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Research on sustainability evaluation of green building engineering based on artificial intelligence and energy consumption

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ABSTRACT

A green building is a structure that avoids or eliminates negative environmental impacts and generates environmental benefits through its design, construction, or functioning. The use of ecologically friendly building materials increases the quality of life. The overuse of electronic equipment hinders the achievement of the overall green aim, even if smart buildings are a beneficial stimulus for sustainability. Demand-side management and green building energy consumption prediction are connected and depend on accurate estimates of how much energy a facility will need. While several approaches have been offered for predicting energy use, each method has advantages and disadvantages, and there is always room for improvement. This paper suggests the **Artificial Intelligence-based Energy Management Model (AI-EMM)** in green building. Adaptable to human choices, it can act intelligently to increase user comfort, safety, and energy efficiency. One of the key components of the AI-EMM model is a universal infrared communication system and subsystems for smart user identification and monitoring of the internal and exterior surroundings. **Long Short-Term Memory (LSTM)** models are used to enhance energy consumption. A green building's energy usage data is analysed using the suggested approach. For a better interior climate, studies examining the relationship between Heating, Ventilation, and Air Conditioning (HVAC) system should focus on airside design optimization. According to the findings, economic gains and environmentally sustainable building coexist harmoniously. A green or sustainable building is one whose structure and characteristics preserve or enhance the local environment. The experimental outcome of the AI-EMM achieved a high-performance ratio of 94.3%, less energy consumption ratio of 15.7%, accuracy ratio of 97.4%, energy management level of 95.7%, and prediction ratio of 97.1%.

Contents

1. Introduction

Green building refers to a structure and the employment of environmentally responsible and resource-efficient practices across all phases of a building's life cycle: planning, design, construction, operation, maintenance, renovation, and demolition (Debrah et al., 2022). One of the most significant advantages of green buildings is to the environment and our climate. Using less money, energy, and environmental assets in green architecture helps the environment by reducing waste, boosting biodiversity, and generating energy. At every project step, the contractor, the architects, and the engineers must work closely with the client (Olanrewaju et al., 2022). Economical, functional, long-term

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comfort and energy efficiency are part of the Green Building approach (Nguyen and Macchion, 2022). The three elements of sustainability, i.e., the planet, people, and profit, must be considered throughout the supply chain Ur Rehman et al. (2022).

Buildings must be environmentally friendly and sustainable if users want to create green and sustainable cities (Salehabadi and Ruparathna, 2022). In addition to new construction, green and sustainable technology should be adopted and implemented in existing structures (Durdyev and Tokbolat, 2022). A green building uses technologies throughout its life cycle, from construction to demolition, to minimize structures' negative environmental effects. Using sustainable building materials and recycling and repurposing these resources can reduce waste (Olawumi and Chan, 2022). The key to creating long-lasting structures is to employ contemporary, energy-efficient construction methods and materials and a deliberate approach to building design and material selection (Filho et al., 2022).

In addition to using environmentally friendly materials, reducing energy use and lowering Co_2 emissions are two of the most important considerations when designing green buildings (Ferdosi et al., 2022). Structures across the world should make use of energy efficiency solutions and operations (Ma'bdeh et al., 2022). Windows and insulation, heat/cold regulators, ventilation systems, and energy-efficient pumps can reduce energy use by 50% (Al-Sakkaf et al., 2023). Smart meters and intelligent management systems can also help (Onososen and Musonda, 2022). An adequate supply of electricity may be ensured by using smart meters. Carbon dioxide emissions may be reduced by 5 to 16% with smart meters, which reduce peak demand. In addition, using environmentally friendly construction materials can significantly decrease emissions of greenhouse gases and other hazardous pollutants (Martínek et al., 2020).

Buildings are becoming more environmentally friendly because of the notion of developing smart buildings (Larsen et al., 2022). Modern digital services and analytics can improve a building management system's efficiency and environmental friendliness (Xu et al., 2022). It has been possible to save a significant amount of energy and provide a more comfortable environment for people and the environment, thanks to sensors for automatic control of lights and air quality (Harja et al., 2022). Smart buildings can play an essential role in power management by connecting with energy networks at a higher level through smart grid technologies (e.g., state or national level) (Soust-Verdaguer et al., 2022). A sustainable and energy-efficient city power is efficiently distributed across the city and among its many structures (Yoffe et al., 2022).

In this paper, the main goal of this idea is to save energy, automate processes, create an efficient power management system, and ensure that the building's residents are satisfied (Bradu et al., 2022; Shukla and Shukla, 2021). For the last several years, experts in this field have been drawn to this dimension to regulate power consumption within green buildings and create a preferred atmosphere for building occupants. Commercial, business, and residential buildings all use electricity significantly (Zhao and Kok Foong, 2022; Meng et al., 2022). Thus, they must be considered when implementing energy management and conservation measures. The user's comfort management within the green building must be overlooked to have an effective energy management system (Valencia et al., 2022). Smart user identification, internal and exterior environment monitoring, AI decision making, and ubiquitous infrared communication. AI-EMM's architecture enables rapid installation and flexible plug-and-play for most home and building management applications without infrastructural adjustments. This project aims to design and construct an energy-efficient smart building management controller. Two phenomena must be considered while constructing an effective building energy management system. As a result of finite power generating resources, it is imperative to minimize energy usage while maintaining occupant comfort levels inside buildings. It is a multi-objective optimization issue since it aims to improve comfort for the user while minimizing power consumption. This is a multi-objective optimization problem. The work done in this suggested architecture for energy conservation systems is mostly focused on this idea.

The main contribution of this paper is,

- AI approaches have been included in a wide range of engineering systems to help them accomplish various objectives. It is possible to create intelligent buildings by coupling new technology with energy management systems and focusing on the needs of the people who use them.
- The primary goal of this integration is to efficiently control the building's energy consumption while ensuring that its occupants are satisfied with the building's interior environment.
- LSTM prediction model to increase the capacity of predicting how much energy a building would need. As the external environment changes, the built model can adjust and retain a high level of predictive capability.
- Consideration of input qualities and data relevancy are key factors in this process. This research examines the impact that binary characteristics have on the overall energy usage of buildings.

The upcoming section in this paper: Section 2 explores the literature study, Section 3 demonstrates the proposed AI-EMM to improve the performance of the green building, Section 4 discusses the results and discussion, and Section 5 concludes the overall paper.

2. Related work

Life Cycle Assessment (LCA) and Green Building Rating System (GBRS) comprehensively examine the environmental and social performance of the complete building expressed by Sartori et al. (2021). As a result, this study proposes future research areas to assist in developing a schematic Environmental Impact Assessment (EIA) framework within the design life cycle. GBRS-compliant buildings were the topic of three separate investigations: a comparison of LCA and GBRS evaluation procedures, an examination of GBRS's LCA parameters, and a study of LCA software tools.

Performance integrated Building Information Modelling (P-BIM) framework for the sake of the environment and energy efficiency throughout the building's life cycle described by Zhuang et al. (2021). The effects of various outer constructions on the internal atmosphere, energy consumption, and expenses are investigated in this research. Based on the established methodology, a P-BIM framework and optimization strategy could be used to expand BIM use and contribute to data-driven green design.

The Green Building Certification Framework (GBCF) for buildings in Ghana that are certified as environmentally friendly is demonstrated by Ampratwum et al. (2021). A framework for establishing green building certification in Ghana was proposed in this study to assist the certifying authority in making judgments. Scheduled interviews with experts from professional organizations were the basis for the research technique. Despite Ghanaian professional organizations in the built environment being aware of green building certification study's results show that they seldom utilize their influence to spread the word about it which was detrimental to its spread.

BIM engaged framework for enhancing the energy efficiency of a building explored by Xu et al. (2021). Information sharing, design review and energy quality control are among the functions in a life-cycle BIM-engaged framework built for the construction industry. The suggested model is designed to help academics and practitioners better understand the use of BIM to systematically enhance the energy efficiency of buildings. A clear set of rules for how each function may utilize BIM to overcome the Bharat eCommerce Payment Gateway BEPG research helps both practical and academic results by offering a clear set of guidelines.

Interpretive Qualitative Approach (IQA) for examining the factors that lead to the success of GB initiatives expressed by Ahmad et al. (2021). The highlighted criteria are linked to the environment, project customers, end-users, society, and the building industry an analysis of the success criteria. The correlations between the success criteria have been examined and although most of the interactions are good some negative ones are as well. Asymmetrical data collection between service providers and customer seekers may solve these constraints in future investigations.

By evaluating all the data and building models that can save the architect time and energy, AI will make an architect's work substantially easier. AI can estimate different elements of a green building's construction. Based on the methodology, some issues exist in the existing method analysis, such as performance, accuracy, energy management, energy consumption, and prediction. The AI-EMM model includes subsystems for smart user identification and systems for monitoring one's immediate and immediate surroundings.

3. Proposed method

The dispersed sharing, retrieval, and updating of information connected to green building processes make green building design difficult, multidisciplinary, and multi-participant. The three most significant aspects of designing a green building are building performance simulation, engineering, code verification, and design review and upgrading. These three processes are intertwined in a complex way. Energy modelling data can aid decisions about modifying fundamental building attributes like geometry, orientation, and material during the design process (Thilakarathne et al., 2021; Banawi et al., 2019; Yusof et al., 2018). A building's most typical use of energy modelling is to help make informed choices about its energy use. Once the basic structure has been created in the system model, it is then re-stimulated utilizing different building energy consumption. The maximum amount of energy that can be used in various kinds of facilities is listed in energy codes. It is possible to get monetary rewards or certification points for green buildings by keeping energy use below the maximum permissible level. Design review and update enable the introduction of human comments and judgement based on their experience, the energy simulation findings, and the energy codes. Thus, it is necessary to take a holistic approach to developing and evaluating green buildings on a single integrated platform.

Green and sustainable building lifecycles are shown in Fig. 1 with the primary factors of sustainability related to each phase. A green building's environmental impact is assessed and minimized at every stage of its lifespan, including the construction process. To maintain the green and sustainability criteria, the many stakeholders (such as building designers, contractors, end-users, etc.) must work together to ensure that each of their turfs and interests is represented throughout each step. This chapter provides an in-depth look at the green and smart building technologies and how they might help create more environmentally friendly and economically viable cities. Even though smart buildings are a beneficial stimulus for sustainability, excessive usage of electronic equipment puts a hold on achieving the overall green aim goal of providing people with a smart and eco-friendly lifestyle, this chapter proposes combining green and smart technology to create Green Smart Buildings (GSB). This goal's promises and problems are thoroughly examined.

Urbanization has resulted in a rise in the number of structures. Insufficient energy management, non-sustainable design and planning, environmentally unfriendly building materials, and inadequate waste management are all putting cities at risk across the globe. Buildings need to be environmentally friendly for cities to be sustainable. Buildings may be made more environmentally friendly in a variety of ways. There are several ways to go green in building construction, such as reusing and recycling waste materials, energy-efficient design, utilizing renewable energy, etc. In addition to rainwater collecting and cultivation on rooftops and walls, green building methods such as these are also beneficial. Internet of Things (IoT)-enabled smart buildings have improved the lives of occupants while also assisting in the construction of environmentally friendly structures. A significant amount of energy is used to send and analyse the enormous data created by electronic gadgets.

The ac voltages produced by these systems are converted to direct high-voltage current by power electronic devices (HVDC). The HVDC electricity can be more readily transformed into three-phase power compatible with the current power grid. The smart buildings' excessive energy usage undermines the ecological purpose of new structures. As a result, it is recommended that green technologies be applied even more strictly to all of the smart buildings' components. However, even with the help of these GSBs, attaining sustainability is not an easy task. The design and execution of GSBs necessitate addressing a variety of obstacles and concerns, including those related to technological, administrative, and sociological aspects. Several GSBs have already been formed to deal with these difficulties, as was to be expected. Hopefully, the GSBs will allow us to live in a smart, eco-friendly, and sustainable green metropolis.

Fig. 2 shows an artificial intelligent decision-making controller in a green building. Artificial Intelligence (AI) has a decision-making process tailored to each user's needs and climatic circumstances observed at the user's home or office. Artificial intelligence (AI) is a pre-programmed system that caters to individual users' preferences for various services in various contexts. It allows us to change the temperature, humidity, lighting, ventilation speed, audio setup sound level, TV programme, electrically controlled curtain position, and shower temperature.

Artificial Intelligence (AI) first uses predefined categories to identify users in the application area (such as managing directors, directors, managers, engineers and other offices) before assigning those users to a priority level. AI can identify specific user preferences from a predefined internal data store. Artificial intelligence (AI) algorithms allow computers to predict future events based on massive volumes of data. Artificial Intelligence (AI) can be used in construction to forecast project cost overruns, the danger of on-site accidents, and the requirement for ongoing maintenance. Iterative processing and optimization techniques training enable machines and computer programmes to emulate human intelligence and learn from their own experiences. AI chooses the appropriate service settings and transmits them to the appropriate appliances based on the prioritized preferences of the users. Real-time interior and exterior weather and physical factors, such as temperature and humidity, light and sound levels and motion detection, are also studied by AI systems. As a result of these findings, Artificial Intelligence (AI) modifies the automation guidelines to maximize energy efficiency and user satisfaction.

With the integration of these capabilities, AI can minimize excessive energy usage by controlling HVAC provisioning, lighting, and other services, resulting in a more energy-efficient, pleasant,

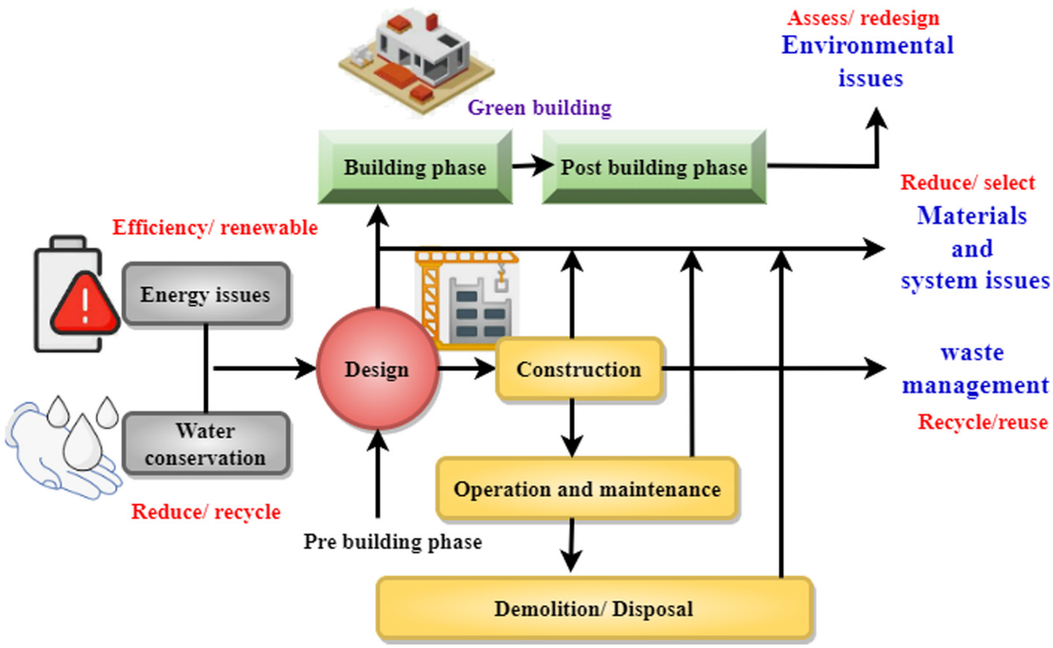

Fig. 1. The construction and maintenance of a green building.

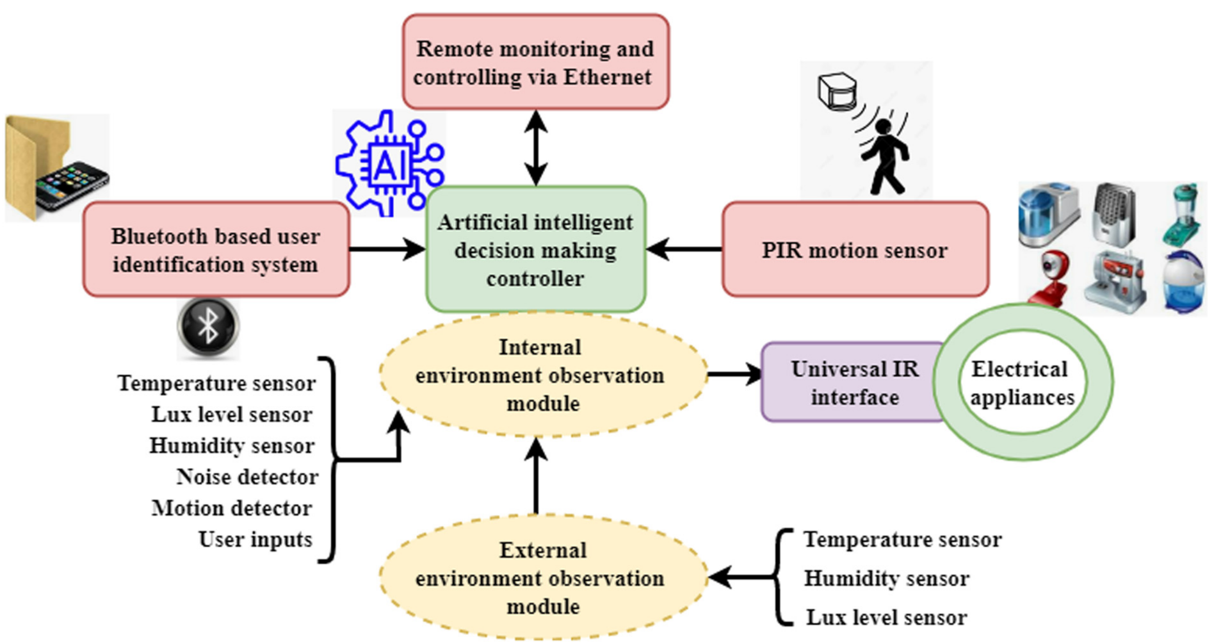

Fig. 2. Artificial intelligent decision-making controller in green building.

and safe environment. Compared to personal computer-based automation systems, using ultra-low power consumption integrated single board computers leads to more energy-efficient and accurate automation processes. Real-time remote system interfaces can be developed using a remote application using a normal Ethernet interface. The internet and a local network can be accessed using Ethernet connections, often found in computers and other electronic equipment. On many devices, they can be plugged into the Ethernet ports. An Ethernet cable is often used to connect a WiFi router or modem to a computer's internet port or phone line. Bluetooth-based user identification has been implemented to make user identification more convenient. Compared to a standard Radio-Frequency IDentification (RFID) or Password-protected access system, this may be done by eliminating the self-authorization step. Using a pre-programmable universal infrared interface module, the control room's AI could connect with its various electrical equipment. It is also a plug-and-play solution with current building automation control systems in both commercial and residential settings.

Fig. 3 shows the Artificial Intelligence-based Energy Management Model (AI-EMM). The concept of AI is offered as a smart controller with a broader data collection system and a multi-appliance control interface. The decision-making process is more complicated than in the case of a Single Input, Single-Output (SISO) control system paradigm, which relies on a single set of inputs and outputs. A microprocessor may be used to implement AI, a problem-solving control mechanism. Based on a variety of inputs, it makes choices for a variety of control nodes. The

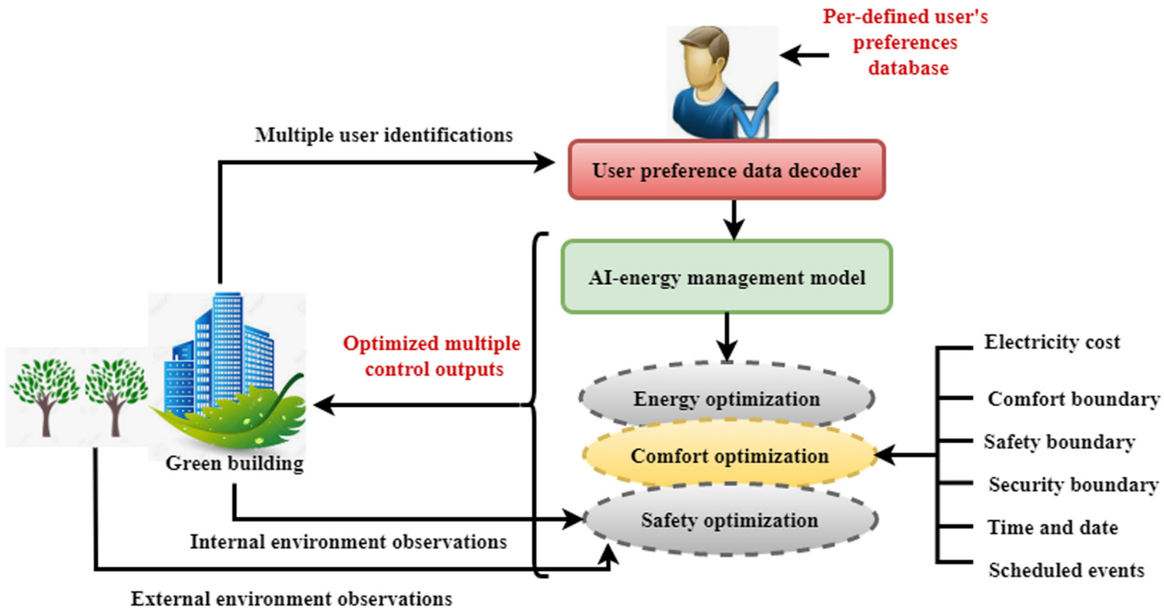

Fig. 3. Artificial Intelligence-based Energy Management Model (AI-EMM).

system's inputs include information gathered from sensors and externally inputted or pre-programmed time-varying parameters.

Energy management can monitor and optimize a green building's energy consumption. A few stages are involved in managing energy: Data gathering and analysis are ongoing processes. Adjust the equipment's schedules, set points, and flow rates to reduce energy use. A green building uses less water, is more energy-efficient, conserves natural resources, generates less waste, and provides a better environment for its occupants than conventional construction. The goal of energy management is tracking and optimizing a building's energy use. The energy management process is broken down into the following steps: Continuous data gathering and analysis. Optimize equipment schedules, and set points and flow rates to reduce energy use. Optimizing a building's energy efficiency and reducing its total cost of ownership are two important goals in green building. An integrated whole-building approach can be achieved when the components of a building are optimized before they are built or retrofitted into place. Sustainability in construction refers to using resources and building materials that can be replenished or reused. Maintaining the natural environment surrounding a building site must be considered while reducing trash and energy consumption throughout a project.

Installing more energy-efficient lighting, such as external solar-powered lighting or LED light bulbs, can help green buildings save money on electricity. When natural light levels are adequate or low building occupancy, dimming or turning off lights can help save electricity. Thermal comfort and internal air quality are among the many aspects that contribute to a person's overall sense of well-being, as well as visual comfort and noise annoyance. Construction safety management is utilized to regulate safety operations to guarantee a safe working environment on the construction site. In addition, choices made throughout the planning and design phase significantly impact the safety of a construction project. Because green buildings have a lower environmental effect than regular structures, they are widely accepted. Their construction avoids on-site grading, saves natural resources by employing alternative building materials, and recycles construction debris instead of shipping truck after truck to landfills. Reduce landfill contamination and prolong landfill life with proper waste management, including the processing of non-recyclables. Reducing the amount of trash generated in the first place is always preferable to recycling or reusing.

Fig. 4 shows the factors contributing to waste energy. It is difficult to design an airside HVAC system that provides comfort, air quality, and the most efficient use of energy. Maintaining a specified amount of temperature, humidity and dust in a confined area is the primary goal of air conditioning. Consistent with its intended function, a conditioned space must meet certain requirements. Air conditioning does more than just cool or heats a room. Comfort demands of the conditioned space occupants are met by the treatment of air to control temperature and humidity, as well as cleanliness and distribution. The process of air conditioning involves treating the air to manage its temperature, humidity, cleanliness, and distribution concurrently to fulfil the criteria of a conditioned area. Therefore, air conditioning is a whole heat exchange operation, including controlling air velocity, thermal radiation, and quality and removing foreign particles and vapours from the airstream.

Studies on the Environment

1. Relying on supply circumstances to conserve energy is not worth the effort. Researchers are getting unrealistic findings because of this pattern. HVAC systems waste a significant amount of energy. Therefore, it is important to find out why this is happening. Indeed, a well-designed airside layout can immediately save energy.
2. Indoor air quality characteristics such as humidity ratio and pollutant concentration are critical for convenience and comfort.
3. It is necessary to redesign the airflow distribution pattern to improve the ventilation systems' performance. For example, there is no definite answer to the problem of recirculation or dead zones when it comes to air-conditioned buildings.
4. New HVAC and airside design traditions must enable architects to choose the finest design from a diversity. The air conditioning system must be customized for each industrial or commercial location based on its unique requirements and problems. There should be no unnecessary features in an air conditioning system. An effective and

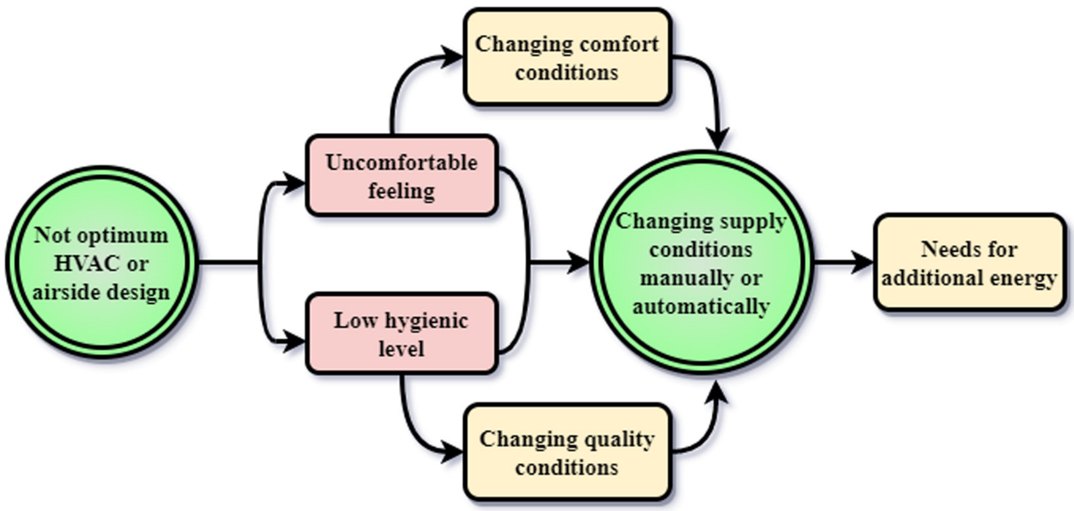

Fig. 4. Factors contributing to waste energy.

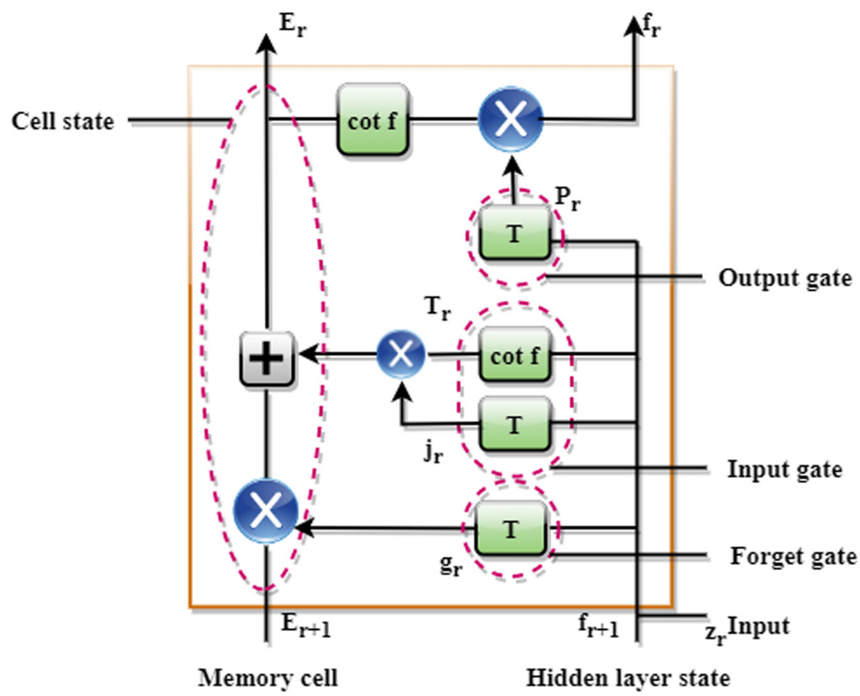

Fig. 5. LSTM networks' internal memory unit.

efficient system should not be too pricey. It is important to note that this new trend brings additional responsibility for evaluating the new designs and determining whether or not they work in the existing environment.

Fig. 5 shows the LSTM network's internal memory unit. This work suggested a hybrid model incorporating LSTM to enhance building energy consumption prediction. With the right input characteristics and data, the suggested model can continually adapt to external changes and retain good predicting ability. This research examines how binary building aspects affect energy use. Binary features better describe non-linear data relationships, enhancing model accuracy and generalization. Using a threshold mechanism, the LSTM addresses the issue of gradient disappearance, and it can be used to analyse and forecast long-term dependent data. As a result, LSTM is considered a cutting-edge approach to solving time series prediction issues. Four layers of memory interact uniquely in the LSTM algorithm. The storage capacity of a network is increased by LSTM, which monitors the output, the current input, and the status of the previous unit.

LSTM

Time series data with long-term dependencies g_r can be processed and V_g predicted with the help of LSTM, which overcomes the issue of gradient disappearance τ. The input gate, forget gate, and output gate all work together to regulate the data flow d_g.

$$g_r = \tau\left(V_g.\left[f_{r+1}, z_r\right]\right) - d_g \tag{1}$$

As shown in Eq. (1), the forgetting gate accepts data z_r at the current moment and f_{r+1} indicates the hidden layer at the preceding time.

The input gate's realization j_r the formula can be obtained as

$$j_r = \tau\left(V_j.\left[f_{r+1}, z_r\right]\right) - d_j \tag{2}$$

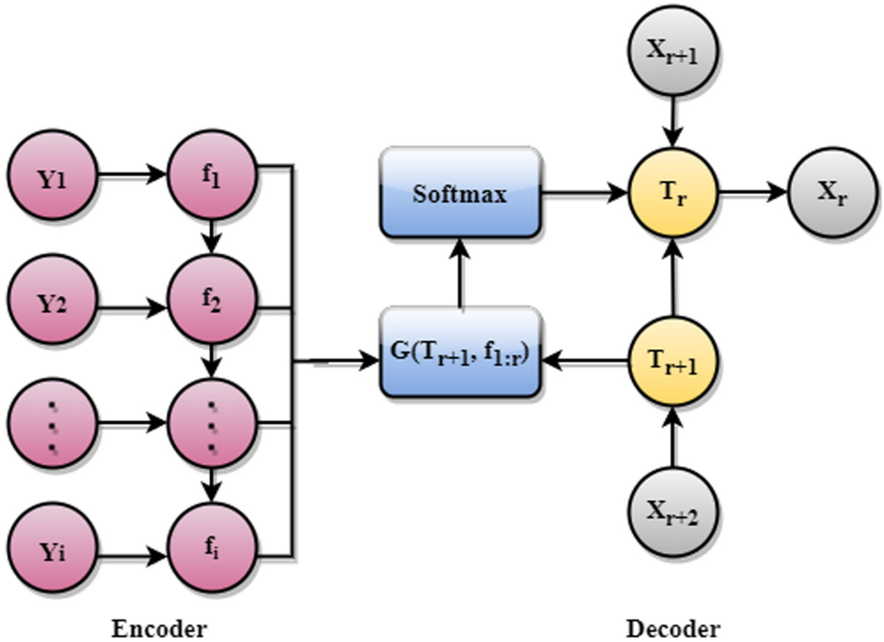

Fig. 6. The design of the attention mechanism.

As shown in Eq. (2), The input gate receives data z_r and f_{r+1}. The input gate's principal role V_j is to determine that many elements of the input d_j remain in τ.

The following equation generates a new variable $\cot f$, a potential memory cell $\hat{E}_r$ stated as

$$\hat{E}_r = \cot f\ (V_E . [f_{r+1}, z_r] - d_E) \tag{3}$$

As shown in Eq. (3), the forget gate V_E, input gate, a memory cell f_{r+1} from the last moment, and a candidate memory cell d_E Memory cells maintain current cell states z_r and regulate the data flow.

The implementation technique for changing the state of a cell E_r is given as

$$E_r = g_r \otimes E_{r+1} - j_r \otimes \hat{E}_r \tag{4}$$

As shown in Eq. (4), $\otimes$ denotes multiplying the relevant components of the respective vectors g_r. Due to the cell state updating the previous cell state j_r, the cell state of E_{r+1} is changed to $\hat{E}_r$.

The hidden layer node f_r and output gate P_r regulate the state variable τ is defined as

$$f_r = P_r \circledast \cot f\ (E_r) \tag{5}$$

$$P_r = \tau\ (V_P . [f_{r+1}, z_r]) - d_P \tag{6}$$

As shown in Eqs. (5) and (6), $\cot f\ (E_r)$ denotes the output value of the output gate. When determining the number of components sent z_r, d_P to the hidden layer V_P, the output gate relies on the control unit f_{r+1}.

Fig. 6 shows the design of the attention mechanism. It is possible to emphasize the impact of input data on output using the probability distribution of attention. This process recalibrates a model by focusing on the most significant data and discarding the rest. Each model can concentrate on predicting its specific probability as effectively as possible due to calibration. Because the interpretation is stable, other system parts do not need to be shifted when models change. The attention mechanism, therefore, has a positive impact on classic models of optimization. A multinomial probability distribution can be predicted using LSTM that employs the softmax function as an activation function in the output layer. Softmax is the activation function in issues requiring class membership on more than two class labels.

An output from the decoder g stands at the moment X_r.

$$X_r = g\ (E_r, T_r, X_{r+1}) \tag{7}$$

St is the output of the hidden layer at the moment of t.

$$T_r = g\ (E_r, T_{r+1}, X_{r+1}) \tag{8}$$

As shown in Eqs. (7) and (8), computing the attention probability distribution E_rThe focus mechanism can emphasize the impact of the input information $T_{r+1}a$ most abundant and significant component of the output X_{r+1} for improving the performance of the proposed system to identify the energy consumption and energy management.

The encoder's hidden layer output f_i and weight b_{ri} is used to calculate E_r at each iteration.

$$E_r = \sum_i b_{ri} f_i \tag{9}$$

The hidden layer f_i is given as

$$f_i = g\ (f_{i+1}, T) \tag{10}$$

As shown in Eqs. (9) and (10), the technique recalibrates a model f_{i+1}, which focuses on crucial data T and ignores unnecessary data g.

Hidden cell load b_{ri} is computed as follows

$$b_{ri} = \frac{exp\ (d_{ri})}{\sum_l exp\ (d_{rl})} \tag{11}$$

$$d_{ri} = g_{brr}\ (T_{r+1}, f_i) \tag{12}$$

As shown in Eqs. (11) and (12), in this case, d_{ri} an aligning model rates how well the input and output positions d_{rl} around positions l and i match. Attention mechanisms g_{brr} have a positive impact T_{r+1}on classic models of optimization f_i to achieve high prediction.

A frequent formula used in early efforts to develop models $T_r^R f_i$ based on attention mechanisms:

$$g_{brr}\ (T_{r+1}, f_i) = \begin{cases} T_r^R f_i \\ T_r^R V_b f_i \\ W_b^R \cot f\ (V_b\ [T_r : f_i]) \end{cases} \tag{13}$$

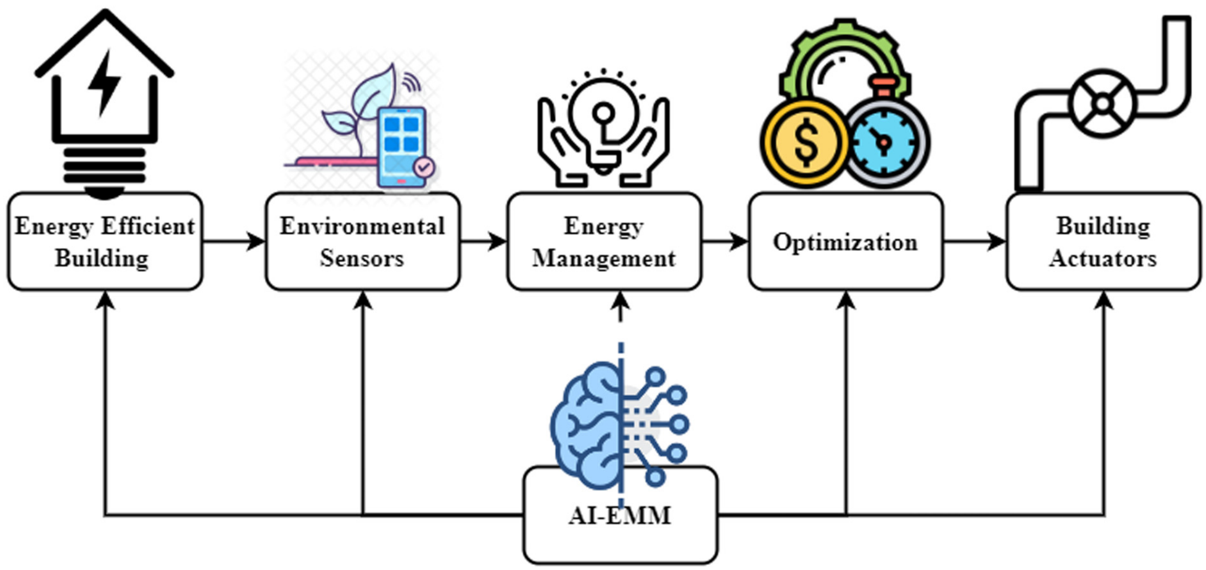

Fig. 7. Structure of energy management model.

Each decoding x_i, T has a probability parameter Q is stated as

$$Q\left(x_i \setminus x > i, T\right) = softmax\left(h\left(f_i\right)\right) \tag{14}$$

As shown in Eqs. (13) and (14), a technique for focusing attention $h\left(f_i\right)$ relies on computation V_b. The W_b^R function represents the many ways in which attention can be focused $\cot f\left(V_b\left[T_r : f_i\right]\right)$ to increase high accuracy.

The term "sustainable home" refers to integrating energy management and conservation systems with the latest artificial intelligence technology. This dimension regulates building power consumption and creates a preferred atmosphere for building occupants. This article analyzes creative strategies to assist the use of AI (Artificial Intelligence) in sustainable construction to ensure sustainable growth. AI in buildings refers to electronic equipment and application systems that are intelligent enough to recognize and act on cues from their surrounding environment to achieve the best possible results in a certain setting. The proposed method could help reduce negative impacts due to population pressure, such as built environmental degradation and climate change.

As a result of the limited resources available for power production amount of energy used in buildings must be minimized. Secondly, the level of user comfort must be maintained. Multi-objective optimization is a process in which many goals are pursued at the same time to enhance the user's comfort while the same time is minimizing power usage. The suggested design for an energy conservation system focuses on this notion as its primary goal. There is a schematic of an energy-efficient structure in Fig. 7. As a result, there must be a trade-off between energy efficiency and user satisfaction. The control system in all residential buildings is critical to ensuring that energy consumption and user comfort are kept to a minimum. Thermal comfort is measured by the average temperature of a building's interior, whereas visual comfort refers to how aesthetically pleasing the space is to the user. An additional cooling or heating system is required to keep the building at a reasonable temperature. Illumination systems and Co_2 concentrations are used to maintain visual comfort in a building, while Co_2 concentrations are utilized for air quality control. All of these amenities are considered to preserve the user's overall comfort. In our research, we considered all three characteristics to ensure that residential buildings are as comfortable as possible for their occupants.

Comfort optimization in green building:

The construction of a green retrofit provides a substantial opportunity to improve energy efficiency and achieve green development objectives. There is, however, a competing criterion between energy-saving c1 and thermal comfort enhancement c2 when generating ideal design solutions for building conversion. A comfort optimization is presented to evaluate different design choices and balance many goals in building green retrofit. To begin, an energy consumption and c3 comfort level of the building is developed. Using this information, a multi-objective optimization is used to identify essential building factors and provide alternative designs for building retrofits based on green standards. After that, the best design options for thermal comfort and energy demand are found.

The following formula is used to calculate the comfort index DJ,

$$DJ = q1\left[1 + \left(c1/R_t\right)^2\right] - q2\left[1 + \left(c2/J_t\right)^2\right] - q3\left[1 + \left(c3/B_t\right)^2\right] \tag{15}$$

As shown in Eq. (15), the temperature R_t, brightness J_t And air quality B_t are all controlled by the user using $q1$ $q2$ and $q3$ parameters. Errors in the optimum temperature and lighting are reflected in e1, while errors in air quality are indicated by e2, with e3 representing the error difference between the optimized and ambient temperatures.

The inputs to the organizer are the entire power required to regulate the heating/cooling, lighting, and ventilation, and the outputs are the power sources STQ as follows

$$STQ = TP1 - TP2 - TP3 \tag{16}$$

As shown in Eq. (16), $TP1$ represents the needed power for the heating/cooling system, $TP2$ denotes the power demand for brightness, and $TP3$ indicates the power needed for ventilation.

Fig. 8 depicts the many ways a green construction handles sustainability. Sustainable green building considers factors such as land efficiency, reduced greenhouse gases, resource efficiency, design efficiency, water efficiency, comfort efficiency, waste management efficiency, material efficiency, indoor environment and energy efficiency. Structures that employ less energy-demanding materials for construction are known as Energy Efficient Structures. New technologies and techniques must be used to provide the same or better service while using less water to achieve water

Fig. 8. Green buildings' sustainability.

efficiency. Green supply chain management and green building operations are combined in this paper to reduce the use of materials and encourage more effective and efficient energy use. Water is currently used and ensures the prevention and avoidance of any waste and to perform environmentally-sensible building design.

The building's environmental and electricity savings are ensured through a single, low-maintenance, low-operating-cost design. Reduce dependence on non-renewable resources like coal, oil, etc. Using renewable energy in a coordinated manner saves money while creating a cleaner atmosphere. As a means to improve the quality of the interior environment, installing an operable window lets in more sunshine to help clear the air of harmful pollutants. Water conservation is a key part of green building design is the reduction in water waste via the use of rainwater collection. With adequate plumbing, water can be recycled and utilized more effectively. The use of long-lasting materials decreases the amount of material that is thrown away. Green architecture may create a healthy atmosphere by reducing the usage of energy resources such as coal and gasoline, which contaminate the environment.

Artificial Intelligence in Green Building, often known as (AI-GB), is a promising approach that can significantly improve the sector's sustainability and overall productivity. AI in government business operations encourages the discovery of new information, intelligent optimization, and the enhancement or automation of decision-making processes. Higher efficiency, reduced costs and saved time, increased dependability, and enhanced accuracy are among the primary benefits offered by AI-GB. There is a tremendous amount of room for additional investigation into AI-GB.

4. Results and discussion

Accurate estimates of building energy use are critical to efficient building operation, issue identification and diagnosis, and demand-side management. This work combined an evolutionary double attention mechanism with an LSTM algorithm to create a unique hybrid model for better building energy consumption prediction. Complex non-linear connections may be completely modelled by the suggested model, which has great generalization and quick parameter learning speed. Prediction performance can be improved by using an LSTM model with a dual-layer attention mechanism. The building's energy usage data will be analysed using the model.

Dataset description:

Better planning and more effective energy usage may be achieved with more precise estimates of building energy demand. As a result, the goal is to predict the amount of energy used given the following information: Over 260 buildings were included in this time series of consumption data. -obs id — An arbitrary ID for the observational. A random ID for the observation's identification. A random building ID number that is compatible across datasets is — SiteId. An indicator for a forecast time series is denoted by the string — ForecastId (which can be matched with the submission file). Date and Time — The date and time of this measurement. Measure the building's consumption in terms of its value. This dataset includes temperature measurements from several nearby stations. Temperature data was obtained from stations within a 30-kilometre radius of each location if possible. https://www.kaggle.com/datasets/arashnic/building-sites-power-consumption-dataset

(i) Energy Consumption Ratio (%)

With artificial intelligence (AI), energy-efficient buildings may be developed by boosting energy savings, simplifying on-site generation, identifying and mitigating operational errors, and managing and assuring that energy savings will continue to be achieved. Integrating enhanced reporting, on-board graphical diagnostics, and cloud connection will ensure the advantages of aiming for maximum energy savings. Buildings with many control systems are more difficult to manage and, consequently, more expensive. Fig. 9 expresses the energy consumption ratio (%) based on Eq. (7) with dataset https://www.kaggle.com/datasets/arashnic/building-sites-power-consumption-dataset to achieve 15.7%.

This research provides a user-friendly system that includes data from many sensors, users, processes, power management systems, and multiple actuators to minimize power usage and increase user comfort. Inputs from temperature and air quality sensors, as well as from the user's selected settings, are used to improve the parameters. Sensors were used to collect data from the energy consumption monitoring platform. The total energy efficiency of the building will be improved while operating expenses will be reduced by using AI technologies with a digital transformation attitude. The digital transformation requires a change in work culture and the adoption of new processes

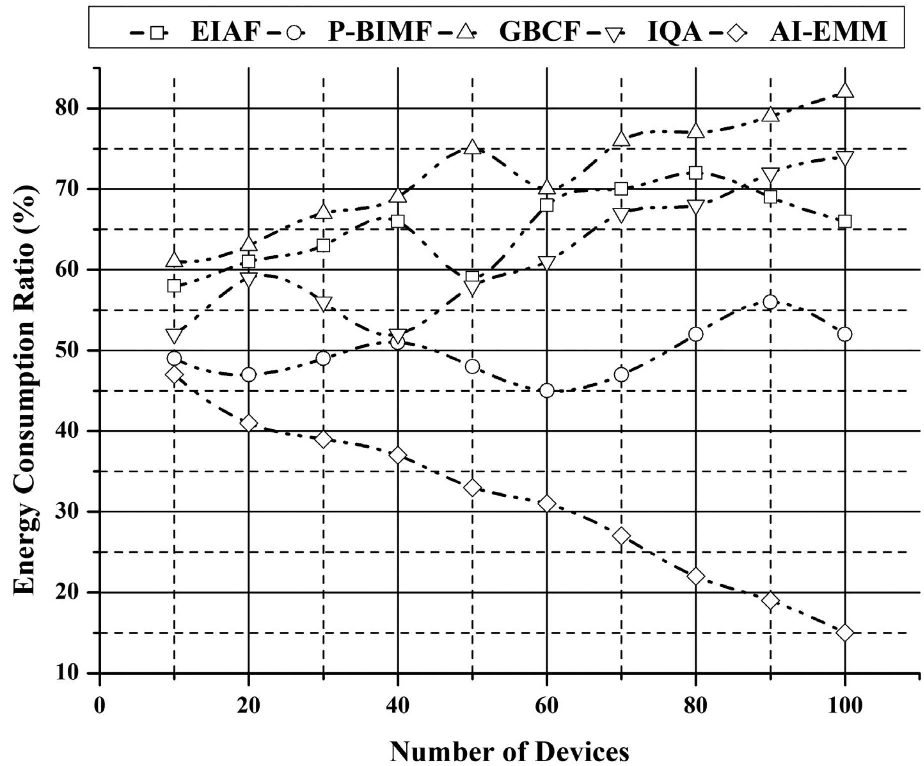

Fig. 9. Energy consumption ratio (%).

as a result of technology advancements. Individuals must be prepared for this change by learning new skills and competencies to improve their performance. A decrease in energy demand accompanies these reductions in greenhouse gas emissions. Smart buildings can preserve the environment while lowering building operating costs and increasing energy efficiency in metropolitan settings.

(ii) Prediction Ratio (%)

Using AI technology in smart buildings allows for greater control, increased dependability, and automation, all of which contribute to a reduction in overall energy usage. This article provides a comprehensive assessment of current research on using artificial intelligence (AI) technology in green buildings via the notion of a building management system (BMS) and improving service programmes. Fig. 10 depicts the prediction ratio (%) based on equation 12 with dataset https://www.kaggle.com/datasets/arashnic/building-sites-power-consumption-dataset when compared to existing methods such as EIAF (Zhao and Kok Foong, 2022), P-BIMF (Zhuang et al., 2021), GBCF (Ampratwum et al., 2021), IQA (Ahmad et al., 2021), and our methods achieve 97.1% In addition to providing details on the principles and practice of the AI-based modelling approaches that are widely used in increasing energy use forecasting and used to assess the recent research that has been conducted in this field and across the major AI domains, which include energy, comfort, design, and maintenance. AI-EMM-based statistical methodologies are applied to modelling frameworks that provide projections of consumer energy demand.

(iii) Performance Ratio (%)

AI is being used by utilities, Independent Power Producers (IPPs), and other energy firms to manage the mismatch between producers and consumers as a result of decarbonization, deregulation, and the spread of innovative technologies. This is being done to keep the energy industry competitive. It may assist the active management of electrical networks when combined with other technologies such as artificial intelligence. This would be accomplished by making it simpler to access renewable energy sources inside buildings. Incentives for renewable energy consumption in green buildings should be in place. Heating, cooling, and lighting can all be provided by renewable energy sources. This study examines and illustrates the benefits of using renewable energy in green power buildings. Fig. 11 illustrates the performance ratio (%) based on equations 7 and 8 with dataset https://www.kaggle.com/datasets/arashnic/building-sites-power-consumption-dataset when compared to an existing method such as EIAF (Valencia et al., 2022), P-BIMF (Zhuang et al., 2021), GBCF (Ampratwum et al., 2021), IQA (Ahmad et al., 2021) and our methods achieve 94.3%.

AI enables customer-centric solutions that recognize evolving consumer needs, allowing AI to make fully automated recommendations. Use predictive intelligence to gain hardware Oil and Maintenance (O&M) and anticipate leisure time, which can expand the life span of the machinery in buildings. A slew of other advanced AI-based technologies enables solutions for customers that comprehend evolving customer needs.

(iv) Energy Management Level (%)

Building automation and energy management systems have been around for a while and concentrate mostly on monitoring and delivering alarms. Developing a single analytics platform to deliver deeper insights from pooled data is becoming more important as smart buildings come together. Smart Green buildings provide owners or renters with actionable information about the building or space inside it. The words smart building and smart house primarily relate to commercial facilities; however, they overlap in functionality. Green buildings minimize operational costs, increase occupant comfort, automate energy consumption management, monitor building assets, and satisfy global norms and environmental requirements. AI monitors gather data regulate, analyse, and manage to build energy use. Energy consumption is controlled and reduced during peak hours, issues are identified and communicated, and equipment breakdowns are detected before they occur. The AI-based

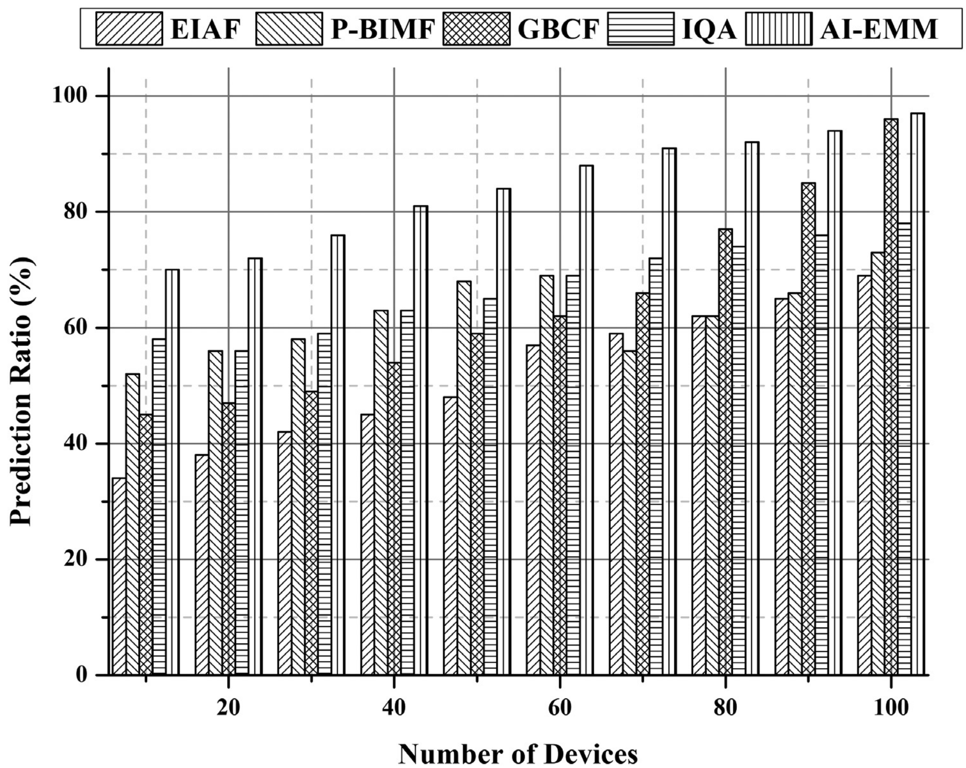

Fig. 10. Prediction ratio (%).

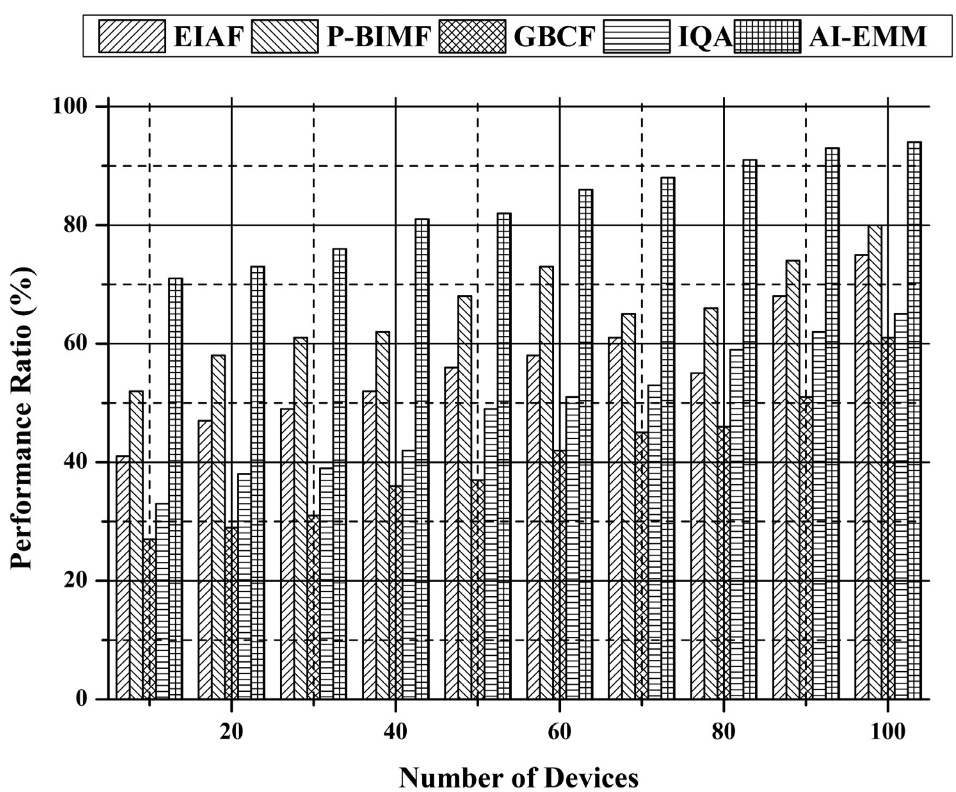

Fig. 11. Performance ratio (%).

technologies may let customers participate in demand response programs by applying them to safeguard their data. HVAC systems are necessary to maintain a comfortable interior climate and contribute significantly to high energy consumption levels. Fig. 12 elaborates on the energy management level based on the using Eq. (8) with dataset https://www.kaggle.com/datasets/arashnic/building-sites-power-consumption-dataset when compared to existing methods such as EIAF (Sartori et al., 2021), P-BIMF

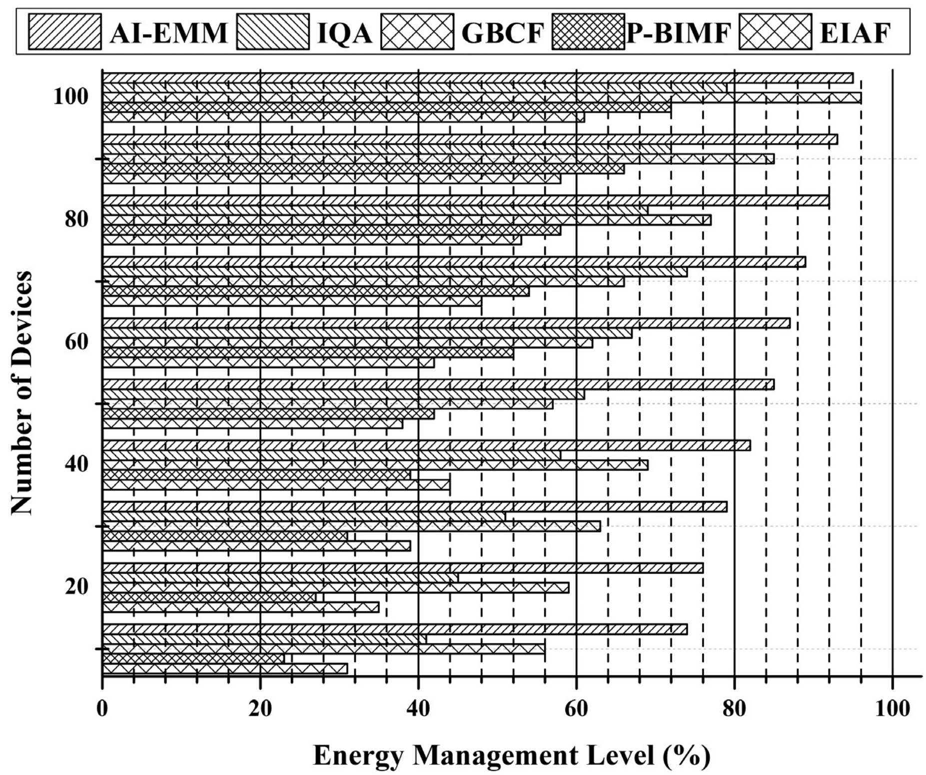

Fig. 12. Energy management level (%).

(Zhuang et al., 2021), GBCF (Ampratwum et al., 2021), IQA (Ahmad et al., 2021) and our methods achieve 95.7%.

For smart cities' new energy economy AI-driven district heating is essential. Heat pumps in smart buildings may be linked to a ground-based heat exchanger loop efficiently and flexibly. Automation of district heating may be enabled by AI when electrification increases the number of controllable components in the energy system, making it more difficult to manage. Customer heat demand may be forecasted, storage utilization managed, and the control room's optimum asset use guided by this system.

(v) Accuracy Ratio (%)

AI-based prediction approaches have the potential to be accurate. These approaches make it easy to collect and import data facilitating the development of a prediction model. The models must be retrained whenever changes are made to the building envelope, system, or operation. The model needs to be retrained if a change in any phase of the dependency pipeline violates the statistical, and technological, dependent when the model was developed. AI-based techniques need considerable training data for model development and the maintenance of prediction quality. Building energy efficiency techniques may benefit from AI-based methodologies applications must be simplified in terms of input parameters. Fig. 13 represents the accuracy ratio using equation 14 based on the dataset https://www.kaggle.com/datasets/arashnic/building-sites-power-consumption-dataset when compared to an existing method such as EIAF (Sartori et al., 2021), P-BIMF (Zhuang et al., 2021), GBCF (Ampratwum et al., 2021), IQA (Ahmad et al., 2021), and our methods achieve 97.4%.

There are several benefits to precise and efficient building energy consumption predictions. Improved efficiency can reduce emissions of Green House Gases (GHGs), as well as other pollutants and water recycling. Economic: Lowering individual utility costs, creating employment, and stabilizing power pricing and volatility can be helped by increasing energy efficiency. Reducing the number of elements influencing building energy usage is done using the rough set theory in this research study. Memory over long periods is suggested and binary characteristics are added via feature combination.

The proposed AI-EMM method achieves high performance, less energy consumption, accuracy ratio, energy management level, and prediction ratio than other methods.

5. Conclusion and future work

Commercial and residential buildings may benefit from AI-EMM which is being developed as a plug-and-play device for easy installation. As a result, the automation of AI-EMM is based on multi-user preferences with smart user identification and observations of environmental variables as inputs to increasing user comfort and the highest possible energy efficiency. A better model for predicting building energy use has been developed this model still has to be improved further. In the future, researchers may approach their work from two directions. Feature selection may be accomplished in a variety of ways. All that is used in the present investigation is a straightforward correlation analysis approach. A neural network called an LSTM is used in the suggested hybrid model. To improve the model's generalization capability and prediction accuracy, researchers will in the future use additional training data and enormous quantities of energy consumption data to train their networks. The limits in this sector are directed at strategies and ideas such as enhancing the performance of sustainable buildings. The simulation test results AI-EMM achieved a high-performance ratio of 94.3%, less energy consumption ratio of 15.7%, accuracy ratio of 97.4%, energy management level of 95.7%, prediction ratio of 97.1%. In the future, researchers will concentrate on reducing sophisticated energy modelling tools' inputs and processing time while maintaining accuracy.

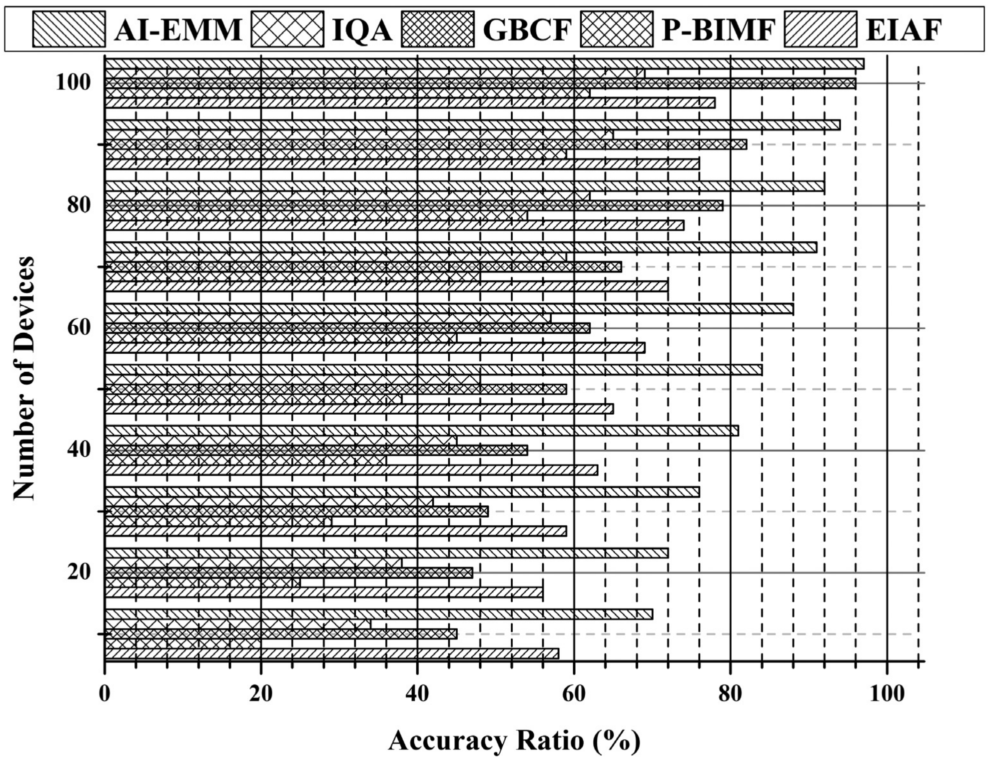

Fig. 13. Accuracy ratio (%).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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