



# Energy Consumption Forecasting In Power Generation Using Machine Learning Models

<sup>1</sup>K.Simon Abhishek, <sup>2</sup>B.Surya Ganga, <sup>3</sup>M.Rama Prasanna Lakshmi, <sup>4</sup>J.Sai Susmitha, <sup>5</sup>E. Ramu

<sup>1</sup>Student, <sup>2</sup>Student, <sup>3</sup>Student, <sup>4</sup>Student, <sup>5</sup>Student

<sup>1,2,3,4</sup> Department Of CSE- ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING,

<sup>1,2,3,4</sup> Aditya College of Engineering and Technology, Surampalem, Andhra Pradesh, India.

**Abstract :** The rapid growth of industrialization has significantly increased energy consumption, particularly in energy-intensive sectors such as manufacturing. Efficient energy management has become a major challenge due to rising operational costs, fluctuating demand, and increasing environmental concerns. Traditional energy management systems rely on manual monitoring and historical data, which lack real-time responsiveness and predictive capabilities. As a result, industries often face issues such as inefficient energy utilization, unexpected power spikes, delayed decision-making, and higher operational costs. Moreover, existing systems fail to integrate multiple influencing factors such as reactive power, power factor, load variations, weather conditions, and renewable energy contributions, limiting their ability to provide accurate insights and effective energy optimization.

To overcome these challenges, the proposed project presents a Machine Learning-based application for efficient industrial energy management. The system uses advanced models such as regression techniques and Random Forest to predict energy consumption and evaluate system efficiency. It analyzes industrial and smart grid parameters to forecast short-term energy demand and classify performance as efficient or inefficient. The solution integrates predictive analytics with smart grid data and is implemented as a web-based application with real-time monitoring, dashboards, and visualization features. This enables industries to make informed decisions, optimize energy usage, reduce operational costs, and improve overall efficiency. The proposed system provides a scalable and intelligent solution that supports sustainable and data-driven industrial energy management.

**Index Terms** - Machine Learning ,Smart Grid, Steel Industry Dataset, Energy Prediction ,LSTM, Random Forest, Efficiency or Inefficiency.

## I. INTRODUCTION

The rapid growth of industrialization has significantly increased energy consumption, especially in energy-intensive sectors like steel manufacturing, making efficient energy management a critical challenge due to rising costs, fluctuating demand, and environmental concerns. Traditional systems rely on manual monitoring and historical data, lacking real-time responsiveness and predictive capabilities, which leads to inefficient energy use, delayed decisions, and higher carbon emissions. To address these issues, advancements in Machine Learning (ML) and smart grid technologies offer a shift toward intelligent, data-driven energy management. ML techniques enable accurate prediction of energy consumption using operational parameters, helping industries anticipate demand and optimize usage, while smart grids improve power distribution through renewable integration and dynamic balancing. The proposed project introduces an integrated framework with a two-stage ML pipeline—predicting energy consumption using regression models and evaluating efficiency through classification models. Implemented as a web-based application, the system supports real-time monitoring, secure interaction, and dynamic visualization, enabling informed decision-making, reduced energy waste, and improved

operational efficiency. Overall, the project promotes sustainable industrial practices by combining predictive analytics, smart grid integration, and intelligent energy management strategies.

## II. EXISTING & PROPOSED SYSTEM:

### Existing System

The existing system refers to the traditional method used by industries to manage energy consumption before introducing the new Machine Learning-based system. In this system, industries mainly depend on manual monitoring and analysis of past energy data to understand energy usage. It does not have advanced prediction capabilities, so decisions are usually made only after problems occur instead of preventing them in advance. Because the system lacks real-time monitoring and intelligent analysis, energy may be used inefficiently, leading to higher electricity costs and increased energy wastage. Another limitation is that the existing system does not integrate industrial energy data with smart grid information, so it cannot provide a complete view of overall energy performance. It also provides only raw data without clear suggestions about whether the system is operating efficiently or inefficiently. Due to these limitations, industries face difficulties in optimizing energy usage and making quick, informed decisions.

### Proposed System

The proposed system uses Machine Learning to improve industrial energy efficiency by predicting energy consumption and classifying it as efficient or inefficient using regression and Random Forest models. It analyzes industrial and environmental data to provide accurate insights and is deployed as a web application for real-time monitoring, alerts, and visualization. The system helps reduce electricity costs, optimize energy usage, minimize energy waste, and supports sustainable operations by promoting the use of renewable energy. The main purpose of the system is to help industries use electricity in a smarter and more efficient way. Industries like steel factories use a large amount of energy every day, so managing energy properly is very important. Traditional systems only monitor past energy usage and do not predict future energy needs. Because of this, industries may waste energy and spend more money. The proposed system solves this problem by using Machine Learning technology to predict how much energy will be required in the future.

## III. RELATED WORKS

Previous research in industrial energy management has explored the use of Machine Learning techniques such as regression models and neural networks for energy consumption prediction. Studies have shown that algorithms like Random Forest and LSTM provide high accuracy in forecasting energy demand in smart grid environments. Research on smart grids highlights the integration of renewable energy sources, real-time monitoring, and demand-side management to improve energy efficiency. Several works also focus on data-driven approaches that combine industrial parameters with environmental factors to optimize energy usage. However, most existing systems handle prediction and efficiency analysis separately, whereas the proposed system integrates both aspects into a unified framework, providing more comprehensive and intelligent energy management.

## IV. METHODOLOGY

The methodology follows a structured, data-driven approach that integrates Machine Learning with smart grid concepts. Initially, industrial and smart grid data such as reactive power, power factor, voltage, current, renewable energy, and environmental parameters are collected through a web-based interface. This raw data undergoes preprocessing steps including data cleaning, encoding of categorical variables, and normalization using scaling techniques to ensure consistency. Feature engineering is then applied to generate meaningful attributes like efficiency score and adjusted load. In the first stage of the methodology, a regression model is used to predict industrial energy consumption based on operational parameters, enabling accurate forecasting of energy usage patterns.

In the second stage, the predicted energy values are combined with smart grid data and passed into a classification model, specifically a Random Forest algorithm, to determine whether the system is operating efficiently or inefficiently. The entire process is integrated within a Flask-based web application that supports real-time monitoring, user authentication, and interactive dashboards for visualization. Additionally, fallback mechanisms and simulated data generation are included to ensure system reliability even when real data or models are unavailable. This two-stage pipeline enables proactive decision-making, improved energy optimization, and supports sustainable industrial operations.

#### 4.1 System Architecture Overview

The system architecture is designed as a modular and layered structure to ensure efficient data processing, scalability, and real-time performance. The architecture consists of multiple components, including the user interface, Flask-based backend, data processing module, Machine Learning models, and database. Users interact with the system through a web dashboard, where they input industrial and smart grid parameters. These inputs are sent to the backend server, which manages authentication, API requests, and communication between different system components.

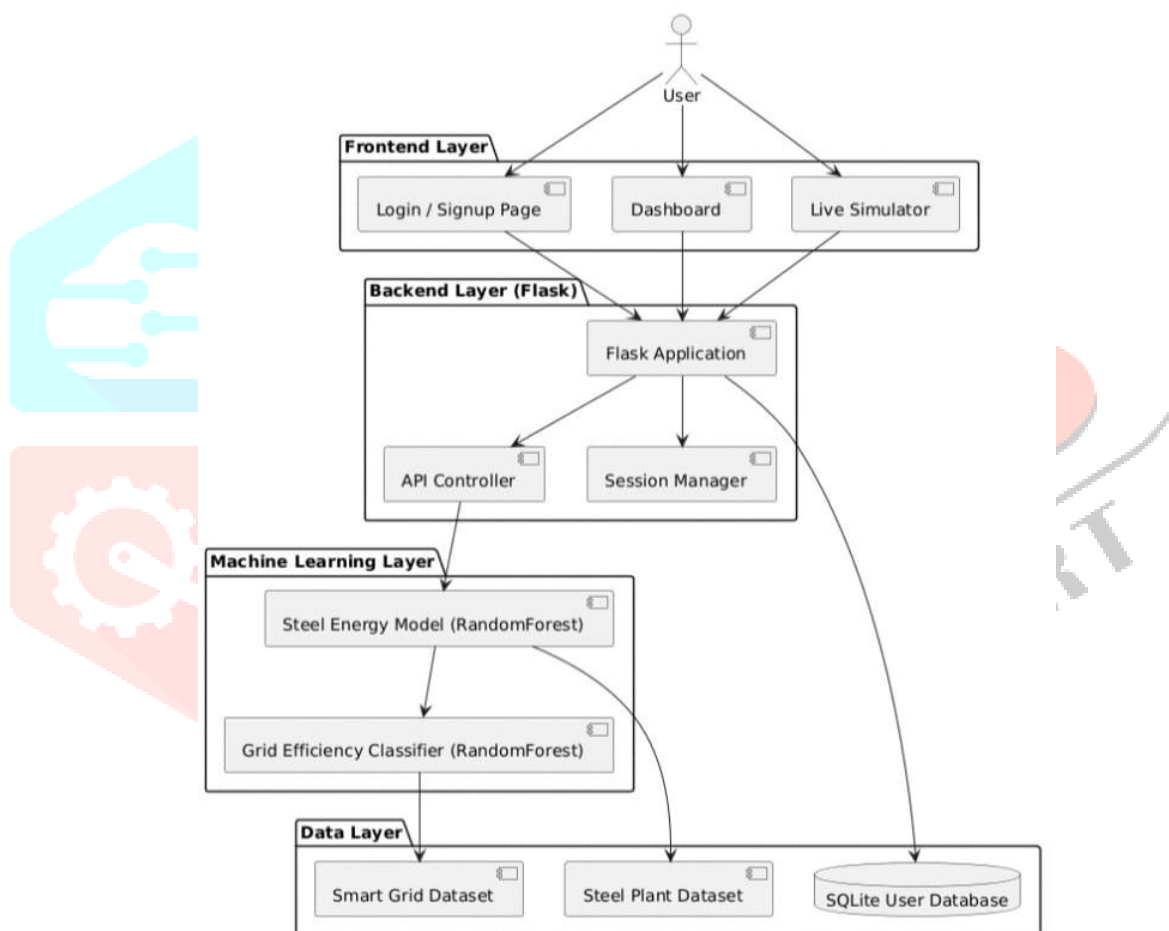


Figure 1: System Architecture

#### 4.2 System Components

**Data Handling Module:** Collects and preprocesses industrial and smart grid data (cleaning, encoding, normalization).

**Machine Learning Module:** Uses regression for energy prediction and classification for efficiency analysis.

**Feature & Analysis Module:** Generates derived features like efficiency score and optimized load.

**Application & Storage Module:** Flask-based web app for dashboards and authentication, with database

support for storing data and logs.

### 4.3 Working Principle

The system begins by collecting input data from the user or simulated sources. The data is preprocessed and passed to the regression model, which predicts industrial energy consumption. This predicted value is then combined with smart grid parameters through feature engineering. The combined dataset is fed into the Random Forest classifier, which determines whether the system is operating efficiently or inefficiently. The results are displayed on a web dashboard for user interpretation and decision-making.

### Key Features

- Real-time energy prediction and monitoring
- Two-stage Machine Learning pipeline
- Integration of industrial and smart grid data
- User-friendly web interface with visualization
- Secure authentication and data handling
- Fallback mechanisms for system reliability

### Advantages

The system provides improved prediction accuracy, proactive decision-making, reduced energy wastage, and better resource utilization. It also supports sustainability by optimizing energy usage and integrating renewable energy factors. The web-based architecture ensures accessibility, scalability, and ease of deployment in modern industrial environments.

### 4.4 Algorithm

#### Procedure ENERGY CONSUMPTION FORECASTING THROUGH ML MODELS

1. Start
2. Collect Steel Industry Dataset
3. Clean and prepare the data (remove errors, scale values)
4. Take input dataset (power, voltage, load, renewable energy, etc.)
5. Register and verify user name and password
6. Enter manual data in results dashboard(Temperature, Energy, Humidity, Weather)
7. Use ML model to predict energy consumption
8. Combine predicted energy with grid data
9. Use another ML model to check efficiency (Efficient / Inefficient)
10. Show results on screen (energy + efficiency)
11. End of Procedure

## V. RESULTS & DISCUSSION

### A. Accurate Energy Prediction

The regression model demonstrated strong performance in predicting industrial energy consumption using operational parameters such as power, voltage, and load conditions. The model maintained consistent accuracy across different scenarios, including low, medium, and high load conditions, indicating its ability to generalize well and capture complex energy usage patterns.

## B. Effective Classification

The Random Forest classification model successfully categorized system performance into “Efficient” and “Inefficient” states. By combining predicted energy consumption with smart grid and environmental parameters, the model provided meaningful and actionable insights, improving the interpretability of results for industrial decision-making.

## C. Real-Time System Performance

The integration of Machine Learning models with a Flask-based web application enabled real-time prediction and visualization. The system showed fast response times and smooth dashboard updates, ensuring usability in practical industrial environments where timely decisions are critical.

## D. Robustness and Reliability

The system performed reliably under different conditions, including scenarios with missing or incomplete data. The implementation of fallback mechanisms and simulated data generation ensured continuous operation, highlighting the robustness of the system in real-world situations.

## E. Improved Decision-Making and Efficiency

The combined approach of prediction and classification provided a comprehensive understanding of energy consumption and system efficiency. This helped in identifying inefficiencies, reducing energy wastage, and optimizing resource utilization, ultimately contributing to cost reduction and sustainable industrial operations.

## VI. Figures and Tables

Test Case ID	Module	Test Scenario	Input	Expected Output	Status
TC01	User Authentication	Verify user signup with valid details	Name, Email, Username, Password	New user account created successfully	Pass
TC02	User Authentication	Verify login with valid credentials	Correct username and password	User redirected to dashboard	Pass
TC03	User Authentication	Verify login with invalid password	Correct username + wrong password	Error message: Invalid credentials	Pass
TC04	Live Simulation	Start real-time simulation	Click Start button	Data rows generated every 2 seconds	Pass
TC05	Live Simulation	Check efficiency classification	Efficiency > 80%	Status shown as Efficient	Pass
TC06	Live Simulation	Check efficiency classification	Efficiency between 60–80%	Status shown as Moderate	Pass

TC07	Live Simulation	Check efficiency classification	Efficiency < 60%	Status shown as Inefficient	Pass
TC08	Manual Data Entry	Enter valid energy parameters	kWh, temperature, humidity	Record added successfully	Pass

Table 1: Test cases

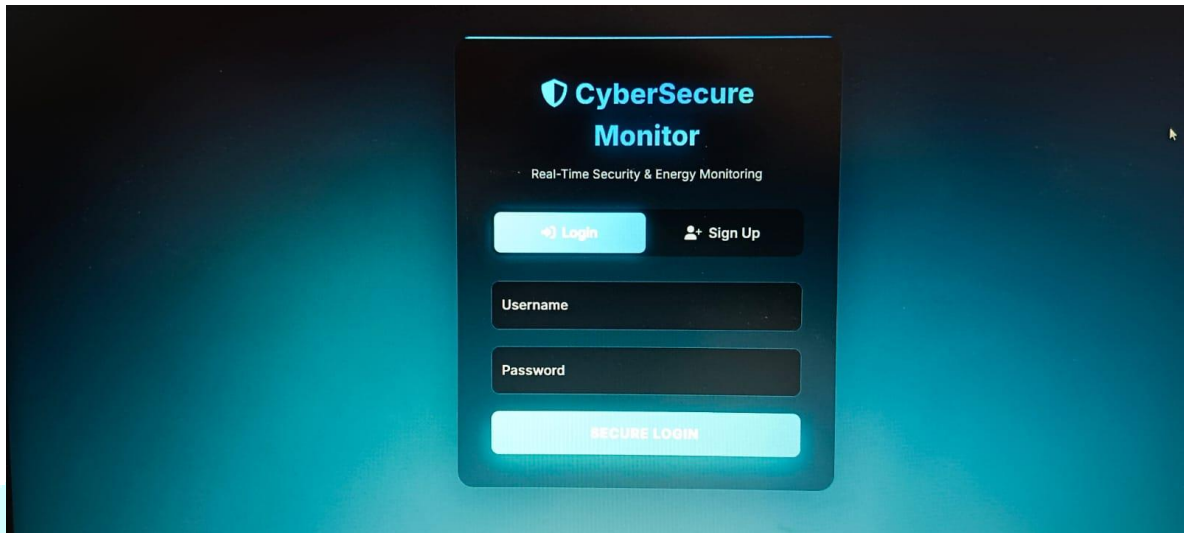


Figure 1: Log In Page

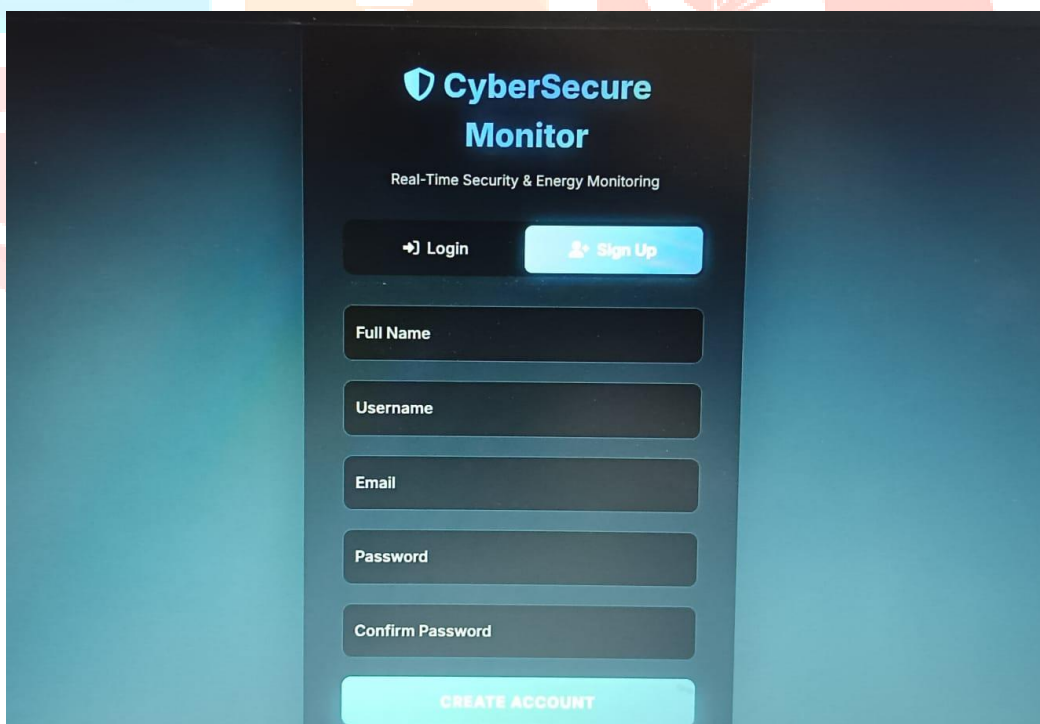


Figure 2 : Sign Up Page



Figure 3 :Dashboard view

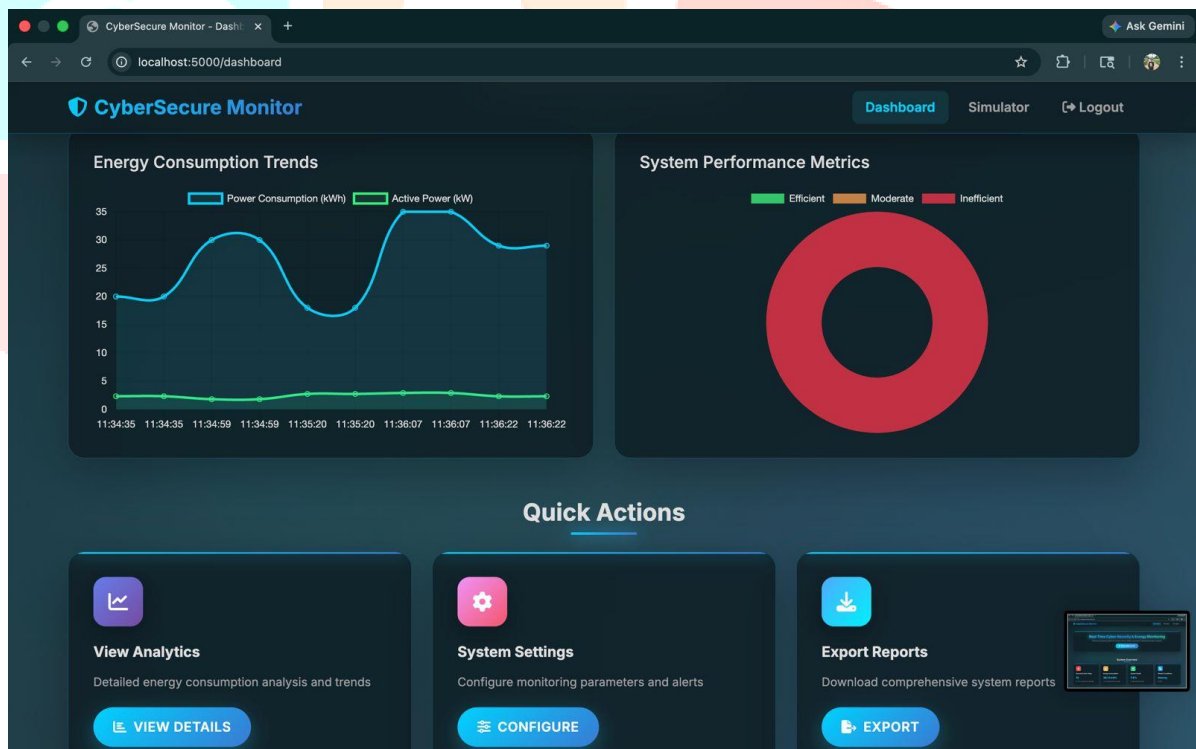


Figure 4 : Graph

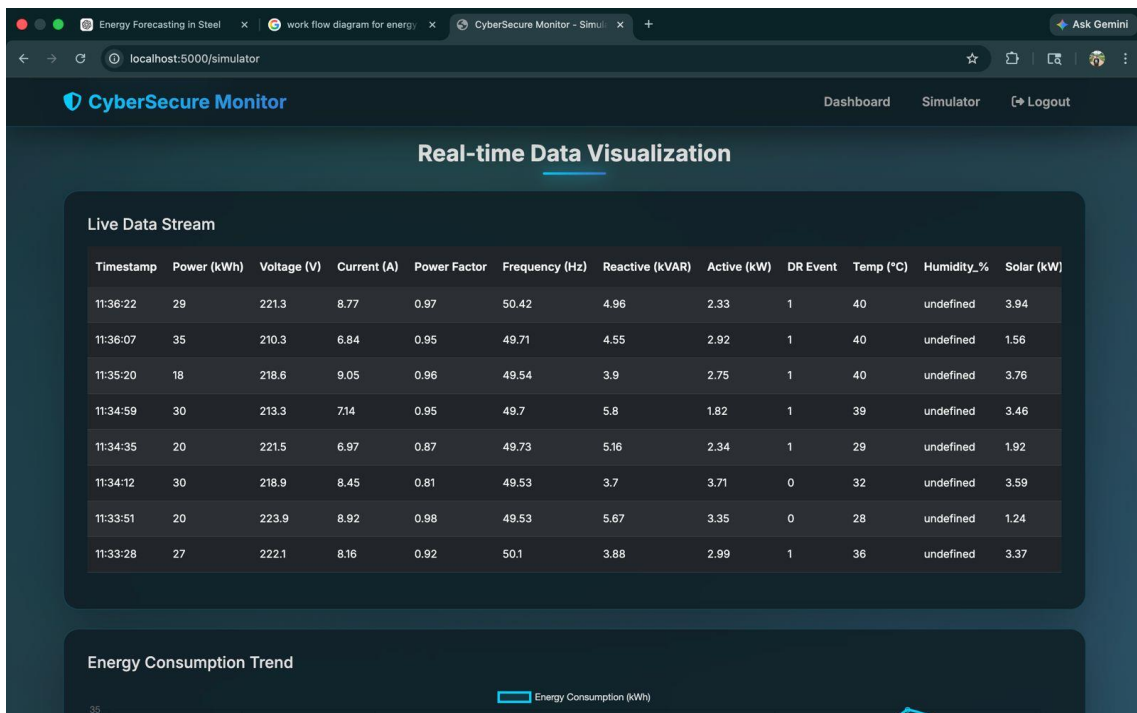


Figure 5 : Real Time Data Visualization

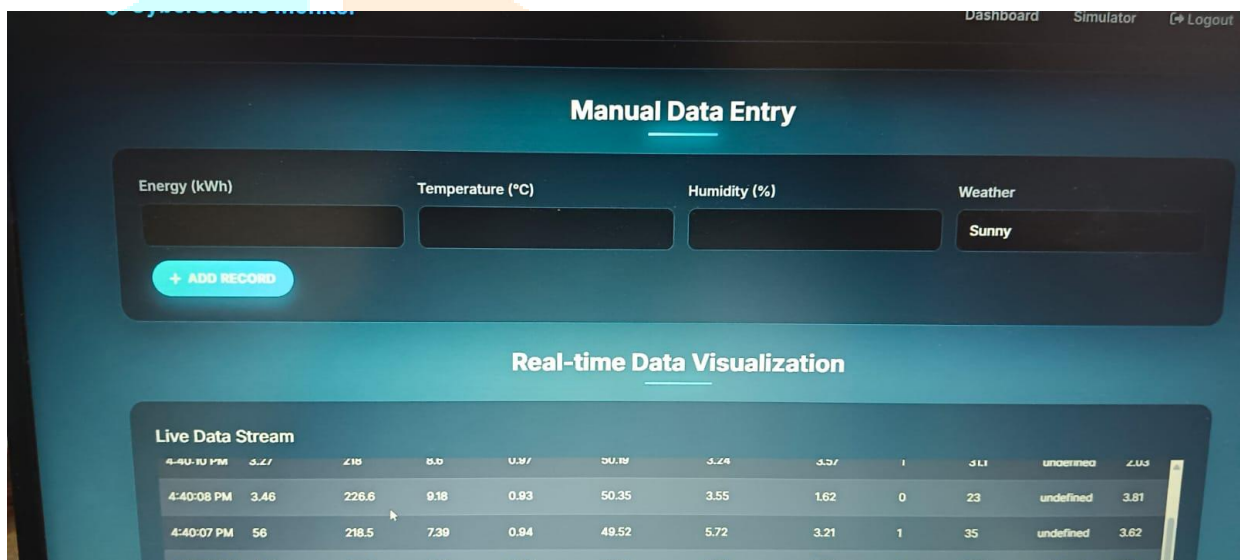


Figure 6: Manual Data Entry

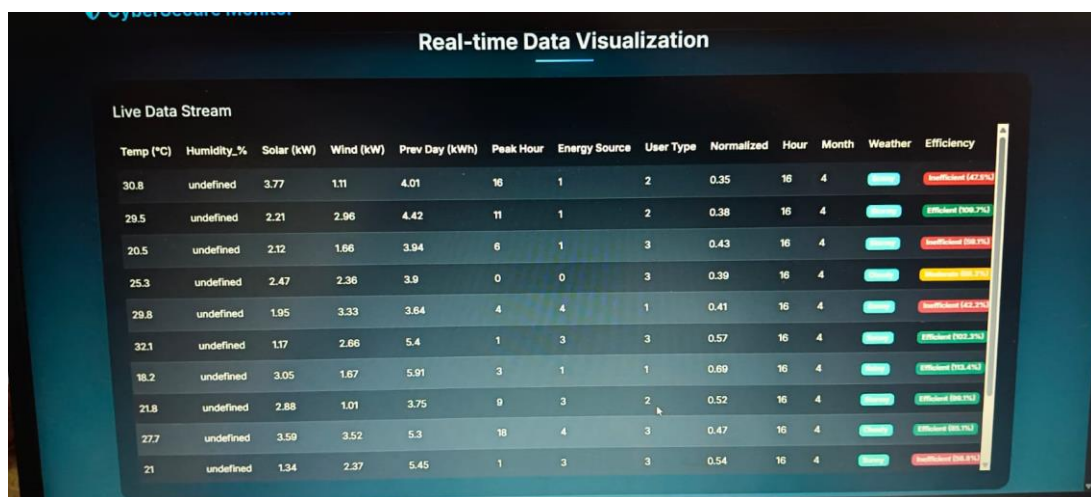


Figure 7: Check Efficient or Inefficient

## VII.FUTURE SCOPE

The future scope of the system shows how the project can be improved and expanded later. In the future, the system can be connected to real sensors and smart meters using IoT technology. These devices can automatically collect energy data from machines and equipment. This means the system will get real-time data without manual input from users. Advanced deep learning models can also be added to the system to make energy predictions more accurate and reliable. Moving the system to cloud platforms can improve performance and allow many users to access it from different locations. Cloud storage can also keep large amounts of data safely and securely.

The system can be connected with real smart grid systems to manage and control energy more efficiently. This will help industries balance energy supply and demand properly. More advanced features like automatic energy optimization can be developed to reduce energy waste. The dashboard of the system can also be improved by adding better graphs, charts, and warning alerts. These visual tools will help users understand energy usage easily. Alerts can notify users when energy consumption becomes too high. Overall, these future improvements will make the system more powerful, smarter, and more useful for industries in managing energy effectively.

## VIII.CONCLUSION

The proposed system effectively addresses the limitations of traditional industrial energy management approaches by introducing a predictive and classification-based framework. The regression model accurately estimates industrial energy consumption based on operational parameters, while the Random Forest classifier evaluates energy efficiency as Efficient or Inefficient. The integration of smart grid data, environmental factors, and renewable energy inputs enhances the system's ability to provide holistic energy analysis. The Flask-based web application ensures real-time monitoring, user interaction, and secure access to energy insights. Overall, the system demonstrates that Machine Learning can significantly improve industrial energy efficiency, reduce operational costs, and support sustainable energy practices in modern industrial environments.

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