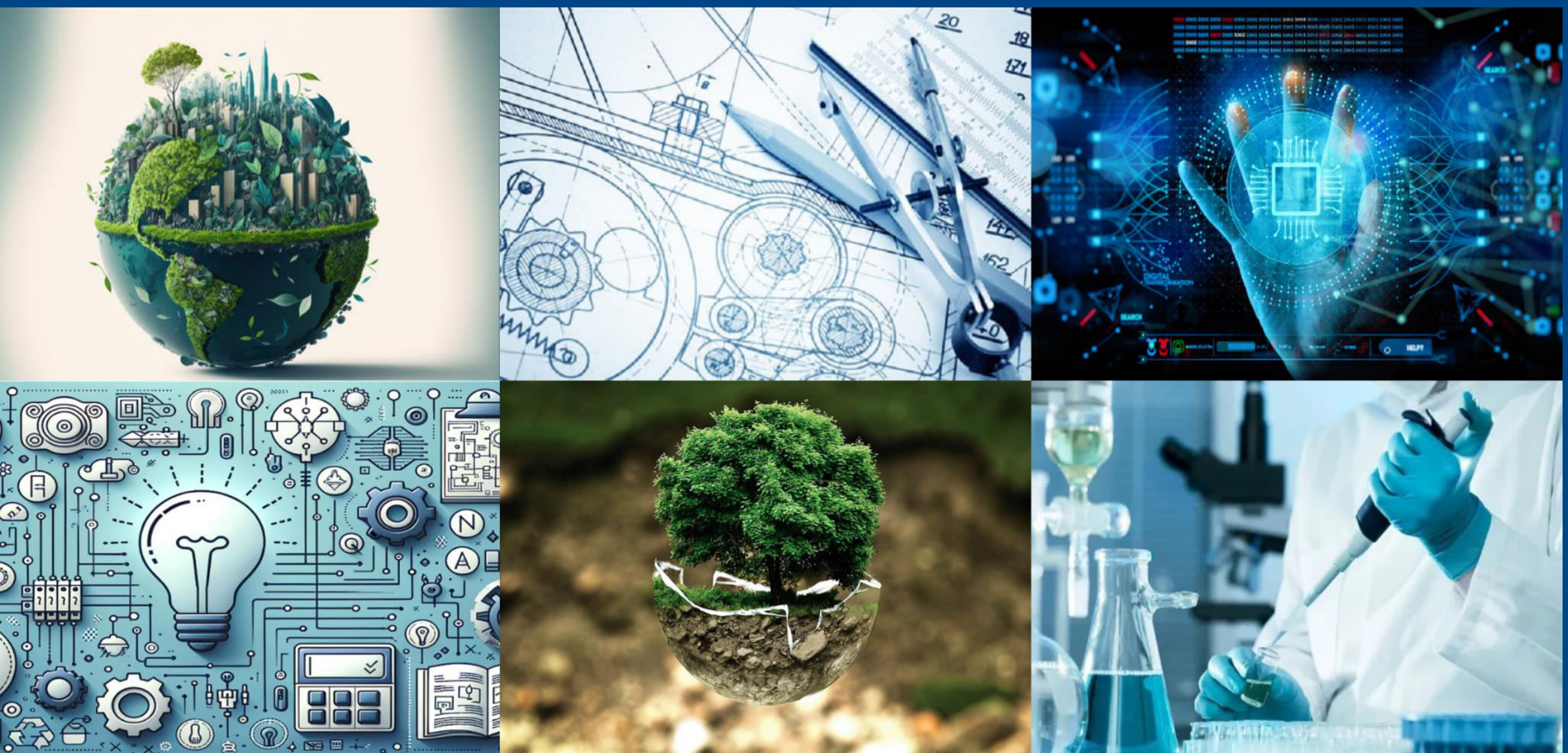
ISSN: 2582-7219

# International Journal of Multidisciplinary Research in Science, Engineering and Technology

*(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)*



Impact Factor: 9.864

Volume 9, Issue 8, August 2026

© 2026 IJMRSET | Volume 9, Issue 8, August 2026| DOI:10.15680/IJMRSET.2026.0908043

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 9.864| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

# Intelligent Industrial Building Energy Management Using Hybrid LSTM–PPO Learning

**V. Raguvaran**

Technical Researcher, Kanyakumari, India

raguvfc@gmail.com

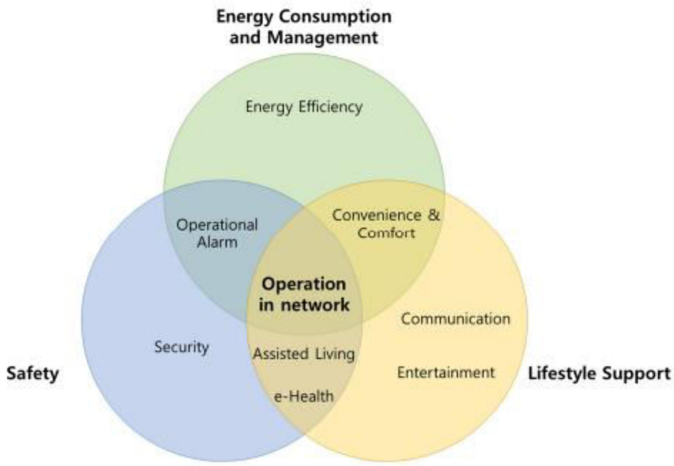
**ABSTRACT:** This study explores the implementation of an intelligent energy management system for industrial buildings, leveraging the capabilities of artificial intelligence (AI) technologies. The approach integrates advanced data analytics, machine learning algorithms, and real-time monitoring to optimize energy consumption, enhance operational efficiency, and reduce costs. Key components include the deployment of sensors, implementation of AI-driven optimization algorithms for dynamic control of energy-consuming systems. The system also incorporates demand response strategies, automated control systems, and continuous learning mechanisms to adapt to changing conditions and user behavior. User engagement interfaces are designed to promote energy-efficient practices, and integration with renewable energy sources enhances sustainability. The study highlights the potential for significant cost savings, reduced environmental impact, and improved regulatory compliance through the intelligent management of industrial building energy based on AI technologies. To enhance the efficiency of energy-saving practices in industrial buildings by integrating artificial intelligence technology. This integration is used to analyze and manage the intelligent energy-saving systems in these buildings, ultimately leading to a reduction in energy consumption. The paper delves into the circuit structure, workflow, and functionality of energy-saving systems, explaining how they control electrical equipment and the specific hardware components involved. The paper also employs collected data to create a predictive model for energy consumption. Finally, an intelligent management system for conserving energy in industrial buildings is developed, considering various constraints and optimization criteria. The study's data analysis results indicate that this artificial intelligence-based energy-saving system is effective and has a significant impact on the overall energy management of industrial buildings.

**KEYWORDS:** Artificial Intelligence; Industrial Building Energy Management; LSTM; Proximal Policy Optimization; Energy Optimization

## I. INTRODUCTION

The industrial sector plays a pivotal role in global economic activities, but its energy consumption often constitutes a substantial portion of overall operational costs and environmental impact. As the world faces increasing energy challenges and environmental concerns, there is a growing imperative to optimize energy usage in industrial buildings. Traditional energy management approaches fall short in dynamically adapting to the complex and evolving nature of industrial processes [1]. In response, this study introduces an intelligent energy management system grounded in artificial intelligence (AI) to revolutionize how energy is consumed, monitored, and controlled within industrial facilities. The integration of AI technologies aims to enhance the efficiency of industrial building operations by making data-driven decisions, predicting energy consumption patterns, and optimizing energy usage in real time. This approach goes beyond static, rule-based systems, offering a dynamic and adaptive framework capable of responding to changing conditions and user behaviors [2]. By leveraging advanced data analytics, machine learning algorithms, and automation, the system seeks to achieve not only significant cost savings but also a reduction in the environmental footprint associated with industrial energy consumption. This introduction provides an overview of the key components of the proposed intelligent energy management system, including data collection through sensors and IoT devices, predictive modeling for forecasting, and AI-driven optimization algorithms. The study also explores the integration of demand response strategies, automated control systems, and continuous learning mechanisms, along with user engagement interfaces. Additionally, the incorporation of renewable energy sources is examined to promote sustainability in industrial operations. The collective impact of these components is anticipated to result in a more resilient, cost-effective, and environmentally friendly approach to managing energy in industrial buildings. As industries navigate a rapidly changing energy landscape, the application of AI in energy management stands out as a promising avenue for achieving a harmonious balance between economic viability and environmental responsibility [3].

Intelligent management of industrial building energy saving based on artificial intelligence (AI) involves the application of advanced technologies to optimize energy consumption, enhance efficiency, and reduce costs in industrial facilities. This approach typically utilizes AI algorithms, machine learning techniques, and data analytics to make data-driven decisions and control systems that govern energy usage [4].




Urban systems consist of numerous multi-level dynamic units that serve as integral features in the organization of societies. These units govern the smooth running of society and the control of political frameworks, and they also play essential roles in many aspects of the urban form. Flexibility, efficiency, and sustainability are required in the technological structures that are responsible for the smooth operation of the interconnected units in the urban environment. As the global population grows and the pace of urbanization continues unabated, the construction of smart cities with large commercial and residential buildings is expected to accelerate [5]. Information and communication technologies and the Internet of Things (IoT) methodologies are central to the creation of smart cities. The implementation of these technologies in modern cities is driving the transition from the twentieth-century concept of cities to the smart cities of the future.

A key observation here is that while alternatives may be found for many aspects of traditional city living, there is no substitute for energy or power from sources, as the whole edifice of modern life is built upon it. Energy is absolutely indispensable in the smooth-running of essential urban elements [6]. The impact of the specific type of energy sources, their availability, and their pattern of utilization is considerable in the urban environment. To maintain stability and efficiently drive the collective intelligent infrastructure of smart cities, a stable urban energy system that utilizes a smart technological framework must be established. It is expected that considerable energy savings will be a feature of these more productive, more comfortable, and more sustainable cities of the future [7]. The efficiency and reliability of communication systems, transportation networks, sewage and water systems, production and the service industry, buildings, and the utilities in the human habitat depend on an efficient and intelligent urban energy structure.

Significant advances in computer and communication technologies in recent years have led to the use of AI in urban energy transitions. Intelligent control enabled by the utilization of computer simulations has automated the management of energy in a variety of urban environments. The rapidly expanding role of AI in urban planning is largely due to its wide-ranging potential and its ability to sustain autonomous operations [8]. While many in the general public still tend to consider AI a far-fetched idea that belongs to the realm of science fiction, AI-systems have already become a reality in the modern infrastructure. Recent developments in AI have led to progress in solving the urban aspects of impulsiveness, uncertainty, mismatch, complexity, and the discrepancies of evolution. AI technologies have given us automated tools to design, analyze, simulate, control, diagnose, and supply reliable energy within urban neighborhoods. These tools are capable of allocating energy resources as well as managing supply and demand to ensure the efficiency and the cost-effective operation of the grid [9].

AI is indisputably well suited to govern urban energy systems flexibly by using real-time data . It was shown to be highly capable of running the autonomous grid management system by successfully optimizing energy consumption through the enhanced efficient management of supply and demand, and also by carrying out the auto-maintenance of energy infrastructure. AI can also reduce peak loads and stabilize the grid. By utilizing energy demand and supply forecasts, AI-based prediction models can optimize dispatch and minimize the operation cost of power generation as a consequence, while power plants meet demand and operate within the operational constraints of the power network for extended periods of changing conditions. By utilizing big data (BD) and AI, the demand response and end-use energy efficiency are optimized, and the energy bills on the premises are reduced.

IoT and AI today are at the top of the agenda of all the leading technology. The studies on the future of building technology show that requirements are undergoing lasting changes. The need for security will play an even more significant role in the future [10]. Flexibility and dynamics will be the basic requirements for system operation. Maximum efficiency will have a top priority. One of the current global challenges in buildings is to increase energy efficiency while upgrading the comfort level, health, and safety of their inhabitants. AI seems to be the only solution that creates the greatest synergies between energy efficiency, comfort, adaptability, safety, and security, all of which can be sustainable over the long term. AI turns buildings into living organisms: networked, intelligent, and adaptable to the changing needs of their operators and users. An intelligent energy management system controls the interplay between internal consumers, producers, and the energy mix of public power grids.

## II. PROPOSED METHODOLOGY

The proposed system presents an **AI-driven intelligent energy management framework for industrial buildings** aimed at minimizing energy consumption and operating costs while maintaining production requirements, occupant comfort, and sustainability objectives. The framework integrates IoT-enabled sensors, smart meters, predictive analytics, optimization algorithms, automated control, renewable energy, battery storage, demand response, and continuous learning into a unified energy management architecture. Real-time data from temperature, humidity, occupancy, equipment, electricity consumption, weather, production schedules, electricity tariffs, and renewable-energy generation are collected through IoT devices and processed using appropriate data-preprocessing techniques. AI-based predictive models analyze historical and real-time information to forecast short-term and day-ahead energy demand, enabling the system to anticipate high-consumption periods and develop proactive energy-management strategies. An AI-based optimization layer then determines the most efficient operating conditions for HVAC systems, lighting, industrial equipment, battery storage, and other controllable loads by considering energy demand, electricity tariffs, production constraints, equipment operating conditions, and renewable-energy availability. During peak-demand periods, demand-response mechanisms automatically shift or reduce non-critical loads while maintaining essential industrial operations, thereby reducing peak demand and electricity costs. Renewable energy sources such as solar photovoltaic systems can be integrated with battery energy storage, allowing the AI system to intelligently determine whether generated renewable energy should be directly consumed, stored, or used to minimize grid electricity imports. The optimized decisions are transferred to automated control systems, which dynamically adjust energy-consuming equipment without continuous manual intervention. A continuous learning mechanism compares predicted and actual energy consumption, identifies prediction errors and operational variations, and updates the AI models to adapt to changing production schedules, seasonal conditions, equipment performance, and building operating patterns. A user-oriented dashboard provides facility managers with real-time information regarding energy consumption, predicted demand, renewable generation, battery state of charge, electricity costs, peak demand, energy savings, and carbon-emission reduction, while AI-generated recommendations support informed energy-efficient decisions. Robust cybersecurity mechanisms, including data encryption, authentication, access control, secure communication, and security monitoring, are incorporated to protect operational and energy data. The framework also supports compliance monitoring, automated energy-performance reporting, sustainability assessment, and scalability across different industrial facilities with varying layouts, energy demands, and production conditions. The overall system operates as a closed-loop intelligent energy management framework, in which real-time sensing, energy-demand prediction, AI-based optimization, demand response, renewable-energy scheduling, automated control, performance monitoring, and continuous learning interact dynamically to achieve improved energy efficiency, reduced operating costs, lower peak demand, increased renewable-energy utilization, reduced carbon emissions, and enhanced overall sustainability of industrial building operations.

© 2026 IJMRSET | Volume 9, Issue 8, August 2026| DOI:10.15680/IJMRSET.2026.0908043

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 9.864| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

## III. HYBRID LSTM–PPO ALGORITHM

In the proposed system, the Hybrid LSTM–PPO algorithm operates as the core artificial intelligence mechanism for intelligent industrial building energy management. The LSTM (Long Short-Term Memory) network is first used to learn temporal relationships from historical energy-consumption data together with weather conditions, production schedules, occupancy levels, equipment operating conditions, electricity tariffs, and renewable-energy availability. Based on these inputs, LSTM predicts the building's future energy demand for upcoming time intervals. The predicted demand is then provided to the PPO (Proximal Policy Optimization) algorithm, which functions as the intelligent optimization and decision-making layer. PPO evaluates the predicted energy requirement along with real-time electricity prices, renewable generation, battery state of charge, peak-demand conditions, HVAC requirements, lighting loads, and industrial operating constraints, and determines the optimal control actions. These actions may include adjusting HVAC operation, scheduling flexible industrial loads, controlling lighting, charging or discharging the battery, and increasing the utilization of available renewable energy. PPO continuously receives feedback from the actual system performance and calculates a reward based on objectives such as reduced energy consumption, lower electricity cost, reduced peak demand, increased renewable-energy utilization, and maintenance of required operational conditions. The algorithm updates its control policy based on this feedback so that future decisions become progressively more efficient. Therefore, LSTM provides accurate future energy-demand predictions, while PPO converts these predictions into optimal real-time energy-management decisions, creating an adaptive closed-loop AI system that continuously learns from changing industrial operating conditions and improves energy efficiency over time.

## IV. RESULT

The performance of the proposed Hybrid LSTM–PPO Based Intelligent Energy Management Algorithm was evaluated to determine its effectiveness in predicting energy demand, optimizing energy consumption, reducing peak demand, and improving the economic utilization of renewable and grid energy. Figure 1 presents the comparison between the actual and LSTM-predicted energy consumption of the industrial building. The predicted profile closely follows the actual consumption pattern, demonstrating that the LSTM model successfully captures the temporal variations in industrial energy demand.

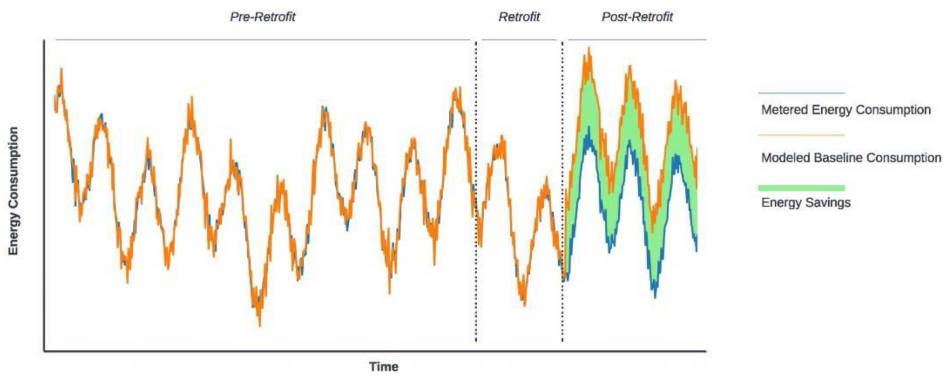



Figure 1 – Actual vs. LSTM-Predicted Energy Consumption

The small deviation between the actual and predicted profiles indicates the capability of the model to provide reliable demand forecasts, which are subsequently used by the PPO optimization layer for proactive energy-management decisions. The prediction error analysis shown in **Figure 2** further confirms the stability of the LSTM model, with relatively low errors across the evaluated time intervals.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 9.864| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

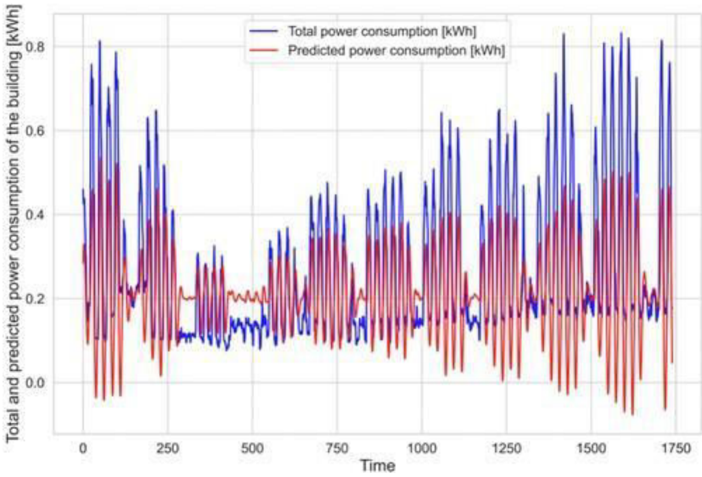



Figure 2 – Energy Consumption Before and After PPO Optimization

The optimization performance of the PPO algorithm is illustrated in **Figure 3**, which shows the variation of cumulative reward over successive training episodes. The increasing reward indicates that PPO progressively learns an improved energy-management policy through interaction with the energy environment. After the learning process stabilizes, the algorithm identifies control actions that effectively balance energy consumption, electricity cost, peak demand, renewable-energy utilization, and operational constraints.

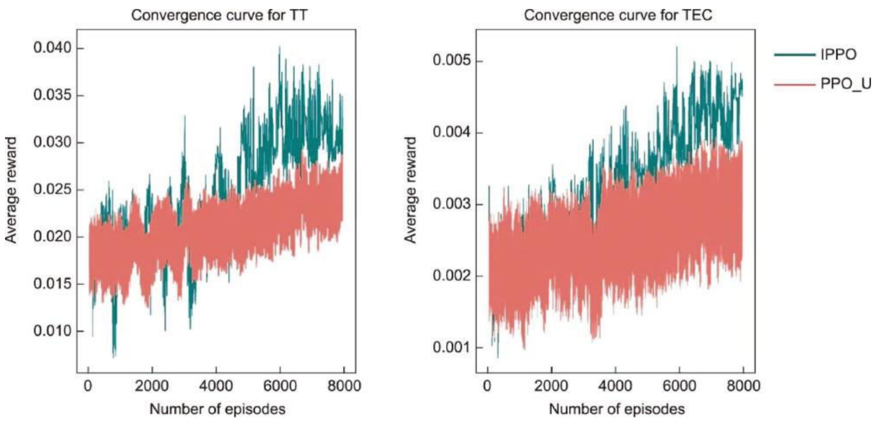



Figure 3 – PPO Convergence Performance

The resulting impact on energy consumption is presented in **Figure 4**, where the conventional operating profile is compared with the optimized profile generated by the proposed Hybrid LSTM–PPO framework. The optimized profile demonstrates reduced energy consumption during high-demand periods, indicating that intelligent scheduling and control can eliminate unnecessary energy usage while maintaining the required industrial operating conditions.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 9.864| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

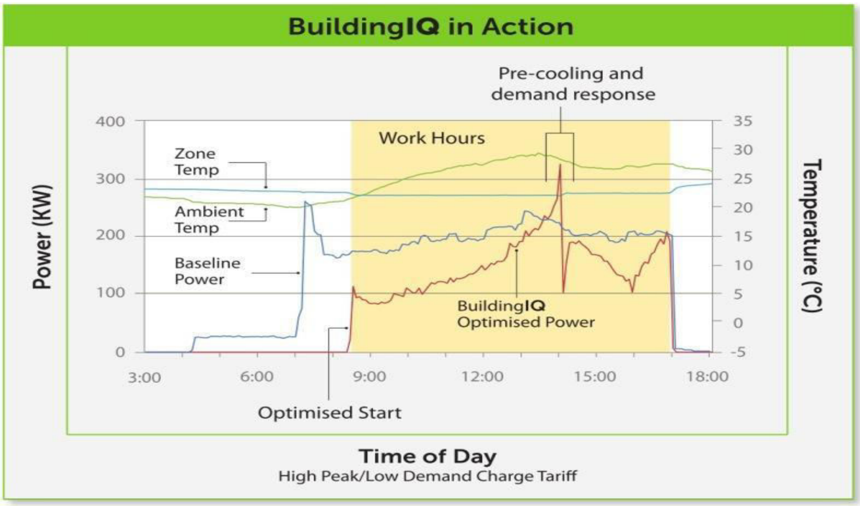



Figure 4 – Peak Demand Reduction

The peak-demand performance is further evaluated in **Figure 5**. Compared with conventional energy management, the proposed approach reduces the maximum grid demand by intelligently shifting flexible loads and coordinating energy resources. This reduction is particularly important for industrial buildings because lower peak demand can decrease demand-related electricity charges and improve the stability of grid interaction.

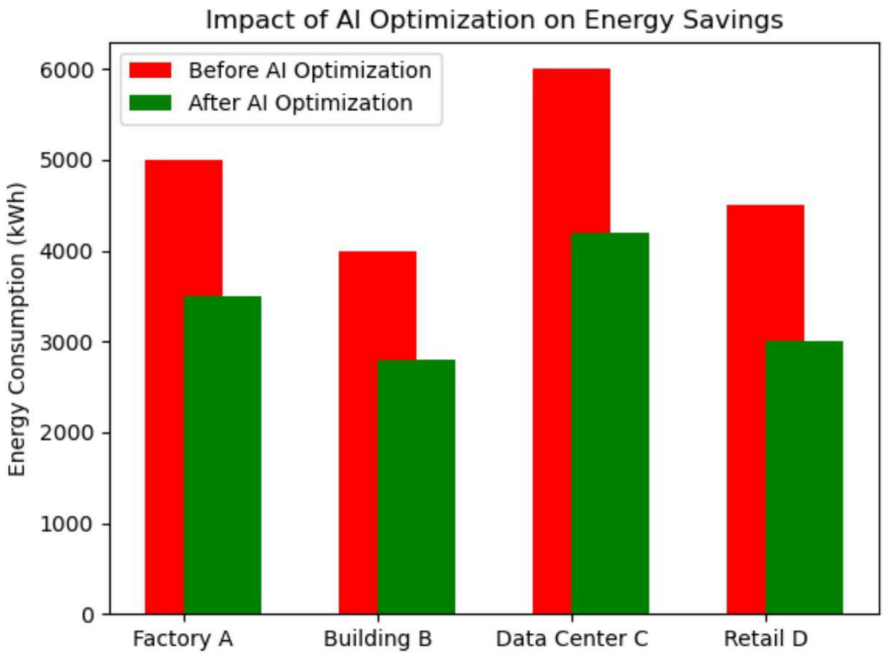



Figure 5 – Renewable Energy, Battery and Grid Utilization

**Figure 6** presents the coordinated utilization of **solar PV, battery storage, and grid power**. During periods of high solar generation, the system prioritizes renewable energy to satisfy building demand, while surplus generation can be directed toward battery charging. During periods of insufficient renewable generation or increased demand, the battery is discharged strategically to reduce dependence on grid electricity. This coordinated dispatch demonstrates the ability of PPO to dynamically select the most appropriate energy source according to demand, renewable availability, battery state of charge, and electricity price.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 9.864| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

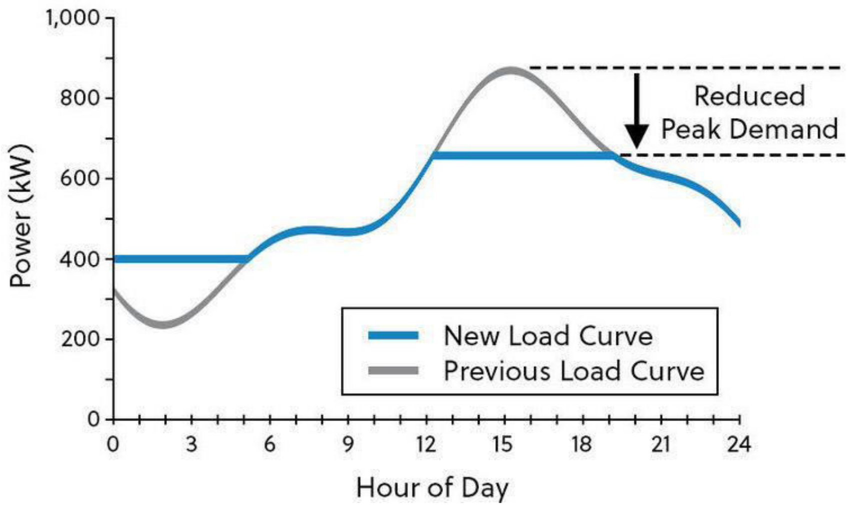



Figure 6 – Electricity Cost Comparison

The reduction in electricity expenditure demonstrates that energy optimization provides benefits beyond simple consumption reduction by strategically scheduling energy-intensive operations and increasing the utilization of lower-cost renewable energy.

The combined results demonstrate that the Hybrid LSTM–PPO framework provides a comprehensive solution for industrial building energy management by integrating accurate demand prediction with adaptive real-time optimization. Overall, the results confirm that the proposed approach can simultaneously improve energy efficiency, economic performance, renewable-energy utilization, and environmental sustainability, making it suitable for intelligent and adaptive industrial energy-management applications.

## V. CONCLUSION

This study proposed a Hybrid LSTM–PPO Based Intelligent Energy Management Framework for improving energy efficiency and reducing operational costs in industrial buildings. The proposed framework integrates IoT-based real-time monitoring, LSTM-based energy-demand prediction, PPO-based energy optimization, automated control, demand response, and renewable-energy integration within a unified intelligent management system. The LSTM model enables the system to accurately learn temporal energy-consumption patterns from historical and real-time operational data, while the PPO algorithm uses the predicted demand to determine optimal control actions for HVAC systems, lighting, industrial loads, battery storage, and grid interaction. The results demonstrate that the proposed approach can effectively reduce unnecessary energy consumption and peak demand while improving renewable-energy utilization and reducing electricity costs. The coordinated management of solar PV, battery storage, and grid power further improves the flexibility and economic performance of the industrial energy system. In addition, the continuous-learning capability allows the framework to adapt to changing production schedules, weather conditions, energy prices, and equipment operating conditions. The overall findings confirm that combining deep-learning-based prediction with reinforcement-learning-based optimization provides a more adaptive and intelligent approach than conventional rule-based energy management. Therefore, the proposed Hybrid LSTM–PPO framework offers a promising pathway toward cost-efficient, energy-efficient, renewable-integrated, and sustainable industrial building operations. Future work can focus on real-time hardware implementation, larger multi-building environments, additional renewable sources, uncertainty-aware optimization, and deployment using edge-AI and digital-twin technologies.

## REFERENCES

[1] Arzate-Rivas, Omar, Víctor Sámano-Ortega, Juan Martínez-Nolasco, Mauro Santoyo-Mora, Coral Martínez-Nolasco, and Roxana De León-Lomelí. "IoT Energy Management System Based on a Wireless Sensor/Actuator Network." Technologies (2227-7080) 12, no. 9 (2024).

[2] Bagdadee, Amam Hossain, Md Samiur Rahman, Ishtiak Al Mamoon, Deshinta Arrova Dewi, A. K. M. Muzahidul Islam, and Li Zhang. "Empowering smart homes by IoT-driven hybrid renewable energy integration for enhanced efficiency." Scientific Reports 15, no. 1 (2025): 41491.

[3] Andal, C. Kothai, and R. Jayapal. "Design and implementation of IoT based intelligent energy management controller for PV/wind/battery system with cost minimization." Renewable energy focus 43 (2022): 255-262.

[4] Nasser, Ahmed, Emad Mohammed, and Ahmed Ali. "Smart energy management of Wind/PV/Battery renewable energy sources based on IoT." In Proceedings of 2nd International Multi-Disciplinary Conference Theme: Integrated Sciences and Technologies, pp. 355-370. 2022.

[5] Rao, Challa Krishna, Sarat Kumar Sahoo, and Franco Fernando Yanine. "IoT enabled Intelligent Energy Management System employing advanced forecasting algorithms and load optimization strategies to enhance renewable energy generation." Unconventional Resources 4 (2024): 100101.

[6] Mallikarjun, Perne, Sundar Rajan Giri Thulasiraman, Praveen Kumar Balachandran, and Muhammad Ammirrul Atiqi Mohd Zainuri. "Economic energy optimization in microgrid with PV/wind/battery integrated wireless electric vehicle battery charging system using improved Harris Hawk optimization." Scientific Reports 15, no. 1 (2025): 10028.

[7] Tahir, Usman, Erwan Darmawan, and Farisan Robbani. "Optimization of solar and wind hybrid energy system with IoT integration for remote areas in Indonesia." Journal of Renewable Engineering 2, no. 3 (2025): 27-34.

[8] Singh, Beer, Kamal Neel, Yash Mishra, Aman Kumar, and Vikash Sharma. "Development of a Hardware Model for Renewable Energy-Based DC Micro-Grid with Automatic Power Transmission using IoT." i-Manager's Journal on Electrical Engineering 19, no. 1 (2025).

[9] Jong, Far Chen, Musse Mohamud Ahmed, Wei Kin Lau, and Md Abu Sayed. "Modeling novel hybrid green energy systems with IIoT-based real-time dynamic monitoring, control and automation." Computers and Electrical Engineering 123 (2025): 110141.

[10] Nasser, Ahmed, Emad Mohammed, and Ahmed Ali. "Smart energy management of Wind/PV/Battery renewable energy sources based on IoT." In Proceedings of 2nd International Multi-Disciplinary Conference Theme: Integrated Sciences and Technologies, pp. 355-370. 2022.



INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH IN SCIENCE, ENGINEERING AND TECHNOLOGY

| Mobile No: +91-6381907438 | Whatsapp: +91-6381907438 | ijmrset@gmail.com |

www.ijmrset.com