

Retrofitting of Existing Building to Green Building - A Case Study

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DOI: <https://doi.org/10.30880/ijscet.2025.16.01.005>

Article Info

Received: 30 November 2024
Accepted: 4 June 2025
Available online: 30 June 2025

Keywords

HVAC, Light Power Density (LPD), retrofitting, sustainability, energy efficiency

Abstract

As the awareness on sustainability is enhancing in all the sectors of the society, as part of it many school and college buildings are also slowly altering from conventional building model to green building. A leading university in Hyderabad, India, has a commitment to environmental stewardship and wants to convert the present building into Indian Green Building Council (IGBC) green building campus. As a part of it the current research paper was attempted in adoption of measures such as water conservation, energy-efficient lighting, and advanced HVAC systems. Few teams are formed to observe and improve the efficiency in electricity, energy and water consumption as per Indian Green Building Council (IGBC) norms. By retrofitting plumbing fixtures and reducing Lighting Power Density (LPD), it is observed that a remarkable reduction of 35% in water consumption and an impressive 81% decrease in LPD through energy-efficient lighting fixtures. The sustainability initiatives implemented, not only lessen their ecological impact but also serve as a guiding light for other educational institutions. Their advocacy for water conservation, energy efficiency, and superior HVAC systems sets a commendable standard for a greener future.

1. Introduction

A leading educational institute of high repute in the area of Infrastructure, construction, real estate and project management is experiencing the high-power bill and high-water consumption charges from last few months due the hike in respective tariffs by the local bodies. The authorities of the university looked at this point and tried to explore the various alternatives to reduce the bills related to power and water, finally they feel that it is better to convert the entire university campus into green building campus as per various green building rating systems like Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), National Green Building Standard (NGBS Green), Well Building Standard, National Green Building Star (energy star), the IGBC green rating systems for water conservation, handling waste, energy efficiency, reduced use of fossil fuels, lower dependence on usage of virgin materials, providing health and well-being of occupants etc. The observation is that many educational institute buildings like schools, colleges have scope to become IGBC certified platinum rated green buildings. These certifications aim to enhance indoor environmental quality, maximize energy efficiency, and conserve water [1]. The university has put in place several initiatives to cut down on water usage, including wastewater treatment and rainwater harvesting. The institution has been able to reduce its water footprint and lead by example in the industry to these efforts. Additionally, the campus has put in place many energy-saving initiatives, including automated sensors and LED lighting, which have saved a significant amount of money while lowering the institution's carbon footprint [2]. The campus has also started various projects aimed at improving the efficiency of its HVAC systems, which have made the indoor

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environment for staff and students healthier and more comfortable. Overall, environmentally friendly operations align with the Indian Green Building Council's (IGBC) Green Campus assessment scheme [3],[4]. The organization's commitment to sustainability demonstrates its dedication to building a brighter future for everyone.

1.1 Problem Statement

Despite increased public awareness of environmental issues, many educational institutions struggle to implement effective sustainability measures due to lack of resources, ignorance, and inadequate infrastructure. This raises concerns about the sustainability of campus development and its long-term impact on the environment and well-being. Educational institutions must provide effective models of sustainable practices to encourage adoption and minimize negative environmental impact. The present study aimed in applying sustainable practices in main areas i.e focusing on (a) How much efficient in water utilization, plumbing fixtures utilization (b) Evaluation of energy-efficient lighting fixtures how effective they are (c) Observing the high-performance air conditioning equipment energy consumption.

1.2 Objective of Study

This study's primary goal is to renovate the present building into sustainable building in terms of water and energy saving initiatives align with the IGBC Green Campus rating system. Among the specific goals include assess the water conservation initiatives, emphasizing the use of low-flow and flush water fixtures as a means of cutting down on water usage; evaluate and implement the success of energy-saving lighting system initiatives, such as the installation of high-performance lighting fixtures and technologies; analyse how the investments in high-performance HVAC systems affect indoor comfort and energy use over a period of time; examine the extent to which eco-friendly operations confirm to the tenets and standards of the IGBC Green Campus assessment framework; based on the new initiatives successful implementation practices, offer recommendations to other educational institutions on how to improve their sustainability initiatives.

1.3 Scope

The current research study evaluates the sustainable practices to be followed in the current building, concentrating on water conservation, energy-efficient lighting, and HVAC system optimization. It examines the technical advancements, tactics, and outcomes achieved in these areas. The research assesses current building in alignment with the IGBC Green Campus rating system, providing insights into how the new initiatives support resource management and environmental sustainability. The study considers various factors such as infrastructure, resources, and overall strategy to determine the effectiveness of these sustainable practices. The conclusions and recommendations can be applied to educational settings, offering guidance to academic institutions aiming to implement eco-friendly practices and obtain Green Campus certification from the IGBC [5].

2. Literature Review

The analysis of life-cycle costs and the performance of green buildings revealed a dearth of empirical support for the presumptive superiority of green buildings in terms of comfort over conventional ones, underscoring the need for strong research methods [6]. They draw attention to the dearth of empirical data supporting the widely held belief that green buildings are more comfortable than traditional ones. They describe characteristics of indoor environmental quality but emphasize the need for strong research methods to confirm their effects. Water conservation measures brought attention to the unintended effects of green buildings on water quality, with particular attention paid to corrosion and microbial growth concerns [7]. Their emphasis on the age of the water in plumbing systems highlights issues with corrosion and the growth of microbial organisms. This lays the groundwork for additional research to create a foundational knowledge of these dynamics. The analysis underlined the need for comprehensive strategies and stressed the significance of comprehending economic factors for encouraging green building practices, particularly in the context of Indian construction [8]. They talk about adoption obstacles and emphasize how crucial it is to comprehend economic factors, especially in the context of Indian construction. This emphasizes the necessity of all-encompassing strategies for sustainable building practices. The importance of occupant behavior in a building's energy performance was emphasized, and new behavioral software models that seek to more precisely forecast energy consumption are promoting the use of multidisciplinary approaches [9]. Acknowledging the impact of occupants on energy consumption, they present novel behavioral software models designed to improve energy use prediction. This highlights the significance of taking human behavior into account in the design of sustainable buildings and stresses multidisciplinary solutions for achieving low- or zero-energy buildings.

3. Methodology

3.1 Water Efficient Plumbing Fixtures

The present buildings in the campus can become more efficient in terms of water management and sustainability by retrofitting water-efficient plumbing fixtures. This program prioritizes fixture upgrades for buildings with higher patterns of water consumption. By carefully choosing and installing these fixtures, the campus can significantly reduce water consumption without compromising functionality or the user experience [10]. The effectiveness of the retrofitting efforts will be verified through comprehensive testing, monitoring, and post-installation procedures, ensuring any necessary adjustments. This systematic approach promotes resource conservation and environmental responsibility while guaranteeing that the total annual water consumption remains within base case limitations mentioned in Table 1.

Table 1 Baseline flow rates/ consumption per plumbing fixtures

Fixture Type	Maximum Flow Rate/Consumption	Duration	Estimated Daily uses per FTE*
Water Closets (Full Flush)	6 LPF	1 flush	1
Water Closets (Half Flush)	3 LPF	1 flush	4
Urinals	4 LPF	1 flush	6
Faucets/Taps	6 LPM	15 seconds	8
Health Faucet	6 LPM	15 seconds	1
Shower Head/ Hand-held Spray	10 LPM	8 Minutes	1

The Full-time equivalent (FTE*) indicates a typical building occupant who is inside the building for eight hours every day. For calculating the total amount of water used in an establishment, need to determine the flow rate of every single plumbing fixture and multiply it by the FTE. By comparing this data with the baseline information, that can estimate the share of water savings achieved by fixture retrofitting. By implementing a comprehensive retrofitting approach and adhering to the baseline specifications, hope to ensure that at least 50% of the campus structures have water-efficient plumbing systems installed or upgraded. This entails employing fixtures with flow rates that are ten percent lower than the prescribed baseline [11].

3.2 Energy-Efficient Lighting Fixtures

To guarantee that more than half of the campus's high-energy-use buildings satisfy the lighting electrical power density standards of ASHRAE Standard 90.1-2010, employ a methodical approach. Following the identification of high-energy-use buildings, determine the LPD for interior spaces, common areas, and parking facilities [12]. Depending on the particular requirements of each building, then choose between the "Building Area Method" and the "Space-by-Space Method" as a compliance approach. In order to determine the LPD of existing buildings, are taking into consideration the "Building Area Method". In the 'Building Area Method', the steps are as followed:

- Identify the gross lighted floor area (square feet) of the building area type.
- Calculate the total wattage of light required by multiplying the number of light fixtures with the wattage rating of each individual light.
- The allowance allowed for interior lighting illumination for the building is the sum of the lighting power allowances of all building area types is measured.
- Then divide the total wattage rating of an area with a gross illuminated floor area to get the LPD of that area.
- Determine the appropriate building area type from ANSI/ASHRAE/IES Standard 90.1-2010 guidelines and the allowed LPD (watts per unit area) from the "Building Area Method" column. For building area types not listed, the selection of a reasonably comparable type will be permitted.
- To assess the building lighting standards, compare the measured LPD with ANSI/ASHRAE/IES Standard 90.1-2010.

$$\text{Reduction In LPD} = \left(\frac{\text{Permissible power usage} - \text{Actual power usage}}{\text{Permissible power usage}} \right) \times 100\% \quad (1)$$

After assessing the existing fixtures for lighting, will create an energy-effective replacement or retrofit plan to meet LPD criteria. After installation, check for compliance and create thorough reports that include LPD estimations, inventory, methodology, and installation processes [13], [14]. This method complies with ASHRAE Standard 90.1-2010, meets requirements for operation, and encourages energy conservation. Hence 50% of campus buildings with higher energy demands must reduce LPD by 20% over ASHRAE Standard 90.1-2010 in order to comply with IGBC regulations.

3.3 High- Performance Air Conditioning Equipment

The used of information such as size, consumption, and history to determine energy-intensive buildings in order to guarantee that more than 50% of high energy-demand college buildings fulfill the requirements for air conditioning efficiency set forth in ASHRAE Standard 90.1-2010. After that, the air conditioning systems assess in each building for things like cooling capacity, energy consumption, equipment age, and maintenance records. Metrics like COP and SEER used to gauge efficiency.

$$\text{Improvement in Efficiency} = \left(\frac{\text{Rated SEER Rating} - \text{Base Line SEER Rating}}{\text{Base Line SEER Rating}} \right) \times 100 \% \tag{2}$$

The SEER (Seasonal Energy Efficiency Ratio) rating of air conditioners installed in buildings with greater energy demands should be compared to its rating according to ASHRAE standards. The COP (Coefficient of Performance)/efficiency of at least 50% of the campus buildings with air conditioning installed and greater energy consumption should be at least 2.5% higher than the ASHRAE standard 90.1-2010 baseline. The campus buildings can have energy-efficient HVAC systems that fulfill energy demand while using less energy by complying with this criterion. Institutions can lower their energy expenses and impact on the environment by adhering to these energy efficiency recommendations [15],[16].

4. Data Collection

The water faucets on campus are designed to foster a welcoming and safe environment for all faculty, staff, and students engaged in learning and work. To facilitate this goal, the campus has made significant investments in robust infrastructure systems, encompassing HVAC, lighting, and plumbing. An extensive data collection initiative was undertaken to guarantee optimal performance and efficiency. This initiative revealed various challenges within the plumbing, lighting, and HVAC systems, which were effectively addressed based on recommendations from a team of experts. The outcomes underscore the importance of strategic upgrades and proactive maintenance in establishing a supportive atmosphere for education and work. By taking the initiative to resolve infrastructure concerns and implementing a thorough maintenance strategy, it can ensure that these systems operate effectively and meet the anticipated standards.

4.1 Water Efficient Plumbing Fixtures

To evaluate the sustainability of water fixtures, their average flow rates are important. The Green Campus Manual listed six basic hygienic elements that are useful in assessing a campus's water efficiency, including showerheads, faucets, urinals, and water closets. The flow rates of these fixtures are compared at a pressure of 3 bar to identify inefficiencies and prioritize replacements or upgrades. Conformity with sustainability criteria is benchmarked against baseline values. Fixtures that achieved or exceed these values show a dedication to resource management and water conservation, supporting overall sustainability objectives as well and portrayed in Table 2.

Table 2 Comparison between baseline and actual flowrates

Fixture type	Baseline flowrates	Actual flowrates
Water closets (Full Flush)	6 LPF	4 LPF
Water closets (Half Flush)	3 LPF	2 LPF
Urinals	4 LPF	2 LPF
Faucets/Taps	6 LPM	6 LPM
Health Faucets	6 LPM	4.5 LPM
Shower Head	10 LPM	6 LPM

The total campus has 287 FTE occupants. The IGBC's Green Campus Manual is used to calculate daily water usage and multiplied the maximum flow capacity of each fixture with the duration of daily use and with the total number of occupants as presented in Table 3.

Table 3 Total daily water consumption as per baseline

Fixture Type	Maximum Flow Rate/Capacity	Duration (in min)	BASELINE	
			Daily Uses	Total Daily Uses
Water Closets	6 LPF	1 flush	1	1722
	3 LPF	1 flush	4	3444
Urinals	4 LPF	0.25	6	1722
Faucets/Taps	6 LPM	0.25	8	3444
Health Faucet	6 LPM	0.25	1	430.5
Shower Head	10 LPM	8	1	22960

Whereas when calculate actual water consumption as per the existing fixtures by comparing the flow rate at 3 bar pressures, get the following result provided in Table 4. The total daily uses are calculated by multiplying total occupants with the actual flow capacity of that fixture along with the duration and daily uses.

Table 4 Total daily water consumption as per actual design

Fixture Type	Flow Rate/Capacity	Duration (in min)	Actual Design	
			Daily Uses	Total Daily Uses
Water Closets	4 LPF	1 flush	1	1148
	2 LPF	1 flush	4	2296
Urinals	2 LPF	0.25	6	861
Faucets/Taps	6 LPM	0.25	8	3444
Health Faucet	4.5 LPM	0.25	1	322.87
Shower Head	6 LPM	8	1	13776

4.2 Energy-Efficient Lighting Fixtures

The 'Building Area Method' is used to measure lighting fixture efficiency as per ASHRAE Standard 90.1-2010. As per this method LPD must not exceed 0.99 W/ft². There are 7 buildings in the present campus and need to meet the LPD value for at least 50% of them. The investigation of the total gross illuminated floor area and wattage of light across all buildings, the details are provided in Table 5.

Table 5 Comparison between permissible and actual lighting power usage

Building Name	Gross Lighted Floor Area (Ft ²)	LPD (W/Ft ²) Permissible	Permissible	Actual
			Gross Lighted Floor Area* LPD (Watt)	Total Lighting Power Usage (Watt)
B1	58213.24	0.99	57631.11	17608
B2	49506.04	0.99	49010.98	9680
B3	44205.57	0.99	43763.51	6536
B4	21935	0.99	21715.65	4892
B5	29312	0.99	29018.88	2724
B6	52776	0.99	52248.24	8300
B7	52776	0.99	52248.24	8300

The gross illuminated area of a building encompasses the complete interior space, which includes restrooms and communal areas. It is essential for each room to adhere to the minimum lighting standards established by the

National Building Code. To determine the Total Lighting Power Usage, one must sum the wattage ratings of all lighting fixtures, omitting any exterior lighting [17].

4.3 High-Performance Air-Conditioning Equipment

The air conditioning facilities studied in three of our seven buildings. The type of air conditioner, refrigeration tonnage, and Bureau of Energy Efficiency (BEE) ratings followed, including EER/SEER values and portrayed in Table 6. The air conditioning units play a vital role in determining energy efficiency and regulating temperature and humidity to maintain comfort. However, inefficient units can cause high energy bills and increase the facility's carbon footprint.

Table 6 EER and SEER value of air conditioners

Make	Model	Total No of AC	TR	EER	SEER
Voltas	1.5T Vertis Elite	10	1.5	2.76	3.15
Voltas	183 JZCT	12	1.5	3.09	3.53
Blue Star	FS318VLTU	9	1.5	3.52	4.02
Blue Star	FA318DNU/BO	12	1.5	3.82	4.37
Daiken	RL50TV16V2	109	1.5	3.64	4.16
Voltas	1.0T Voltas 123 DYa	20	1	2.76	3.15
Daiken	RQG60TV16U2	2	2	4.45	5.09
Voltas	4501467	1	2	2.91	3.33
Voltas	2.0T VERTIS PLUS	29	2	2.8	3.20
Voltas	2.0 T VOLTAS 243 LYU	5	2	3.13	3.58
Voltas	Vertis Classic/4501243	5	2	2.58	2.95
Blue Star	FMA36AAMUP3	6	3	3.2	3.66
Voltas	2T VENTURE E CASSETTE SPLIT	5	2	3.3	3.77

5. Result and Discussion

5.1 Result

The data gathered on three sections and compare it with the standard parameters from the Indian Green Building Council and ASHRAE Standard 90.1-2010 to determine the parameters encounter the required standards. This ensures buildings are designed and constructed efficiently in an environmentally-friendly manner.

5.1.1 Water Efficient Plumbing Fixtures

By comparing the total daily water consumption based on the baseline with the total daily water consumption based on the actual design, fixture by fixture, it can determine the percentage of water saved due to the use of retro-fit water-efficient plumbing fixtures. The comparison of both can be found in the Fig. 1 in the form of bar graph.

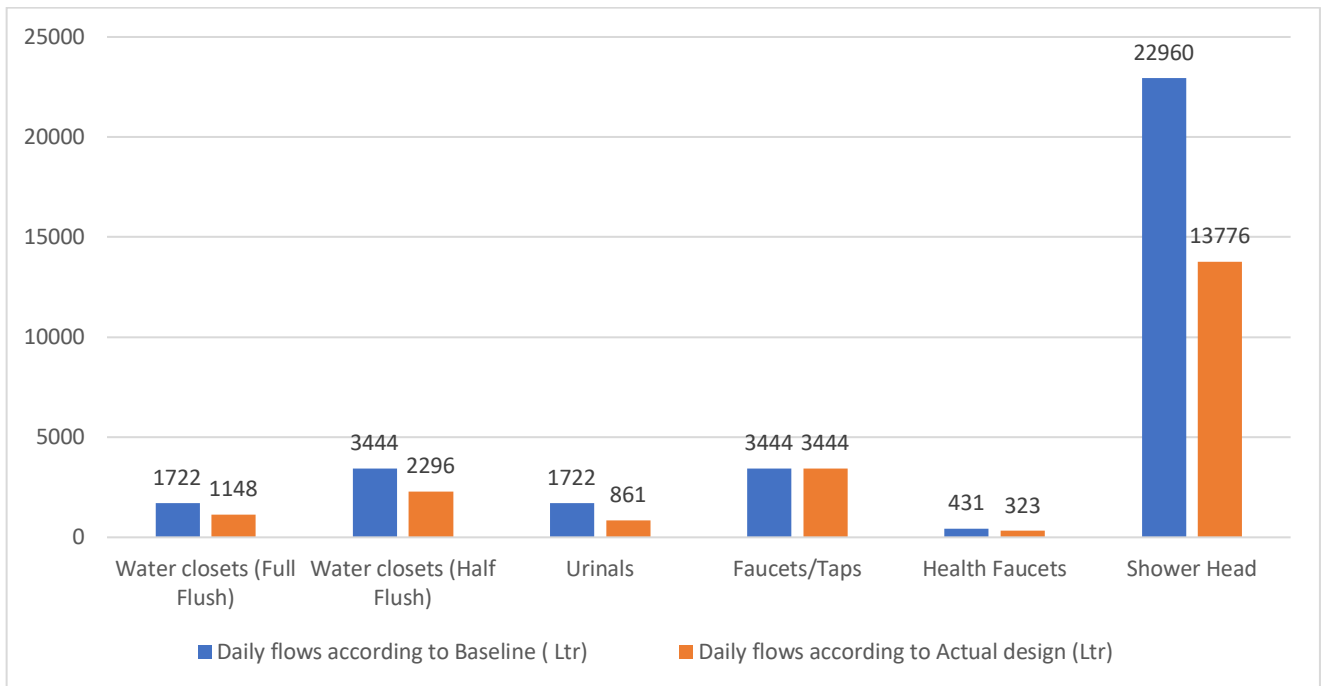


Fig. 1 Comparison of daily water consumption in liters

Hence, the percentage saving in water according to the actual design by fixture can be determined by comparing it with baseline water consumption shown in Fig 2.

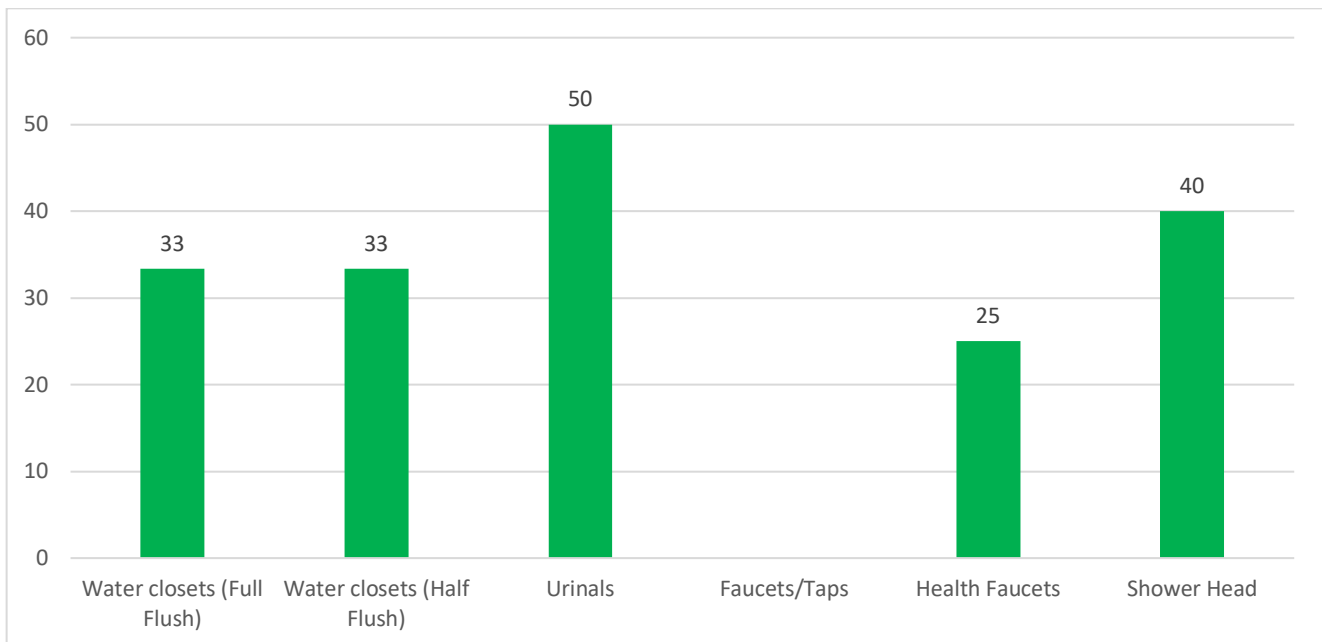


Fig. 2 Fixture wise water saving in percentage

As it can infer from the comparison graph the faucets/ taps have the same flow rate as the baseline flow rate so there will be zero percent amount of water saving in comparison to baseline flow rate standards.

5.1.2 Energy-Efficient Lighting Fixtures

The energy efficiency in lighting fixtures can be measured by comparing between permissible and actual lighting power usage. In the campus for every building, calculated the reduction in LPD due to the usage of good-rating lighting fixtures, the results are very good in numbers.

For example the building B1 the permissible power usage for lighting as per Building Area Method is 57631.11 Watts. The Actual power usage for lighting in B1 is 17608 Watts. So, by application of the equation 1, the reduction

of LPD is found to be 69 %. Similarly, the reduction in LPD for the other six buildings was calculated and results were shown in Fig. 3.

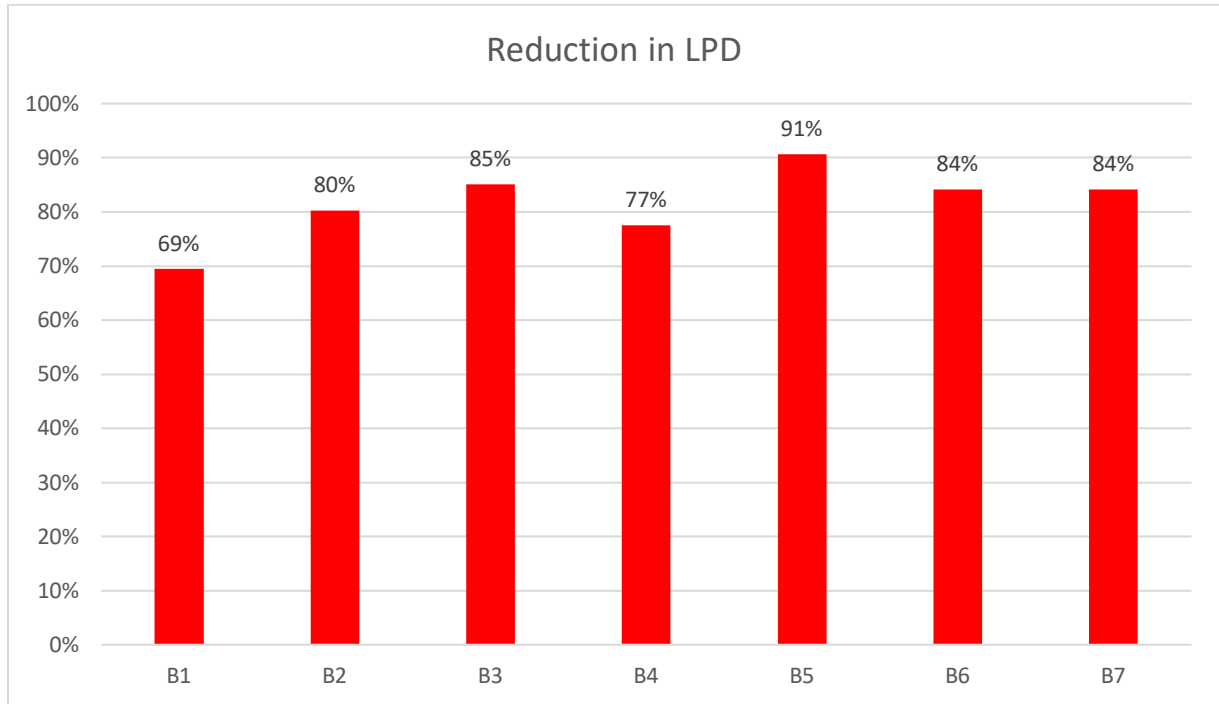


Fig. 3 Reduction in LPD

5.1.3 High-Performance Air-Conditioning Equipment

In the premises there are a total 225 no of air conditioners that are available in three buildings. Out of which 220 Air conditioners satisfy the minimum SEER rating as per ASHRAE Standard 90.1-2010. The improvement in efficiency of a type of Air Conditioner can be evaluated by comparing it with the baseline SEER rating.

For example Daiken company AC having model no RL50TV16V2 is 1.5-ton AC with 3-star BEE rating. The SEER value of this AC is 4.16 and the baseline SEER value for 1.5-ton AC is 3.

So, by application of the equation no 2 the improvement in Efficiency is found by 38.67 %. Similarly, calculated the improvement in efficiency for all the types of Air Conditioners available and the result is mentioned in the Table 7. According to the table, the only Air Conditioner that does not meet the minimum SEER value is the Vertis Classic/4501243 Make-Voltas, which is showing a negative percentage improvement in SEER.

Table 7 Percentage improvement in SEER rating

Make	Model	% Improved SEER
Voltas	1.5T Vertis Elite	5.14
Voltas	183 JZCT	17.67
Blue Star	FS318VLTU	34.10
Blue Star	FA318DNU/BO	45.52
Daiken	RL50TV16V2	38.67
Voltas	1.0T Voltas 123 DYa	5.14
Daiken	RQG60TV16U2	69.52
Voltas	4501467	10.86
Voltas	2.0T VERTIS PLUS	6.67
Voltas	2.0 T VOLTAS 243 LYU	19.24
Voltas	Vertis Classic/4501243	-1.71
Blue Star	FMA36AAMUP3	21.90
Voltas	2T VENTURE E CASSETTE SPLIT	25.71

After the critical evaluation of IGBC green building principles and implementing the recommended changes the output of savings is tabulated in Table 8.

Table 8 Savings in various parameters

Description	Improved Efficiency in %
Water faucets flow reduction	35
Both room water consumption reduction	50
Overall energy efficient lighting fixtures	81
Air conditioners efficiency/ SEER value Improvement	70

5.2 Discussion on Results

Sustainable site planning is a critical aspect of any campus that aims to reduce its environmental impact and promote eco-friendliness. In the observed campus, the evaluation is based on three critical factors for sustainable site planning: efficient in water utilisation, plumbing fixtures, energy-efficient lighting fixtures, and high-performance air conditioning equipment. Regarding water-efficient plumbing fixtures, tested on six different fixtures against benchmark standards and observed in the campus has achieved a 35% reduction in water usage, meeting the criteria set by the IGBC standards. The evaluation helped to identify that urinals with the least amount of water flow saved the highest percentage of water by 50%, the least amount of water is saved while using faucets/taps. By realising these results, can significantly reduce our water consumption further and promote water conservation. The second factor evaluated is the use of energy-efficient lighting fixtures. The evaluation process exhibited that the implementation of energy-efficient lighting fixtures has resulted in an 81% reduction in Lighting Power Density (LPD). Among the buildings, building- 5(B5) achieved the highest reduction in LPD i.e., 91%, while building-1(B1) achieved the lowest reduction in LPD i.e., 69%. These results are indicative that our campus is moving in the right direction toward promoting energy-efficient practices. Thirdly, the assessment on the use of high-performance air conditioning equipment. Out of 225 air conditioners, 220 meet the minimum SEER rating as per ASHRAE standards. The present study revealed that Daiken (RQG60TV16U2) achieved the highest percentage of improved SEER i.e., 70%. However, the only model from Voltas (Vertis Classic /4501243) could not satisfy the base SEER value as per ASHRAE standards as portrayed in table 7. It is observed that, need to plan better to ensure that all air conditioning equipment meets the minimum SEER rating as per ASHRAE standards. Finding areas for improvement was made easier by evaluating these three essential components of sustainable site planning. By making the required adjustments, the environmental impact can be significantly reduced and eco-friendliness can be promoted. These pathways are dedicated to carrying on this work and creating a more environmentally friendly and sustainable campus.

6. Conclusion

The problem of global warming has resulted in increased attention towards reducing carbon footprint at various levels, including educational institutions. The research was initiated due to high power and water consumption charges paid by the campus management to local authorities, study revealed that the green building council standards are very effective in minimizing environmental impact and promoting sustainability within existing campus with noteworthy changes in water, energy and power consumption charges for last few months. The installation of low-flow and flush water fixtures resulted in a significant reduction in water consumption, indicating the institution's commitment to resource efficiency. Similarly, using high-performance lighting fixtures and technology led to significant energy savings, consistent with global initiatives to reduce energy consumption and greenhouse gas emissions. The investment in high-performance HVAC systems in existing buildings improved energy efficiency and indoor occupant comfort, aligning with sustainable development principles, and enhancing the campus community's well-being. In addition, the study evaluated compliance with the IGBC Green Campus grading system, highlighting the institution's commitment to meeting and exceeding sustainability goals. The research study focused on three aspects like how efficiently using of water, energy and study energy utilisation air conditioning equipment is as per green building rating systems or not. The results obtained are satisfactory to meet the IGBC standards, the campus has been accredited with IGBC platinum rated campus. By achieving an IGBC PLATINUM rating certificate, our institute sets an example for other educational institutions to improve their sustainability efforts by adhering to established sustainability standards. Water conservation, energy efficiency, and compliance with sustainability requirements are critical in reducing environmental impact and promoting a healthier, more sustainable future. The study emphasizes the importance of educational institutions highlighting and implementing effective sustainable practices, as they can play a crucial role in addressing environmental issues and fostering a sustainable culture for current and future generations by working together.

Acknowledgement

Authors affirm that they have no conflicts of interest in publication of this research paper. The authorities who supported in conducting this research study are acknowledged by all authors.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Sandeep Kumar Sahoo, U Kaarthikesh; **data collection:** Sandeep Kumar Sahoo; **analysis and interpretation of results:** Sandeep Kumar Sahoo, U Kaarthikesh, P. Muralidhar; **draft manuscript preparation:** Sandeep Kumar Sahoo, P. Muralidhar. All authors reviewed the results and approved the final version of the manuscript.*

References

- [1] Vyas, G. S., & Jha, K. N. (2018). What does it cost to convert a non-rated building into a green building. *Sustainable cities and society*, 36, 107-115.
- [2] Fachrudin, H. T. (2020, May). Green campus concept based on architect perspective. In *IOP Conference Series: Materials Science and Engineering* (Vol. 801, No. 1, p. 012028). IOP Publishing.
- [3] Zuo, J., & Zhao, Z. Y. (2014). Green building research–current status and future agenda: A review. *Renewable and sustainable energy reviews*, 30, 271-281.
- [4] Manna, D., & Banerjee, S. (2019). A review on green building movement in India. *Int. J. Sci. Technol. Res*, 8(10), 1980-1986.
- [5] Almeida, L., Tam, V. W., Le, K. N., & She, Y. (2020). Effects of occupant behaviour on energy performance in buildings: A green and non-green building comparison. *Engineering, Construction and Architectural Management*, 27(8), 1939-1962.
- [6] Paul, W. L., & Taylor, P. A. (2008). A comparison of occupant comfort and satisfaction between a green building and a conventional building. *Building and environment*, 43(11), 1858-1870.
- [7] Rhoads, W. J., Pruden, A., & Edwards, M. A. (2016). Survey of green building water systems reveals elevated water age and water quality concerns. *Environmental Science: Water Research & Technology*, 2(1), 164-173.
- [8] Gavit, N. S., Vyas, G. S., & Nikhar, C. K. (2023, February). Identification of Green Rating Attributes for Metro Station: An Indian Case Study. In *International Conference on Sustainable Built Environment* (pp. 277-295). Singapore: Springer Nature Singapore.
- [9] Eisenstein, W., Fuertes, G., Kaam, S., Seigel, K., Arens, E., & Mazingo, L. (2017). Climate co-benefits of green building standards: water, waste and transportation. *Building Research & Information*, 45(8), 828-844.
- [10] Das, O., Bera, P., & Moulick, S. (2015). Water conservation aspects of green buildings. *Int. J. Res. Eng. Technol*, 4(25), 75-79.
- [11] Lai, F., Zhou, J., Lu, L., Hasanuzzaman, M., & Yuan, Y. (2023). Green building technologies in Southeast Asia: A review. *Sustainable Energy Technologies and Assessments*, 55, 102946.
- [12] Illankoon, I. C. S., Tam, V. W., Le, K. N., & Shen, L. (2017). Key credit criteria among international green building rating tools. *Journal of cleaner production*, 164, 209-220.
- [13] Rhoads, W. J., Pruden, A., & Edwards, M. A. (2016). Survey of green building water systems reveals elevated water age and water quality concerns. *Environmental Science: Water Research & Technology*, 2(1), 164- 173.
- [14] ASHRAE, S. (2007). 90.1: Energy standard for buildings except low-rise residential buildings. American Society of Heating, Refrigerating and Air-Conditioning Engineers.
- [15] Şirin, C., Goggins, J., & Hajdukiewicz, M. (2023). A review on building-integrated photovoltaic/thermal systems for green buildings. *Applied Thermal Engineering*, 229, 120607.
- [16] William J. Rhoads, Amy Pruden, and Marc A. (2016). Survey of green building water systems reveals elevated water age and water quality concerns, *Environmental Science Water Research & Technology*, 2, 164-174. Retrieved May 6, 2020, from <https://coronavirus.jhu.edu/map.html>.