iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: III Month of publication: March 2021

DOI: https://doi.org/10.22214/ijraset.2021.33317

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue III Mar 2021- Available at www.ijraset.com

Retrofitting in Existing Educational Building for Energy Efficiency in Hot and Dry Climate

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Abstract: The building stock consumes approximately 40% of the energy and emits one-third of greenhouse gas emissions (GHG). Improving the energy efficiency in buildings is essential to address climate change, reduce energy efficiency, and build a net-zero energy building. In the current scenario, improving energy performance in existing buildings has been receiving significant attention, which will reduce energy demand for building operations without affecting its occupants' health and comfort. This approach requires strategies which is not only a technical approach but as well as in the operation and management level. However, there is limited published literature that has comprehensively addressed these issues. This dissertation aims to critically review existing body-of-the-knowledge on improving the energy efficiency of operating institutional buildings. Peer-reviewed journal articles published in reputed journals were reviewed. This review investigated new energy efficiency approaches, including technical, organizational, and behavioral changes. Based on the intense literature review, a strategy was developed for achieving better building energy performance in Educational Building in Hot and Dry climate in India. This study's findings provide an essential basis for setting up a national and organization-wide strategy for improving the energy efficiency of educational buildings in India.
Keyword: Retrofitting, Energy Efficient, Educational Building, Hot and Dry Climate, India

I. INTRODUCTION

In July 2012, the historic blackouts across India revealed the level of the energy crisis of India. To meet India's energy demand, Scaling up energy efficiency programs is the best way. In 2005, the building occupied area was 8 billion square meters, and it will be projected by 41 billion square meters in 2030 due to rapid urbanization in the country. To fulfill the requirement of the growing population, there is a vast demand for infrastructures. (NRDC, Saving Money and Energy: Case Study of the Energy-Efficiency Retrofit of the Godrej Bhavan Building in Mumbai, 2013). The construction of buildings and their operation contribute more than 40 % of the total energy end-use worldwide. The existing buildings exhibit the most severe excessively high energy problems, poor indoor environmental quality, thermal comfort, and low productivity.

In contrast, the replacement rate of existing buildings by the new-build is only around 1.0 - 3.0% per annum. The concept of demolishing and rebuilding after 20-25 years of operation is not sustainable for the future. To demolish and to rebuild, a lot of material and energy used are very scarce. For the majority of existing buildings that were built before the energy crisis, energy efficiency was not a concern at all, and most of these buildings will still be in function until 2050 or beyond. In India, unconditioned buildings form the most significant chunk of the existing building stock due to a favorable climate. To achieve reliable energy in the future and boost the economy while addressing the threat of climate change, incorporating energy-efficient measures in the new and existing building is a very efficient approach.

Incorporation of end-use energy efficiency can save nearly 25,000 MW in India. The concept assumes even greater importance because one unit of energy kept at the consumption level reduces the need for fresh capacity creation more than two times. Without much investment, energy efficiency measures will reduce the wastage of energy. (TERI, 2013).

Therefore, researchers worldwide recognized that green building retrofit is one of the main approaches to achieve reduced building energy consumption, greenhouse gas emissions, and sustainability in the built environment at a relatively low cost. Reduce energy consumption, and its operation and management are essential.

Retrofits for existing buildings have various results , such as green energy and zero-emission building retrofits. Green building retrofits improve the environmental response of a structure, reduce water consumption, and increase the space's comfort and value. On the other hand, retrofitting in the existing building for energy efficiency optimizes a building's energy performance. It is vital to initiate energy conservation retrofits to reduce energy consumption to limit the cost of heating, cooling, and lighting in buildings and decrease the overall fossil fuel dependency (N.A., 2018).

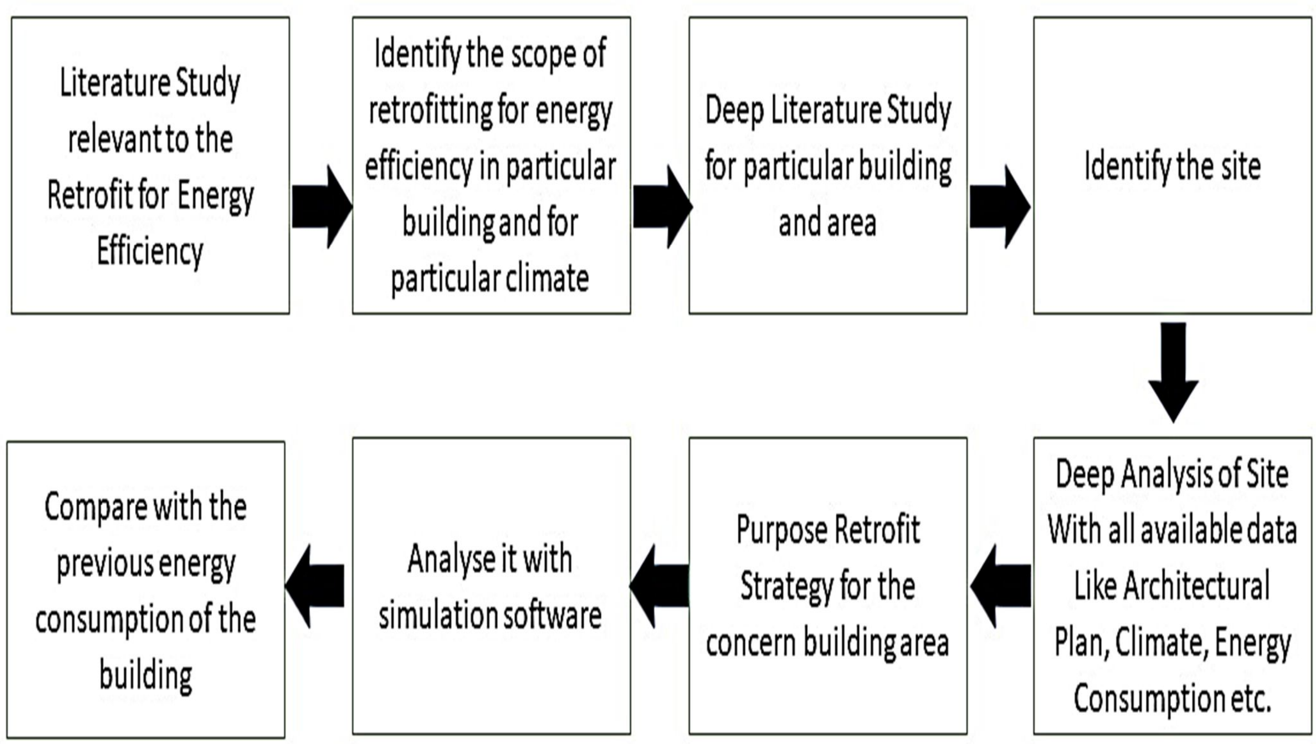
The benefit of retrofitting a building can be categorized into three benefits, which is, environmental-benefits, economic-benefits, and social-benefits. The environmental-benefits include the reduction of greenhouse emissions and improving water self-sufficiency. The economic benefits of retrofitting can be one of the most potent means of convincing someone to consider retrofitting; a financial analysis showing the payback period is usually prepared as a standard indicator (Amstalden, Kost, Nathani, & Imboden, 2007) (Huang, Yang, Mauerhofer, & Guo, 2012). Moreover, retrofitting is a cost-effective means of increasing an existing building's asset value than building a new facility (Hensen, 2004). The most complicated part of building retrofitting is determining optimal solutions and understanding the relationships through energy efficiency measures (Senel Solmaz, Halicioglu, & Gunhan, 2018). To reduce the energy consumption of buildings, many technical methods and approaches have been developed, including building energy simulation software, such as Energy Plus, eQUEST, and Ecotect. Energy software deals with a building's parameters and the surrounding environment; for example, the heating, ventilation, and air conditioning (HVAC) system the operation schedules, climate conditions, shading information, insulation, and new building technologies (El-Gohary, 2018), (Esen, Esen, & Ozsolak, 2017).

Non-domestic buildings such as offices, educational, commercial, and institutional buildings have greater complexity than domestic structures regarding internal environments: a larger number of occupants, a greater diversity of contaminants, mechanical systems for heating, ventilation, and air conditioning (HVAC), and reduced personal control over thermal and ventilation conditions. There is a significant concern about the thermal performance of educational buildings. A comfortable environment is an essential factor in the development of the activities of its occupants. Discomfort conditions caused by extreme temperatures, inadequate ventilation, and high humidity may be harmful in a school environment, causing undesirable physiological effects like drowsiness, sweating, and apathy.

The study aims to Propose a feasible strategy for retrofitting in India's existing educational building for Hot and Dry Climate to reduce energy consumption. The survey's research question is how much energy consumption will reduce after retrofit the building for energy efficiency and if the retrofitting process is cost-effective. The research objective are-

1) To analyze the various available retrofit technology in India
2) To identify the different factor which takes part in energy consumption.
3) To identify the Passive, Active, and renewable energy source suitable in Hot and Dry Climate

II. METHODOLOGY



Scope and Limitations of the research are due to low construction techniques applied by builders and a continuous increase in temperature every year; almost every building category is either newly built, old, or under construction required to reduce energy consumption. This study focused on the educational establishment in Hot and Dry Climate. How to retrofit strategy effect in Energy consumption is discussed in this research. Probable Outcome of the study are-

1) Mandatory requirements for building envelope reduced air infiltration and increased air leakage requirements to overhead coiling doors.
2) More stringent prescriptive requirements for building roofs, walls, doors and windows.
3) Improved exterior wall details, building orientation, and clarity around the effective U-values and R-values.
4) As per climate zone, new requirements for the existing building as well as the new buildings

III.ENERGY EFFICIENCY IN INDIAN EDUCATIONAL BUILDING

With a projected peak load of 2499 TWh in 2030, the ongoing schemes may not be sufficient in curbing energy consumption to cater to the increasing demands for energy use in India. To achieve these standards, it has become imperative to adopt more ambitious energy efficiency policies and programs to meet these targets- for instance, the efficient lighting program is projected to save energy up to 100 billion kWh per year. Analysis by IEA and New Climate Economic shows opportunities to implement energy efficiency at national, state, and local levels. For unlocking billions of investments potential, jobs, and business opportunities in India, a greater thrust towards increasing domestic energy efficiency practices is needed. Building an energy-efficient economy will facilitate the reduction of the primary energy demand by 9% by 2040, as compared to the business-as-usual scenario shown by IEA's New Policies, with two-thirds of the total contributions coming from energy efficiency measures. Energy efficiency is also the most cost-effective way of decarbonizing the Indian economy. This makes energy efficiency a solid lever to address the social and economic transformation in energy consumption practices and responding to climate change. In India, to achieve universal energy access without exhausting existing energy sources and avoiding sourcing additional energy sources from neighboring countries, it is essential to teach a robust E.E. market. In a country that houses a third of the world's poor, ensuring a consistent supply of energy for meeting basic needs and creating sources of livelihood, habitats, and development areas without increasing the oil import is both a challenge and an opportunity. The Indian energy requirements are growing at a much higher rate than the world growth rate. There have limited energy reserves in India, and therefore, it will need to increase its energy efficiency and re-evaluate its existing building stock. The existing buildings offer one of the greatest potentials in energy restoration and, if not evaluated, they also provide the challenge of being energy hogs. Schools are faced with optimizing limited budgets to ensure maximum payback for students, teachers, and facilities. The rising energy costs associated with additional expenditure for replacing equipment adds strain to an already tight budget. Energy maintenance is often overlooked in school buildings as the associated costs are relatively lower than other expenses. By effectively implementing an energy management program, the schools can effectively reduce their energy consumption, increase energy savings, and extend equipment lifetime. Implementing an energy management program can save anywhere between 5-20% on energy bills. That will help improve your bottom line and holds down operating costs. An operation and maintenance-based program can be relatively low in cost and still yield adequate payback.

Due to reduction in energy cost and increase in the profitability allowing school to use their savings towards fulfilling other requirements, including purchasing additional amenities, staff salary increases, etc.

In addition to optimizing energy and its costs, schools also offer a critical platform for creating a better environment that includes favorable sound, light, and temperature, helping students learn better. Improving these attributes can also reduce energy consumption. The research captured in Greening America's Schools: Costs and Benefits highlights 17 studies demonstrating the increase in productivity of 2% to more than 25% from improved indoor air quality, acoustically designed indoor environments, and high-performance lighting systems. Some of these studies show that daylighting, glare-free lighting can enhance academic performance by 20%. Quality lighting systems include a combination of daylighting and energy-efficient electric lighting systems. These, in combination, can reduce visual strain and provide a better lighting quality. Advanced, energy-efficient cooling and heating systems create cleaner, healthier indoor environments that lower student and staff absentee rates and improve teacher retention. That results in lower staff costs. An example of Ash Creek Intermediate School in Oregon shows reduced absenteeism (compared to the previous facility) by 15%. Lower construction and operating expenses also show responsible stewardship of public funds. That results in more significant community support for financing school construction. Those Schools that incorporate energy efficiency and renewable energy technologies make a strong statement about the importance of protecting the environment. They also provide hands-on opportunities for students and visitors to learn about these technologies and the importance of energy conservation.

IV. SCHOOL BUILDING ENERGY OPTIMIZATION DESIGN

A. Thermal Insulation

Since the school buildings have specific occupancy patterns, certain regulations should be considered for their thermal insulation. To investigate the building envelope's effectiveness, U-values given in the ECBC code are considered in the base-case school model, and the energy demand is calculated and compared to the buildings with the existing U-values.

B. Infiltration

Infiltration is an essential construction parameter that affects the energy demand in buildings and is determined by air change per hour. Airtightness of the building envelope relates to the window and door type, materials used, and the quality of the construction process. Air tightening the building envelope will reduce the heat lost and improve the indoor air quality.

C. Window-to-Wall Ratio

The Window area in different orientations is an essential architectural factor affecting the building's energy demand. Windows provide solar heat gain, daylight, and even natural ventilation for indoor spaces. Since windows are the weakest thermal link in the building envelope, their design directly impacts thermal comfort and energy demand in buildings. In school buildings, due to the room size, the window-to-wall ratio is usually high. By designing appropriate windows, a balance between lighting, heating, cooling, and ventilation would be obtained.

D. Sun Shading

Sun penetration in indoor spaces is the main reason for space overheating in warm seasons. To provide appropriate daylight level in classrooms, windows are relatively large, and shading these windows to prevent sun penetration in warm months is critical. Sun shading is an effective strategy in decreasing cooling energy demand in hot and dry climates.

E. Building Orientation

Building orientation is an essential architectural factor in building energy consumption. This parameter on the lighting, heating, cooling, and primary energy demand of the base case school building is investigated by simulating the structure in different orientations.

By optimizing the school building orientation, the solar radiation and daylight can increase in summer and winter, and the energy demand for lighting, heating, and cooling can decrease. The school building's orientation and the energy demand are directly linked due to the window orientations.

The sun radiation that surfaces receive in summer and winter relates to the building's orientation and the context's altitude. The dominant wind direction is also considered in defining the optimum exposure.

F. Class Arrangement

Class arrangements should be based on the heating and lighting, and cooling demands of the space. Class arrangement in school design is a significant consideration. Classrooms build on both sides of the building, and classrooms on only one side can cause different design challenges.

G. Architectural Form Analysis

The energy demand of buildings specifically depends on the shape and typology of the building. Form and shape are critical factors in absorbing and radiating heat during the day and night and thus a critical parameter in the building's heating and cooling energy demand.

Various formal factors, including elongation and compactness, number of stories, plan shape, roof form, wall slope, and ground adjacency level, are investigated to find the optimum value for each parameter. (Zomorodian & Nasrollahi, 2013).

As per ECBC Design Guide, 2017, the optimum requirement for the various Building Element for a particular building type. For Educational Building following are the required value- Roof Assembly U-Value= 0.47; Wall Assembly U-Value= 0.85; WWR= <40% Maximum allowed EPI Ratio is 1- foe ECBC, 0.77 for ECBC+, 0.66 for Super-ECBC U-value is a unit to describe how well or bad a building component is insulated. It is defined as the rate at which heat is transferred through the external envelope of a building. The lower U-value a building component has, the slower heat transfers through the element.

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V. CASE STUDY

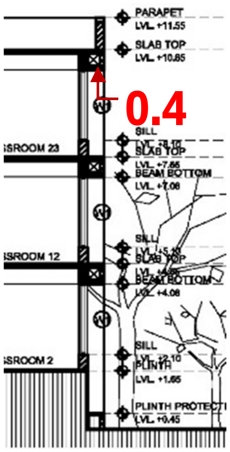
This section focus on the energy-efficient retrofitting of four cases-building from worldwide identified the most suitable retrofitting technology in a hot and dry climate and how much energy is saved with these technologies' implementation. The case study will provide details about the methodology used for the particular climate and the organization's challenge to implement the retrofitting technologies, and the method to overcome those.

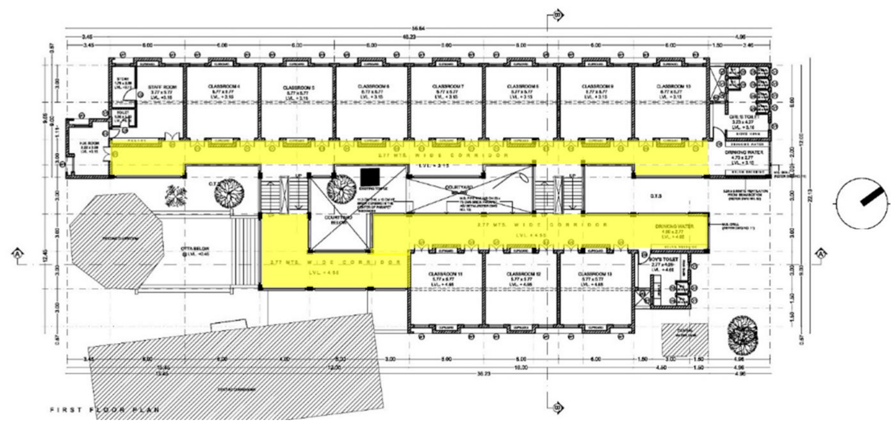
Table 1: Comparison of Case Studies

	Aranya Bhawan, Jaipur	Arab Academy for Science, Technology & Maritime Transport in Alexandria city, Egypt	Byron Rogers Federal Office Building, Denver, CO, USA	Beardmore Building, Priest River, ID, USA
Typology	Office	Education	Office	Office
No. of Floor	G+5	G+5	G+17	G+1
Retrofit Technology Used				
Wall	Cavity wall with insulation (50 mm Extruded polystyrene used); U value: 0.44 W/m2.K	external paint 2mm on plaster applied on a brick wall (25 cm), an air gap of 13 mm, then a-12mm Gibson board covered with calk and internal paint; U value: 0.250 W/m2 K.	Super-insulated envelope achieves overall R-20 value	Extensive insulation
Roof	150 mm thick RCC slab with insulation (75 mm polyurethane foam used)1 U value: 0.41 W/m2.K	Green Roof		R-50 for the roof cavities
Window	Double glazed unit; U-value: 1.8 W/m2.K; Solar Heat Gain Coefficient (SHGC): 0.24; Visual Light Transmittance (VLT): 40%	Double glazing low-E glazing	high-efficiency glazing with a thermal break.	Low-E, argon-filled insulated glass
HVAC	High-efficiency water-cooled chiller	None	Active chilled beam system with thermal storage	High-efficiency, packaged rooftop heat pumps with economizers; Demand control ventilation (DCV) with CO2 sensors
Solar Energy	Grid-connected rooftop solar P.V. system	None	Solar thermal for water heating	None
Lighting	None	None	LED lighting	High efficiency compact fluorescent; lighting system has a night set-back
Other Measures	Passive downdraft evaporative cooling (PDEC) for the stairwell and corridors	None	Coverings that blocked windows were removed	occupancy sensors
Energy Saved	44%	15.13%	68%	60%

VI. BASE CASE STUDY

The selected site is located in Valketgate village, Bhavanagar, Gujarat, India. The climate of the city is Hot and Dry climate.
The orientation of the building is S-E direction. In a hot and dry climate, the maximum heat gain occurs from the south and west direction. Here the north-west direction wall is covered by the adjacent building, which provides shade to the school building. Box window is provided throughout the structure of 0.45m recess. Windows for the classroom is provided in all wall which is present either in S-E or N-W wall. A covered corridor is provided alongside the classroom





It is a primary school with 25 classrooms, a play area, washrooms, and a staircase block. The site area of the selected building is 2020.00 sq.m. The ground floor area is 140.00 sq.m. The ground floor has three classrooms, one toilet, and drinking water space with a play area of 505.00 sq.m. and a green courtyard. The green courtyard area is 145 sq.m., 7% of the plot area. Open space on the site is 1008.00 sq.m. 49% of the site area. The building has a G+2 floor with a floor-to-floor height of 3.0m.

A. Building Simulation

The software used for the simulation process is Design-Builder. The simulation is done based on data from Gujarat, India. The analysis is done on annual basis. Firstly, the existing condition is simulated and finds out the building's current condition then after the building is simulated for the proposal.

VII. RESULTS AND DISCUSSION

For the ECBC+ compliances maximum allowed EPI Ratio is 0.77

Table2: Site Analysis on Constructional Parameter

Constructional Parameter			
	ECBC+ Requirement	Existing Condition	Proposal
	Thermal Insulation		
Wall	U-Value= 0.85	230 mm standard brick wall with plaster and paint U-Value = 2.09	Wall Insulation- Cavity wall with insulation (50 mm Extruded polystyrene) U-Value= 0.47
Roof	U-Value= 0.47	100 mm slab with plaster U-Value= 4.14	Cool Roof U-Value= 2.72
	Infiltration		
Window Frame	U-factor <2.20 SHGC= 0.25 VLT <0.27	Aluminum Frames Single Glass Panel 6mm	Fibre Glass Frame Double layer, Low-E glass panel, argon-filled insulation

Window Panel		U-factor = 5.77 SHGC= 0.819 VLT= 0.88	U-factor = 2.51 SHGC= 0.70 VLT= 0.78
Architectural Parameter			
Window-Wall Ratio	<15%	S-E= 23% N-W=20%	Instead of reducing the WWR, louvers are provided to decrease the daylight.
Sun Shading	Daylight = 50%	450mm recess	450 mm oblique Louvre is added to the structure to reduce the daylight
Building Orientation		South-East	
Class Arrangement		S-E & N-W followed by a corridor	
Architectural Form		The rectangular form has a centric green area and open space	

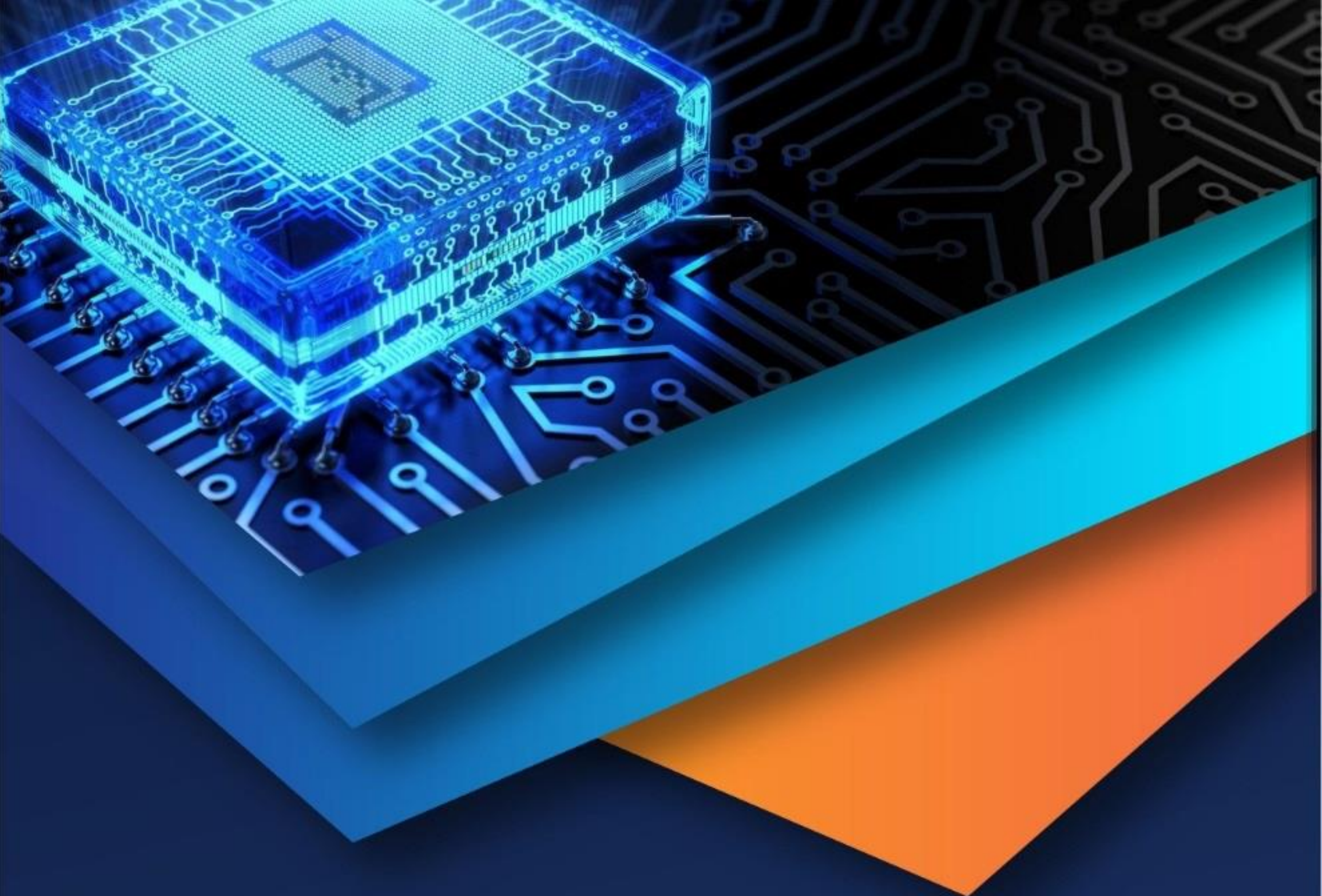
VIII. CONCLUSION

In hot and dry climates, incorporation of simple energy-efficiency measures, such as insulation of roof and walls, use of double glazed windows and efficient air-conditioning system, can reduce energy consumption significantly. In the case of Base Case Building, a reduction of 47 percent in the annual electricity consumption is estimated by adopting these measures. Use of Integrated solar system help to generate electricity for the building.

REFERENCES

[1] Aboulnaga, M., & Moustafa, M. (2016). Sustainability of higher educational buildings- Retrofitting approach to improve energy performance and mitigate CO2 emissions in hot climates. Renewable Energy Environmental Sustainability.
[2] Alajmi, A. (2012). Energy audit of an educational building in a hot summer climate, Energy and Buildings.
[3] Amstalden, R., Kost, M., Nathani, C., & Imboden, D. (2007). Economic potential of energy-effcient retrofitting in the Swiss residential building sector. Energy Policy 2007.
[4] Baek, C., & Park, S. (2012). Changes in renovation policies in the era of sustainability, Energy and Buildings.
[5] Basarir, B., Diri, B. S., & Diri, C. (2016). Energy efficient retrofit methods at the building envelopes of the school buildings.
[6] BEEP. (2015). Implementing Energy Efficiency in Buildings A compendium of experiences from across the world. International Conference on Energy Efficiency in Buildings (ICEEB 2015). New Delhi, India: United Nations Development Programme.
[7] CIBSE. (2004). Energy Efficiency in Buildings: CIBSE Guide F, Chartered Institution of Building Services Engineers. London.
[8] Divsalar, R. (2011). Building Problems in Hot Climate, Energy Efficient Building Design.
[9] EBC. (2017). Business and Technical Concepts for Deep Energy Retrofit of Public Buildings – Case Studies. Energy in Buildings and Communities Programme (EBC).
[10] ECBC Design Guide. (2017). Energy Conservation Building Code - Design Guide. Bureau of Energy Efficiency.
[11] El-Gohary, C. (2018). A review of data-driven building energy consumption prediction studies. Renew. Sustain.Energy.
[12] Esen, H., Esen, M., & Ozsolak, O. (2017). Modelling and experimental performance analysis of solar-assisted ground source heat pump system. J. Exp. Theor. Artif. Intell.
[13] Harris, J., Anderson, J., & Shafron, W. (2000). Investment in energy efficiency: a survey of Australian firms, Energy Policy.
[14] Hensen, J. (2004). Eindhoven, The Netherland: Building Simulation 2003—Final Report 8th International IBPSA Conference.
[15] Huang, B., Yang, H., Mauerhofer, V., & Guo, R. (2012). Sustainability assessment of low carbon technologies–case study of the building sector in China. J. Clean. Prod.
[16] Jha, B., & Bhattacharjee, B. (2017). Retrofitting Building Roof for Energy Efficiency. 71st RILEM Annual Week & ICACMS 2017, Chennai, India.
[17] Khoukhi, M., Darsaleh, A. F., & Ali, S. (2020). Retrofitting an Existing Offce Building in the UAE Towards Achieving Low-Energy Building. College of Engineering. United Arab Emirates: MDPI.
[18] Kumar, A., Chani, D., & Deoliya, D. (2013, March). Green Retrofit Potential in Existing Research Laboratories and Demonstration of Energy Efficient and Sustainable Technologies: Case Study. International Journal of Science, Engineering and Technology Research (IJSETR), 3(3).

[19] Kumar, A., Chani, D., & Deoliya, D. (2014, March). Green Retrofit Potential in Existing Research Laboratories and Demonstration of Energy Efficient and Sustainable Technologies: Case Study. International Journal of Science, Engineering and Technology Research (IJSETR), 3(3).
[20] Ma, Z., Cooper, P., Daly, D., & Ledo, L. (2012). Existing building retrofits: Methodology and state-of-the-art. Elsevier.
[21] N.A., A. (2018). Energy Retrofitting of Existing Residential Buildings: Developing a Decision Process for Energy Saving and Cost E. PhD. Thesis, University of Wollongong, Sustainable Buildings Research Centre, Australia.
[22] NRDC. (2013). Saving Money and Energy: Case Study of the Energy-Efficiency Retrofit of the Godrej Bhavan Building in Mumbai. Mumbai, India.
[23] NRDC. (2013). Saving Money and Energy: Case Study of the Energy-Efficiency Retrofit of the Godrej Bhavan Building in Mumbai.
[24] Owens, J., & Wilhite, H. (1988). Household energy behaviour in Nordic countries – an unrealized energy saving potential, Energy.
[25] Ruparathna, R., Hewage, K., & Sadiq, R. (2015). Improving the energy efficiency of the existing building stock: A critical review of commercial and institutional buildings.
[26] Ruparathna, R., Hewage, K., & Sadiq, R. (2016). Improving the energy efficiency of the existing building stock: A critical review of commercial and institutional buildings. Science Direct.
[27] Santin, O., Itard, L., & Visscher, H. (2009). The effect of occupancy and building characcharacteristics on energy use for space and water heating in Dutch residential stock, Energy and Buildings.
[28] Senel Solmaz, A., Halicioglu, F., & Gunhan, S. (2018). An approach for making optimal decisions in building energy efficiency retrofit projects. Indoor Built Environ.
[29] TERI. (2013). Roadmap for Incorporating Energy Efficiency Retrofits in Existing Buildings. India: The Energy and Resources Institute.
[30] Y.G. Yohanis. (2012). Domestic energy use and householders' energy behaviour, Energy Policy.
[31] Zomorodian, Z., & Nasrollahi, F. (2013). Architectural design optimization of school buildings for reduction of energy demand in hot and dry climates of Iran. International Journal of Architectural Engineering and Urban Planning.



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