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Smart Energy Optimization Using Occupancy Detection and Real-Time Monitoring

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Abstract: Energy wastage in educational institutions is a major issue caused by unnecessary operation of lighting and ventilation systems in unoccupied spaces. Continuous energy loss increases electricity cost and indirectly raises carbon emissions associated with power generation. This paper presents an IoT-based Smart Campus Carbon Footprint Management system for intelligent monitoring, automated control, and energy awareness in campus environments. The proposed system uses an ESP32 microcontroller as the central controller with occupancy sensing, energy measurement, relay-based load control, and cloud connectivity. A Passive Infrared sensor detects room occupancy and automatically switches electrical loads according to user presence. Electrical parameters are monitored in real time and uploaded to a cloud dashboard for visualization and supervision. Energy consumption data is further used to estimate carbon footprint, enabling users to understand environmental impact. The integrated system improves energy efficiency, reduces manual dependency, lowers operational cost, and supports sustainable campus infrastructure. Prototype-level evaluation shows reliable occupancy detection, stable remote monitoring, and measurable reduction in unnecessary energy usage.
Keywords: IoT, Smart Campus, Carbon Footprint, ESP32, Energy Monitoring, Occupancy Detection.

I. INTRODUCTION

Educational institutions consume significant electrical energy for classrooms, laboratories, libraries, offices, and common facilities. In many campuses, lights and fans remain switched ON even when rooms are vacant. Such avoidable wastage increases electricity bills and contributes to greenhouse gas emissions. Traditional manual control methods depend on human attention and are often unreliable.(SPACE)(SPACE)Recent developments in embedded systems and the Internet of Things (IoT) enable intelligent automation for efficient resource management. Smart sensors, wireless communication, and cloud platforms can continuously monitor energy usage and automatically control connected appliances. These technologies create opportunities for sustainable campus operation.(SPACE)(SPACE)This work proposes a Smart Campus Carbon Footprint Management system that combines occupancy-based automation, real-time energy monitoring, and environmental impact estimation in a single low cost platform. The system is designed for easy deployment in classrooms and similar indoor spaces.

II. LITERATURE SURVEY

Many researchers have proposed smart energy management systems for homes and buildings. Sensor-based automation methods are commonly used to reduce unnecessary load operation. PIR sensors are widely preferred because of their low cost and simple implementation. However, several systems focus only on switching control without providing energy analytics.(IoT-based monitoring systems use microcontrollers and cloud dashboards to display voltage, current, power, and energy data. These solutions improve visibility of consumption patterns, but some lack automatic decision-making capability. Other studies discuss carbon footprint assessment using total energy consumption, yet they do not integrate direct appliance control. From the review, it is observed that an effective campus solution should combine three features: automated control, real-time monitoring, and carbon emission awareness. The proposed system addresses this requirement through a unified architecture.

III. PROPOSED METHODOLOGY

The proposed system consists of sensing, processing, control, communication, and analytics layers.

A. Occupancy Detection

A PIR sensor detects movement inside the room by sensing changes in infrared radiation. When occupancy is detected, the controller activates required loads such as lights or fans. If no presence is detected for a predefined duration, the loads are turned OFF automatically.

B. Energy Monitoring

A current and energy sensing unit measures electrical parameters including voltage, current, power, and cumulative energy consumption. These values are periodically read by the controller.

C. Processing Unit

The ESP32 microcontroller acts as the decision-making core. It receives sensor inputs, executes control logic, processes measurements, and manages Wi-Fi communication.

D. Cloud Connectivity

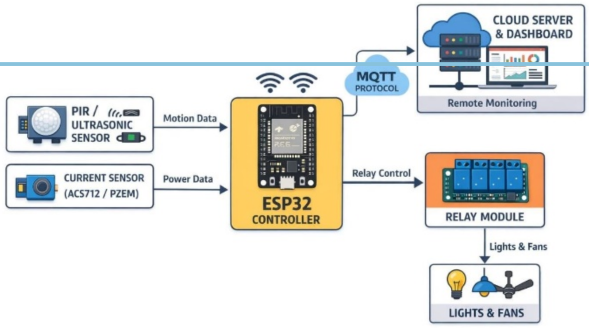
Measured data and device status are transmitted to an IoT dashboard for real-time visualization. Users can observe consumption trends and system operation remotely.

E. Carbon Footprint Estimation

The carbon footprint is estimated from electrical energy consumed using an emission factor.

Carbon Emission = Energy Consumed × Emission Factor

(This helps campus administrators evaluate environmental impact and adopt conservation measures.



IV. SYSTEM OPERATION

The system continuously executes the following sequence:

1) Read occupancy sensor status.
2) Measure voltage, current, and power.
3) Apply load control logic.
4) Upload data to cloud dashboard.
5) Update energy and carbon emission values.
6) Repeat in real time.

When a classroom becomes vacant, connected loads are switched OFF after a delay. This prevents energy loss due to human negligence.

V. HARDWARE COMPONENTS

A. ESP32

MicrocontrollerProvides processing capability, GPIO interfacing, ADC support, and built-in Wi-Fi.

B. PIR Sensor

Used for occupancy detection based on motion sensing.

C. Energy Sensor

Used for measurement of current, power, and energy consumption.

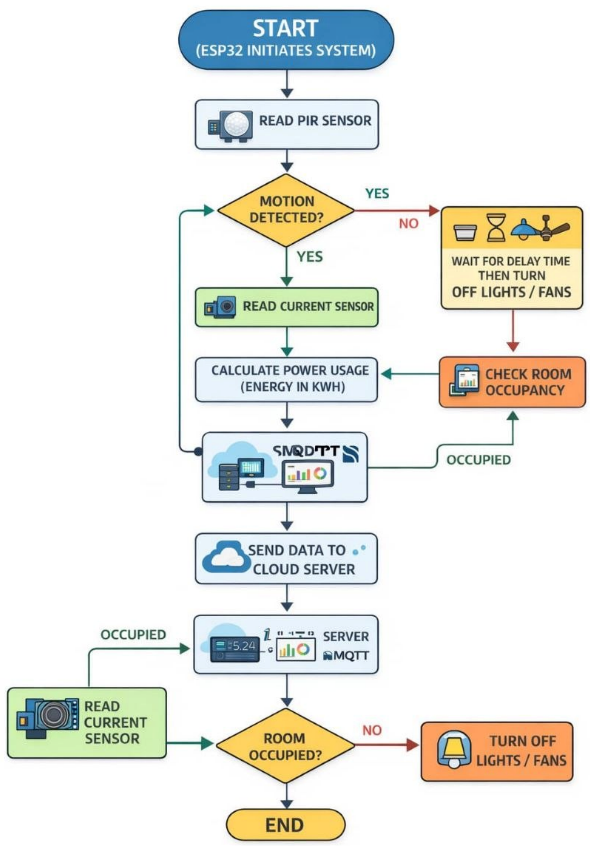
D. Relay Module

Interfaces the low-power controller with AC loads.

E. Power Supply Unit

rovides regulated DC supply for the controller and sensors.

VI. SYSTEM FLOWCHART AND OPERATION



The system operation begins with the initialization of the ESP32 controller, which activates all connected modules and prepares the system for monitoring and control.First, the Passive Infrared (PIR) sensor continuously monitors the environment to detect human motion. If no motion is detected, the system waits for a predefined delay period. After this delay, it automatically turns off electrical appliances such as lights and fans to conserve energy. The system then proceeds to verify the room occupancy status.If motion is detected, the system assumes the presence of a user and proceeds to read data from the current sensor. This sensor measures the electrical current drawn by connected loads. Using this data, the system calculates the power consumption and converts it into energy usage in kilowatt-hours (kWh).The calculated energy data is then processed and transmitted using the MQTT communication protocol. The ESP32 sends this information to a cloud server, where it is stored and analyzed for monitoring purposes.On the server side, the system evaluates the room occupancy condition based on received data. If the room is identified as unoccupied, control signals are generated to switch off the appliances. If the room is occupied, the system continues monitoring energy consumption by repeatedly reading the current sensor and updating the cloud server.This process operates in a continuous loop, ensuring real-time monitoring, efficient energy utilization, and automated control of electrical devices based on occupancy.

VII. RESULTS

The proposed smart energy management system was successfully implemented and evaluated under real-time conditions to assess its performance in occupancy detection, automated control, and energy monitoring. The PIR sensor effectively detected human presence, enabling the system to automatically control electrical appliances such as lights and fans based on occupancy, thereby minimizing unnecessary energy consumption. The current sensor provided reliable measurement of load current, and the calculated energy usage values were consistent with expected operating conditions. The system was integrated with the Blynk platform, enabling real-time monitoring of device status and energy consumption through a user-friendly interface. Experimental observations indicated a noticeable reduction in energy usage during unoccupied periods, with an estimated savings of approximately 20–30% compared to conventional manual operation. The system demonstrated fast response, stable communication, and consistent performance over extended durations. Overall, the results confirm that the proposed solution enhances energy efficiency and provides a practical, low-cost approach for intelligent automation in indoor environments such as homes, classrooms, and office spaces

VIII. ADVANTAGES

1) Reduces unnecessary energy consumption.
2) Lowers electricity cost.
3) Provides real-time monitoring.
4) Reduces dependence on manual switching.
5) Supports carbon footprint awareness.
6) Scalable for multiple rooms and buildings.

IX. FUTURE SCOPE

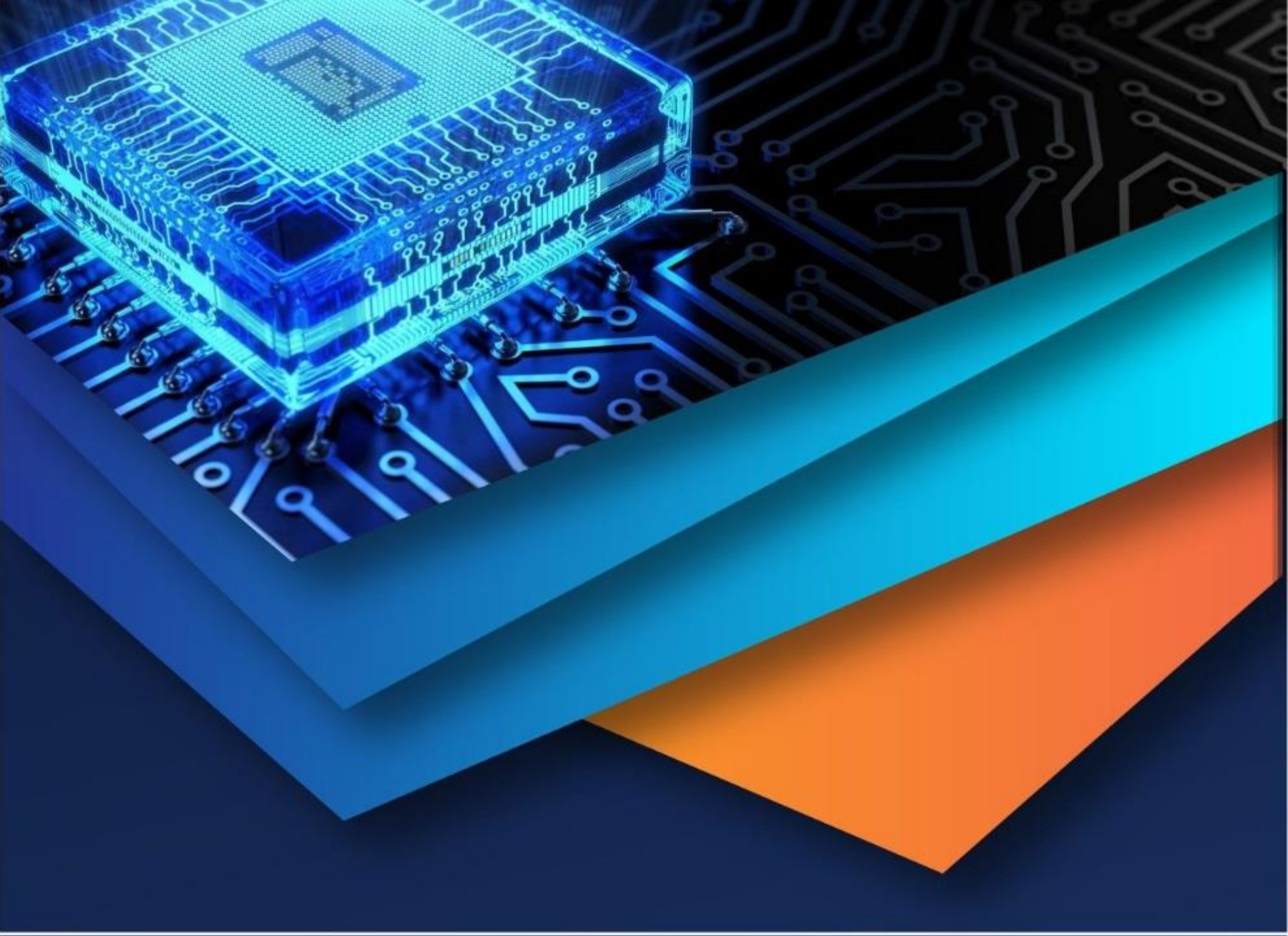
The system can be enhanced using machine learning for occupancy prediction and demand forecasting. Integration with solar energy systems, smart meters, and campus-wide dashboards can further improve sustainability. Additional sensors for temperature, air quality, and daylight-based dimming may also be included.

X. CONCLUSION

This paper presented an IoT-based Smart Campus Carbon Footprint Management system for intelligent energy conservation in educational environments. By integrating occupancy sensing, automated load control, cloud monitoring, and carbon emission estimation, the proposed solution addresses both operational efficiency and sustainability goals. The system is economical, scalable, and suitable for real-world deployment in classrooms, offices, and institutional buildings.

REFERENCES

[1] U. N. C. Change, “The paris agreement.” [Online]. Available:https://unfccc.int/process-and-meetings/the-paris-agreement
[2] U. Archana, A. Rajeshwaran, M. McLain, K. Bijlani, B. Rao, andR. Jayakrishnan, “Game based learning to reduce carbon foot print,”in Emerging Research in Computing, Information, Communication andApplications: ERCICA 2015, Volume 2. Springer, 2016, pp. 89–98.
[3] A. R. Devidas and M. V. Ramesh, “Wireless smart grid design for monitoring and optimizing electric transmission in india,”2010 Fourth International Conference on Sensor Technologies and Applications, pp. 637–640, 2010. [Online].
[4] A. M S, M. Vinodini Ramesh, A. Devidas, and K. Athira, “Fractal iot: A scalable iot framework for energy management in connected buildings,”11 2019, pp. 10–17.
[5] K. Athira, A. R. Devidas, M. V. Ramesh, and V. P. Rangan, “User centered energy management scheme for smart buildings,” in 2017International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2017, pp. 1296–1302.
[6] S. L. Samraj, N. V. Bhalke, A. Aarthi, R. Srinath, and E. Prabhu,Robust smart home monitoring system based on 802.11 MESH network,Nov 2019, p. 38–47. [Online]. Available: https://doi.org/10.1007/978-3-030-33846-6 5
[7] M. Varon-Hoyos, J. L. Osorio-Tejada, and T. Morales-Pinz ́ on, ́“Carbon footprint of a university campus from colombia,” Carbon Management, vol. 12, pp. 93 – 107, 2021. [Online]. Available:https://api.semanticscholar.org/CorpusID:231938602
[8] R. J. Tom, S. Sankaranarayanan, and J. J. Rodrigues, “Smart energy management and demand reduction by consumers and utilities in an iot-fog-based power distribution system,” IEEE Internet of Things Journal, vol. 6, pp. 7386–7394, 2019. [Online].
[9] K. Valls-Val and M. D. Bovea, “Carbon footprint assessment tool for universities: Co2unv,” Sustainable Production and Consumption, 2021. [Online].
[10] R. Clabeaux, M. Carbajales-Dale, D. Ladner, and T. Walker, “Assessingthe carbon footprint of a university campus using a life cycle assessment approach,” Journal of Cleaner Production, vol. 273, p. 122600, 2020.



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