Enhancing Sustainability in Educational Buildings through Retrofitting:

Case Study of a School in Mira Bhayandar, Maharashtra

Under Subtheme: SDG 7: Affordable and Clean Energy

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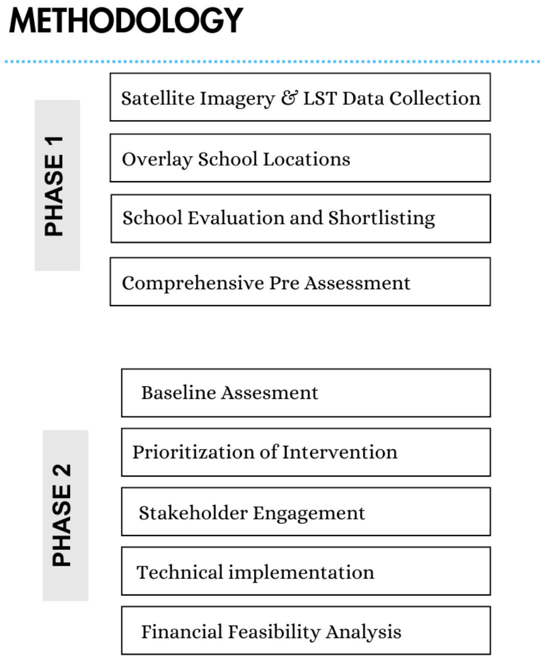
India's rapid urbanization has led to increased greenhouse gas emissions, particularly from buildings, which account for 37% of the nation's energy consumption. In Mira Bhayandar, this project focuses on retrofitting three selected schools to enhance sustainability and resilience, targeting a minimum 20% improvement in energy and water efficiency. These schools were chosen based on factors such as structural stability, student population, building orientation, and their potential to serve as emergency shelters during crises. Heat reduction measures include applying solar reflective index (SRI) paint on the roof to reduce solar heat gain, complemented by passive cooling strategies that naturally lower indoor temperatures. Energy efficiency is aimed to be improved through the installation of LED lighting and BLDC fans, while water conservation measures include installation of dual flush cisterns and aerators. The project involves key stakeholder's local government, community members, and students, who will engage in capacity-building initiatives to understand the benefits of green retrofitting. Educational workshops on energy conservation and climate awareness will empower students to adopt sustainable practices. The interventions will be evaluated using the EDGE certification framework to ensure compliance with global green standards. A financial feasibility analysis will assess the payback period for these upgrades. This case study aims to serve as a replicable model for sustainable retrofitting across India's educational institutions, contributing to lowcarbon development and community resilience.

KEYWORDS: EDGE certification, Energy efficiency, Greenhouse gas emissions, Green Retrofitting, Sustainability, Water efficiency

Introduction

As awareness of environmental challenges grows, adopting sustainable practices has become the need of the hour in every aspect of life. Among these challenges, over reliance on fossil fuels not only contributes to global warming but also exacerbates energy shortages (Zhao et al., 2015). The core causes of today's environmental problems are sociocultural fragility and inadequate understanding of the interdependence of humans and the natural world (Meiboudi et al., 2016). Only with comprehension and understanding can an environmentally friendly society be established, and to practice sustainability and engage with habitats, educational systems must reform (Ferrer-Balas et al., 2010; Jabbour et al., 2013). In recent years, the emphasis on sustainability has been increased and institutional buildings are not untouched from it. Schools stand at the forefront of this movement and serving both as educational hubs and community role models for sustainability. According to the U.S. Department of Energy (2019), buildings account for approximately 40% of total energy use and 38% of carbon dioxide emissions in the United States. This highlights the need for sustainable practices in the design, construction, and operation of educational facilities. Retrofitting is the practice of adding modern elements, materials, and technologies to older structures to increase the structure's performance in terms of energy and water efficiency (Khan et al., 2020). This approach is particularly relevant in the context of existing educational buildings. Retrofitting of existing educational buildings presents a feasible solution to promote sustainability, reduce energy consumption, and create healthier learning environments for learning. Educational institutions can use retrofitting to turn old buildings into models of environmental sustainability and energy efficiency in order to satisfy sustainability goals and lower their carbon footprints (Gonzalez et al., 2019).

Sustainability in educational buildings is not only a trend, it is an essential that it aligns with broader global efforts to tackle climate change and promote environmental sustainability prioritizing shared responsibility. Educational institutions have a unique opportunity to lead by example demonstrating sustainable practices to students and he community at large. By promoting sustainability, educational buildings can nudge a culture of environmental awareness and responsibility among students preparing them to be informed citizens and future leaders in sustainability (Zhang et al., 2018). Sustainable educational buildings contribute to improved indoor environmental quality, which is crucial for student health and academic performance. Thermal comfort, lighting, and air quality all have a big influence on how well students study (Miller & Spence, 2021). Higher student performance on assessments has been linked to improved ventilation and air quality in schools (Shaughnessy et al., 2015).



Retrofitting educational buildings involves a range of strategies aimed at improving energy efficiency, reducing water consumption, and increasing the overall sustainability. Common retrofitting measures include upgrading insulation, installing energy-efficient windows, implementing advanced heating, ventilation, and air conditioning (HVAC) systems and solar panels (Alsharif et al., 2016). In retrofit projects, brushless direct current (BLDC) fans significantly enhance indoor air quality and energy efficiency by using up to 70% less energy than traditional fans (Kumar et al., 2021; Sharma & Gupta, 2022). Solar Reflective Index (SRI) paint and aerators play crucial roles in enhancing energy efficiency and water efficiency in buildings. SRI paint reflects solar radiation, reducing heat absorption and lowering cooling energy demands, which leads to significant energy savings, especially in hot climates (Mardiana et al., 2020). Meanwhile, aerators improve water efficiency by reducing flow rates in faucets and fixtures, which not only conserves water but also decreases the energy required for heating water, further contributing to overall energy efficiency in residential and commercial settings (Smith & Johnson, 2021).

Mira Bhayandar

Area	79 sq km
Average temp	26 °C
Climate	Hot and humid weather
Population	809378 (Census, 2011)
Average Rainfall	1639mm

While existing studies have explored various technologies for enhancing energy efficiency in building retrofitting, there remains a significant gap in understanding the combined impact of BLDC fans, SRI paint, dual flush system and aerators on overall energy and water efficiency. Most of the research has concentrated on individual technologies, ignoring the potential cumulative impact of implementing them together (Mardiana et al., 2020; Smith & Johnson, 2021). Furthermore, there is limited empirical data on the long-term performance and cost-effectiveness of these technologies when integrated into retrofitting projects, particularly in diverse climatic conditions (Kumar et al., 2021). Existing literature highlights the potential of building retrofitting to reduce energy consumption and improve resilience (Almusaed & Almssad, 2021). Frameworks like EDGE have been successfully applied to evaluate green retrofitting projects in diverse settings (IFC, 2022). However, there is a lack of case studies focusing on Indian schools, particularly in urban contexts like Mira Bhayandar. This research aims to bridge that gap, providing a replicable model for sustainable retrofitting in educational institutions.

In a city like Mira-Bhayandar, where development is happening at a rate which is uncomprehensible, it is essential we look at solutions which provide with the most sustainable solution for existing buildings. Given that the buildings in Mira-Bhayandar are already being built at a rapid rate, its essential for architects to look for solutions which are more sustainable than resorting to demolition of the buildings. The entire process of demolition of a building incorporates multiple steps, each of which creates more problems than it solves. Green retrofitting in existing buildings becomes a solution with least time-consuming process and least waste generated and a process which is both sustainable in terms of finance and materials in the longer run.

Methodology

1. Mapping of Hotspots in the city context using GIS for selection of school.
    a. The context of Mira Bhayandar was studied through GIS to analyse the heat hotspots in the city, once done, this was overlapped with the vulnerable population, and about 10 schools were selected for further analysis. *(Should we add a map here of the same?)*
    b. *How GIS was used. Method in GIS,*
2. The selected schools were then further bifurcated using following parameter,
    a. Green Retrofitting carters to majorly 4 sectors of a building, energy, waste, water, and materials.
    b. In the Mira-Bhayandar Municipal Schools which were selected for demonstration, the option for demolition the existing building was an option which would not yield sustainable results; hence we opted for an existing green retrofitting of the building.
    c. The chances of redevelopment of the MBMC Schools were high in some the schools falling under the heat stressed spots as the buildings were 15-20 years old.
    d. Due to the possibility of redevelopment in the school buildings the selection then came down to 3 buildings, school number 2, 11 and 35.
    e. Since the project was being funded by Grant Money, the money had to be used wisely and hence the buildings which were finalised were thoroughly assessed by a structural engineer, Green Building Expert, and an Architect.
3. Design Information of the Schools –
    a. A team of Architects conducted the documentation of the buildings, formulating the as-built drawings and identifying the number of Energy and Water Fixtures in each of the buildings. *During the documentation phase a detail was noticed that even though most of the municipal schools had solar panel installed on the rooftops, a thorough calculation as to how much wattage is required from the solar energy was missing along with an analysis of lux level in the spaces. It was found that even though the spaces were comfortably lit in the day time, light fixtures were installed in the passages and classrooms making the spaces over lit.*

Table 1 Basic Design Information

Name of the School, Address, City and State
Location in Latitute - Longitude - GPS
Name of the Person - Point of contact
Contact Number

Number of Occupants	**67**
Opertaional Hours	**7-8 Hours**
School Days / Week	**6 Days**
Holidays Days/ Year	**141**
Age of the Building years	**4**
Number of Floors	**4**
Floor to Floor Height *(m)*	**3**
Total Floor Area *(sq.m)*	**1689**
Total Terrace Area *(sq.m)*	**311.8**
Landscaped Area *(sq.m)*	
Occupation density *(sq.m./ student)*	**25.21**
External Wall Type and Thickness	**Concrete 9''**
Ground/Intermediate Slab Type and Thickness	**Concrete 6''**
Roof Type and Thickness	**Slab 6''**

Table 2 Orientation Wise - Facade Dimension

Façade Dimensions (m)	School 11
North	**121.4**
East	**30.1**
South	**121.4**
West	**30.1**
Height	**16.5**

Table 3 Orientation - Door Window

Door Window Orientation	Number of Door Window oriented in this direction on the external facade
North	12P1,8w1,2p2, 8W2,
East	12V
South	2P1,16W2,E1,15V,10W3,
West	E2

b. Based on the survey and documentation of the buildings we can go ahead with an understanding of the structural systems of the buildings has reinforced concrete structure with brick walls. On the exterior façade building is coated with a 12mm layer of paint and water proofing and on the interior finish of the building is of gypsum plaster finish. The flooring of the building is done with granite tiles and service areas with ceramic tiles.

c. As per our documentation we recorded the temperature in the indoor spaces, such as classrooms, computer rooms, library, staff room and common areas which can be found in the following table.

d. An inventory needs to be prepared for the Annual Utility Costs which shall contain the following parameters –
   i. Electricity Usage (kWh)
   ii. Electricity Cost (INR)of at least last 5 years.
   iii. Solar Electricity Generation (kWh -Units) – if solar is installed and connected to the grid
   iv. LPG (Kg) usage in the building
   v. LPG Bill (INR)
   vi. Diesel for generator Set (L)
   vii. Diesel Expense (INR)
   viii. Water Use (L)
   ix. Water Bill (INR)

Table 4 All Electrical Equipment's

Category	Type	Power in watts (W)	Quantity (No's)	Hours of Operations
Lighting Fixtures	LED Tube Lights	20	300	7
Fans	Ceiling Fans	53	96	7
Classrooms fixtures	Desktop Computers		3	3
	Printer		1	2
	Smart Screen	575	1	7
Miscellaneous Equipment's	Electric Geyser	3000	1	2

Table 5 Water Fixtures

Type of Water Fixtures	Total Number	Flow Rate
Bathroom Faucet	36	1L/30S
Water Closets (WC) flush tank	36	10L/20S

Urinals	12	6L/20S

Table 6 Water Supply Details

Source of drinking water	Municipal Supply
Is water balance diagram available?	NO
Are water meters installed on source water consumption?	NO
Is rainwater harvesting done on-site?	NO
If yes, what % of total runoff is guided to the borewell?	NO
Are native/local species planted in landscape area?	YES

Table 7 Existing Energy and Water Conservation Measures

Checklist of Energy + Water Conservation		Description	**Yes/ No**
Roof	Insulation	Insulation to reduce heat transmission through roof	No
Wall	Insulation	Insulation to reduce heat transmission through wall	No
Window	Double glazed units to reduce heat transmission into the building	Windows with double glazing	No
Window	Shading on windows to reduce heat transmission into the building	Chajja / sunshade to block direct sunlight from entering the rooms	Yes
Wall	Reflective Paint	Cool wall paint with high SRI value	No
Roof	Reflective Paint /Tiles on roof	China Mosaic, reflective tiles, cool roof paint with high SRI value	No
Window	High performance film for sun control	Tinted films on windows to reduce IR / UV	Yes

Water	Rain water Harvesting / Recharge	Roof top or ground water recharge in well, trenches etc	No
Water	Aerators / low flow fixtures for reducing flow of water	Fixing aerators to reduce flow in faucets of wash basins, sink and shower heads	Yes
Water	Dual Flush	WC with 3 litre and 6 litre - dual flushing system	No
Water	Waste-Water Recycling System and reuse	Sewage treatment plant on site for recycling waste water	No
Water	Reuse of recycled Waste-Water	Resue in landscaping, flushing, etc	No
Water	Water Metering for different uses	metering for Drinking, landscaping, flushing, etc uses have separate meters	No
Water	Rain water storage and reuse	Sump or tank for collecting rain water for reuse	No
Water	Water efficient landscaping	Xeriscaping, use of native species, Drip irrigation and timers for water management	No
Energy	Using daylight /motion sensors	Common areas, toilets and circulations spaces have sensors to save energy by predicting occupancy	Yes
Energy and Water	Facilities Management Plan	Reducing, reusing and recycling - reducing wastage of energy & water through maintenance plans/ programs. Contract with an agency which provides efficient building management practices.	No
Energy	Monitoring indoor air quality parameters	CO2, Indoor temp and humidity, PM 2.5 and Air quality Index	No

Energy	Roof top Solar PV panels	Use of solar PV system for common areas lighting	Yes
Energy	Solar water heaters	Use of solar PV system for hot water	No
Energy	Energy Metering	Building Wise metering for monitoring consumption	Yes

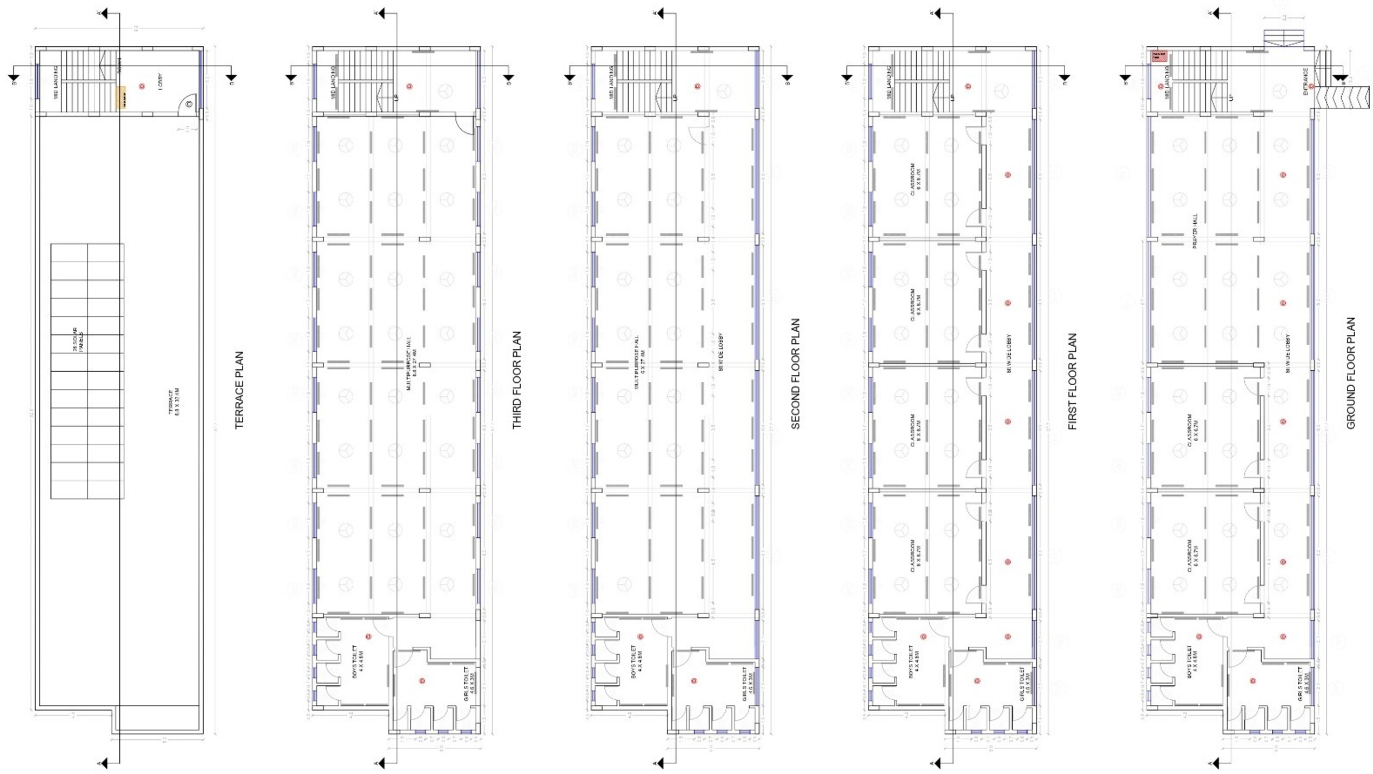


Figure 1 Plans of Schools

Results and Discussion

As stated before, the schools were at each of the corners of Mira Bhayandar city hence experiencing different microclimatic conditions. The buildings however similar in geometric and envelope. The total built up area of the buildings is considered to generate all the results in meter square per area.

First the energy consumptions of the buildings were calculated based on their annual utility bill mentioned in the Table 4 All Electrical Equipment's. Regarding the primary energy consumption, the highest is for the Lighting amounting for -- % and the cooling for -- %. Due to the proximity to the coastal regions and Mira-Bhayandar being a Warm and humid climatic zone, the high levels of humidity often create uncomfortable situations during summers and rainy seasons.

The usage of electric fans is also increased during this period to mitigate heat. In such situations, the ideal solution is to design a building which responds to its immediate context using passive cooling strategies such as orientation, fenestration sizes, self-shading, proper placement of vegetation etc. One of the components of green retrofitting measure is the BLDC fans. By using BLDC fans, which uses approximately 1/3rd of electricity consumption as compared to traditional fans, the energy consumption will be reduced. EDGE analysis shows that payback period for BLDC fans is 4.17 years. After 4 years, the cost of installing BLDC fans will be recovered, and any additional energy savings beyond this period will translate into direct financial benefits. This makes BLDC fans a cost-effective and energy-efficient solution for long-term electricity savin

The south and west façades of the school buildings are overly exposed to harsh solar radiation, which significantly heats the internal spaces. The construction materials used are predominantly low-albedo materials that absorb sunlight throughout the day and release it as heat, further increasing indoor temperatures. As a green retrofit solution, modifying the external façade offers a viable way to address this challenge. Among these solutions, the application of SRI paint emerges as a cost-effective option. SRI paint works by reflecting solar radiation, reducing heat absorption on surfaces such as roofs and walls. This helps lower indoor temperatures and decrease cooling energy demands. For SRI paint on roofs, the payback period is 6.09 years, with an annual savings of ₹19,843 and a CAPEX cost of ₹120,934. This makes it a highly impactful and cost-effective measure, contributing to 15.32% energy savings as per the EDGE analysis. It significantly reduces cooling loads and proves to be a practical retrofit option for improving energy efficiency. On the other hand, SRI paint on walls appears less favourable. Despite a higher CAPEX cost of ₹353,378, the annual savings are only ₹7,686 resulting in an extended payback period of 45.98 years. This long payback period diminishes the financial viability of SRI paint for walls. Additionally, walls, especially in schools, may not experience the same intensity of direct solar radiation as roofs, making their thermal impact comparatively less critical. Considering these factors, while SRI paint on roofs is a highly effective solution for reducing energy consumption and enhancing building sustainability, its application on walls is not a cost-effective measure and should be reconsidered. Alternative solutions for instances shading devices, vertical gardens, or high-albedo wall finishes may offer better performance and returns for wall façades.

The assessment of common spaces revealed that these areas were excessively illuminated despite being equipped with LED lights. It shows a need for more efficient lighting management. Installing lighting controls, such as daylight and occupancy sensors, is a practical and cost-effective solution to optimize energy consumption. These sensors ensure that artificial lighting is used only, when necessary, automatically adjusting based on the availability of natural daylight and the presence of occupants. This approach not only reduces electricity usage but also enhances occupant comfort by maintaining appropriate lighting levels. With a capital expenditure of ₹45,600, the implementation of these sensors yields annual savings of ₹13,229 resulting in a short payback period of just 3.45 years. While the energy savings percentage, as indicated by the EDGE App is relatively modest at 1.05%, the measure remains impactful for achieving energy efficiency in overly lit spaces and contributes to the broader goal of sustainable energy management.

A significant portion of water consumption in these buildings was observed to come from the flush tanks, which were releasing 10 liters of water with each flush. This inefficiency was contributing to substantial water wastage. Therefore, single flush system is less efficient. Dual-flush tanks are designed to release 3–4 liters of water for liquid waste and 6–8 liters for solid waste, offering a water-saving potential of 50–70%. This simple yet effective conversion leads to considerable water conservation and lower utility bills. With a capital cost of ₹12,800, this measure provides an annual savings of ₹28,512, resulting in an incredibly short payback period of just 0.45 years. By installing dual-flush systems, the buildings achieve water efficiency improvements of 47–60% (in EDGE analysis), significantly contributing to sustainable water management efforts.

S.No.	Type of Measure	Measure Description	Impact	Intensity of Impact	CAPEX Cost (INR)	Annual Savings (INR)	Payback (in years)	% of savings in EDGE App
1	Energy Reduction Measure	BLDC Fans	BLDC Fans consume 1/3 of electricity compared to conventional fans, thereby making an important energy reduction measure.	Medium	192,000	46,080	4.17	6.55%
2	Energy Reduction Measure	SRI Paint on Roof	SRI paint reflects solar radiation, reducing heat absorption and cooling costs. It lowers energy consumption, mitigates urban heat islands, and decreases greenhouse gas emissions. Additionally, it enhances surface durability and is versatile for various applications, including roofs and walls. Easy to apply and environmentally friendly.	High	120,934	19,843	6.09	15.32%
3	Energy Reduction Measure	SRI Paint on Walls		Medium	3,53,378	7,686	45.98	5.81%
4	Energy Reduction Measure	Lighting Controls - Daylight with Occupancy Sensor	Since there is enough daylight but a lack of awareness in general, installing daylight with occupancy sensors will help reduce energy consumption.	Low	45,600	13,229	3.45	1.05%
Water Efficiency Measures								
5	Water Efficiency Measure	Water Efficient Faucets and Flushing Cistern	Install dual flush external flush tank with full flush of 6L and half flush of 3L or only full flush of 5L.	High	32,000	33,858	0.95	47-60%

Conclusion

The retrofitting project for the selected schools in Mira Bhayandar showcases the potential of green interventions in reducing energy and water consumption, while simultaneously enhancing the comfort and resilience of the built environment. By incorporating passive cooling strategies, energy-efficient technologies, and water-saving measures, the project achieves a significant improvement in sustainability and resource efficiency.

The implementation of BLDC fans, LED lighting, and dual-flush cisterns demonstrates how simple yet impactful solutions can provide long-term environmental and financial benefits. The application of SRI paint on roofs further highlights the importance of targeted interventions for reducing cooling loads in warm and humid climatic zones. Additionally, the use of advanced lighting controls and water-saving technologies underlines the effectiveness of resource optimization strategies.

Beyond the physical upgrades, the project emphasizes the value of capacity building and community involvement. Workshops for students, teachers, and local stakeholders foster a culture of sustainability and ensure the long-term success of these initiatives. By aligning with the EDGE certification framework, the project establishes a benchmark for green building practices and demonstrates the feasibility of achieving global green standards in Indian educational institutions.

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