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Achieving Energy Efficiency in Buildings through Retrofitting Strategy: A Literature Review

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Abstract

Office buildings constructed in the 2000s often face significant challenges in achieving energy efficiency, as they were not designed to adapt to modern climate conditions. This limitation leads to high energy consumption, reduced functionality, and performance degradation over time. Addressing these issues requires the implementation of retrofit strategies to improve energy efficiency, space comfort, and building resilience. This study focuses on analyzing existing research to identify effective retrofitting approaches for enhancing energy performance in office buildings. The study emphasizes passive strategies such as shading, double-skin facades, green roofs, and the use of environmentally friendly technologies and materials for building envelope modifications. Utilizing a literature review method, data were gathered from 90 research articles on retrofit strategies for existing buildings. The findings demonstrate that building envelope retrofits can significantly reduce energy consumption, improve occupant comfort, and enhance overall performance. Additionally, these strategies contribute to lowering carbon emissions, supporting a low-carbon economy, and reducing operational energy costs, making them essential for sustainable building practices.

Keywords: Energy Efficiency, Retrofitting Strategy, Resilience, Literature Review

Introduction

Achieving energy efficiency is a major difficulty for many office buildings built in the early 2000s. These buildings frequently fail to satisfy contemporary energy demands and adapt to the effects of climate change, even with sporadic restorations like exterior improvements or interior adjustments. Because they were created using antiquated standards, they frequently use excessive energy and gradually lose performance. These difficulties highlight the importance of implementing efficient retrofitting techniques to improve energy efficiency and guarantee sustainability in the built environment. The building's inability to adapt to technological advancements and enhanced environmental standards has led to high operational costs and significant carbon emissions [1]. This situation reflects the challenges many office buildings face in Indonesia, especially those designed in past decades without considering future energy efficiency needs.

In the last decade, the development of green building concepts and energy efficiency has become a crucial agenda for various sectors, particularly in industries heavily dependent on energy usage, such as the oil and gas sector[2], [3]. One widely applied solution to improving energy efficiency in existing buildings is the retrofit strategy, which involves enhancing and updating building systems using more environmentally friendly and energy-efficient technologies [4], [5]. Retrofits aim to reduce energy consumption and enhance comfort, build resilience to climate change, and reduce carbon emissions.

Retrofit strategies involve replacing outdated equipment with more efficient and modern alternatives to improve a building's performance and efficiency. Technically, this process may include updating heating, cooling, and lighting systems, as well as improving building insulation [6]–[9]. Research indicates that implementing retrofit strategies can significantly reduce energy consumption and increase occupant comfort and productivity [10]–[12]. These measures allow existing buildings to better adapt to energy demands and contribute to environmental sustainability efforts.

Retrofit is a strategy to enhance building efficiency and performance by replacing outdated equipment or systems with more modern and efficient alternatives. This process includes not only physical improvements but also modifications to energy, lighting, and ventilation systems to achieve a more sustainable environment. According to Jafari & Valentin (2017), retrofitting can create opportunities to reduce energy consumption and carbon emissions, aligning with global sustainability goals. Additionally, Luo & Oyedele, (2022) explain that retrofitting can also improve user comfort, which is an essential factor in modern building design. Thus, implementing retrofit strategies not only benefits energy efficiency but also positively contributes to the quality of life for building occupants.

As awareness of the importance of sustainable development increases, retrofit strategies are gaining attention as one of the solutions to address the environmental challenges faced by existing buildings. Retrofitting can be an effective tool for reducing the environmental impact of buildings by upgrading existing infrastructure [10]. Research by Weber & Wolff (2018) also shows that investment in retrofitting not only reduces energy costs but can also increase property value and appeal to tenants. Considering these various aspects, retrofitting becomes a strategic approach to achieving sustainability and energy efficiency goals in the building sector, in line with global initiatives to reduce emissions and improve environmental quality.

One way to improve energy efficiency in existing office buildings is through retrofitting. Retrofit strategies involve updating or replacing existing systems and components with more efficient technology. For example, replacing windows with better-insulated glass or installing advanced energy management systems can have a significant impact on a building's energy use. According to research, implementing retrofit strategies can yield annual energy savings of up to 30% in some cases, depending on the building's condition and the technologies applied [13], [14].

Architectural design also plays a crucial role in the energy efficiency of office buildings. Design that considers building orientation, the use of environmentally friendly materials, and natural ventilation can reduce reliance on artificial heating and cooling systems. Additionally, design elements such as green roofs and shading techniques can lower internal building temperatures and improve occupant comfort. Research shows that good design can improve a building's energy efficiency by up to 20% [15]. Investment in energy efficiency not only provides short-term benefits such as energy cost savings but also brings long-term advantages. With reduced energy consumption, buildings can increase market value and appeal to tenants who prioritize sustainability. Furthermore, implementing energy efficiency measures can extend the building's lifespan and reduce the need for costly maintenance. Good energy performance can also enhance occupant comfort and productivity, which in turn positively impacts the company [16].

Issues faced by existing buildings include the increasing need to enhance energy efficiency and indoor comfort (thermal comfort and visual comfort), especially in extreme tropical climates. This necessitates the implementation of effective retrofit strategies such as shading techniques, secondary skins (double skin facades, DSFs), and green roofs. In the past five years, several articles have been published discussing retrofit strategies on building envelopes, with shading techniques, double skin facades, and green roofs as efforts to improve thermal comfort and energy efficiency in buildings. Effective shading, double skin facades, and green roofs are essential in reducing direct solar radiation entering the room, thus reducing the use of air conditioning, artificial lighting during the day, and increasing occupant comfort. Table 1 describes the number of articles discussing retrofit strategies with various techniques or approaches.

Tabble 1. The implementation of Retrofiting Strategy for Existing Building.

Year of Research	Ammount of the articles published	Discussion
2019 – 2024	30	Retrofit strategy with shading and shading techniques.
2019 – 2024	30	Retrofit strategy with Double Skin Facades (DSFs) technique
2019 – 2024	30	Retrofit strategy with green roof techniques

Articles were gathered from a number of reliable databases, including ScienceDirect, Scopus, EBSCOhost, Web of Science, MDPI, SAGE, and WILEY, to guarantee a thorough grasp of retrofit techniques for enhancing building energy efficiency. These databases made a large number of excellent research that were pertinent to the subject available. Following that, the gathered publications were divided into three main categories: green roof approaches, double skin facades (DSFs), and retrofit strategies employing shading and shading procedures. A targeted examination of the best methods for building retrofitting was made possible by this theme grouping.

The result of the first group Literature Study Analysis was promoted by Chung-Camargo et al. (2024). This research indicates that retrofit strategies, such as improved thermal insulation, natural ventilation, energy-efficient materials, and cooling technologies, are efficient and effective in reducing energy consumption in buildings in tropical climates. However, most of the research in this article focuses on residential and commercial buildings in general, highlighting a gap in studies on the application of these retrofit strategies in existing office buildings. Office buildings have unique characteristics, such as high energy loads from electronic equipment and lighting, as well as the need for consistent thermal comfort throughout the day, making the application of retrofit strategies more complex. Therefore, more studies are needed to understand the effectiveness and adaptation of retrofit strategies, particularly for existing office buildings in tropical climates, to achieve optimal energy efficiency without disrupting office operations.

The second group of the Literature review was represented by Lops et al. (2023) who demonstrate that double-skin facades (DSFs) are effective in improving the energy efficiency of buildings in temperate regions like central Italy, with benefits including reduced energy consumption for heating and cooling, and enhanced thermal comfort. However, the application of DSFs in Jakarta, Indonesia, which has a tropical climate with high temperatures and humidity, faces different challenges. In tropical climates like Jakarta, high temperatures and constant humidity throughout the year pose challenges for the performance of DSFs, which in many cases are designed for climates with clear seasonal variations. The research gap that emerges is the lack of empirical studies on the effectiveness of DSFs in reducing excess heat and cooling needs in tropical regions. Additionally, the optimal design adaptations of DSFs for high humidity environments have not been extensively explored, necessitating further studies to understand whether DSFs can be optimized for office buildings in Jakarta to be efficient and suitable for local climate conditions without causing unexpected increases in energy consumption.

The third group of Literature Review Analysis found by Jaffal et al. (2012) and show that green roofs can significantly enhance energy efficiency in buildings by reducing cooling loads, especially in warm climates. Green roofs act as an additional insulation layer that helps reduce heat absorption, maintain stable indoor temperatures, and lower the energy needed for cooling. However, the application of this technology to existing office buildings in high-humidity and tropical climates, such as Jakarta, faces several challenges. The research gap identified is the lack of studies on the long-term effectiveness of green roofs in high-humidity conditions, which can affect plant health and energy performance. Additionally, the optimal design of green roofs to manage high temperatures and consistent humidity in tropical climates has not been extensively explored, necessitating further research to assess whether this solution can be effectively applied to existing office buildings in tropical areas without incurring additional maintenance costs or excessive humidity risks that could damage building structures.

Existing office buildings are an interesting topic for energy efficiency research, especially when it comes to meeting the rising demand for sustainability and assisting with carbon emission reduction goals. According to the body of available research, retrofit techniques provide workable answers for improving these buildings' energy efficiency. In order to find efficient retrofit techniques that might enhance aging office buildings' overall performance, resilience, occupant comfort, and energy efficiency, this study will examine earlier research.

Methodology

This research employs the literature review method to analyze and examine the application of retrofit strategies in existing office buildings [19]. A literature review provides a strong theoretical foundation and up-to-date information on best practices and relevant innovations in sustainable building design [20]. Data collection was carried out through a review of 90 literatures, which included various scientific articles, research reports, and case studies relevant to the topic of retrofitting and energy efficiency. The selected literature focuses on various retrofit strategies and techniques on building envelopes, including shading, double skin facades (DSFs) / secondary skins, green roofs, and the use of environmentally friendly technologies and materials. Data analysis utilized the Systematic Literature Review method by categorizing findings from the collected literature, then identifying patterns and relationships between the application of retrofit techniques with energy efficiency and occupant comfort.

Results and Discussion

Shading

The results of research on retrofit strategies using shading techniques and canopies show a positive impact on energy efficiency and thermal comfort in buildings, especially in tropical climates. A systematic review reveals that the implementation of retrofit measures, such as installing shading devices and optimizing glass, can improve the indoor thermal environment by reducing operative temperatures by up to 3.4°C in winter and 3.2°C in summer. This strategy not only lowers energy consumption but also increases the duration of comfort for occupants [14], [21], [22]

Double Skin Façade

Research on the application of retrofit strategies with double skin façades (DSFs) on existing buildings shows that using this façade has significant potential to improve energy efficiency and occupant comfort. Studies conducted on several buildings found that the implementation of double skin façades can reduce the annual energy demand of buildings by between 37% to 56% by 2030, and between 42% to 59% by 2070, depending on the configurations used and the projected climate conditions [13], [17], [23].

Green Roof

The application of retrofit strategies with green roof techniques on existing buildings shows significant results in various environmental and functional aspects. Green roofs, which consist of vegetation planted on top of the roof structure, not only enhance the building's aesthetics but also contribute to rainwater management by absorbing water before it flows into the drainage system. This helps reduce the impact of rainwater runoff in dense urban areas. Additionally, green roofs play a role in reducing the urban heat island effect by absorbing sunlight and lowering the temperatures around the building. By providing habitats for birds and insects, green roofs also increase biodiversity. In terms of sustainability, green roof systems can extend the lifespan of existing roof materials by protecting them from direct UV exposure and other elements, thereby reducing maintenance and replacement needs. Overall, retrofitting with green roof techniques not only improves building quality but also offers broad environmental benefits [15], [18]

Discussion

Retrofit strategies involving shading techniques, double skin façades, and green roofs show great potential in enhancing energy efficiency and thermal comfort in existing buildings, particularly in tropical climates. Implementing shading techniques has proven effective in reducing indoor operative temperatures, both in summer and winter, thereby improving occupant comfort and reducing energy consumption [14], [16], [24]. The double skin façades (DSFs) strategy shows significant potential for reducing the annual energy needs of buildings in the long term, especially considering climate change projections, which could reduce energy consumption by over 50% by 2070 [13], [17]. On the other hand, the use of green roofs provides not only thermal and aesthetic benefits but also contributes to rainwater management and reduces the urban heat island effect, while enhancing building sustainability by extending the lifespan of roof materials [15], [18], [25], [26]. Despite all these significant benefits, the main challenges lie in applying these strategies to existing buildings, particularly concerning high initial costs, maintenance requirements, and design adjustments needed to ensure their effectiveness under various climate conditions and existing buildings.

Conclusion

This literature research finds that the application of retrofit strategies on building envelopes through shading approaches, double skin facades, and green roofs demonstrates a reduction in indoor temperatures, direct natural lighting, and visual comfort. This significantly reduces the energy consumption of air conditioning (AC) and lighting during the day. Additionally, the analysis results indicate that retrofit strategies impact not only carbon emission reduction but also operational energy cost savings. This literature research underscores the importance of modifications to the existing building / office building envelope in Indonesia ; especially existing building of the PT. Pertamina Patra Niaga-ITJ Jakarta office building to achieve building energy efficiency, improve building performance, and enhance sustainability for climate change mitigation.

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