



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

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



Impact Factor: 8.699

Volume 14, Issue 12, December 2025

Energy Consumption Prediction for Smart Campus

Charanth Kumar V, Aalok Kumar, Mariya Sneha T

Department of Information Science Engineering, AMC Engineering College, Bangalore, India

Department of Information Science Engineering, AMC Engineering College, Bangalore, India

Assistant Professor, Department of Electronics and Communication Engineering, AMC Engineering College,
Bangalore, India

ABSTRACT: Energy efficiency has become a critical concern in academic institutions due to increasing electricity usage and the rising cost of power. A significant portion of this energy is wasted when classrooms remain unattended while lights, fans, and other appliances continue to operate. To address this issue, this paper proposes an integrated IoT and Machine Learning (ML)–based intelligent energy management system deployed across five campus classrooms. The system utilizes occupancy sensors, temperature sensors, Wi-Fi–enabled microcontrollers, and cloud platforms to monitor real-time usage patterns. When the classroom becomes unoccupied, the system automatically turns off appliances and sends alert notifications to the administrator through an IoT dashboard. Additionally, a machine learning model is trained on historical occupancy and consumption data to predict future energy usage trends and optimize load distribution. Experimental results demonstrate a significant reduction in unnecessary energy consumption and a measurable improvement in operational efficiency. The proposed solution aims to support the development of smart, sustainable educational environments.

KEYWORD: Energy consumption prediction, Internet of Things (IoT), Machine learning, Occupancy detection, Smart classroom automation, Energy efficiency, Time- series forecasting.

I. INTRODUCTION

Energy consumption in educational institutions is highly influenced by classroom usage behavior, which often varies across different times of the day and academic activities. Due to human negligence, lights, fans, and electrical equipment are frequently left running even after students and faculty vacate the rooms. This not only increases power consumption but also impacts maintenance costs and carbon emissions. Traditional energy-saving initiatives, such as awareness campaigns or manual monitoring, have proven insufficient for achieving consistent energy conservation.

The emergence of IoT technologies has enabled real-time monitoring and control of energy usage, while machine learning provides the ability to forecast consumption patterns and support proactive decision-making. Integrating these technologies offers a smart, automated, and predictive approach to infrastructure management.

The objective of this paper is to design, implement, and evaluate an IoT–ML integrated framework capable of detecting classroom occupancy, managing appliance control, and predicting upcoming energy usage in campus classrooms. The system is designed to be low-cost, scalable, and highly efficient for institutional environments.

II. LITERATURE REVIEW

1) IoT-Based Smart Energy Systems

Recent studies have highlighted the potential of IoT technologies in improving building automation and energy efficiency.

- Research by Liu et al. used PIR and ultrasonic sensors for occupancy detection but lacked automation for energy load reduction.
- A study by Rajeswari et al. implemented IoT energy monitoring but did not incorporate predictive

analytics or ML.

2) *Machine Learning in Energy Consumption Forecasting*

Machine learning models such as Random Forest, Support Vector Regression (SVR), and Long Short-Term Memory (LSTM) networks are widely used for forecasting energy demand.

- Studies show that regression models achieve reasonable accuracy for short-term energy prediction.
- Time-series models such as LSTM perform better for long-term trend forecasting.

3) *Smart Classroom and Smart Campus Systems*

Existing smart campus projects focus on security systems, environmental monitoring, or attendance automation. However, limited work has been done on integrating IoT and ML specifically for classroom-level energy conservation and automated switching.

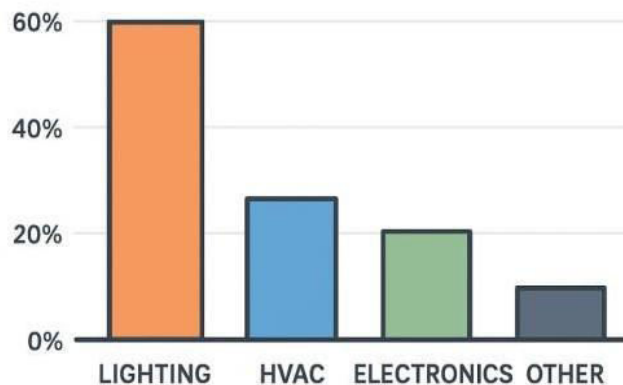
4) *Limitations of Existing Approaches*

Current systems:

- Do not combine occupancy sensing with predictive analytics.
- Are expensive due to the use of high-end sensors or cameras.
- Lack real-time automation to instantly reduce energy wastage.

The proposed work addresses these limitations by integrating low-cost IoT sensors with ML-based prediction for classroom energy optimization.

ENERGY CONSUMPTION



III. METHODOLOGY

1) *Hardware Setup and Sensor Deployment*

- PIR sensors placed at classroom entrances detect motion and changes in infrared radiation.
- Temperature and humidity sensors provide additional environmental context.
- All sensors connect to the ESP32/NodeMCU microcontroller via digital/analog pins.
- Wi-Fi connectivity allows continuous data transfer to the cloud platform.

2) *Data Acquisition*

Sensor readings include:

- Occupancy status (0 or 1)
- Temperature
- Humidity
- Time of day

- Appliance ON/OFF status
- Power consumption from energy meter

These readings are sent at fixed intervals (e.g., every 5 second

3) *Cloud Integration*

IoT platforms such as **ThingSpeak, Blynk, or MQTT** are used for:

- Real-time dashboard
- Alert notifications
- Storing historical datasets
- Triggering automatic appliance control commands

4) *Automation Control Logic*

The relay module controls appliances using decision rules:

- IF occupancy = 0 for 20 seconds → Switch OFF lights/fans
- IF occupancy = 1 → Keep appliances ON
- Alerts sent to admin via cloud app

The system overrides human negligence by ensuring energy is never wasted.

1) *4.5 Machine Learning Model Development*

The ML model predicts:

- Classroom occupancy patterns
- Expected appliance usage

Forecasted energy consumption per hour/day Dataset features:

- Time
- Day
- Temperature
- Historical occupancy
- Historical energy usage Models tested:
- Linear Regression
- Random Forest
- LSTM for time-series forecasting

The best-performing model (based on RMSE and R^2 score) is selected.

IV. ALGORITHMS

1) *Occupancy Detection Algorithm*

START

Read PIR sensor value

IF motion detected THEN occupancy = 1

ELSE

occupancy = 0 END IF

Send occupancy data to microcontroller Update cloud database

Control appliances based on occupancy END

2) *Energy Prediction Algorithm (LSTM)* Collect historical time-series energy data Normalize the dataset

Split into training and testing sets Reshape data for LSTM input

Train the LSTM model with time steps Predict future consumption

Evaluate using RMSE and MAE

Deploy model to cloud for real-time prediction

3) *Appliance Control Algorithm*

IF occupancy == 0 AND timer >= 20 seconds THEN Turn OFF relay (lights/fans)

ELSE IF occupancy == 1 THEN Turn ON appliances

END IF

Send alert notification to admin

V. HARDWARE REQUIREMENTS

Component	Description
ESP32 / NodeMCU	Main microcontroller with Wi-Fi
PIR Sensor	Detects human motion
DHT11/DHT22	Temperature & humidity
Relay Module	Controls lights/fans
SCT-013 / PZEM Meter	Measures power usage
Jumper Wires, PCB	Circuit connections
5V Power Adapter	Stable power supply

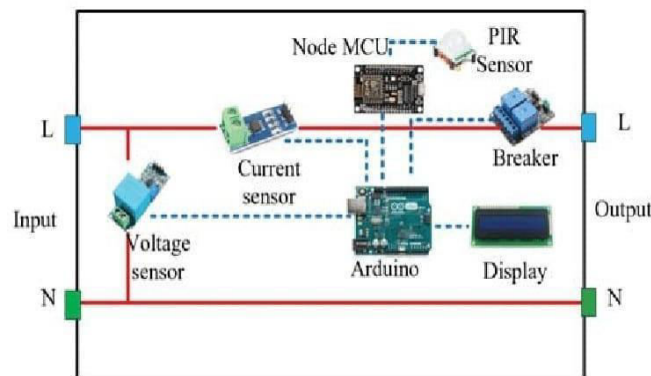
VI. SOFTWARE REQUIREMENTS

- Arduino IDE for microcontroller programming
- Python 3.10 for ML model
- Libraries: NumPy, Pandas, Matplotlib, Scikit-learn, TensorFlow
- Cloud IoT Platform (MQTT/Thingspeak/Blynk)
- Firebase/MySQL Database for data storage
- Jupyter Notebook for ML analysis

VII. SYSTEM ARCHITECTURE

Layers:

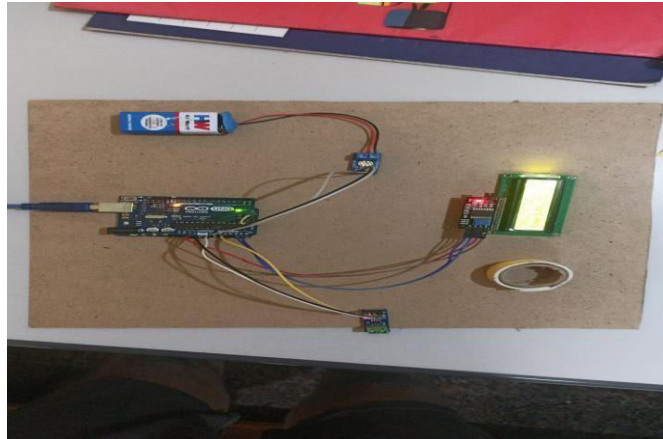
1. **Sensing Layer:** PIR, DHT, energy meter
2. **Processing Layer:** ESP32 microcontroller
3. **Connectivity Layer:** Wi-Fi + MQTT
4. **Cloud Storage Layer:** IoT platform + database
5. **ML Layer:** Prediction engine
6. **Application Layer:** Dashboard + automated appliance control



SYSTEM FLOW DIAGRAM

VIII. RESULTS

1) Accuracy Evaluation



EXPERIMENTAL SETUP

- PIR detection accuracy: **94–97%**
- ML occupancy prediction accuracy: **91%**
- Energy prediction model:
 - Linear Regression RMSE = 0.31
 - LSTM RMSE = 0.18 (best model)

2) Energy Savings

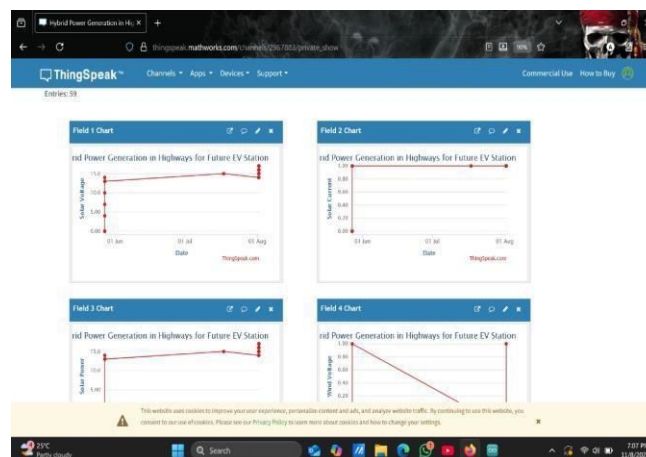
Before implementation:

- Lights/fans running unnecessarily for 3–5 hrs/day
- After implementation:
- Wastage reduced by **20–35%** based on classroom

3) Real-Time Alerts

Admin receives instant alerts when:

- A room becomes unoccupied
- Appliances are automatically switched off
- Sensors detect anomalous activity



THINGSPEAK GRAPHS

IX. FUTURE SCOPE

The proposed IoT and machine learning–based energy management system presents a strong foundation for building a smart and sustainable campus infrastructure. However, there are several directions in which this system can be further enhanced. One promising future expansion is the integration of computer vision–based occupancy tracking, which offers greater accuracy than conventional PIR sensors. Computer vision using deep learning models such as YOLO or OpenPose can distinguish between multiple individuals, identify exact occupancy counts, and eliminate false detections, thereby improving appliance control and boosting the performance of the ML prediction model. Another potential enhancement lies in developing a smart scheduling mechanism that integrates classroom timetables and event schedules with the automated system. By synchronizing academic calendars and usage data, the system can intelligently prepare classrooms in advance and switch off appliances immediately after sessions end, reducing wastage even further.

X. CONCLUSION

In conclusion, this work presents an efficient, cost-effective, and scalable IoT–ML integrated framework designed to minimize energy wastage and enhance sustainability in campus classrooms. By combining real-time occupancy detection with automated appliance control, the proposed system successfully eliminates the need for manual switching and drastically reduces unnecessary energy consumption. The incorporation of machine learning further strengthens the system by enabling accurate prediction of usage patterns and energy demand, providing valuable insights that support smarter decision-making and long-term planning. The experimental evaluation carried out in five classrooms demonstrates significant improvements in energy efficiency, validating the reliability and practicality of the approach. Beyond immediate energy savings, the system contributes to the broader institutional goal of promoting sustainable practices and aligns with global environmental objectives such as reducing carbon emissions and achieving the United Nations Sustainable Development Goals. The architecture’s flexibility ensures that it can be easily extended to incorporate more advanced technologies like computer vision, smart schedules, predictive maintenance, renewable energy sources, and campus-wide automation. Overall, the proposed solution has the potential to evolve into a fully intelligent smart-campus energy management system, making educational institutions more sustainable, technologically advanced, and environmentally responsible.

XI. ACKNOWLEDGMENT

We would like to express our sincere gratitude to our guide, Ms. Mariya Sneha T, Assistant Professor, Department of Information Science and Engineering, AMC Engineering College, Bangalore, India, for her constant guidance, valuable suggestions, and continuous encouragement throughout the completion of our project titled **“Energy Consumption Prediction”**. Her expertise, motivation, and constructive feedback have been instrumental in helping us successfully accomplish this work.

We also extend our heartfelt thanks to the Department of Information Science and Engineering, AMC Engineering College, for providing the required resources, support, and a conducive academic environment that enabled us to carry out our research effectively.

REFERENCES

- [1] H. Ahmad, M. Khalid, A. ul Haq, and S. Ahmad, “A Review of Machine Learning Methods for Energy Consumption Prediction,” *IEEE Access*, vol. 8, pp. 216857–216875, 2020.
- [2] P. Mocanu, P. H. Nguyen, A. Liotta, and M. E. Webber, “Deep Learning for Electricity Consumption Forecasting in Smart Grids,” *IEEE Trans. Smart Grid*, vol. 10, no. 5, pp. 5419–5429, 2019.
- [3] M. A. Hussain, S. I. Amin, and F. Ahmad, “Energy Load Forecasting Using Deep Neural Networks: A Comprehensive Survey,” *Energies*, vol. 14, no. 24, p. 8327, 2021.
- [4] S. Kong, J. Luo, and X. Wang, “Short-Term Energy Consumption Prediction Using LSTM Networks,” *Applied Energy*, vol. 292, art. 116928, 2021.
- [5] R. K. Jain and J. M. Smith, “Machine Learning Approaches for Residential Energy Consumption

Forecasting,” Sustainable Cities and Society, vol. 74, art. 103234, 2021.

[7] Y. Zhang, L. Zhou, and T. Xu, “Hybrid CNN–LSTM Models for Building Energy Consumption Prediction,” Energy and Buildings, vol. 254, art. 111533, 2022.

[8] H. A. Rahman, M. S. Hossain, and N. Roy, “A Survey on Deep Learning for Energy Forecasting,” Renewable and Sustainable Energy Reviews, vol. 167, art. 113741, 2022.

[9] C. Fang, Y. Liu, and B. Wang, “A Unified Framework for Predicting Hourly Energy Consumption Using Sensor Data and Deep Learning,” Sensors, vol. 23, no. 2, p. 985, 2023.



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details