rate as Rs 8/ kWh, the annual saving of around INR 9.61 lakhs per block is predicted. Assuming the cost of installation as Rs 45,000 per kWp the payback period is calculated to be 3.75 years.

| Installation Cost | Savings | Payback Period |
|-------------------|---------------------|----------------|
| Rs. 36, 03,600 | Rs. 9,60,960 / year | 3.75 years |

- ii. Solar Water Heaters: Considering solar water being used for around 5 months a year, and each flat needs around 100 litre warm water per day. Taking energy required to heat 100 l water as 2.5 kWh. For 24 flats and 5 months it totals to 9000 kWh / year per block. Assuming the rate to be Rs. 8/kWh it helps to save around Rs. 72000 per year per block. Taking the estimated cost of installation as Rs. 4,50,000-5,00,000, the payback period is calculated to be 6.25-6.9 years.

| Installation Cost | Savings | Payback Period |
|-----------------------|----------------------|----------------|
| Rs. 4,50,000-5,00,000 | Rs. 72000/year/block | 6.25-6.9 years |

- iii. Roof insulation through ceramic tiles: This helps to reduce the indoor temperature by 2-4 degree Celsius which reduces the AC cooling demand by 10-20%. Assuming 2 to 3 AC have been present in each and being used for around 6 hours a day for 6 months a year.

The annual saving comes out to be Rs. 77,760- 1,16,640 per block. Taking the installation cost to be Rs. 1,50,000 the payback period is calculated to be 1.3-2.0 years.

| Installation Cost | Savings | Payback Period |
|--------------------------|--------------------------------|-----------------------|
| Rs. 1,50,000 | Rs.77,760 -1,16,640/block/year | 1.3 – 2 years |

- iv. External Sunshade and Dedicated Outlets: On windows it helps to reduce the solar gain by 8-15%, saving around INR 3,888 per year per flat. It will last for around 5-10 y and the payback period is calculated to be 7 months.

Studies shows that 5-10% energy saving is observed with the use of external shade. It helps to save around INR 54,432 per year per block.

The payback period is calculated to be 7.5 months. Dedicated outlets for the condensate coming out of the AC units helps to prevent damp patches and seepage on the walls as well as the balcony improving overall indoor environment.

- v. Tank Cool: Tank-Cool is a novel insulation sheet designed to combat the rising discomfort and health risks caused by overheated rooftop water tanks and building roofs in summer, developed by Prof. Animangsu Ghatak and his team at IIT. Kanpur. It is Light, flexible, foldable, cooling insulation sheet for placing on roof and wall of a building. Decrease in inner wall surface temperature of room by 10-12 degree Celsius and the air conditioning requirement is expected to decrease by at least 15%.

2. Water Conservation Measures:

- i. Low flow fixtures: Based on National and GRIHA studies, the average water consumption = 160 l/c/d, taking 80% i.e. 128 l/c/d, low flow fixtures help to save around 30% of the indoor water usage. It gives a saving of 38.4 l/c/d. Assuming 4 per flat, 3686.4 litre water is saved in each block per day totaling to an annual saving of around 1.35 million litre waters. The total installation costs around Rs.1,17,600 per block.
- ii. Dual Flush system: The traditional single flush toilets use around 10-13 L/flush, implementing dual flush systems significantly helps to save water as for half flush it uses 3 L/flush and for full flush it uses 6 L/flush. Considering 6 flushes per day, with the traditional single flush toilets the water consumption would have been 60 litres but with the dual flush system, taking 4 half and 2 full flushes, it would be 24 litres. It depicts the saving of 36 l/c/d. This totals to an annual saving of 1.26 million litres of water annually per block. For retrofitting assuming 2 toilets in each flat,

totaling to 48 toilets per block and taking average cost to be Rs.1250, the total cost comes to be Rs. 60,000.

- iii. Landscape Water Demand: Traditionally hosepipes are being used manually for watering purposes, replacing it with drip and sprinkler irrigation system helps to reduce the landscape demand. Per 1000 m² assuming the hosepipe uses 6 l/m²/day = 12,00,000 l/ year and for Drip + Sprinkler [1.5 l/m²/d + 3.5 l/m²/day] = 5,00,000 l/year, saving around 7,00,000 litres water per year. Hence reducing the landscape demand by around 58.3%.

3. Occupant well-being and awareness:

- i. Providing dedicated, segregated and hygienic storage spaces before treating or recycling solid waste.
- ii. Providing accessible parking, and signage for differently abled individuals and dedicated resting rooms and washrooms for service staff.
- iii. Awareness programs could be organized including dedicated eco-notice boards, residents' clubs and workshops, and sign boards for saving energy and water resources could also be installed.

4.4 Post – Retrofitting GRIHA Ratings

Sustainable site planning: additional 3 points are awarded due to the adoption of additional low- impact design strategies and the use of renewable energy sources.

Energy optimization: ratings have increased significantly, additional 13 in Block A & B and 8 in Block C & D. 80.08 kWp Solar panels are advised to be installed in Blocks A & B, compliance with ECBC 2017 mandatory requirements. Further the use of solar water heaters, roof insulation and external sunshade also improves the ratings.

Occupant Comfort: Indoor plants like snake plant, money plant, aloe vera, spider plant improves indoor air quality and well-being, contributing an additional 0.5 points.

Water Management: Replacing hosepipes with drip and sprinkler irrigation, along with low-flow fixtures and dual-flush systems, adds 2.5 points.

Solid Waste Management: Dedicated, segregated and hygienic storage spaces within the site before recycling further adds a point.

Socio Economic Strategies: Adopting measures for the workers at the site, person with disability or elderly person, and providing dedicated rooms for service staff further increases points

Performance Metering and Monitoring category: Ensuring installation of smart metering systems for energy and water and sharing of monthly energy and water consumption data by connecting with GRIHA online benchmarking platform for 5 years further help to increase points under this category

Table 4 shows the re-evaluated GRIHA ratings. After implementing the proposed retrofitting strategies, both groups of blocks have showed improvement, with Blocks A & B achieving a score of 63.5% and Blocks C & D a score of 68. Both being eligible for a GRIHA provisional rating of 3 star. Table 5 shows the final GRIHA ratings post retrofitting.

Table 4: Final GRIHA score distribution

| | | | | | |
|----------------------|-------|-----------|---|---|---|
| Block A and B | 63.5% | [50-70] % | ★ | ★ | ★ |
| Block C and D | 68% | [50-70] % | ★ | ★ | ★ |

Data based on GRIHA V 2019 Self-evaluation checklist

Table 5: Final GRIHA Ratings after Retrofitting

| Parameters | Max Points | Block A and B [Final] | Block C and D [Final] |
|---|-------------------|------------------------------|------------------------------|
| 1. Sustainable Site Planning | 12 | 10 | 10 |
| 2. Construction Management | 4 | 1.5 | 1.5 |
| 3. Energy Optimization | 18 | 14 | 14 |
| 4. Occupant Comfort | 12 | 10 | 10 |
| 5. Water Management | 16 | 6 | 6 |
| 6. Solid Waste Management | 6 | 6 | 6 |
| 7. Sustainable Building Materials | 12 | 4 | 5.5 |
| 8. Life cycle costing and Socio-Economic Strategies | 13 | 10 | 10 |
| 9. Performance Metering and Monitoring | 7 | 2 | 5 |

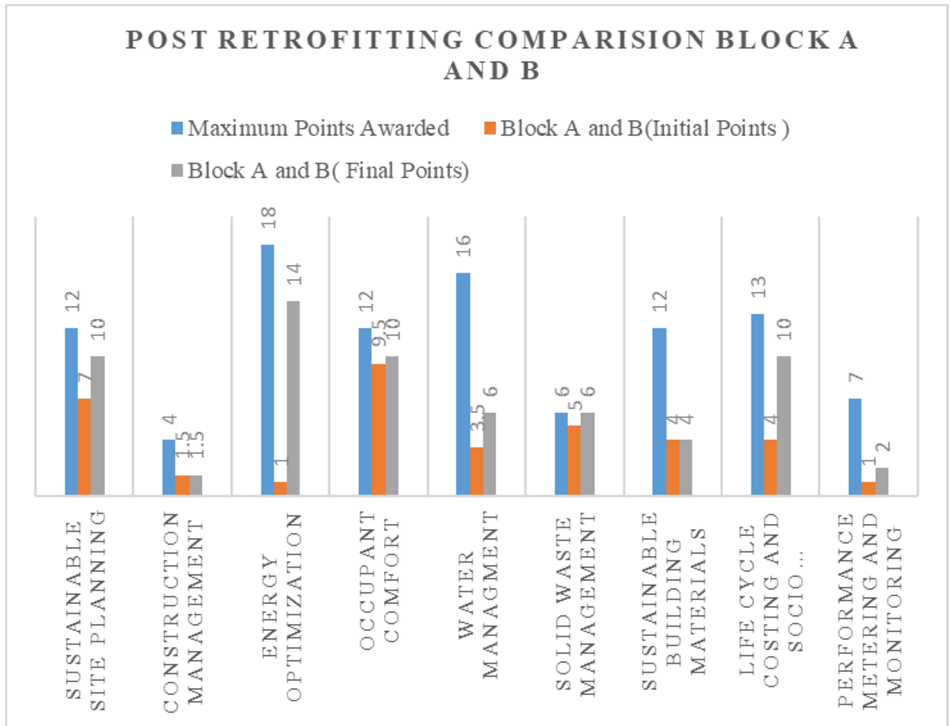


Fig.2. Post Retrofitting Comparison Block A and B

5 Discussion

The discussion interprets the results obtained from the GRIHA assessment of the faculty apartment at IIT Kanpur before and after retrofitting. The comparative analysis of category wise performance depicts a noticeable improvement in the sustainability indicators following the implementation of energy- and water-efficient measures.

The cluster chart [Figure 2 and 3] represents the variation in maximum achievable, pre-retrofit, and post-retrofit points for major GRIHA categories for block [A & B] and [C & D] respectively, showing that retrofitting significantly helps to enhance energy efficiency, water management, and indoor environmental quality.

The maximum improvement is observed in categories such as energy optimization and water management. This enhancement can be attributed to the proposed measures like the installation of solar panels [block A & B], solar water heaters, roof insulation, and external sunshades, which promote a shift toward renewable energy sources and help reduce overall energy demand.

Similarly, the use of low-flow fixtures, dual-flush systems, and the replacement of conventional hoses with drip and sprinkler irrigation systems significantly lowers landscape water consumption-contributing to the conservation of water, a vital and limited natural resource essential for life.

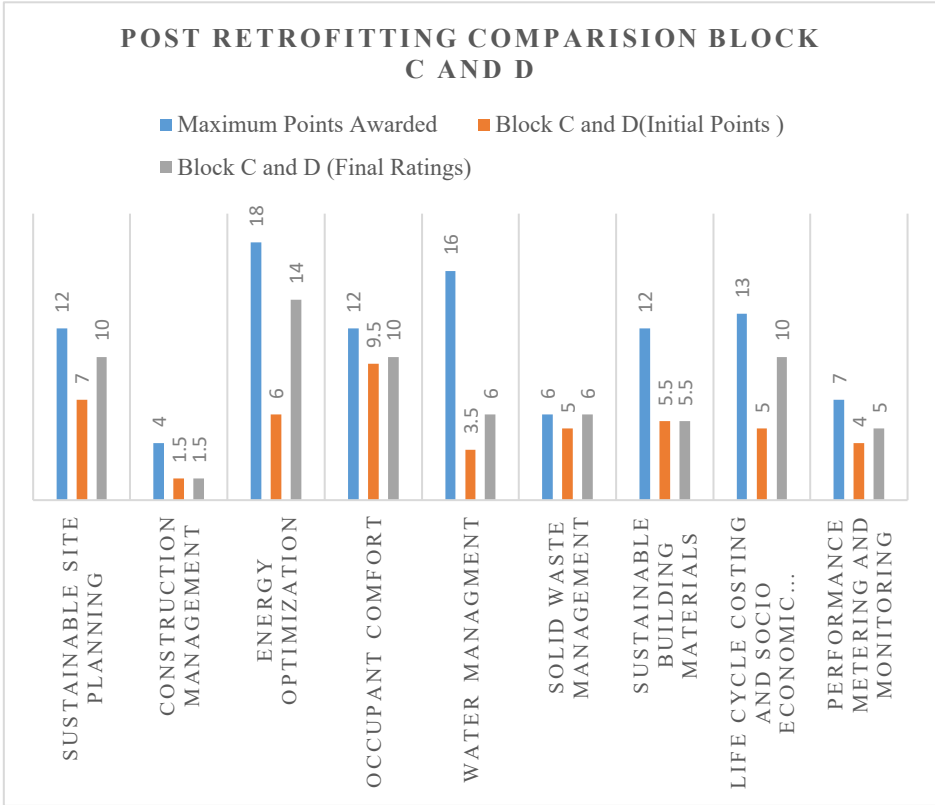


Fig.3. Post Retrofitting Comparison Block C and D

[Data based on GRIHA V 2019 Self-evaluation checklist]

No improvement is observed in categories such as construction management and sustainable building materials, as these aspects pertain to the assessment of materials and practices used during the initial construction phase. Since this study focuses on retrofitting an existing building, these categories remain unchanged and unaffected by the proposed interventions.

In a broader sense, these parameters represent more than just numerical improvements - they signify a shift toward a more sustainable future. For instance, India’s grid electricity emits approximately 0.82 kg of CO₂ per kWh generated. Thus, installing an 80.08 kWp solar PV system for Blocks A and B helps avoid about 98.5 tons of CO₂

emissions annually, equivalent to planting nearly 4,500 trees or removing over 20 petrol cars from the road. Similarly, the use of solar water heaters prevents around 7.38 tons of CO₂ emissions each year, comparable to planting about 350 mature trees.

Water is a vital and limited resource, essential for all forms of life. Conserving it through efficient management is essential for ensuring a sustainable future. By introducing dual flush systems, low flow fixtures and replacing the hosepipes with drip and sprinkler system we can reduce the water demand by around 2.176 million litres per year [Figure 4 represents individual reduction in water demand].

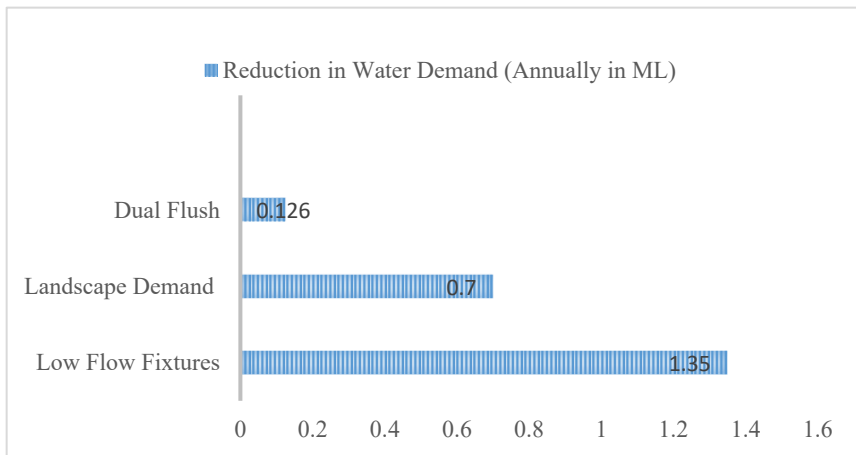


Fig.4. Annual reduction in water demand post retrofitting

Residential reduction [low flow fixtures and dual flush systems] is around 1.476 million litres of water annually per block. Each block has 24 flats and as we assumed earlier 4 occupants in each flat summing up to 96 people per block. Based on GRIHA benchmark is 135 l/c/d i.e. each individual is assumed to be using 135 litres of water per day. The total daily water demand for the block is approximately 12,960 litres. Hence, the water conserved annually could meet the entire domestic water requirement of all 96 residents for about 114 days, equivalent to nearly four months of usage. This demonstrates the substantial potential of efficient fixtures and water-saving interventions in reducing dependence on conventional water sources and promoting sustainable resource management.

Overall, the discussion highlights that the implemented retrofitting measures have notably improved the building's GRIHA performance, particularly in energy and water efficiency. While certain areas such as materials use remain below the desired benchmark, the overall gains emphasize that retrofit-based upgrades are a practical and scalable approach for improving sustainability in existing housing projects

6 Conclusion

This study highlights the current sustainability performance of the Faculty Apartment complex at IIT Kanpur. Through the GRIHA-based assessment, several good practices were identified, such as the use of LED lighting, adequate ventilation, and organized waste management, alongside areas needing improvement, including outdated plumbing fixtures and inefficient water usage. Targeted retrofitting strategies can significantly enhance the building's environmental performance and overall, GRIHA rating.

These findings depict the importance of systematic monitoring and maintenance schedules, prioritizing low-cost, high-impact retrofits. Facility managers and institutional planners can use such assessments to develop phased retrofitting roadmaps and ensure long-term operational efficiency. At the policy level, incorporating periodic sustainability evaluations for institutional housing can accelerate India's transition toward net-zero campuses.

The study emphasizes that retrofitting reduces costs and environmental impacts while supporting IIT Kanpur's broader vision of achieving campus-wide sustainability and becoming a carbon-neutral, waste-free campus by 2030. Overall, green building practices not only reduce environmental impact but also enhance occupant well-being. Rating systems like GRIHA translate sustainability goals into measurable outcomes, helping institutions like IIT Kanpur advance India's vision for a sustainable and resilient future.

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Declaration of Generative AI in Scientific Writing

Generative AI tool [ChatGPT, developed by OpenAI] was used to refine vocabulary and improve sentence structure in this paper.

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