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Research Article

Promoting Energy Efficiency and Sustainability in High-Rise Buildings: A Critical Review

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Abstract – High-rise buildings are essential for addressing land shortages in urban areas and recognize as key to the future of smart cities. However, they consume significant energy for lighting, air conditioning and electrical appliances contributing to greenhouse gas emissions and global warming. Efficient energy use in pre-designed high-rise buildings is crucial for sustainable urban growth. This study explores strategies to enhance energy efficiency in high-rise buildings focusing on advanced technologies and innovative measures. Upgrading the building envelope, particularly improving its thermal properties is a key strategy for better energy efficiency. Efficient high-rise engineering emphasizes passive strategies, natural ventilation and energy saving methods to reduce energy consumption and promote environmental sustainability. Incorporating modern insulation, green technologies and innovative features like smart energy glass windows, recuperators, solar panels, passive solar shades, active double-curtain walls, daylighting and natural ventilation can significantly reduce energy use and boost sustainability. Structural insulated panels (SIPs) are prefabricated parts that enable faster construction, better strength, improved energy and sound efficiency. Regulations like the Energy Conservation Act and the Energy Conservation Building Code aim to promote energy efficient building construction. By adopting tailored energy saving methods suitable for different climates and leveraging advanced technologies, high-rise buildings can pursue more sustainable energy practices and aid global greenhouse gas emission reduction efforts.

Keywords – High-Rise Buildings, Energy Efficiency, Passive Strategies, Sustainable Urban Growth and Green Technologies

I. INTRODUCTION

Energy is crucial for economic growth and is fundamental to the social and economic development of a country [1]. Efficient energy use in pre-designed high-rise buildings is a key to sustainable urban growth. To meet the rising energy needs of growing population of the world, tall and supertall buildings are now designed with energy efficiency. Architects and engineers are focusing on saving energy through creative designs and smart operations supporting the increasing push for green construction [2]. Worldwide, the building and construction industry is responsible for about 39% of greenhouse gas emissions with 28% coming from building operations and 11% from the energy used to produce construction materials [3]. The building sector, especially high-rise buildings is a major source of CO_2 emissions. Promoting ultra-low energy, eco-friendly high-rise buildings is crucial for reducing energy consumption and greenhouse gas emissions [4]. High-rise buildings are essential for addressing land shortages in big cities and are seen as key to the future of smart cities [5]. The construction industry faces significant challenges like increasing energy use, pollution, climate change and resource depletion. Governments are working to address these issues through regulations, policies and research efforts [6]. Energy efficiency in buildings is becoming more important because of the harmful effects of CO_2 emissions and their connection to global warming. It has been prompted the identification of key areas where energy use can be reduced and improved. Standards have been created to ensure buildings meet minimum sustainable requirements for various parts of the building [7]. Energy use is going up fast worldwide, particularly in homes as more people live in cities. This increase leads to more carbon dioxide emissions pushing the world to find ways to make buildings more energy efficient [8]. The rapid growth of the world population significantly impacts the expansion and density of urban areas [9]. High-rise buildings use a lot of energy and contribute to global warming. To save energy, it is helpful to use modern technology and green building methods in the construction. High-rises are becoming a big part of city planning focusing on sustainability and creating pleasant green spaces for people [10]. Reducing energy consumption in buildings is crucial as they are essential components of our communities and cities [11]. High-rise buildings consume significant energy for lighting, air conditioning and electrical appliances attributed to higher occupancy and longer operational periods. Lighting and air conditioning alone can make up 50% to 80% of the total energy usage in such structures [12]. Energy efficiency is a recognized method to decrease energy demand [13]. As energy resources diminish and demand rises, it becomes important to develop methods for improving building energy efficiency [14]. To address this high energy usage buildings, need to become more energy efficient [15]. Constructing energy efficient buildings using environmentally friendly alternative energy is a crucial aspect of energy conservation [16]. To enhance energy efficiency and sustainability in high-rise buildings, several innovative measures have been introduced to reduce energy usage and operational expenses. One effective method is improving building energy management systems (BEMS) settings and control strategies to meet both energy efficiency and occupant comfort goals concurrently [17]. Boosting energy efficiency in pre-designed high-rise buildings involves several methods. These include using modern insulation, green technologies and innovative features like smart energy glass windows, recuperators, solar panels, passive solar shades, active double-curtain walls, daylighting and natural ventilation are being incorporated into their design and operation to cut energy use and boost sustainability. By adopting these tailored energy saving methods suitable for different climates and leveraging advanced technologies, high-rise buildings can pursue more sustainable energy practices and aid global greenhouse gas emission reduction efforts [18]. Structural insulated panels (SIPs) are prefabricated parts with insulation between two layers of concrete, wood or masonry used for walls, floors and roofs. They enable faster construction, better strength and improved energy and sound efficiency making them popular in various building projects for their durability and sustainability [19]. Increased energy use has led to a nationwide focus on energy savings. Regulations like the Energy Conservation Act and the Energy Conservation Building Code aim to promote energy efficient building construction. Comfortable living environments influence behaviour of the occupants and productivity in commercial buildings [20]. Improving energy efficiency in commercial buildings is now a significant need. As sustainable energy sources become more common, energy systems need to be adaptable. Regulations aim for nearly net-zero energy buildings but it is unclear if they truly reduce energy use and increase flexibility [21]. High-rise buildings need a lot of energy for services and equipment. Air conditioning, lighting and other equipment use the most energy, so strategies are used to lower energy demands in these buildings [22]. High-rise buildings can be made more efficient by considering their inherent structural characteristics, which can either help or hinder energy systems for various activities in future designs. To maximize efficiency, energy measures must be systematically implemented both within and around the building for different uses. Efficient energy use in and around the building can be improved by reducing losses through conservation measures and by enhancing system operations. This can include incorporating renewable energy technologies to perform specific functions.

II. ENERGY EFFICIENCY STRATEGIES

To boost energy efficiency in pre-designed high-rise buildings, advanced technologies are essential. Upgrading the building envelope, particularly improving its thermal properties is a key strategy for better energy efficiency in skyscrapers. High-rise buildings have distinct features like unique architecture, advanced technology and energy considerations compared to low-rise structures. Efficient high-rise engineering emphasizes passive strategies, natural ventilation and energy-saving methods to reduce energy consumption and promote environmental sustainability. Consideration of geographical location is crucial for understanding an energy needs of the buildings. Sustainable trends emphasize green buildings with low-carbon energy sources particularly challenging for high-rise buildings in extreme climates. To address heat and light issues in high-rise, parallel self-shading patterns or overhanging devices like louvers used. To save energy, outer shell of the building like the envelope and frame plays a crucial role in providing a comfortable indoor climate and suitable external conditions. The choice of construction materials especially insulation materials can greatly impact energy use based on their thermal properties. Various insulation materials available in the market with composite materials being common due to their ability to control multiple properties like performance and cost. Basalt fibres, polyurethane foam and expanded polystyrene foam are emerging as efficient insulation materials offering stiffness and processability, and are considered a better alternative to traditional options like glass fibres and asbestos. Modern tall buildings rely heavily on electrical lighting systems but windows are crucial for reducing energy usage by providing natural light. However, the design of high-rise buildings can affect energy consumption, as opaque areas may limit light and increase the need for artificial lighting and air conditioning. Despite this, high-rise buildings generally have ample ambient light especially in upper levels compared to residential buildings. Different types of window systems impact building energy consumption by affecting passive design and lighting which in turn affects air conditioning usage. It includes various window options like low-emissivity windows, argon-filled vacuum glass, multi-layered door and window glass, coloured glass, dynamic glazing, phase change glass and insulated daylighting glass. Solar panels, whether photovoltaic (PV) or solar thermal (ST) can be installed on vertical facades facing south or west, or incorporated into balcony parapets if there is sufficient sunlight. When mounted on facades to preserve views of the occupants, efforts are made to minimize the reduction in electrical yield due to glazing. The design of the building greatly influences the feasibility of rooftop and integrated wind turbines. Design considerations to enhance turbine efficiency such as positioning them on windward building walls if rooftop winds are insufficient. Combining wind turbines with solar panels in hybrid systems reduces energy consumption and greenhouse gas emissions. While integrating wind turbines into building structures is beneficial for reducing energy demand, effectiveness depends largely on the site. For high-rise buildings energy efficiency is increasingly important, with studies showing that lighting layout can significantly reduce energy demand. Building automation systems (BAS) and smart building infrastructure techniques play vital roles in enhancing building efficiency. BAS, are intelligent networks of electronic devices linked by a central control computer primarily used for monitoring and controlling HVAC systems to minimize electricity wastage and ensure fault-free service. Energy management processes can benefit from predictive algorithms and automation tools that optimize HVAC settings and energy storage systems. Data and algorithms play a crucial role in optimizing building usage for energy, sustainability and comfort. Efforts across various disciplines have led to the development of algorithms for controlling energy-intensive systems like HVAC resulting in significant energy savings. Real-time data logs are used to study energy performance and comfort in different building types, but there is a need for more data-driven optimization as building design and operation evolve over time. Smart meters offer a solution by reducing measurement acquisition costs and enabling advanced features like energy savings and grid connectivity. This project introduces a smart meter infrastructure for managing and measuring electrical energy in buildings. The meters provide real-time electrical parameter estimates and communicate with a home controller using Zigbee technology. An energy management system, developed using coalition game theory through the fog platform, uses data from smart meters to control various devices like lights, occupancy sensors and actuators reducing building consumption while maintaining comfort levels. The architecture offers easy implementation, flexibility and an affordable solution for those seeking comprehensive features in a single system. Integrating smart meter infrastructure with energy management strategies can help control power demand, improving efficiency and reducing wear on electrical systems. These meters should not only measure energy but also other physical quantities like water, gas, temperature and humidity. Energy management systems (EMS) can function independently to monitor and control specific tasks or be integrated into building energy management systems (BEMS) or district energy management systems (DEMS) for groups of buildings such as server or data centres. These systems are responsible for enhancing energy efficiency in areas like space heating, cooling, waste heat and hot water production with heat pump assistance. An energy management system (EMS) is a technology used to plan, control and monitor energy usage. Initially used in manufacturing industries, it is now widely applied in various sectors including buildings. For buildings, EMS ensures real-time monitoring, data aggregation from sensors and optimization for efficiency aiming to reduce operational expenses. Integrated with intelligent devices and IoT, EMS helps in decision making and waste reduction. Facility energy management software (FEMS) optimizes energy consumption within organizations offering benefits like continuous monitoring, performance visualization and cost savings on operation and maintenance. Improving energy efficiency in high-rise buildings involves reducing the need for artificial lighting. It can be achieved by using light transmitting materials for interior lighting and integrating LEDs into the glazing for exterior lighting. LEDs offer several advantages over traditional lighting options including lower energy consumption, longer lifespan and greater durability. Using recycled materials for LED production can further reduce emissions and create a fully recyclable system. Additionally, employing LED technology in daylighting systems allows for highly efficient facades with reduced thickness, saving materials such as steel, concrete and glass. To conserve energy in HVAC systems, it is important to choose the right size equipment and incorporate waste-heat recovery using advanced energy exchange systems. These systems include technologies like thermal wheels, desiccant systems, refrigeration recovery and various refrigeration cycle variations. Using heat exchangers, appropriately sized piping and efficient machinery with advanced designs helps optimize energy exchange. Additionally, the growing use of natural gas power plants noted as a cleaner energy option supporting the shift towards renewable energy in high-rise buildings. The study uses BIM and EnergyPlus to analyse energy performance and applies a GA-based optimization technique to improve the HVAC control schedule for better energy efficiency. Simulation tools like EnergyPlus and Ecotect analysis help assess how advanced envelope designs affect heating and cooling loads in buildings of different heights and uses. Combining building energy management systems (BEMS) with building information modelling (BIM) marks a significant advancement in sustainable building practices. This integration enables users to enhance energy efficiency and promote occupant comfort throughout the lifecycle of the building from planning to maintenance. By uniting BEMS data with BIM detailed analysis, stakeholders can make well-informed decisions based on complete information. One of the most recent developments in the construction industry is the innovation of the structural insulated panels (SIPs). This is a new strategy that is being employed to reduce the construction time and also improve the energy conservation properties of a building. Structural insulated panels (SIPs) are quickly gaining popularity in the construction sector. They consist of a foam plastic insulation core sandwiched between two structural panel facings like oriented strand board (OSB) or plywood. Its core materials such as polyurethane (PUR) and expanded polystyrene (EPS), have further propelled the adoption of SIPs in residential and commercial construction. They are typically used in walls and roofs providing structure, insulation and sheathing all in one piece.

III. Benefits of Improved Energy Efficiency

The analysis found significant electricity savings in high-rise buildings with up to 91.64% in hospitals and 89.33% in residential buildings by implementing suggested measures. Recently, there is a focus on Green and ECBC compliant office buildings with energy savings of 33.24-37.55 MWh and 34.31-38.75 MWh annually and substantial cost savings. Energy needs including heating, cooling and lighting are determined by a location of the building and natural surroundings with potential for up to 20-59% energy savings. Insulation is crucial for shielding buildings from harsh weather conditions helping to cut down energy usage by around 40% each year. The insulation materials can be categorized into layer structures, sprinkle structures and insulation cover layers all showing promising properties in terms of fire behavior, thermal characteristics and mechanical strength. Typically, lighting accounts for 10-20% of total energy use in buildings. Integrating LEDs with control units adjusting lighting based on natural light intensity can lead to substantial energy savings ranging from 10% to 75%. Additionally, such systems can improve occupant comfort, well-being and satisfaction. Factors like the shape of building, window design and interior depth affect how much sunlight it gets. This assessment helps decide things like where to put windows, what kind of shading to use and how to modify the structure of building to maximize sunlight while minimizing energy use. Tall buildings with a high aspect ratio often receive more sunlight and can save more electricity especially when neighboring buildings do not block the sun. There are different ways to optimize the layout and energy efficiency of tall building like manual adjustments, automated methods for pre-designed buildings and building codes. The modern shading devices improve thermal management, save energy and enhance visual comfort by combining traditional self-shading features. They are designed to block sunlight effectively under different conditions, considering factors like the angle of sun and the position of shading device over time. ST panels may be useful for covering fire escape stairs or providing shading especially where noise and bird collision risks are concerns. The energy output from panels varies throughout the year and different times of the day with PV panels generating more power during sunny hours while ST panels are more effective during cloudy periods. Newly constructed buildings are now tasked with integrating energy efficiency and on-site energy supply. Solar panels are a great option for new high-rise buildings to generate renewable energy especially in crowded urban areas. This helps reduce the demand for grid electricity and lowers the carbon footprints of building if the electricity is not already sourced from renewable sources. Developing technologies and tools to connect occupants with renewable energy systems in buildings is essential. Long-term savings from the unused cost improving methods suggest a profitable scenario emphasizing key conclusions about the proposed energy reduction measures. In terms of numbers, energy saving measures have payback periods of about 10 years while reduced maintenance costs can save up to 20%. It is suggested that European and USA building standards should be the minimum requirement, with LEED standards offering significant improvements especially in envelope and mechanical design which affect over 60% of total savings. A wind power installation is proposed to harness small winds and low-potential thermal flows, reduce low-frequency vibrations and increase the stability and efficiency of wind energy use. This system is easy to install, maintain and repair. It has been shown that integrating solar and wind energy in buildings can save 11% to 15% of annual energy consumption. Building integrated wind turbines help cut electricity costs and overall life cycle expenses. Furthermore, studies examine factors like building dimensions, terrace size and wind direction impact on wind turbine efficiency. The Energy Conservation Bill and the Energy Conservation Act were passed in 2001 and later amended in 2010. In 2002, the Energy Management Center was re-established and renamed the Bureau of Energy Efficiency (BEE). In 2007, BEE launched the Energy Conservation Building Code (ECBC) to set minimum requirements for constructing energy efficient buildings by following specific design specifications. The main goal of ECBC is to meet the growing energy demand in new buildings. Similarly, Energy Conservation Policies of Buildings (ECPB) in China combine national plans, laws and regulations to improve building energy efficiency. This work aims to ensure energy efficient building design and construction by setting minimum requirements. The ECBC standards cover building envelopes, heating, ventilation, air conditioning, lighting, service water heating and electric power distribution. All electric systems, transformers, energy-efficient motors and diesel generators must meet mandatory regulations. This study used EnergyPlus software to simulate a building design based on the ECBC standards. The simulation considered various factors like latitude, longitude, weather, time zone, elevation, building area, lighting, heating and cooling. Following ECBC standards for energy-efficient building design resulted in a 27.4% increase in energy savings qualifying the building as ECBC compliant. Buildings are classified by function, design and construction for ECBC implementation. For an ECBC building, the minimum energy savings should be 25%, for ECBC Plus at least 35% and for Super-ECBC 50% or more. Major classifications include hospitality buildings (hotels, lodges, resorts) and healthcare buildings (hospitals, research centers, laboratories) that provide medical assistance. They introduced an automated algorithm to check energy compliance reducing the need for manual inspection. Using energy-efficient techniques when constructing residential buildings helps save a lot of energy and resources during the operation of high-rise buildings making them more energy efficient overall. To cool the building, energy efficient air conditioners used with a higher energy efficiency ratio (EER). These are air conditioners with better BEE ratings that provide the same cooling output while using less power. This led to a 24.4% reduction in power consumption meeting ECBC compliance standards. To meet ECBC standards, it is suggested that replacing traditional lighting systems (tube lights, incandescent bulbs, CFL bulbs) with energy efficient options such as the latest LED bulbs. Switched out the traditional fans for ones equipped with BLDC or DC Motors or certified by Energy Star. These options consume less energy compared to standard ceiling fans. By choosing fans with BLDC or DC Motors, power savings of up to 46.3% can achieved. The main job of water pump is to pump water to the tanks. By kept its working capacity intact to ensure it continues to pump water effectively. Therefore, the same power rated pump opted as recommended in EnergyPlus. However, this setup does not meet the requirements for ECBC compliance. Heat rejection is the process of getting rid of extra heat produced during cooling by using a condenser or cooler. It is like a combination of the work done by a compressor and the total heat energy moved from the colder side to the warmer side. So, it is closely linked to cooling. It has been found that saving power in heat rejection can reach up to 27.3%. SIPs offer a 22% cost saving over a 17-years lifespan of the buildings compared to timber framing. This is because SIPs have minimal environmental impact, improve energy performance significantly and reduce labour costs over time. The airtightness of SIP buildings minimizes air infiltration and enhances insulation, maintaining consistent indoor temperatures and reducing the need for heating or cooling. Buildings constructed with structural insulated panels (SIPs) perform well during earthquakes due to the high mechanical strength and low flexibility of panel.

IV. CONCLUSION

Energy is a major source of pollution contributing to global warming and climate change. Rising demand and production costs make it hard to address these issues. Strong energy conservation measures are needed, and everyone must help conserve energy to sustain our lifestyle. High-rise buildings use a lot of energy especially for HVAC, lighting and electrical systems. Efficient operation of HVAC, lighting and control systems is crucial as poor operation increases energy consumption. Solar control devices in building glass, improve energy efficiency but have higher embodied energy costs. Improving building performance to nearly zero-energy standards is essential. Factors like building shape, layout and climate are key in enhancing energy efficiency. Optimizing energy efficiency in tall buildings can be done through manual adjustments, automated methods and building codes. Efficient energy use benefits the environment, economy and occupant well-being. smart energy building management systems (SEBMS) are vital for enhancing energy efficiency. These systems support long-term energy policies and climate goals. Technological advances in the building industry include better insulation, recycled materials, green roofs, special windows and smart systems like automated windows and sensors. These helps manage energy use and improve building performance. Strategies for improving energy efficiency and reducing CO_2 emissions in high-rise buildings involve using insulation materials and assessing energy costs. Passive and active design methods reduce pollution and energy use. Active strategies use solar, wind and geothermal energy while passive methods maximize natural light. Using photovoltaics (PVs) and wind turbines reduces external energy use but adds complexity. Matching internal energy generation with demand is smart and cost-effective. Energy-efficient high-rise buildings offer many benefits, including lower energy costs and environmental impact making them attractive for investments and sustainable growth.

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REFERENCES

[1] Javeria A. Rehma, Babar Hussain, Aamir Habib, and Rizwan Mughal (2021, June). Current Energy Crisis of Pakistan: Status, Impact and Potential Solutions. Volume 1, No. 1 (1-5); Pakistan Journal of Scientific Research.

[2] Mir M. Ali, Kheir Al-Kodmany, and Paul J. Armstrong (2023, February). Energy Efficiency of Tall Buildings: A Global Snapshot of Innovative Design. MDPI. https://doi.org/10.3390/en16042063.

[3] Building Options to Improve Energy Efficiency and Reduce Environmental Impacts (2024, April). Cooper Carry.

[4] Yassine Himeur, Abdullah Alsalemi, Ayman Al-Kababji, and Faycal Bensaali (2020, September). Data fusion strategies for energy efficiency in buildings: overview, challenges and novel orientations. Arxiv. https://doi.org/10.1016/j.inffus.2020.07.003.

[5] Matheus Roberto Cabral, Pierre Blanchet, Eddie Koenders, and Academic Editor (2021, April). A State of the Art of the Overall Energy Efficiency of Wood Buildings—An Overview and Future Possibilities. MDPI. https://doi.org/10.3390/ma14081848.

[6] Raaid Rashad Jassem Al Doury, Saadet Ozkan, and M. Pinar Menguc (2020, April). Cascaded Thermodynamic and Environmental Analyses of Energy Generation Modalities of a High-Performance Building Based on Real-Time Measurements. MDPI.
https://doi.org/10.3390/e22040445.

[7] Izabela Kowalczyk, Damian Kozanecki, Sylwia Krasoń, and Martyna Rabenda (2022, February). Computational Modelling of VIG Plates Using FEM: Static and Dynamic Analysis. MDPI.
https://doi.org/10.3390/ma15041467.

[8] Haolan Liao, Rong Ren, and Lu Li (2023, March). Existing Building Renovation: A Review of Barriers to Economic and Environmental Benefits.
MDPI. https://doi.org/10.3390/ijerph20054058.

[9] Tanya Saroglou, Isaac A. Meir, Theodoros Theodosiou, and Baruch Givoni (August, 2017). Towards energy efficient skyscrapers. Volume 149; (PP 437-449). Science Direct.
https://doi.org/10.1016/j.enbuild.2017.05.057.

[10] Matheus Roberto Cabral and Pierre Blanchet (2021, April). A State of the Art of the Overall Energy Efficiency of Wood Buildings—An Overview and Future Possibilities. MDPI. https://doi.org/10.3390/ma14081848.

[11] Mohamed Farghali, Ahmed I. Osman, Israa M. A. Mohamed, Zhonghao Chen, Lin Chen, Ikko Ihara, Pow-Seng Yap, and David W. Rooney (2023, March). Strategies to save energy in the context of the energy crisis: a review. Springer Link. https://doi.org/10.1007/s10311-023-01591-5.

[12] Vishwajit, Anand, Vishnu Lakshmi Kadiri, and Chandrasekhar Putcha (2023, January). Passive buildings: a state-of-the-art review. Springer Link. https://doi.org/10.1186/s43065-022-00068-z.

[13] Yangluxi Li , and Lei Chen (2019, December). Study on the influence of voids on high-rise building on the wind environment. Springer Link.
https://doi.org/10.1007/s12273-019-0584-7.

[14] S. G. Sheina, L. V. Girya, A. E. Shvets, and N. S. Larin (December, 2022). Methods of Enhancing energy efficiency at the stage of construction of High-Rise Residential Buildings. Volume 1 (PP 17-23). Modern Trends in construction, urban and territorial planning. https://doi.org/10.23947/2949-1835-2022-1-1-17-23.

[15] Yasser Arab, Ahmad Sanusi Hassan, Zeyad Amin Al-Absi, Hussam Achour, Boonsap Witchayangkoon, and Bushra Qanaa (February, 2023). Retrofitting of a High-Rise Residential Building for Energy Efficiency with OTTTV as an Assessment Tool. Volume 102; Semarak Ilmu. https://doi.org/10.37934/arfmts.102.2.110119

[16] Nikolay Rudenko and Valery Ershov (2020, October). The use of green energy for energy conservation in high-rise buildings. Volume 164; E3S web of conferences. https://doi.org/10.1051/e3sconf/202016401023.

[17] Maria Kozlovska, Stefan Petkanic , Frantisek Vranay, and Dominik Vranay (August, 2023). Enhancing Energy Efficiency and Building Performance through BEMS-BIM Integration. MDPI.
https://doi.org/10.3390/en16176327.

[18] S. G. Sheina, L. V. Girya, A. E. Shvets, and N. S. Larin (December, 2022). Methods of Enhancing energy efficiency at the stage of construction of High-Rise Residential Buildings. Volume 1 (PP 17-23). Modern Trends in construction, urban and territorial planning. https://doi.org/10.23947/2949-1835-2022-1-1-17-23.

[19] Karma Gurung and Mustafa Mashal (2018, January). Innovating Construction with Structural Concrete Insulated Panels. Research Gate.
https://doi.org/10.13140/RG.2.2.34546.76489.

[20] Angalaeswari Sendrayaperumal, Somyak Mahapatra, Sabuja Sanket Parida, Komal Surana, Parandhaman Balamurugan, L. Natrayan, and Prabhu Paramasivam (2021, September). Energy Auditing for Efficient Planning and Implementation in Commercial and Residential Buildings. Volume 2021; Hindawi. https://doi.org/10.1155/2021/1908568.

[21] Shalika Walker, Waqas Khan, Katarina Katic, Wim Maassen, and Wim Zeiler (2020, February). Accuracy of different machine learning algorithms and added-value of predicting aggregated-level energy performance of commercial buildings. Volume 209; Science Direct. https://doi.org/10.1016/j.enbuild.2019.109705.

[22] I. C. Ezema and S. A. Maha (2022, August). Energy Efficiency in High-rise Office Buildings: An Appraisal of its Adoption in Lagos, Nigeria. 3rd International Conference on Energy and Sustainable Environment. IOP Publishing.
https://doi.org/10.1088/1755-1315/1054/1/012037.