International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 2, Mar-Apr-2026, ISSN (Online): 2395-566X

smart campus energy usage analysis and prediction

sasiram anupoju, Lakshmi Narasimham gorthi, sai kalyan nallamadhi, suhas rallabandi
Department of CSE (AI and ML) of ACE Engineering College, Hyderabad, India

Abstract- — This project presents the design and development of a Smart Campus Energy Usage Analysis and Prediction system that monitors and forecasts energy consumption across campus facilities. The system collects energy usage data from different buildings such as hostels, academic blocks, and libraries, and processes it using data analytics and machine learning techniques. A predictive model based on linear regression is used to estimate future energy consumption patterns. The system also provides interactive dashboards for real-time visualization, including consumption trends, building-wise distribution, and forecast insights. The proposed system aims to improve energy efficiency, reduce wastage, and support sustainable energy management in smart campus environments.

Keywords: Smart Campus; Energy Prediction; Machine Learning; Data Visualization; Energy Analytics.

I. INTRODUCTION

Traditional campus environments often lack efficient monitoring and predictive systems, which leads to excessive energy consumption and poor resource management. The absence of real-time analysis and forecasting results in unnecessary energy wastage and increased operational costs. With the advancement of smart technologies, data analytics and machine learning have emerged as powerful solutions to monitor, analyze, and optimize energy usage in large-scale environments such as campuses.

A Smart Campus Energy System is a data-driven approach that analyzes energy consumption patterns and predicts future usage based on historical data. In this project, energy consumption data from various campus buildings is processed and analyzed using machine learning models. Factors such as daily usage patterns, building-wise consumption, and time-based variations influence the prediction of future energy demand.

The system provides an interactive and visual dashboard where energy consumption trends, weekly aggregation, and future predictions are displayed dynamically. Graphs and charts represent real-time insights, helping users understand energy usage patterns more effectively. This approach improves decision-making, enhances energy efficiency, and demonstrates how data analytics and machine learning can be integrated into smart campus infrastructure.

II. LITERATURE SURVEY

2.1.A. Capozzoli et al. (2015) – Data Analytics for Smart Energy Management in Buildings

Capozzoli et al. (2015) presented a data-driven approach for energy management in smart buildings using advanced analytics techniques. Their work focuses on analyzing large-scale energy consumption data to identify patterns and inefficiencies in building operations. The study highlights how data analytics can be used to optimize energy usage, reduce costs, and improve sustainability. By applying statistical models and machine learning techniques, the system provides insights into consumption behavior and supports decision-making. This work is directly relevant to the proposed project, where energy usage data is analyzed to predict future consumption in a smart campus environment.

2.1.1. Methodologies and Algorithms

The methodology involves collecting historical energy data and applying data mining and statistical analysis techniques. Algorithms such as regression analysis and clustering are used to identify usage patterns and anomalies. The system processes large datasets and generates predictive insights based on historical trends. This approach relies on data-driven decision-making and is similar to the proposed system, where machine learning models are used to forecast energy consumption.

2.2. Y. Bengio et al. (2013) – Representation Learning: A Review and New Perspectives

Bengio et al. (2013) explored machine learning techniques, particularly representation learning, for analyzing complex datasets. Their work explains how machine learning models can automatically extract meaningful features from raw data and improve prediction accuracy. These techniques are widely used in energy prediction systems where large volumes of consumption data need to be analyzed. This study is relevant to the proposed project as it supports the use of machine learning models for predicting energy usage patterns based on historical data.

2.2.1. Methodologies and Algorithms

The methodology involves training machine learning models on large datasets to learn hidden patterns and relationships. Algorithms such as neural networks, regression models, and deep learning techniques are used for prediction tasks. The system improves performance through training and optimization. In the proposed system, a similar approach is used where machine learning algorithms such as linear regression are applied to predict future energy consumption.

2.3.T. Hong et al. (2016) – Advances in Energy Forecasting Models

Hong et al. (2016) reviewed various energy forecasting techniques used in smart grids and buildings. Their study compares statistical and machine learning approaches for predicting energy demand. The paper highlights the importance of accurate forecasting in energy management systems to ensure efficient resource utilization. It also discusses different forecasting models such as time series analysis, regression models, and hybrid approaches. This work is highly relevant to the proposed system, where forecasting techniques are used to predict campus energy usage.

2.3.1. Methodologies and Algorithms

The methodology includes time series analysis, regression techniques, and machine learning-based forecasting models. Algorithms such as ARIMA, linear regression, and neural networks are used to predict energy demand. These models analyze historical consumption data and generate future predictions. In the proposed system, a simplified version of these methodologies is implemented using regression-based prediction models.

2.4. S. Wang et al. (2019) – Intelligent Energy Management System Using IoT and AI

Wang et al. (2019) developed an intelligent energy management system that integrates IoT and artificial intelligence for monitoring and controlling energy usage. Their work demonstrates how real-time data collection combined with AI-based analysis can significantly improve energy efficiency. The system automatically adjusts energy usage based on demand patterns and environmental conditions. This approach is directly related to the proposed project, where energy data is analyzed and used for predictive decision-making in a smart campus environment..

2.4.1. Methodologies and Algorithms

The methodology involves collecting real-time data using IoT devices and processing it using AI-based algorithms. Machine learning models are used to analyze patterns and predict future energy consumption. Control algorithms are also implemented to optimize energy usage. In the proposed system, a similar approach is followed using historical data and predictive models to forecast energy demand and improve efficiency.

Table 1 Comparison Table of Literature Survey

S. No	Author(s)	Title	Methodology Used	Findings from the Reference Paper
1.	A.Capozzoli et (2017)	Data Analytics for Smart Energy Management in Buildings	Used data analytics and statistical methods to analyze large-scale building energy consumption data and identify usage patterns.	Demonstrated that data analytics improves energy efficiency and reduces operational costs. Effective for decision-making but depends on data quality and requires large datasets
2.	Y. Bengio et al. (2013)	Representation Learning: A Review and New Perspectives	Applied machine learning techniques such as neural networks to automatically extract features from	Showed that machine learning improves prediction accuracy and handles large data effectively. However, it requires high computational

			complex datasets.	resources and model training time.
3.	T.Hong et al. (2016)	Advances in Energy Forecasting Models	Used time series analysis and machine learning models like ARIMA and regression for energy demand forecasting..	Highlighted the importance of accurate forecasting in energy systems. Improves planning and efficiency but model accuracy depends on historical data and parameter tuning.
4.	S.Wang et al (2019)	Intelligent Energy Management System Using IoT and AI	Integrated IoT for real-time data collection and AI algorithms for analyzing and optimizing energy usage.	Demonstrated improved energy efficiency through automation and predictive analysis. However, implementation complexity and data security are major challenges.

III. SYSTEM ARCHITECTURE

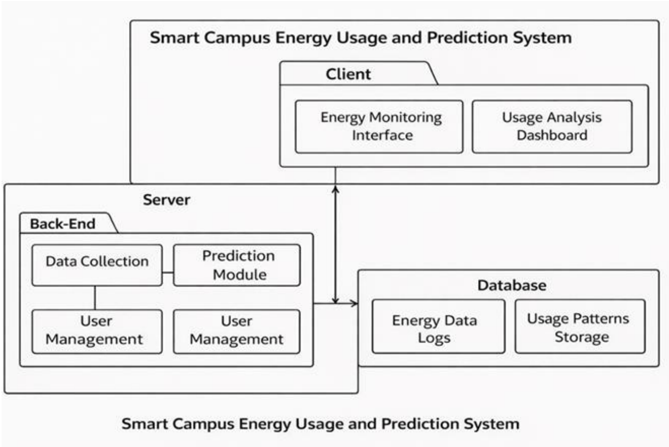

Figure 1 System Architecture

The system architecture of the Smart Campus Energy Usage Analysis & Prediction is designed based on three main layers: User Layer, Application Layer, and Processing Layer, which together monitor, analyze, and predict energy consumption across the campus environment.

The User Layer represents the interaction of the user with the system. In this project, the user monitors energy usage through a dashboard interface. The user can view real-time electricity consumption, building-wise energy usage, and graphical representations of energy trends. The user can also view prediction results and receive alerts when abnormal energy usage is detected. This layer acts as the entry point where users interact with the system and observe overall campus energy performance.

The Application Layer acts as the core logic of the system. It is implemented using programming tools such as Python or web technologies. The Energy Data Module collects data such as electricity consumption, HVAC usage, lighting usage, occupancy levels, and weather conditions. The Analysis & Prediction Module processes this data using algorithms and machine learning techniques to identify usage patterns, forecast future energy demand, and detect anomalies. The Control Logic evaluates these results and can suggest optimization actions such as reducing unnecessary energy consumption. The Status Handler updates the system and displays current energy information and predictions on the dashboard.

The Processing Layer is responsible for executing data processing and visualization. The Sensor Data Module collects or simulates data from smart meters, temperature sensors, occupancy sensors, and other sources. This data is processed through data cleaning, aggregation, and feature extraction techniques. The Prediction Engine uses time series models such as ARIMA or LSTM to generate future energy consumption predictions. The Visualization Module displays the processed data using charts, graphs, and dashboards for easy understanding.

The system runs continuously using loop-based or real-time data processing methods, where energy data is collected, analyzed, and visualized repeatedly. This creates an intelligent system that behaves like a smart monitoring and prediction tool for campus energy management. The architecture ensures proper interaction between data collection, system logic, and visualization, making the system efficient, accurate, and useful for reducing energy consumption and improving sustainability.

IV. PROPOSED METHODOLOGY

4.1. Campus Energy System Modeling

The first step in the methodology involves designing a structured model of the smart campus energy system. The campus is divided into different zones such as academic buildings, hostels, administrative blocks, and common areas. Each zone includes energy-consuming components such as lighting systems, HVAC systems, computers, and other electrical equipment.

Special attention is given to identifying major energy consumption points and organizing them logically. This model acts as the foundation of the system, where all monitoring, analysis, and prediction processes are performed.

4.2. Data Simulation and Input Generation

Since real-time sensors may not be used in this project, energy-related data such as electricity consumption, occupancy levels, and weather conditions are simulated using Python. Random or predefined values are generated at regular intervals to represent varying campus conditions.
Different buildings or zones generate different levels of energy usage based on simulated occupancy and environmental factors. This simulated data acts as input to the system, similar to how real smart meters and sensors would provide data in an actual smart campus.

4.3.Analysis and Prediction Logic

The analysis and prediction logic is implemented using Python programming. Data is processed using statistical methods and machine learning techniques. The system analyzes energy consumption patterns, identifies peak usage periods, and detects unusual spikes in energy usage.
Prediction models such as time series forecasting (ARIMA or LSTM) are used to estimate future energy demand. Based on these results, the system can suggest optimization strategies such as reducing energy usage during peak hours or improving efficiency in specific buildings.

4.4. Visualization and System Update

The system uses dashboards and graphical interfaces to display real-time and predicted data. Charts, graphs, and tables are used to represent energy consumption trends, building-wise usage, and prediction results.

The system runs continuously using loop-based or time-based execution, where data is generated, processed, analyzed, and visualized repeatedly. This creates an interactive system that behaves like a smart monitoring and prediction platform for campus energy management.

V. ALGORITHMIC FLOW OF THE SYSTEM

- Initialize the campus energy model with different buildings and energy-consuming components.
- Start the system using Python or a simulation environment.
- Generate dynamic input data such as energy consumption, occupancy, and weather conditions.
- Update building-wise energy usage based on simulated inputs.
- Analyze energy consumption patterns using data processing techniques.

Check for peak load conditions:

– If energy usage exceeds the threshold value, mark it as high consumption.
– Otherwise, maintain normal status.

- Apply prediction models to forecast future energy demand.
- Detect anomalies such as sudden spikes or unusual consumption patterns.
- Generate insights and suggestions for energy optimization.
- Display results through dashboards, charts, and reports.
- Repeat the above steps using continuous execution to maintain real-time monitoring and prediction.

VI. OUTPUT SCREENS

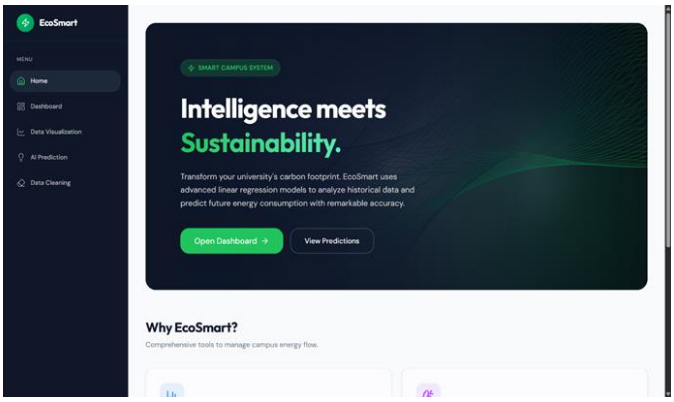

Fig 1: Home screen of the Smart Campus energy usage and prediction

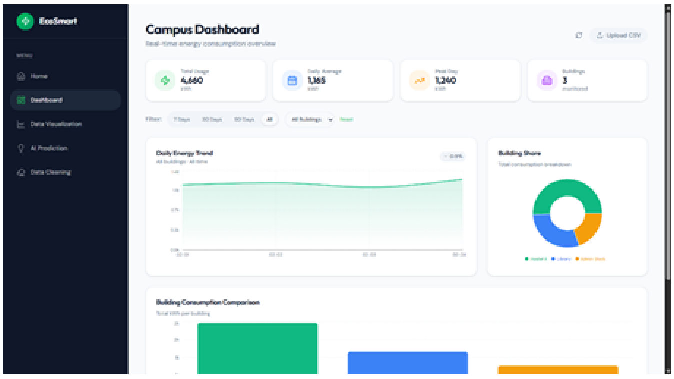

Fig 2: Dashboard

Fig 3: Data vizualization

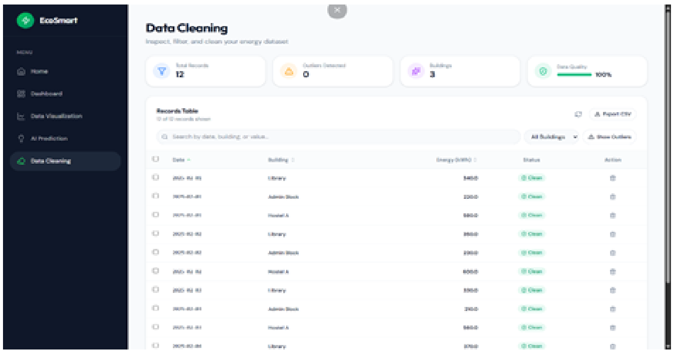

Fig 4: Data cleaning

Fig 5: Real-Time AI prediction

VII. CONCLUSION

The Smart Campus Energy Usage Analysis & Prediction project successfully illustrates the application of data analysis and predictive technologies in a campus environment. By integrating data processing techniques with Python-based models, the system monitors and predicts energy consumption across different campus facilities.

The project highlights how factors such as energy usage patterns, occupancy, and environmental conditions can be analyzed to optimize energy consumption, reduce wastage, and improve overall efficiency. The use of visualization tools and real-time updates enhances the effectiveness of the system and makes the analysis easy to understand.

This work provides a strong foundation for future developments in smart campus systems, where real-time sensor data and IoT integration can further improve accuracy and automation. The project demonstrates the potential of intelligent prediction systems in building energy-efficient and sustainable campus environments.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

REFERENCES

1. A. Capozzoli, M. Savoldi, and A. Gorrino, "Data Analytics for Smart Energy Management in Buildings," Energy and Buildings, vol. 98, 2015.
2. Y. Bengio, A. Courville, and P. Vincent, "Representation Learning: A Review and New Perspectives," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 35, no. 8, 2013.
3. T. Hong, P. Pinson, and S. Fan, "Global Energy Forecasting Competition 2012," International Journal of Forecasting, vol. 32, no. 3, 2016.
4. UCI Machine Learning Repository, "Individual Household Electric Power Consumption Dataset," Available: https://archive.ics.uci.edu
5. Python Software Foundation, "Python Programming Language," Available: https://www.python.org/
6. Scikit-learn Developers, "Scikit-learn: Machine Learning in Python," Available: https://scikit-learn.org/
7. S. Wang, X. Zhang, and Y. Wang, "Intelligent Energy Management System Based on IoT and AI," Sustainable Cities and Society, 2019.
8. Online Resources and Tutorials on Energy Data Analysis and Machine Learning.