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Article

A case study of the energy performance of A-J hostel block in IIM, Bangalore

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Abstract: Hostel accommodations are vital to urban landscapes, serving diverse occupants like students and travelers. With rising energy demands and environmental concerns, enhancing the energy performance of hostels is increasingly essential. This research focuses on hostel buildings in Bangalore, India, a city known for its technological and educational excellence. Using advanced computational analysis and simulation tools such as Autodesk 2024 Revit and Insight, the study evaluates current energy consumption patterns and proposes optimization strategies. Detailed digital models of selected hostels are developed to examine factors influencing energy efficiency, including architectural design, insulation quality, and HVAC systems. The findings offer insights for hostel stakeholders in Bangalore and beyond, providing a framework for better energy efficiency and sustainability. Strategies encompass passive design principles and renewable energy integration. A case study of an IIM Bangalore hostel block demonstrates potential energy savings and cost reductions through these measures. The paper emphasizes that by adopting energy-efficient practices, hostels can significantly contribute to a greener urban environment.

1. Introduction

The building evolves by continuously upgrading its infrastructure to meet user's expectations [1]. This challenges architects as facilitators to understand the dynamic nature of user expectations. Hostel accommodations are integral to cities and urban landscapes, providing temporary shelter to various occupants, from students pursuing education to adventurous travelers exploring new horizons. Although hostels are known for their transient nature, their significance in urban sustainability and energy efficiency cannot be underestimated [1]. It is marked by an increasingly urgent need to reduce energy consumption, reduce environmental impact, and optimize the utilization of resources available; it is critical to scrutinize and strategically enhance the energy performance of hostel buildings [2].

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Along with the increasing student population, the universities are also growing to accommodate the rise. Studies have found that students' quality of life influences their academic performance. There is a need for hostel owners, architects, occupants and stakeholders worldwide to be made aware of enhanced energy efficiency and cost savings [3]. In India, more than 10 million students of different ages reside in hostels [2,4–6]. While acknowledging the importance of optimizing energy consumption in the context of urban sustainability, several research gaps emerge with limited focus on user expectations, transience of hostel occupants, comprehensive data, and comparative analysis integration of renewable energy impact on academic performance.

Bangalore city located in the heart of India's technological and educational landscape, is a vibrant hub for students and professionals. Within this dynamic urban ecosystem, hostel buildings represent microcosms of energy consumption and environmental responsibility. Their energy dynamics are influenced by many factors, spanning from architectural design and insulation quality to the efficiency of heating, ventilation, and air conditioning (HVAC) systems [3]. This paper embarks on a comprehensive exploration of the energy performance of AJ hostel building in IIM, Bangalore, utilizing advanced computational analysis and simulation tools. Specifically, by harnessing the capabilities of Autodesk Revit 24 and Insight software to meticulously craft intricate digital models of selected case study hostel buildings, diving into the complicated realm of energy consumption and energy efficiency.

The objectives of this research are dual-fold: first, to assess the present energy consumption pattern within IIM, Bangalore's AJ hostel building, and second, to chart a course toward energy optimization and sustainability. While understanding the relationship between architectural design, insulation, HVAC systems, building occupancy, and the integration of renewable energy, the paper aspires to empower those involved in hostel accommodations to make informed decisions and contribute to a greener and more sustainable campus environment. Here, the findings, insights, and recommendations are revealed from our computational analysis. Beyond understanding the energy performance of hostel buildings, this research aims to be a catalyst for transformative and progressive changes, fostering a culture of energy awareness and resilience within the environment of hostel accommodations.

1.1. Key Dimensions of Building Energy Performance

The key dimensions of building energy performance include - Energy Efficiency, Environmental Impact, Economic Sustainability, and Occupant Well-being which are elaborated in Figure 1 below.

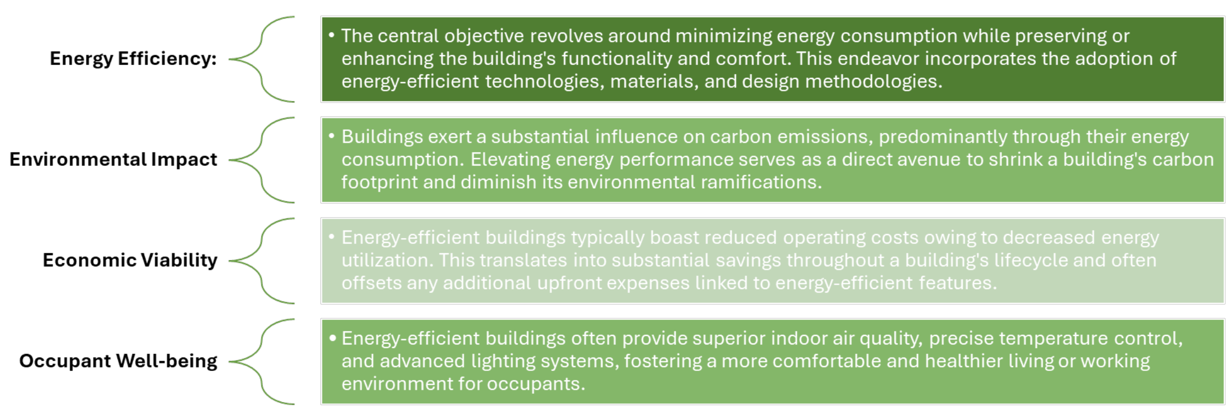

Figure 1. Key dimensions of building energy performance.

1.2. Building Energy Performance

The energy performance of buildings plays a crucial role in the global endeavor to combat climate change, promote resource efficiency, and cultivate sustainable urban environments. It is a well-known fact that buildings account for a significant portion of worldwide energy consumption and greenhouse gas emissions, optimizing their energy performance is not just an environmental imperative but also an economic and societal necessity today. This pursuit yields substantial cost savings, enhances the comfort of occupants, and contributes to a healthier living environment. Building energy performance encompasses the art of efficiently utilizing energy resources for various functions, including heating, cooling, lighting, and the operation of appliances and equipment. It entails a complex journey that spans the entire lifecycle of a building, from its initial design and construction to its operational phase and eventual decommissioning [6].

1.3. Essential Components of Energy Performance

The essential components of energy performance include Building Envelope, Heating, Ventilation, and Air Conditioning (HVAC) Systems, Lighting, Appliances and Equipment, Integration of Renewable Energy, and Building Automation Systems (BAS) which are elaborated in Figure 2 below:

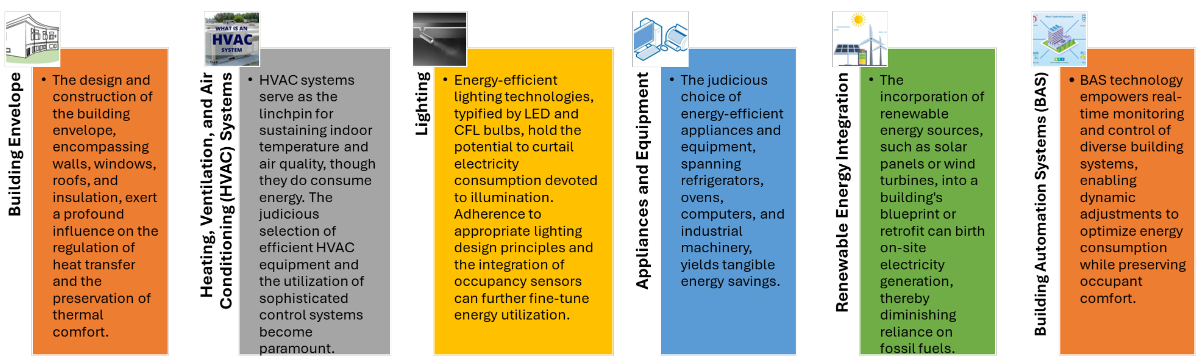

Figure 2. Essential components of energy performance.

1.4. Strategies for Enhancing Energy Performance

Achieving superior energy performance relies on the implementation of a range of strategies and best practices as seen in Figure 3 below:

1.5. Sustainable Development Goals

The study discusses hostel accommodations in Bangalore, emphasizing the need to improve their energy performance for sustainability. Several Sustainable Development Goals (SDGs) are relevant to this context which are as under:

- **SDG 3 (Good Health and Well-being):** Energy-efficient buildings improve indoor air quality and comfort, enhancing occupant well-being.
- **SDG 4 (Quality Education):** Sustainable hostel accommodations support a betterlearning environment for students, promoting equitable education.
- **SDG 7 (Affordable and Clean Energy):** Reducing energy consumption and integrating renewable technologies advance access to clean energy.
- **SDG 9 (Industry, Innovation, and Infrastructure):** Advanced tools like Autodesk Revit foster innovation and sustainable infrastructure development.

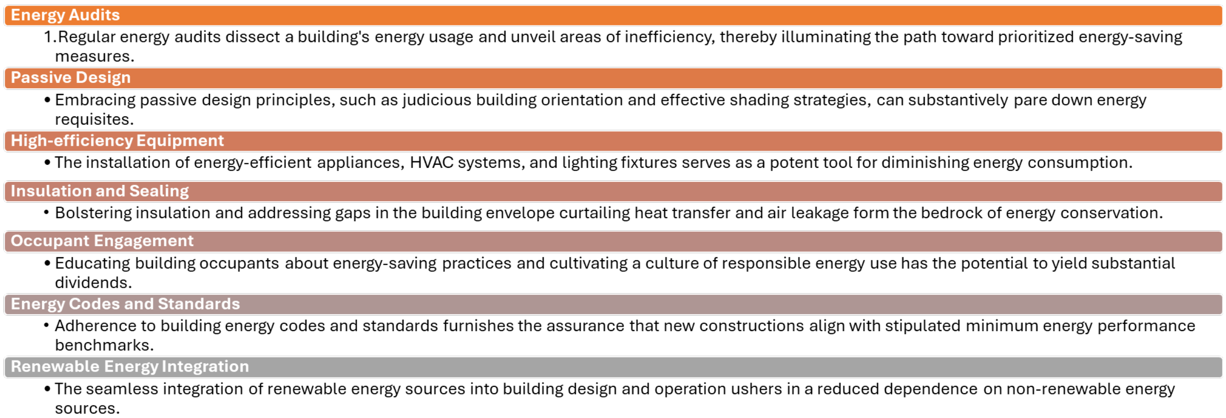

Figure 3. Strategies for enhancing energy performance.

- **SDG 11 (Sustainable Cities and Communities):** Optimizing energy performance in hostel buildings contributes to sustainable urban development and resource efficiency.
- **SDG 12 (Responsible Consumption and Production):** Emphasizing energy audits and efficient appliance selection promotes responsible consumption and production practices.
- **SDG 13 (Climate Action):** Reducing energy use and carbon emissions in hostel buildings supports urgent climate action initiatives.

The study focuses on improving the energy performance of A-J hostel building in IIM, Bangalore, and intersects with multiple SDGs, primarily those related to affordable and clean energy, sustainable cities, climate action, industry innovation, health and well-being, responsible consumption, and quality education. The study **uses**, Autodesk 2024 Revit and Insight software as indispensable tools. They enable the creation of accurate digital models, conduct energy simulations, and provide valuable insights for data-driven decisions to enhance energy efficiency, reduce costs, and promote sustainability [7–9].

1.6. Software for study

The study utilizes the student version of the Building Information Modelling (BIM) approach with Autodesk Revit 2024 and Insight software (free student version) for creating digital models of the hostel buildings. Autodesk 2024 Revit is a building information modeling (BIM) software application developed by Autodesk, inc. BIM technology enables architects, engineers, and construction professionals to design, model, and document building projects in a collaborative and data-driven manner. Autodesk 2024 Revit insight refers to a powerful combination of two software tools provided by Autodesk, Inc. as seen in Figure 4. These tools are instrumental in conducting comprehensive energy analysis and simulations for building designs, specifically focusing on aspects related to energy efficiency, sustainability, and environmental impact.

The level of Building Information Modelling (BIM) can be categorized as Level of Development (LOD) 300 to LOD 400.

LOD 300 Characteristics:

- **Detailed Geometry:** Includes comprehensive architectural and structural elements.
- **Accurate Material Properties:** Specific materials assigned to walls, roofs, and windows.
- **Defined Systems:** HVAC systems specified by type, capacity, and efficiency.
- **Spatial Definition:** Rooms defined for precise energy simulation.

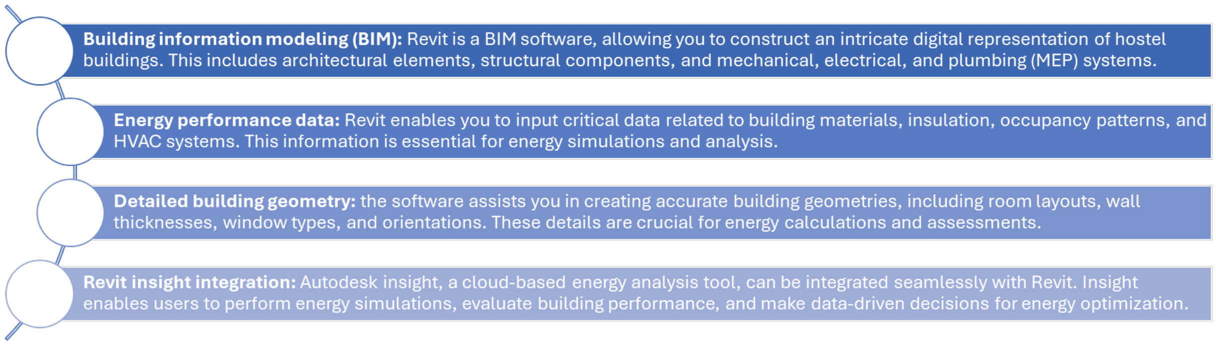

Figure 4. Key aspects of Autodesk Revit 2024.

Steps for LOD 300:

1. Create a 3D model in Autodesk Revit with detailed elements.
2. Assign accurate material properties.
3. Define HVAC systems with detailed specifications.
4. Collect data to build the digital model.

LOD 400 Characteristics:

- **Construction Details:** Incorporates fabrication and assembly-level details.
- **Enhanced Accuracy:** Provides precise specifications for materials and systems, aligned with actual construction needs.

Overall, the study primarily utilizes LOD 300, with some elements potentially extending into LOD 400.

The input and output parameters along with the dependent and independent variables and the constants are elaborated in Tables 1 and 2 and Figure 5 below.

Table 1. Input parameters used.

S.no.	Input Parameters	Description
1	Building Geometry and Design	Architectural and structural elements, Room boundaries, Building materials
2	Material Properties	Thermal conductivity, U-values and R-values for different construction materials like concrete, granite stone, and Kota stone
3	HVAC Systems	Type of equipment, Capacity and efficiency ratings
4	Climate Data	Local climate data specific to Bangalore, Weather station data for accurate simulation
5	Occupancy Data	Number of occupants, Occupancy patterns and schedules
6	Building Components and Energy Systems	Types of lighting (e.g., LED, CFL), Appliances and equipment energy ratings, Building envelope including walls, windows, roofs, and insulation, HVAC systems and their efficiency, Lighting systems and technologies, Appliances and equipment used within the building, Renewable energy sources like solar panels, Building Automation Systems (BAS).

Table 2. Output parameters in software.

S.no.	Output Parameters	Description
1	Energy Consumption	Total energy required per square meter per year (kWh/sqm/yr), Breakdown of energy use for heating, cooling, lighting, and appliances.
2	Energy Efficiency Metrics	Energy Use Intensity (EUI), Savings in energy consumption
3	Cost Analysis	Cost required per square meter per year (USD/sqm/yr or INR/sqm/yr), Total cost savings after optimization
4	Simulation Results	Energy performance profiles, Impact of different factors on energy efficiency
5	Optimization Recommendations	Specific strategies for improving insulation, HVAC system upgrades, Implementation of energy-efficient lighting, Integration of renewable energy sources
6	Savings and Performance Improvements	Total energy saved after optimization in a year, Total cost saved after optimization in a year, Specific improvements in HVAC efficiency, plug load efficiency, lighting efficiency, and daylighting & occupancy controls

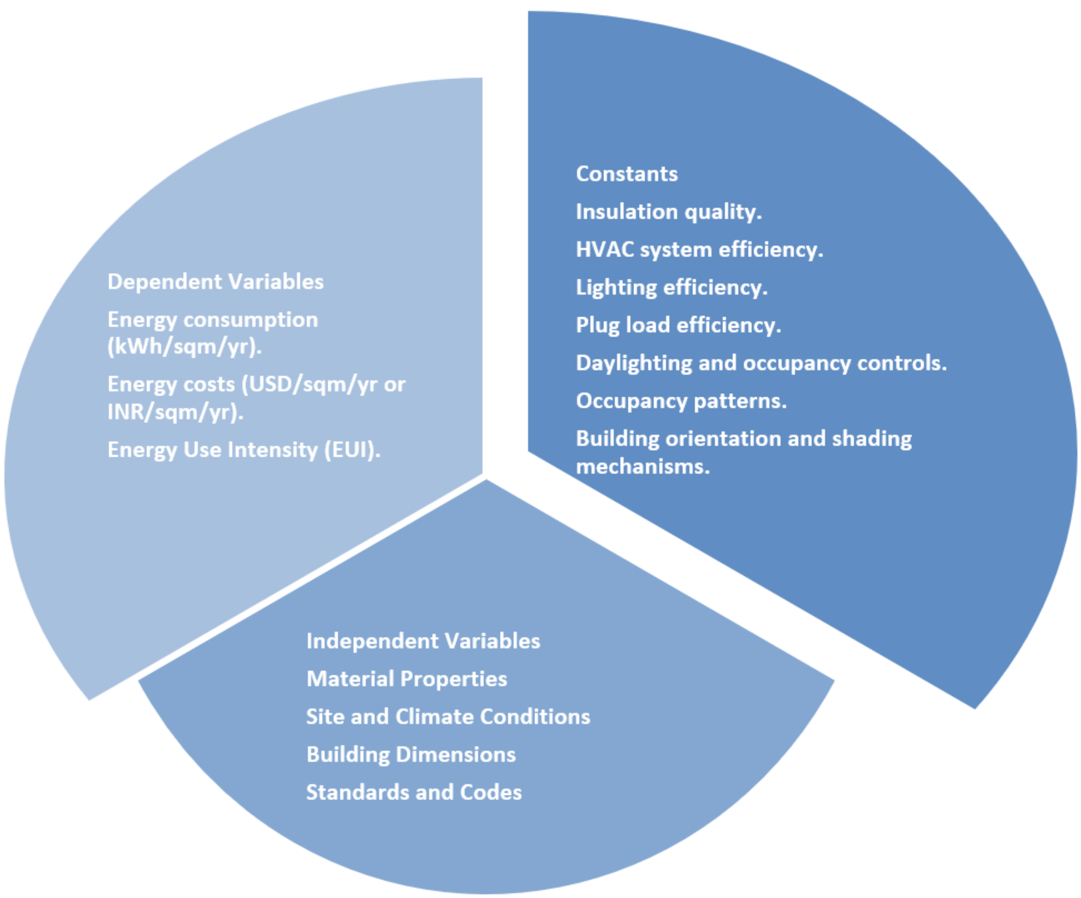

Figure 5. Variables and the constants in the study.

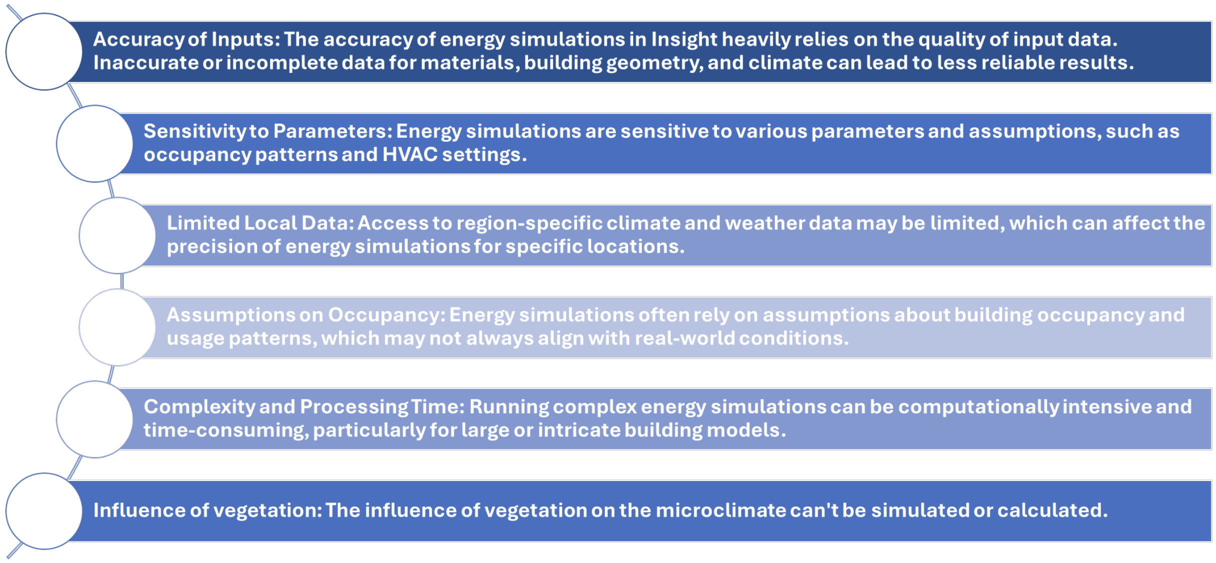

Figure 6. Limitations of the Autodesk Revit 2024.

Due to the limitations of the software the influence of vegetation on the microclimate could not be included in the study.

2. Methodology

The comprehensive methodology followed for this study is explained in Figure 7 below. The detailed process of methods adopted is discussed in this section.

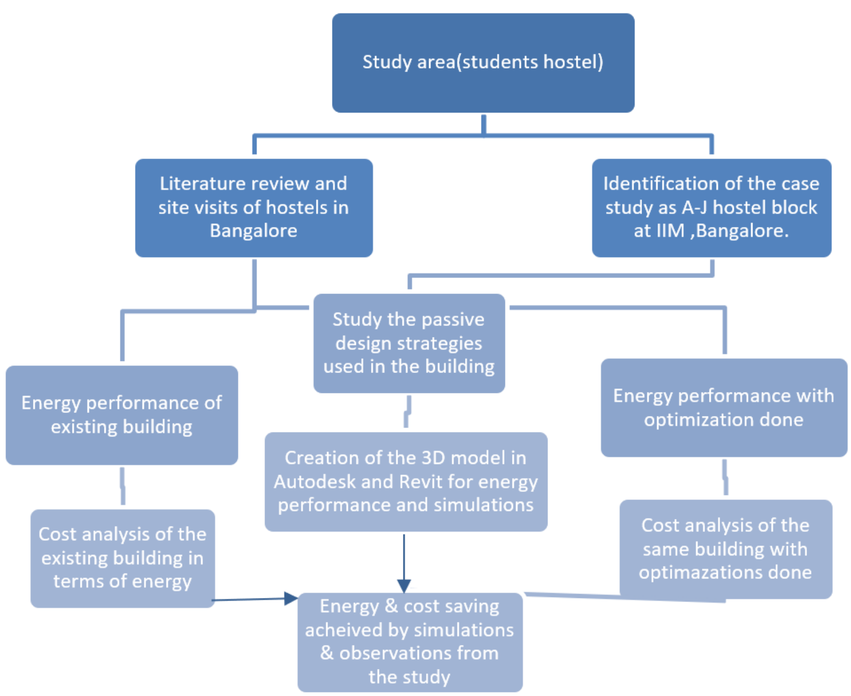

Figure 7. Methodology for the Study.

The study is an academic exercise done for dissertation studies and was initiated with the study of hostel buildings. In the process of doing the literature studies, the importance of energy performance was brought forth. While doing the secondary studies of various well-designed hostel buildings, the A-J hostel block of IIM, Bangalore was selected. The energy performance of the block was done with AutoCAD 2024 and Revit insight software which gave the energy required in the existing context with only the passive design strategies used along with the cost incurred for the same energy use. The next part of the study included the optimization of the parameters in the 3d block generated to bring down the energy and the cost incurred in the working of the hostel block. The conclusions were drawn based on the energy and cost savings achieved by simulations and software which had some limitations.

Study Area

A-J Hostel Block IIM Bangalore, Karnataka

The site is situated in the hilly terrain to the south of Bangalore, near Bannerghatta, in an urban area connected by a highway. It covers an area of 102 acres with an undulating topography featuring a gentle slope. The climate in this region is moderate, with a lush tropical rainforest and well-maintained landscaping. The total site area remains at 102 acres. The total built-up area for the entire campus is 54,000 square meters. This institution was established in 1973 and was designed by the architect B. V. Doshi. It was completed in 1983. The ground coverage of all the constructed structures amounts to 5.93 hectares, that is equivalent to 15.6% of the site. Figure 8 below shows the plan of the hostel building selected and Figure 9 shows the aerial view of the campus with the hostel block highlighted in red.Community statistics: the campus accommodates 700 students, with a faculty of 100 members, and a resident population of 1,636 people. For the case study, we've chosen only the A-J hostel block, which covers an area of 14,692 square meters.

The A-J hostel blocks at the Indian Institute of Management (IIM) Bangalore incorporate several passive design strategies to optimize energy efficiency and enhance occupant comfort [10, 11]. Some of these passive strategies include:

1. **Natural Ventilation:** The design facilitates cross-ventilation, allowing air to flow freely through the buildings. This helps in maintaining comfortable indoor temperatures and reduces the need for mechanical cooling.
2. **Orientation and Shading:** The buildings are strategically oriented to minimize direct solar heat gain. Overhangs, louvered screens, and other shading devices are used to reduce solar exposure and keep interiors cooler.
3. **Use of Courtyards:** The inclusion of courtyards in the design promotes airflow and natural light, creating cooler microclimates and providing natural ventilation to adjacent spaces.
4. **Thermal Mass:** The use of thick walls and concrete helps in absorbing and storing heat during the day, which is then released during cooler periods, thereby moderating indoor temperature fluctuations.
5. **Green Spaces:** Landscaping around the hostel blocks helps cool the surrounding air, reduces the heat island effect, and enhances the overall microclimate.

These strategies work together to create a sustainable living environment, reducing the dependence on artificial heating and cooling systems. Visual performance depends on the windows and electric lighting systems. In this building, windows and courtyards are used for passive cooling, supplemented by fans to enhance their thermal performance. Noise control measures are limited to considering the orientation of fenestration relative to adjacent spaces. For fire safety, both active and passive systems are in place.

Regarding hygiene, a reliable flush water supply, efficient drainage discharge facilities, and regular room cleaning by maintenance staff are essential for the residents. Lastly, communication infrastructure ensures safety and security through the provision of network cables, sockets, Wi-Fi, and CCTVservices.

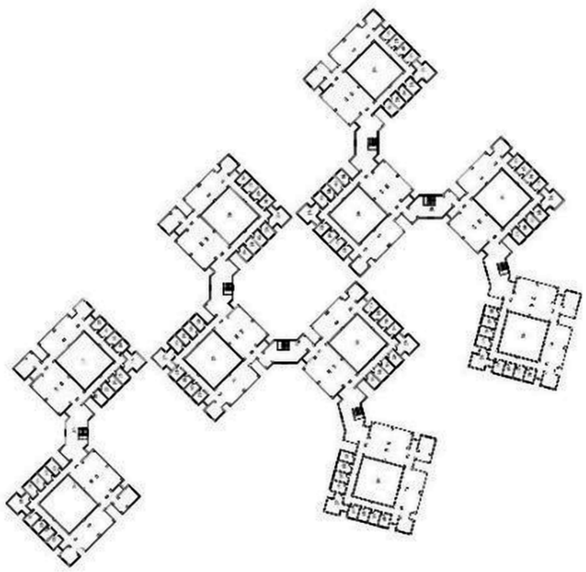

Figure 8. Plan of the selected hostel for study.

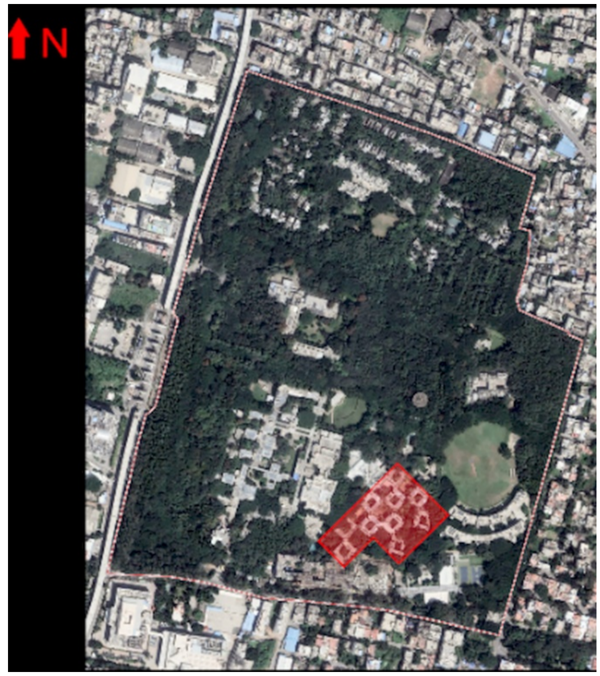

Figure 9. Arial view of the campus with the highlighted area being the location of the hostel building.

2.1. Model Creation in Autodesk Revit 2024

1. **Building Geometry:** Start by creating a 3D digital model of the building in Autodesk Revit. Include detailed architectural and structural elements.
2. **Materials and Components:** Assign material properties to building elements such as walls, roofs, windows, and insulation. Ensure accuracy in material specifications.
3. **HVAC Systems:** Define the HVAC systems within the Revit model, specifying the type of equipment, capacity, and efficiency ratings.
4. **Create Rooms:** Define the boundaries of rooms so that they are identified by Insight later during the simulation.
5. **Climate Data:** Import local climate data for the building's location in Bangalore or the specific region of interest using the closest weather station location. This data is critical for the accuracy of simulating energy performance based on climate variations [12,13]. Figure 10 shows the BIM model of the hostel and Figure 11 shows the analytical model generated.

2.2. Integration with Insight Software student version

1. **Insight Integration:** Utilize the integration capabilities between Autodesk Revit and Insight software. Typically, Insight is accessed directly within Revit.
2. **Setup and Analysis:** Configure the software to perform energy analysis on the Revit model. Specify the analysis type that is energy and define the simulation parameters.

2.3. Energy Simulations

1. **Scenario Setup:** Develop multiple simulation scenarios to analyze different aspects of energy performance.
2. **Run Simulations:** Initiate energy simulations for each scenario. The software will use the building model, climate data, and simulation parameters to calculate energy consumption.
3. **Results Interpretation:** Review the simulation results, which typically include energy consumption figures for heating, cooling, lighting, and appliances. Identify variations in energy usage among different scenarios [14, 15].

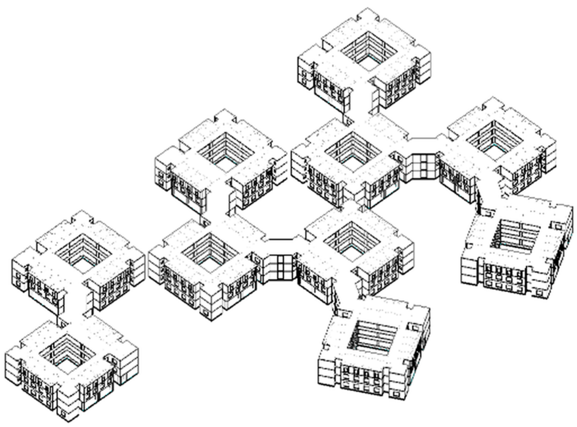

Figure 10. BIM model of the hostel.

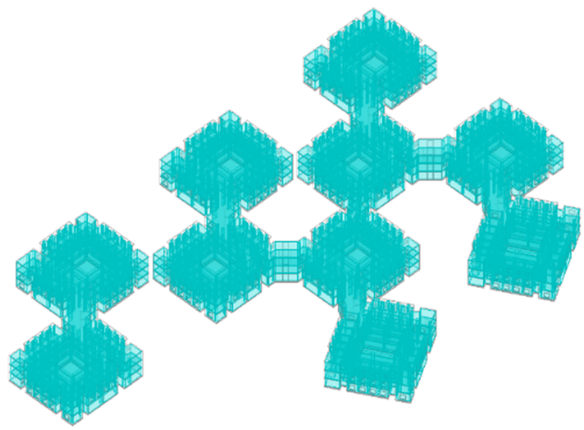

Figure 11. Analytical model generated.

In this study, the inputs consist of various parameters related to building design, material properties, HVAC systems, climate data, and occupancy information. The outputs focus on energy consumption, energy efficiency metrics, cost analysis, and specific recommendations for optimization. The dependent variables are mainly energy consumption and costs, while the independent variables include factors like insulation quality, HVAC efficiency, and lighting efficiency. The constants include fixed material properties, site and climate conditions, building dimensions, and adherence to standards and codes. Through the systematic manipulation and analysis of these inputs and variables, the study aims to optimize the energy performance of the selected hostel building at IIM, Bangalore. The optimization method in the study relies on a systematic approach combining BIM modeling, energy simulations, and data-driven analysis. Advanced tools like Autodesk Revit and Insight software are used to create detailed models and run simulations, while the results guide the implementation of specific optimization strategies to improve energy efficiency and sustainability.

2.4. Optimization of Model

1. **Creation of Digital BIM Models:**

   - **Software Used:** Autodesk Revit 2024 is used to create detailed digital models of the hostel buildings, including architectural and structural elements, material properties, and HVAC systems.
   - **Input Parameters:** Building geometry, materials, HVAC systems, climate data, and room boundaries.

2. **Energy Simulations:**

- **Software Used:** Insight software, integrated with Autodesk Revit, is used for performing energy analysis and simulations.
- **Simulation Scenarios:** Multiple scenarios are developed to analyze different aspects of energy performance. These scenarios consider varying parameters such as insulation quality, HVAC efficiency, lighting efficiency, and the integration of renewable energy.

3. **Data Analysis:**

- **Results Interpretation:** The simulation results are reviewed to identify variations in energy usage among different scenarios. Energy consumption figures for heating, cooling, lighting, and appliances are analyzed.
- **Optimization Strategies:** Based on the analysis, key factors impacting energy efficiency are identified. Recommendations for optimization are developed, including improvements in insulation, upgrades to HVAC systems, and implementation of energy-efficient lighting.

4. **Implementation of Optimization Measures:**

- **Adjustments in Parameters:** Changes are made to the parameters with the most significant impact on energy consumption, such as HVAC systems, plug load efficiency, lighting efficiency, and daylighting & occupancy controls.
- **Energy and Cost Savings:** The optimized scenarios are compared with the initial runs to quantify energy savings and cost reductions.

2.5. Specific Techniques for Optimization

- **Energy Audits:** Regular energy audits are suggested to analyze a building's energy usage and identify inefficiencies.
- **Passive Design:** Incorporating passive design principles like building orientation and effective shading to reduce energy requirements.
- **High-efficiency Equipment:** Installing energy-efficient appliances, HVAC systems, and lighting fixtures.
- **Insulation and Sealing:** Enhancing insulation and sealing gaps in the building envelope to prevent heat transfer and air leakage.
- **Renewable Energy Integration:** Incorporating renewable energy sources like solar panels to generate on-site electricity.
- **Building Automation Systems (BAS):** Utilizing BAS for real-time monitoring and control of building systems to dynamically optimize energy consumption.
- **Occupant Engagement:** Educating occupants about energy-saving practices and fostering a culture of responsible energy use.

Optimization Parameters and Their Adjustments

- **HVAC Systems:** Changed to ASHRAE Package Terminal Heat Pump for better efficiency.
- **Plug Load Efficiency:** Improved to 6.46W/sqm.
- **Lighting Efficiency:** Improved to 3.23W/sqm.
- **Daylighting & Occupancy Controls:** Implemented daylighting and occupancy control systems.

Outputs of Optimization

- **Energy Consumption:** Reduction from initial to optimized runs.

- **Energy Use Intensity (EUI):** Decreased from 220 kWh/sqm/year to 78.3 kWh/sqm/year.
- **Cost Savings:** Significant reduction in energy costs per square meter per year.

The optimization method relies on a systematic approach combining BIM modeling, energy simulations, and data-driven analysis. Advanced tools like Autodesk Revit and Insight software are used to create detailed models and run simulations, while the results guide the implementation of specific optimization strategies to improve energy efficiency and sustainability.

2.6. Benchmarks or Standards

The established benchmarks or standards used to assess the accuracy and reliability of simulation outcomes in the context of energy performance for the hostel buildings typically include:

a) **ASHRAE Standards:** The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) provides various standards (e.g., ASHRAE 90.1) that outline minimum energy efficiency requirements for hostel buildings. These standards serve as a benchmark for evaluating the energy performance of HVAC systems and overall building design used in AJ hostel block, IIM, Bangalore.

b) **LEED Certification:** The Leadership in Energy and Environmental Design (LEED) program offers a framework for assessing building sustainability and energy efficiency. The energy performance metrics from simulations can be compared against LEED criteria to determine if the building meets the necessary standards for certification.

c) **Energy Star Ratings:** The Energy Star program provides benchmarks for energy performance based on the energy use of similar buildings. The simulation results can be compared to Energy Star ratings to evaluate how the building performs relative to others in the same category.

Out of the above benchmarks discussed, the ASHRAE standards have only been considered for comparisons of the simulations done on the AJ hostel block.

3. Results

3.1. Optimization and Recommendations

1. **Identify Key Factors:** Analyze the simulation results to identify which factors have the most significant impact on energy efficiency. This could include insulation quality, window types, HVAC efficiency, occupancy patterns, and panel placements.
2. **Develop Recommendations:** Based on the identified factors, propose energy optimization strategies. Recommendations might include improving insulation, upgrading HVAC systems, or implementing energy-efficient lighting [14].
3. **Inputs into the Model:**
    - Building material and space occupation scenario.
    - Building type - thermal conductivity.
    - Thickness construction of the material.
    - U-value of materials.
    - Determining the number of occupants – Wall, Roof, Glass, Resident occupation period in major spaces.

Important value input into the model for the materials used [16].

Table 3. U and R-Value Input in Software.

S.no	Material	Heat transfer coefficient (U) (W/m²K)	Thermal resistance (R) (m²K/W)
1	Concrete	6.9733	0.1434
2	Hand-chipped granite stone	17.3043	0.0578
3	Kota stone	14.333	0.0698

3.2. Financial Analysis

- **Cost Estimation:** Estimated the costs associated with implementing the recommended energy optimization measures. This includes material and equipment costs, labor, and any associated expenses.
- **Savings Projection:** Calculated the potential energy cost savings resulting from the recommended strategies. Estimated how long it would take to recoup the investment through reduced energy bills.

3.3. Comparison of the Initial Simulation Run and Optimized Result

Energy Consumption Analysis

The hostel indoor environments are specially designed to live comfortably and study effectively. Therefore, the rooms have to be provided with qualitative lighting and ventilation. The following four are the parameters that can be changed which will have the most impact on the energy consumption of the building.

- **HVAC:** Represents a range of HVAC system efficiency which will vary based on location and building size.

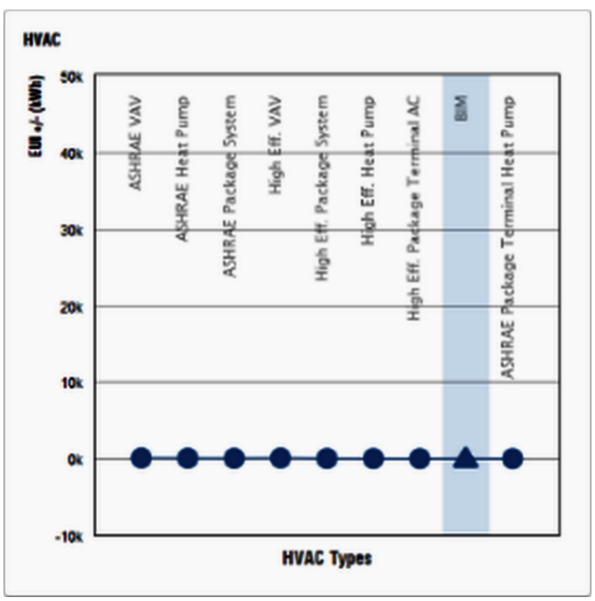

Figure 12. HVAC system.

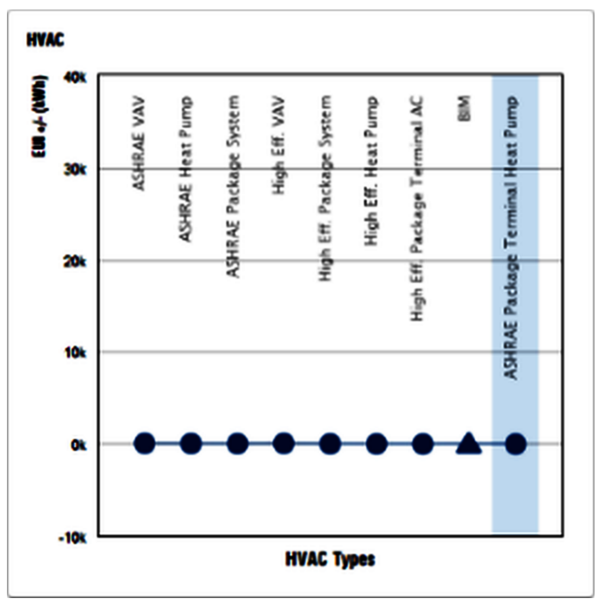

Figure 13. ASHRAE package for optimization.

Figure 12 shows the HVAC system changed to an ASHRAE Package Terminal Heat Pump for simulation purposes, as shown in Figure 13. An ASHRAE terminal heat pump is an HVAC system endorsed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers. It's designed to provide both heating and cooling within a building or specific zones. Operating on the principle of heat exchange, it transfers heat between the indoor environment and the outdoors.

Their importance lies in several factors:

1. **Energy Efficiency:** These pumps can significantly reduce energy consumption and associated costs by transferring heat instead of generating it.
2. **Zoning Control:** They offer the ability to control temperatures independently in different areas, enhancing comfort and energy efficiency.
3. **Environmental Considerations:** Heat pumps can contribute to a greener footprint, particularly when powered by renewable energy sources.
4. **Flexibility in Design:** Their adaptability makes them suitable for various building designs and applications.
5. **Year-round Comfort:** With both heating and cooling capabilities, they ensure occupants' comfort regardless of external conditions.
6. **Plug Load Efficiency:** The power used by equipment i.e., computers and small appliances; excludes lighting or heating and cooling equipment.

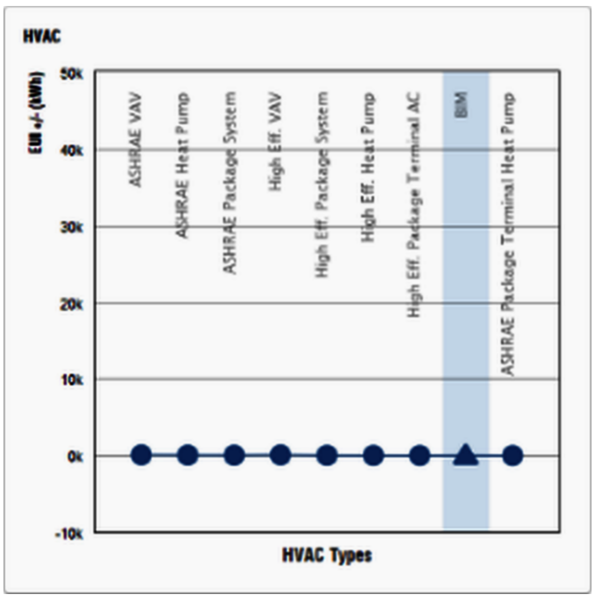

Figure 14. Plug load efficiency initially.

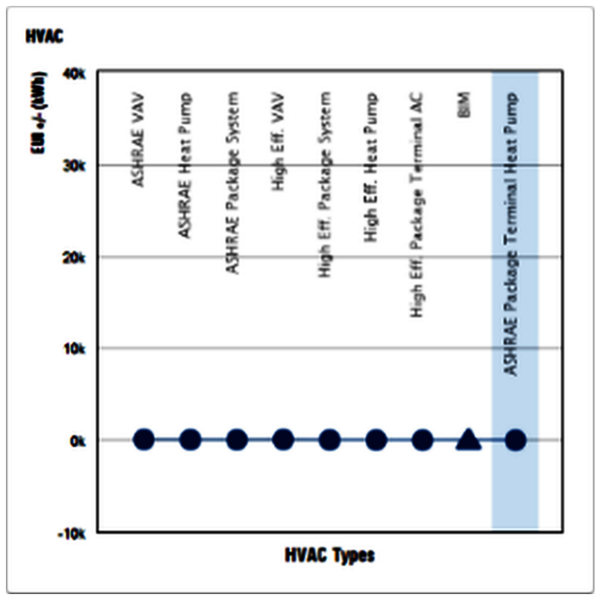

Figure 15. Plug load efficiency improved.

The plug-in load efficiency initially was between 12 to 17W/sqm which was changed to 6.46W/sqm for optimization. It represents the power usage per square meter for electrical devices plugged into a building. It signifies how effectively these devices utilize energy within the given space. Figure 14 shows the plug load efficiency initially and Figure 15 shows the plug load efficiency when improved to better values. Incorporating this efficiency measure into building operations aids in better energy management. Additionally, utilizing plug-in load efficiency data in the initial simulation run has helped identify consumption patterns and areas where energy-saving measures can be applied to lower costs and environmental impact henceforth it is upgraded to 6.46W/sqm with regards to the selection of energy-efficient appliances, implementation of power-saving technologies, and promotion of energy-conscious behaviors among occupants.

- **Lighting Efficiency:** Represents the average internal heat gain and power consumption of electric lighting per unit floor area.

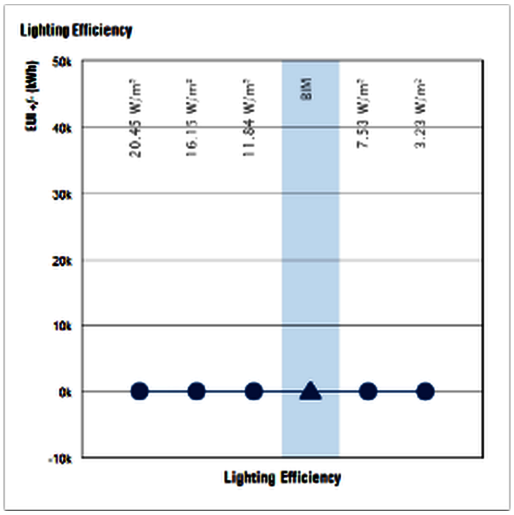

Figure 16. Lighting efficiency.

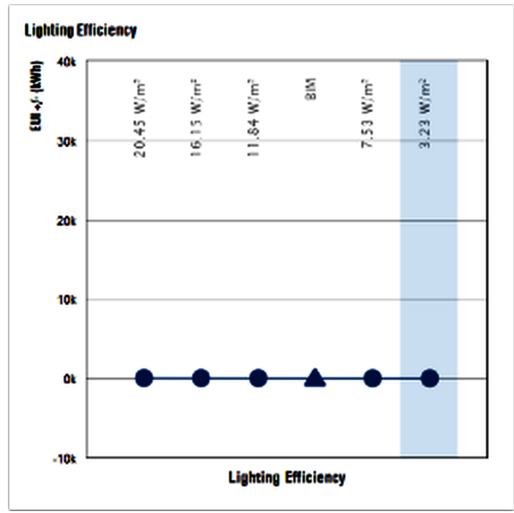

Figure 17. Lighting efficiency improved.

The lighting efficiency measured initially as per the BIM was between 7.5 to 11.5W/sqm which was changed to 3.23W/sqm for optimization. It denotes the amount of power used per square meter for lighting purposes in a building. It signifies how effectively lighting systems utilize electricity within that specific area. By considering the initial simulation energy efficiency data as shown in figure 16, the lighting upgrades are made towards the adoption of energy-saving lighting technologies, and the implementation of strategies aimed at reducing energy consumption and associated expenses as shown in figure 17.

- **Daylighting & Occupancy Controls:** Represents typical daylight dimming and occupancy sensor systems.

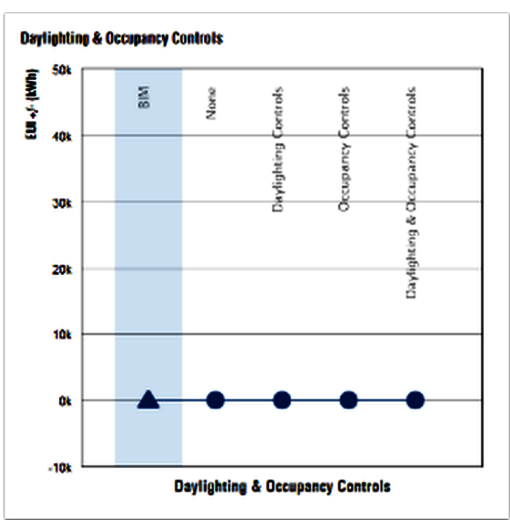

Figure 18. Daylighting & occupancy control.

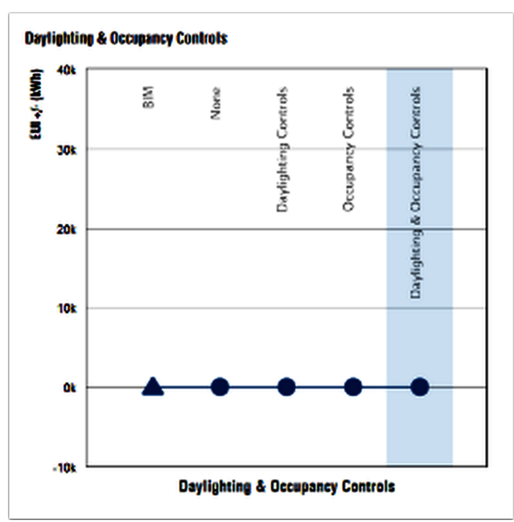

Figure 19. Daylighting & occupancy control together.

Daylighting refers to the deliberate use of natural light to brighten indoor spaces. It involves managing the entry of natural light, direct sunlight, and diffusing skylight into a building to decrease the need for electric lighting and conserve energy as shown in Figure 18. By connecting indoor environments with the ever-changing patterns of outdoor light, daylighting can create a visually engaging and productive environment for occupants, while reducing up to one-third of total building energy costs. A daylighting system is more than just having windows and skylights; it also includes a daylight-responsive lighting control system as shown in Figure 19. When daylight alone provides sufficient ambient lighting, this system can reduce the power of electric lighting. The design of daylighting requires a comprehensive approach, as it can involve decisions about the building form, location, climate, building components, lighting controls, and lighting design criteria. Occupancy control, in contrast, is a system that adjusts the level of natural and artificial light in a room based on its occupancy. These controls are essential to lighting design that incorporates both daylight and artificial light. They can enhance both visual and thermal comfort while significantly reducing energy use. For example, occupancy-based shutoff alone can save up to 38% of lighting energy for private offices, 50% in conference rooms, and 58% for classrooms. The success of lighting control design is measured by testing visual comfort in the room during occupied times and measuring the daily or monthly lighting energy use. The goal is to require less energy while still achieving comfort.

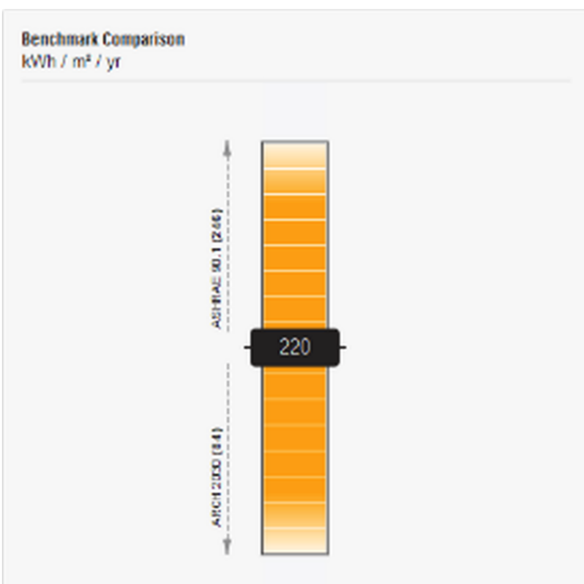

Figure 20. Initial Energy Run Results (EUI) 220 kWh/sqm/yr.

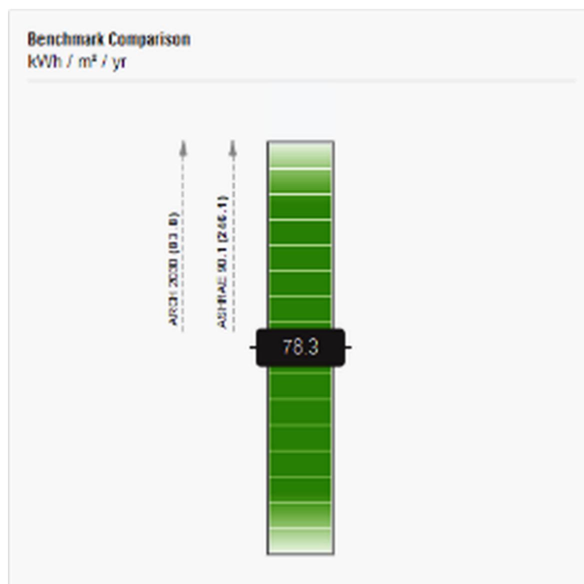

Figure 21. Optimized Energy Run Result (EUI) 78.3 kWh/sqm/yr.

The building performance is assessed by finding the gap between the existing and the optimized energy consumption which is lowered from 220 to 78.3 Kwh/sq.m/yr.

3.4. Comparison of the costs with initial simulation run and optimized result

The following four are the parameters that can be changed which will have the most impact on the running cost of the building in providing the following results.

- **HVAC:** Represents a range of HVAC system efficiency which will vary based on location and building size.

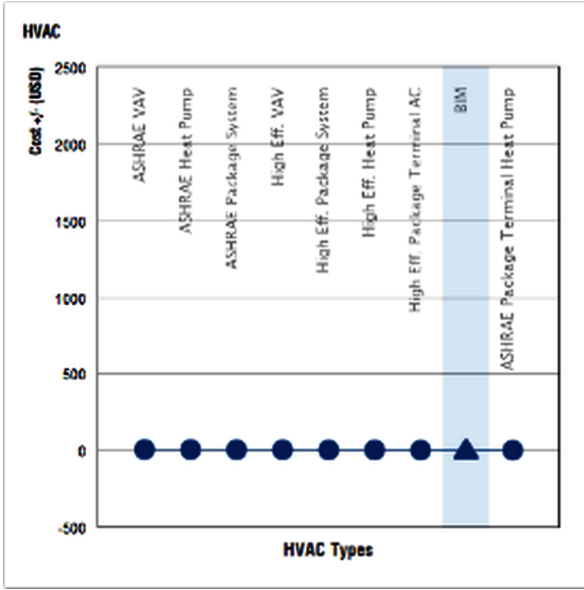

Figure 22. HVAC system cost.

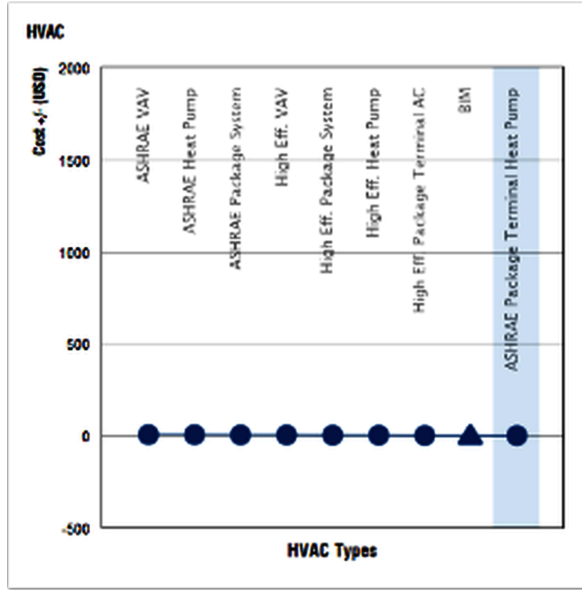

Figure 23. ASHRAE Package Terminal Heat Pump Cost.

- **Plug Load Efficiency:** The power used by equipment i.e., computers and small appliances; excludes lighting or heating and cooling equipment.

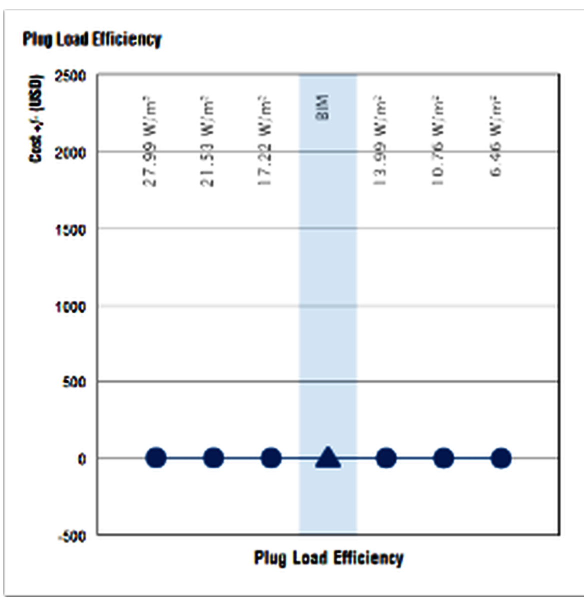

Figure 24. Plug load efficiency cost.

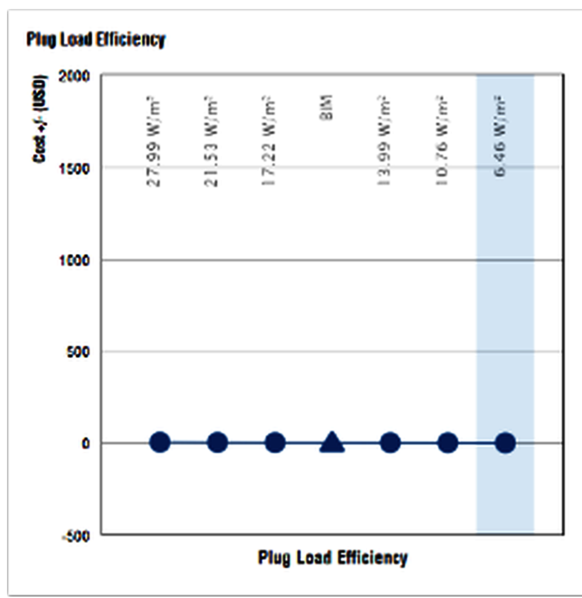

Figure 25. PLE improved & cost.

- **Lighting Efficiency:** Represents the average internal heat gain and power consumption of electric lighting per unit floor area.

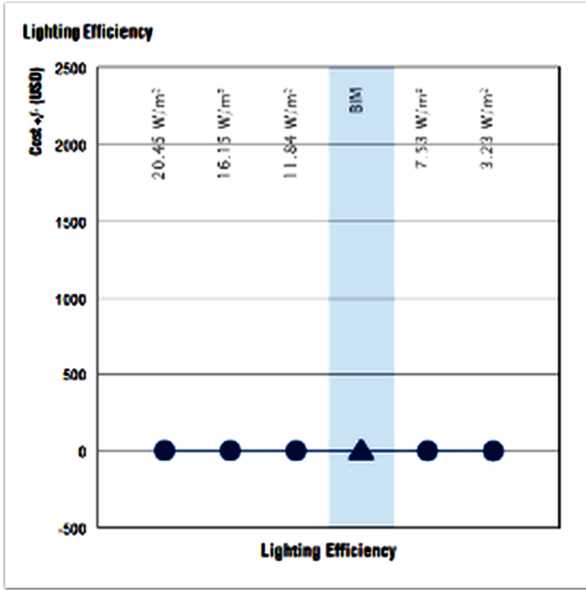

Figure 26. Lighting efficiency initial cost.

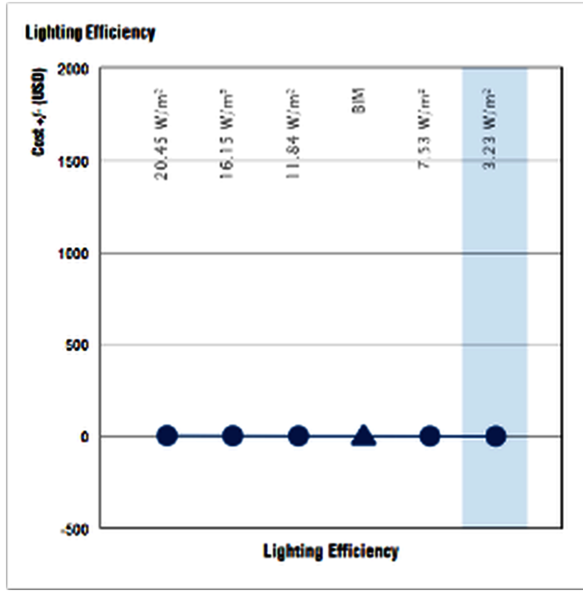

Figure 27. Lighting efficiency improved cost.

- **Daylighting & Occupancy Controls:** Represents typical daylight dimming and occupancy sensor systems.

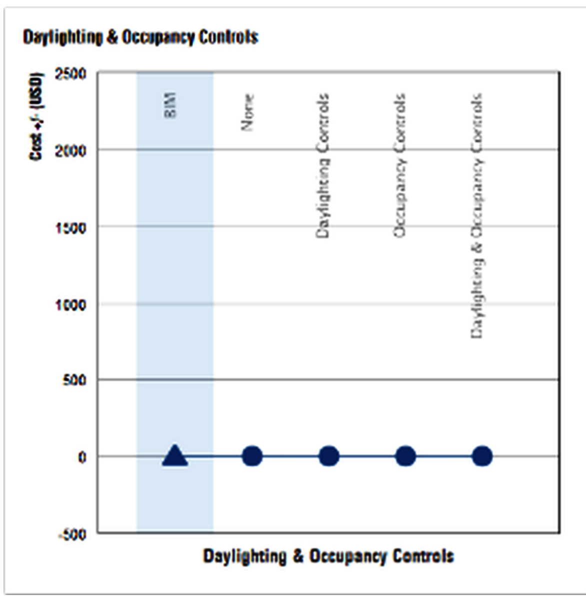

Figure 28. Daylighting & ocuppancy initial cost.

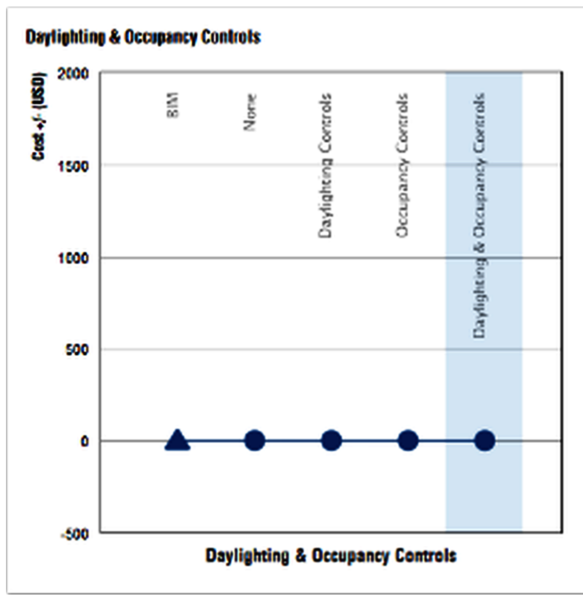

Figure 29. Daylighting & occupancy improved cost.

Daylighting & Occupancy Controls changed to Day lighting and occupancy control.

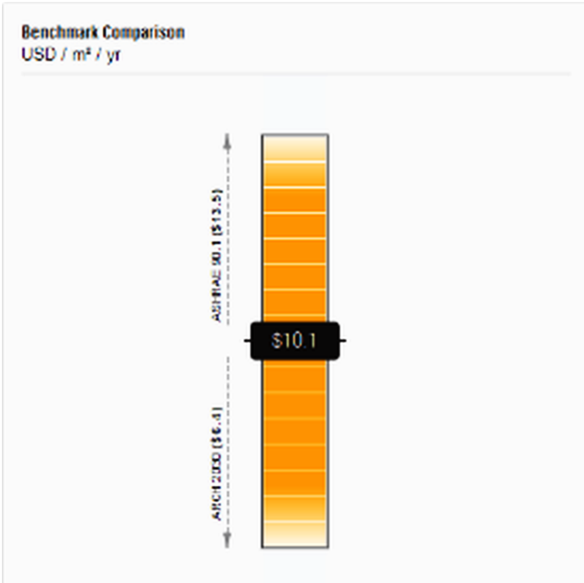

Figure 30. Cost Required - Initial Run (EUI): 10.1 USD/sqm/yr = 840.73 INR/sqm/yr.

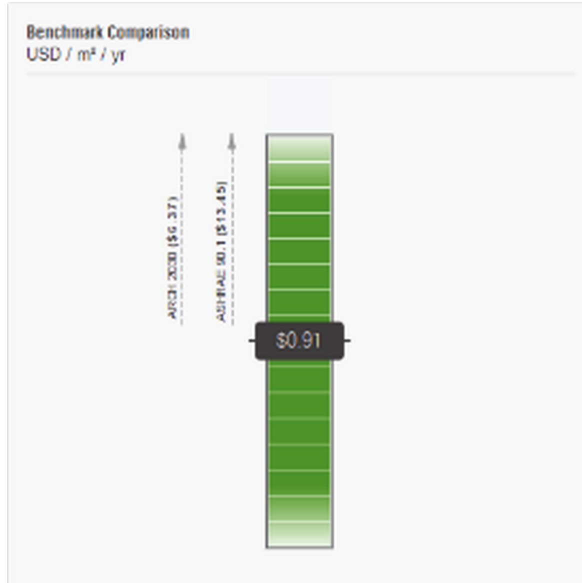

Figure 31. Cost Required - Optimized (EUI): 0.91 USD/sqm/yr = 75.75 INR/sqm/yr.

Cost analysis

4. Discussions

4.1. Total energy saved after optimization in a year

The table provides data on energy consumption and savings for a building with a total area of 14,692 square meters. In summary, optimizing energy use reduces consumption significantly, with the building saving an estimated 2,081,856.4 kWh/year compared to its initial energy usage.

Table 4. Energy Saved After Optimization.

S.no.	Energy required-initial run (EUI)	Energy required-optimized (EUI)	Energy required-initial run (EUI) for building	Energy required-optimized (EUI) for building	Energy saved	ASHRAE values
1	220 kWh/sqm/yr	78.3 kWh/sqm/yr	3,232,240 kWh/yr	1,150,383.6 kWh/yr	2,081,856.4 kWh/yr (estimated)	90.1 kWh/sqm/yr

Total area: 14692 sqm

4.2. Total cost saved after optimization in a year

Initially, the cost of energy usage is significantly higher at 10.1 USD per square meter per year, amounting to a total of 148,389.2 USD annually for the entire building. After optimization, the cost drops substantially to 0.91 USD per square meter per year, resulting in a total of approximately 13,369.72 USD annually. The optimized cost is also compared to the ASHRAE standard value of 1.15 USD per square meter per year, indicating that the optimized cost is well below this benchmark.

Table 5. Cost Saved After Optimization

S.no.	Cost required-initial run (EUI)	Cost required-optimized (EUI)	Cost required-initial run for building	Cost required-optimized (EUI) for building	Savings	ASHRAE values
1	10.1 USD/sqm/yr. = 840.73 INR/sqm/yr.	0.91 USD/sqm/yr. = 75.75 INR/sqm/yr.	148389.2 USD/sqm/yr. = 12352069.4 INR/sqm/yr.	13369.72 USD/sqm/yr. = 1112909.22 INR/sqm/yr.	135019.48 USD/yr. = 11239160.18 INR/sqm/yr. (estimated)	1.15 USD/sqm/yr

Total area: 14692 sqm

4.3. Recommendations for Optimization

The simulation results discussed above have led to some key recommendations for enhancing energy efficiency for the AJ hostel block at IIM, Bangalore which include:

- Improving insulation in the building like glass, walls, roof and floor.
- Upgrading the present cooling systems to energy-efficient HVAC systems.
- Implementing smart temperature controls in the hostel block.
- Exploring renewable energy options like solar power in hostel block.

These insights into the energy dynamics of the A-J Hostel Block identify critical improvement areas for sustainability.

Research Findings

- **Diverse Energy Profiles:** The study reveals significant variations in energy performance among hostel buildings in Bangalore, influenced by architectural design, insulation quality, HVAC systems, building orientation, and occupancy patterns.
- **Impact of Insulation:** High-quality insulation significantly reduces heating and cooling demands, emphasizing the need to enhance the building envelope.
- **HVAC Efficiency:** Energy-efficient HVAC systems lower temperature control energy requirements.
- **Occupancy Patterns:** Energy consumption is notably affected by occupancy schedules, suggesting benefits from occupancy-responsive management systems.
- **Renewable Energy Potential:** Integrating renewable sources, particularly solar panels, can substantially offset electricity use and support sustainability goals.

5. Conclusions

This study examined the energy performance of a hostel building at IIM Bangalore, utilizing tools like Autodesk Revit and Insight. The framework of the research integrates computational modeling, energy performance simulation, and sustainable design principles to propose energy optimization strategies for hostel buildings. The research is context-specific (focused on Bangalore) and has broader implications for urban energy efficiency and sustainability. Key findings highlighted factors influencing energy consumption, particularly the importance of architectural design, insulation quality, and HVAC system efficiency. Enhanced insulation was shown to improve thermal comfort while reducing energy use. The study emphasized the role of efficient HVAC systems, advocating for energy-efficient models and smart temperature controls. Some future study recommendations include occupancy-driven energy management systems to optimize usage in shared and unoccupied spaces.

The integration of renewable energy sources, such as solar panels, was also proposed to decrease reliance on conventional energy and promote sustainability. Furthermore, fostering energy awareness among residents was deemed very essential for responsible energy practices in India. The research offers a framework for improving hostel energy performance and suggests further investigation into user expectations, occupancy impacts on energy strategies, and the role of renewable technologies in enhancing student life and academic performance. The way forward in this study should focus on refining the energy models, scaling the research to a broader set of hostels, evaluating the performance of proposed measures in real-world settings, and ensuring that findings contribute to practical and policy-level change. Emphasizing long-term monitoring, cost-benefit analysis, and interdisciplinary collaboration will be essential for translating these findings into impactful, sustainable solutions.

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