Achieving Energy Efficiency through Retrofitting of Building Envelope: The Case of a Hospital in Meerut, India

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Abstract: In order to reduce operating costs, lessen the impact on the environment, and guarantee a sustainable healthcare infrastructure, hospital facilities must practice energy saving. Carbon dioxide emissions have a major impact on the environment and contribute significantly to worries about global warming. In order to give the best possible thermal comfort, a significant amount of energy is used in hospital buildings for lighting, ventilation, heating, and cooling. For these constructions, energy conservation is crucial. Insulating exterior walls is a common way to boost a building's energy efficiency. This is a tried-and-true method given the ongoing rise in energy prices worldwide and the commitment to furthering global climate initiatives. Healthcare institutions must undergo energy retrofits in order to reduce energy use and improve sustainability. For this, a variety of materials can be used, each with unique benefits and challenges. The feasibility of several materials, including roofing, window glazing, and insulation, for energy retrofitting in healthcare buildings is investigated in this article. This paper describes how to use sustainable materials, including polyurethane spray and composite panels (ETICS) for thermal insulation on the roof and external walls, to increase energy efficiency in healthcare buildings, namely the Nutema multispecialty hospital in Meerut, India. Using Rhino 7 and Climate Studio software, the present building's Energy Performance Index is evaluated. Analysis and comparison have been done on a number of examples. Energy-efficient roof and wall insulation can be achieved during retrofitting by using sustainable materials like polyurethane spray, external thermal insulation composite panels (ETICS), and double-glazed windows.
Keywords: energy performance index, building energy simulation, assessment tool, building envelope, hospitals, India

1. Introduction

All of the main facets of the Indian economy — agriculture, industry, transportation, commerce, and residential areas — depend on energy for economic growth. Because buildings require greater and more cooling in the summer, developing nations have faced a significant energy crisis for the past three decades (Bano and Kamal, 2016). Environmental pollution brought on by this increased energy use has resulted in global warming and the ozone layer's depletion. Energy demand is increasing as a result of rising living standards and a growing global population. Additionally, it is probably going to continue rising (Bangre et al., 2023; Kamal, 2013). The population of the planet is constantly increasing. It is projected to increase from 7.7 billion in 2019 to 9.7 billion in 2050, and it is likely to reach 10.9 billion or more by the end of this century. Emissions of carbon dioxide are a major contributor to the issue of global warming and have a significant impact on the environment. CO_2 is the biggest concern for the building and construction industries. Therefore, studies have been conducted to identify new technologies and construction systems that can aid in lowering greenhouse gases, which are gradually depleting the ozone layer (Morales-Méndez & Silva, 2018).

Overexploitation of biological systems will result from rising demands for energy, water, and natural resources brought on by the growing world population. By using more energy, this will eventually harm the built environment and progressively worsen the environment (Hafez et al., 2023; Ran et al., 2017). Therefore, conserving existing structures and making them more energy efficient are essential to lowering carbon emissions worldwide. Sustainable features like window roofing, outside wall components, and roof insulation can be used to save energy while retrofitting older buildings. Adding thermal insulation to outside walls and roofs is one potential substitute. With a U-value of 0.579 W/m²K, polyurethane spray is used to insulate exterior roofs from heat. All windows have been replaced with double low-E 3mm, 13mm air gap windows, which have a U-value of 1.53 W/m²K, and extra projections have been added to the windows. The wall is constructed using External Thermal Insulation Composite Panel (ETICS), which has a U-value of 0.252 W/m²K. To find the most practical solution with the highest energy efficiency, simulation models of every scenario are built and then assessed. By evaluating the Energy Performance Index (EPI) and then examining all feasible options, this study investigates the hospital's energy use. While the approach is described in Section III, the literature review and case study of the current system are outlined in

Section II. The results and remarks are shown in Section IV. The conclusion is given in Section V.

2. Literature Review

Numerous factors must be considered in order to sustain economic growth, with energy efficiency and conservation playing a key role in bolstering the economy. Both freshly built buildings and existing structures must be considered in building energy conservation studies (Huang et al., 2022; Dadzie et al., 2022). Optimizing construction methods and optimizing energy use are key components in designing energy-efficient buildings. Buildings use over 31% of the energy consumed overall, with the business sector responsible for almost 9% of this, according to Energy Audit Studies. Due to their ongoing activities, healthcare facilities become significant energy consumers. Enhancing insulation, integrating renewable energy systems, and improving structural stability are only a few of the factors that must be taken into account while renovating existing buildings (Ansari et al., 2025). Of these, most people agree that energy-saving changes to a building's exterior envelope are both sensible and economical. By taking such steps, building operations are less disrupted and efficiency is increased. In the context of energy-saving retrofits, changes pertaining to the building's windows and façade are particularly pertinent (Tong & Chen, 2020). In India, the building industry accounts for about 31% of all electricity use. According to energy audit studies, it is possible to save about 40% on systems like refrigeration, ventilation, air conditioning, and lighting. By 2030, the built-up area of the business sector is expected to increase by almost 66%, which would result in a large increase in energy demand. Nearly 56% and 21% of energy use in commercial buildings, respectively, is attributed to air conditioning and lighting (Radwan et al., 2016).

Therefore, lowering energy consumption in this industry requires the use of energy-efficient solutions. Insulating exterior walls has become a well-known method to increase building energy efficiency due to the growing demand to enhance climate conditions and the rising cost of energy worldwide. Research demonstrates how adding more outside insulation can change the freezing point of wall structures, improving performance in multi-unit residential buildings (Simona et al., 2017). Between 2000 and 2006, hospital infrastructure in India rose by 67.6%, and this expansion is predicted to continue until 2030 to meet healthcare needs (Central Bureau of Health Intelligence, 2010). Because of their extended operation hours, heating, ventilation, and air conditioning (HVAC) systems consume the most energy in hospitals (William et al., 2020). Because it saves money and time, retrofitting healthcare buildings is frequently more feasible than building new ones (Mohammadpour et al., 2012). These initiatives do, however, have drawbacks, such as worker and patient interruptions. However, in India's fast expanding healthcare sector, increasing hospital energy efficiency can drastically reduce demand (Pedamallu et al., 2016). It has been demonstrated that retrofitting using Energy Conservation Measures (ECMs) increases energy savings [13]. Retrofitting offers more advantages than only cost savings on heating and cooling, including increased property prices, better rental returns, and increased occupant comfort (Liu et al., 2018).

Hospitals have implemented energy-saving measures such as installing solar heating panels, replacing outdated elevator systems with variable frequency drives, upgrading indoor and outdoor lighting systems, replacing CFLs with electronic chokes, and setting up desktop PCs to have a two-minute screensaver feature. Dynamic façade systems, which include smart windows and electrochromic glazing, are examples of advanced technology that help control daylight entry and solar radiation. Hospitals are a good fit for these systems because they maximize natural light while minimizing heat gain, which saves energy and improves occupant comfort (Zinzi, 2006; Buonomano et al., 2014). Using Phase Change Materials (PCMs) in building retrofits is another interesting strategy. The ability of PCMs to store and release thermal energy lowers the burdens associated with heating and cooling. Their use in hospitals has demonstrated efficacy in reducing HVAC energy consumption and stabilizing indoor temperatures, especially in areas with notable temperature fluctuations (Zalba, 2003). There have been reports of using sustainable materials in hospital retrofits, despite the fact that the majority of implemented retrofit procedures are conventional. For example, double-glazed windows improve thermal performance, and polyurethane spray foam and composite panels (ETICS) are frequently used to insulate external walls and roofs (Bangre et al., 2023; Simona et al., 2017). Spray foam made of polyurethane is prized for its powerful insulation and air-sealing qualities, which significantly lower building energy losses. By stopping heat transfer via walls, ceilings, and floors, polyurethane spray insulation has been shown in studies to significantly reduce energy use in hospitals. In a similar vein, Environmentally friendly materials like mineral wool or expanded polystyrene (EPS) used to make External Thermal Insulation Composite Systems (ETICS) offer superior thermal resistance and lessen thermal bridging. According to research, ETICS considerably raises healthcare buildings' energy efficiency (Simona et al., 2017).

3. Research Methodology

This part has a case study of the current system, an energy evaluation of the current system, and finally retrofitting the hospital's base model or existing system. Figure 1 shows a flowchart that explains how to retrofit or optimize the energy or energy conservation for an existing structure.

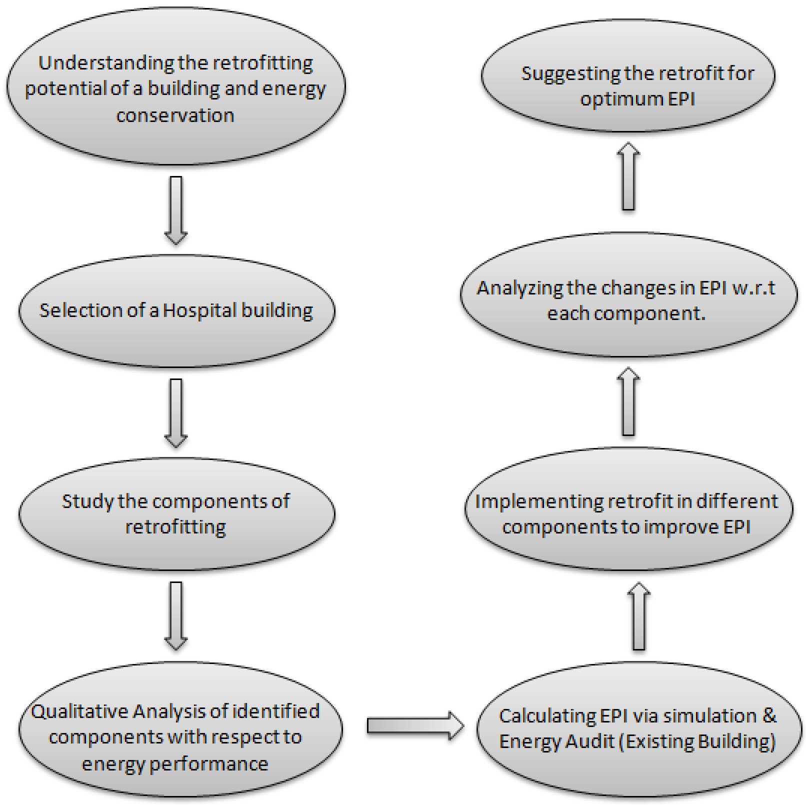

Figure 1. Retrofitting approaches for enhancing energy efficiency in existing buildings.

3.1 Case Study

This study involves a detailed analysis and assessment of Nutema Hospital, a multispecialty healthcare facility located in Meerut. The hospital has a total ground floor area of 1,968 m² and an overall built-up area of approximately 7,872 m². It is a four-story structure consisting of a ground floor, two upper floors, and a basement. Figure 2 shows the Ground floor plan of Nutema Hospital at Meerut, India.

Figure 2. Demonstration of the Ground floor plan.

The spaces identified in the floor plan (figure) correspond to the following functions:

1 - Reception	2 - Drug store
3 - Back of House	4 - SC
5 - Room	6 - OPD
7 - Waiting area	8 - Radiology

9 - Elevator Lobby
10 - Elevator
11 - Dialysis
12 - ISO
13 - Cheif Medical Officer
14 - Waiting area
15 - Minor Operation Theatre
16 - Examination of Eye
17 - Waiting
18 - Emergency Hall
19 - CAT scan
20 - Dirty Utility
21 - Clean Utility
22 - Washroom
23 - Differently abled toilet
24 - Ultrasound
25 - Console
26 - X-Ray
27 - X-Ray TMT
28 - X-Ray Dark room
29 - Reverse Osmosis water
30 - Washing Area
31 - Potable water
32 - Gallery

The hospital envelope consists of 230 mm thick clay brick outer walls finished with plaster on both sides (Figure 3). The walls, fitted with aluminum cladding panels, provide a U-value of 2.13 W/m²K. The roof structure is a flat reinforced concrete slab with brick tiling on top, offering a U-value of 2.07 W/m²K.

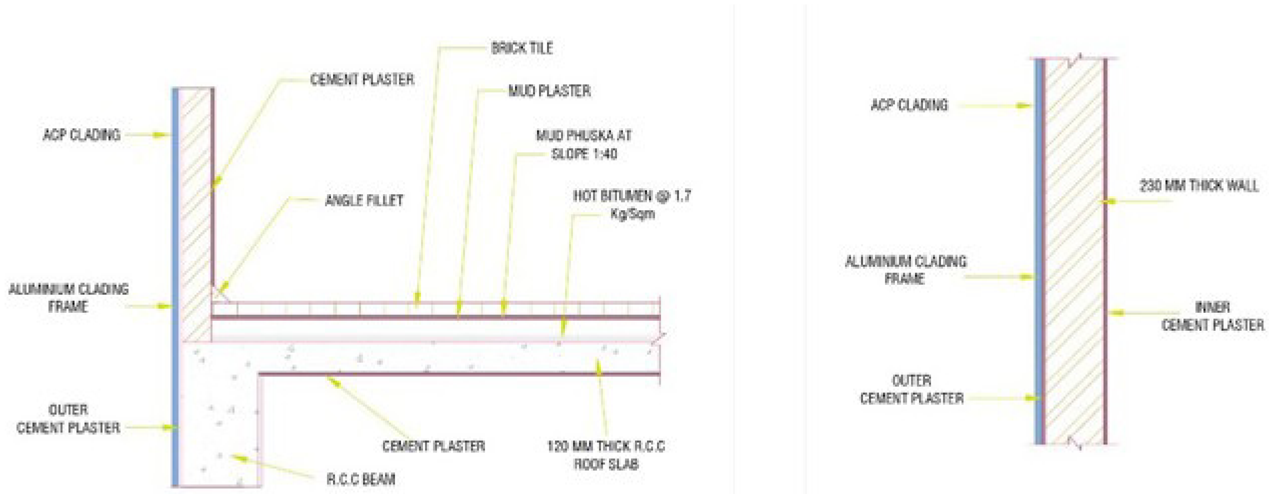

Figure 3. Section of the terrace and the section through exterior wall.

The hospital windows consist of 10 mm single-glass panels with aluminum frames, offering a U-value of 7.1 W/m²K. Figure 4 shows the section of window Type 1 and the section of window Type 2.

Figure 4. Section of window Type 1 and the section of window Type 2.

3.2 Energy Evaluation

To assess the hospital's overall energy use, a preliminary energy study is conducted. Using Rhino 7 and Climate Studio 1.9, a simulation model of the current building was created for this purpose, taking into account the building's current parameters. The facility's Energy Performance Index (EPI) is the main result of this investigation. When it comes to tracking and comparing building energy usage, the EPI is a trustworthy indication. The total floor space has a direct impact on the index because energy use is measured per unit of built-up area. A baseline strategy was created after a thorough review and collection of data. This plan identifies the performance gaps and offers a framework for putting corrective actions into action.

3.3 Sustainable Materials For Retrofitting:

For important elements including the hospital's external walls, windows, and roof, various retrofit techniques were found. One workable approach among these was to insulate the roof and walls with thermal insulation. Polyurethane spray insulation with a U-value of 0.579 W/m²K was taken into consideration for the roof. External Thermal Insulation Composite Systems (ETICS) with a U-value of 0.252 W/m²K were suggested for the external walls. A U-value of 1.53 W/m²K was also attained by replacing all of the original windows with double low-E glazing (3 mm glass + 13 mm air gap + 3 mm glass) and extending window projections to lessen solar gain. To identify the best course of action, simulation models were created and examined for every retrofit scenario. The comparative evaluation identified the configuration that delivered the highest energy efficiency improvements.

4. Findings and Discussion

4.1 Base Case

A base model was developed for simulation with the following specifications:

The external wall is constructed with 230 mm thick clay brick, plastered on both sides, providing a U-value of 2.13 W/m²K.

The roof consists of a flat reinforced concrete slab with brick tiling, having a U-value of 2.07 W/m²K.

The windows are single-glazed, 10 mm thick glass panels fitted in aluminum frames, with a U-value of 7.1 W/m²K.

The simulation results, presented in Figure 5, indicate that the Energy Performance Index (EPI) for the existing system (base model) is 293 kWh/m²/year, as calculated from Figure 4.

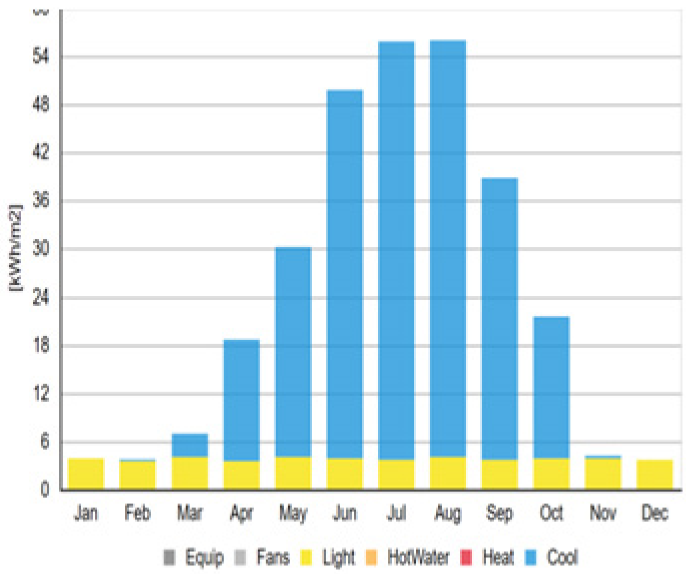

Figure 5. EPI for the existing or base model.

4.2 Base Case with Roof Insulation

Figure 6 presents the simulation results for the existing building with an insulated roof using polyurethane spray (U-value = 0.579 W/m²K). After analysis, the Energy Performance Index (EPI) for this case was found to be 293 kWh/m²/year, which shows no improvement in energy savings (EPI saved = 293 – 293 = 0 kWh/m²/year).

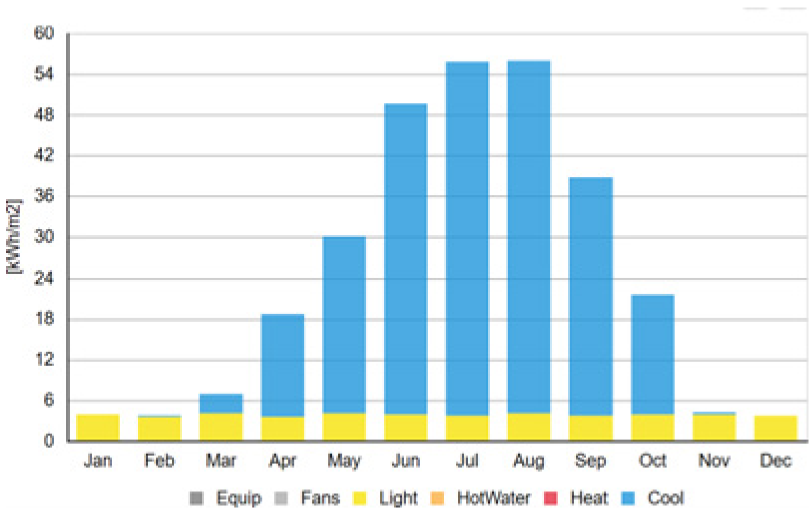

Figure 6. EPI for the existing building with roof insulation.

4.3 Base Case with Roof Insulation and Outer Wall Insulation

Figure 7 illustrates the simulation results for the existing building with both roof and wall insulation applied. In this case, the External Thermal Insulation Composite System (ETICS), with a U-value of 0.252 W/m²K, was used. The calculated Energy Performance Index (EPI) is 257 kWh/m²/year, indicating an energy saving of 36 kWh/m²/year (EPI saved = 293 – 257 = 36 kWh/m²/year).

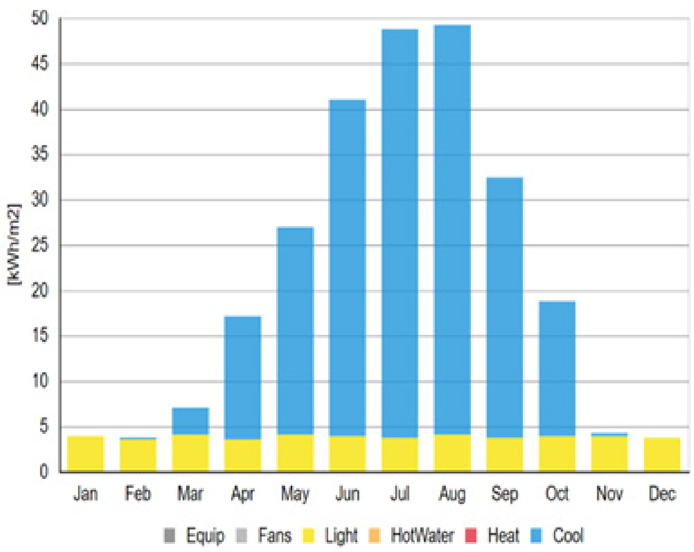

Figure 7. EPI for existing building with roof and outer wall insulation.

4.4 Base Case with Roof Insulation and Outer Wall Insulation and Replacing Windows

In this case, the existing windows in the base model were replaced with double-glazed windows having a U-value of 0.579 W/m²K. As shown in Figure 8, the simulation results indicate an Energy Performance Index (EPI) of 243 kWh/m²/year, reflecting an energy saving of 50 kWh/m²/year (EPI saved = 293 – 243 = 50 kWh/m²/year).

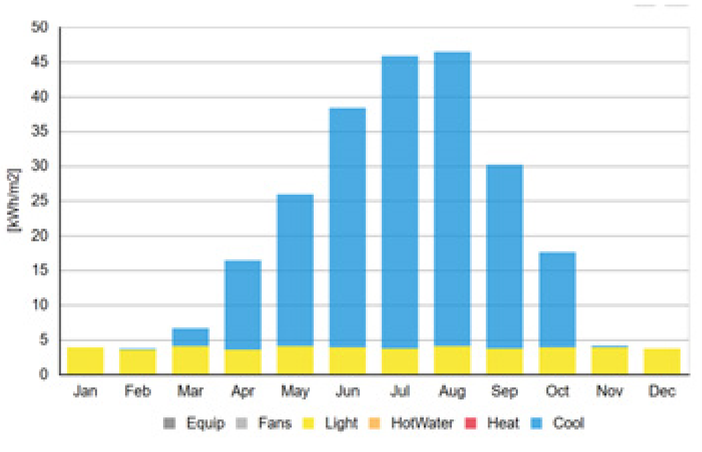

Figure 8. EPI for existing building with roof and outer wall insulation and replacing windows.

5. Conclusions

In order to lower operating costs, lessen environmental effect, and guarantee the sustainability of healthcare infrastructure, this study offers a thorough analysis of methods for enhancing hospital energy efficiency. A major issue made worse by population increase and rising worldwide energy demands is the growing demand for energy in buildings, especially in healthcare facilities. Using cutting-edge building techniques and technology that reduce greenhouse gas emissions and protect environmental health is necessary to address these problems. The paper demonstrates the efficacy of retrofitting existing buildings with environmentally friendly solutions through a review of the literature and a case study of Nutema Hospital in Meerut, India. Among the methods assessed, External Thermal Insulation Composite Systems (ETICS) and polyurethane spray foam insulation shown efficacy in improving thermal performance and reducing heat loss via bridging. Energy conservation was further enhanced by installing double-glazing systems in place of single-glazed windows. The Energy Performance Index (EPI) was used as a baseline to measure retrofit results, and simulation models were used for energy assessment. The results showed significant energy savings, with EPI reductions ranging from 13% to 19%, highlighting the obvious benefits of sustainable retrofit techniques. In conclusion, the study highlights how important energy-saving measures are for healthcare facilities. Hospitals can continue to provide high-quality healthcare services while actively supporting international efforts to mitigate climate change and reducing their energy usage and operating costs by implementing sustainable retrofitting measures. Without a doubt, these building retrofitting solutions will reduce the environmental problems caused by excessive energy and other resource use and our need on artificial means for thermal comfort. As a result, a more climate-responsive, sustainable, and environmentally friendly built form will emerge in the future (Kamal, 2012).

References

[1] Ansari Z. A., Mujumdar P., Brar T. S. and Kamal Arif M. (2025). Building Envelope Retrofitting Strategies for Energy-Efficient Healthcare Architecture in India. Architecture Engineering and Science, 6(3), 211-216.

[2] Bangre A., Surwade R. and Kamal, Arif M. (2023). Prospects of double glazed windows in buildings: energy conservation and environmental sustainability. American Journal of Civil Engineering and Architecture, 11(3), 64-69.

[3] Bano F. and Kamal, M. A. (2016). Examining the role of building envelope for energy efficiency in office buildings in India. Architecture Research, 6(5), 107-115.

[4] Buonomano A., Calise F., Ferruzzi, G. and Palombo, A. (2014). Dynamic energy performance analysis: Case study for energy efficiency retrofits of hospital buildings. Energy, 78, 555-572.

[5] Cui Y., Xie J., Liu, J., Wang J., and Chen S. (2017). A review on phase change material application in building. Advances in Mechanical Engineering, 9(6), 1687.

[6] Dadzie J., Pratt I., and Frimpong-Asante, J. (2022, November). A review of sustainable technologies for energy efficient upgrade of existing buildings and systems. In IOP Conference Series: Earth and Environmental Science, 1101(2), 22028. IOP Publishing.

[7] Hafez F. S., Sa'di B., Safa-Gamal M., Taufiq-Yap Y. H., Alrifaey M., Seyedmahmoudian M. and Mekhilef S. (2023). Energy efficiency in sustainable buildings: a systematic review with taxonomy, challenges, motivations, methodological aspects, recommendations, and pathways for future research. Energy Strategy Reviews, 45, 101013.

[8] Huang H., Wang H., Hu Y. J., Li C., & Wang X. (2022). The development trends of existing building energy conservation and emission reduction—A comprehensive review. Energy Reports, 8, 13170-13188.
[9] Kamal Arif M. (2013). An assessment of climatic design strategy for low energy residential buildings in hot and arid climate.
[10] Kamal Arif M. (2012). Reinventing traditional system for sustainable built environment: An overview of Passive Downdraft Evaporative Cooling (PDEC) technique for energy conservation, Journal of Research in Architecture and Planning, 11(2), 56-62.
[11] Liu Y., Liu T., Ye S. and Liu Y. (2018). Cost-benefit analysis for Energy Efficiency Retrofit of existing buildings: A case study in China. Journal of cleaner production, 177, 493-506.
[12] Mohammadpour A., Anumba C. and Messner J. (2012). Energy Efficiency in Healthcare Facility Retrofits–Key Issues. In 7th International Conference on Innovation in Architecture, Engineering and Construction (AEC), São Paulo, Brazil.
[13] Morales-Méndez J. D. and Silva-Rodríguez R. (2018). Environmental assessment of ozone layer depletion due to the manufacture of plastic bags. Heliyon, 4(12).
[14] Pedamallu L. R. T., Singh V. K. and Gomes A. P. F. (2016). Quantitative assessment of advanced energy efficiency retrofitting for hospitals in India. In Energy Sustainability, 50220, 10, American Society of Mechanical Engineers.
[15] Radwan A. F., Hanafy A. A., Elhelw M. and El-Sayed A. E. H. A. (2016). Retrofitting of existing buildings to achieve better energy-efficiency in commercial building case study: Hospital in Egypt. Alexandria engineering journal, 55(4), 3061-3071.
[16] Simona P. L., Spiru P. and Ion I. V. (2017). Increasing the energy efficiency of buildings by thermal insulation. Energy Procedia, 128, 393-399.
[17] Tong H. and Chen K. (2020). Renovation Measures for Energy-saving Skin of Existing Buildings. In E3S Web of Conferences, 194, 1023. EDP Sciences.
[18] William M. A., Elharidi A. M., Hanafy A. A., Attia A. and Elhelw M. (2020). Energy-efficient retrofitting strategies for healthcare facilities in hot-humid climate: Parametric and economical analysis. Alexandria Engineering Journal, 59(6), 4549-4562.
[19] Zalba B., Marín J. M., Cabeza L. F. and Mehling H. (2003). Review on thermal energy storage with phase change: materials, heat transfer analysis and applications. Applied thermal engineering, 23(3), 251-283.
[20] Zinzi M. (2006). Office worker preferences of electrochromic windows: a pilot study. Building and Environment, 41(9), 1262-1273.