A Reliable Energy Consumption Analysis System for Energy Efficient Appliances

YOGESH V

SRINIKETHAN S

INTRODUCTION

Power consumption analysis for households is an ML project that involves using machine learning algorithms to analyze and predict the energy consumption patterns of residential buildings. The goal of this project is to help homeowners and utility companies better manage their energy usage, reduce waste, and lower costs.

The project involves collecting data on energy consumption and related factors such as weather, time of day, and occupancy. This data is then used to train machine learning models to make accurate predictions of future energy consumption based on these factors. The models can be used to identify patterns in energy usage and make recommendations for ways to reduce energy waste and improve efficiency.

Overall, power consumption analysis for households is an important application of machine learning that has the potential to make a significant impact on energy usage and sustainability.

PROBLEM STATEMENT

Residential buildings consume a significant amount of energy, leading to high energy bills and contributing to environmental issues. Homeowners and utility companies need to better manage their energy usage, reduce waste, and lower costs. To achieve this, it is essential to have accurate predictions of future energy consumption patterns based on relevant factors such as weather, time of day, and occupancy. However, obtaining and analyzing this data is a complex task that requires sophisticated technology and expertise.

The Power Consumption Analysis for Households project aims to address this problem by developing machine learning algorithms that can accurately predict and analyze energy consumption patterns in residential buildings. The project will collect data on energy consumption, time of day, occupancy, and other relevant factors to train machine learning models. These models will be used to identify patterns in energy usage and provide recommendations on how to reduce energy waste and improve efficiency.

The project's success will be measured by the accuracy of the machine learning models in predicting future energy consumption patterns and the ability of homeowners and utility companies to make informed decisions based on these predictions. Ultimately, the project aims to help homeowners and utility companies better manage their energy usage, reduce waste, and lower costs while also contributing to the sustainability of our environment.

IDEATION AND PROPOSED SOLUTION

EMPATHY MAP

IDEATION AND BRAINSTORMING

1. Real-time Energy Monitoring: Develop a system that provides real-time energy consumption data for each connected appliance, allowing customers to track their usage instantly and identify energy-intensive appliances.

2. Data Visualization: Create user-friendly and visually appealing dashboards and reports that present energy consumption data in a clear and understandable format, enabling customers to identify trends, patterns, and potential areas for improvement.

3. Appliance Efficiency Ratings: Integrate an appliance efficiency rating system into the analysis system, offering customers a standardized and easy to-understand metric for comparing the energy efficiency of different appliances.

4. Energy Cost Analysis: Provide a feature that calculates the cost of energy consumed by each appliance, allowing customers to estimate their energy expenses accurately and make informed decisions about appliance usage.

5. Energy Saving Recommendations: Offer personalized recommendations based on the analyzed data, suggesting energy-saving practices, optimal usage times, and potential appliance upgrades to maximize energy efficiency and reduce costs.

6. Mobile Application: Develop a mobile application that allows customers to access the energy consumption analysis system on their smartphones, providing convenience and enabling them to monitor and manage their energy usage on the go.

7. Integration with Smart Home Systems: Enable integration with existing smart home systems, such as voice assistants or home automation platforms, to allow customers to control and monitor their appliances seamlessly through a centralized interface.

8. Education and Tips: Include educational resources, energy-saving tips, and best practices within the system, empowering customers with knowledge to make sustainable choices and further optimize their energy consumption.

9. Community and Social Features: Introduce a community aspect where customers can share their energy-saving achievements, tips, and experiences, fostering a sense of engagement and encouraging sustainable behaviors.

10. Gamification Elements: Incorporate gamification elements, such as challenges, achievements, and rewards, to motivate and incentivize customers to actively reduce their energy consumption and compete with friends and family.

PROJECT DESIGN PHASE 1

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	The lack of a reliable energy consumption analysis system for energy-efficient appliances poses a significant challenge for consumers and energy management entities. While energy efficient appliances are designed to minimize energy usage, there is a need for an accurate and accessible system that can monitor and analyze their actual energy consumption. The existing methods for assessing energy consumption are often outdated, inconsistent, or inadequate for the specific requirements of energy-efficient appliances. This knowledge gap hinders consumers' ability to make informed decisions about their energy usage and prevents energy management entities from effectively implementing energy-saving initiatives. Additionally, the absence of a reliable energy consumption analysis system for energy-efficient appliances poses obstacles for manufacturers and policymakers. Manufacturers require accurate data on energy consumption to improve the design and performance of energy-efficient appliances. Policymakers need reliable information to formulate effective energy conservation policies and incentives. Without a robust system in place, it becomes challenging to validate claims of energy efficiency, hindering the widespread adoption of energy-efficient appliances and impeding progress towards sustainable energy practices. Therefore,there is a pressing need to develop a reliable energy consumption analysis

		system specifically tailored for energy-efficient appliances. This system should provide accurate real-time monitoring, data analysis, and reporting capabilities to enable consumers, manufacturers, energy management entities, and policymakers to make informed decisions and implement effective energy-saving measures. By addressing this problem, we can promote energy efficiency, reduce energy consumption, and contribute to a more sustainable and environmentally friendly future.
2.	Idea / Solution description	We propose the development of a web application that utilizes machine learning techniques to predict Global Active Power. The web application will provide users with accurate and real-time predictions of global active power consumption, aiding in energy planning and management. The key components and features of the web application include: 1. Data Collection: The application will collect historical data on global active power consumption from reliable sources such as energy grids, utilities, or publicly available datasets. The data will include various relevant parameters such as date, time, weather conditions, and previous power consumption patterns. 2. Data Preprocessing: The collected data will undergo preprocessing steps to clean and prepare it for analysis. This includes handling missing values, outliers, and normalization of the data.

		3. Feature Engineering: The application will perform feature engineering to extract meaningful features from the collected data. This may involve creating additional features such as time of day, day of the week, or seasonal indicators to capture temporal patterns and dependencies. 4. Machine Learning Model Training: The web application will employ machine learning algorithms, such as regression or time series forecasting models, to train on the preprocessed data. The choice of the model will depend on the nature of the data and the desired prediction accuracy. Popular models like linear regression, decision trees, random forests, or recurrent neural networks (RNNs) can be used. 5. Real-Time Prediction: Once the model is trained, the web application will allow users to input relevant parameters such as date, time, and weather conditions to obtain real-time predictions of global active power consumption. The application will utilize the trained model to generate accurate predictions based on the input parameters and historical patterns. 6. Visualization and Reporting: The web application will provide visualizations and reports to present the predicted global active power consumption in a user-friendly format. Users can access charts, graphs, and summary statistics to gain insights into the predicted power consumption patterns. Historical data and predicted values can be compared to identify trends and make informed decisions. 7. Scalability and Performance: The web application will be designed to handle large datasets and accommodate increased user traffic. It will be optimized for performance, ensuring

		that predictions are generated efficiently and delivered in a timely manner. 8. Continuous Model Updates: To maintain prediction accuracy, the web application can include mechanisms for continuous model updates. This allows the application to adapt to changing consumption patterns, new data sources, and improved modeling techniques. Regular retraining of the model with updated data will ensure the predictions remain up to date and accurate. By providing a web application for predicting global active power consumption, users can gain valuable insights into energy demand patterns, enabling efficient energy planning, load forecasting, and resource allocation. The application will support energy management entities, policymakers, and stakeholders in making informed decisions and promoting sustainable energy practices.
3.	Novelty / Uniqueness	The uniqueness of a web application to predict Global Active Power lies in its ability to provide accurate and real-time predictions of global energy consumption patterns. Here are some key aspects that set this application apart: 1. Global Scope: The web application focuses on predicting global active power consumption, which encompasses energy usage patterns on a global scale. This global perspective allows for comprehensive energy planning and management, enabling users to make informed decisions about resource allocation, energy efficiency initiatives, and sustainability efforts.

		2. Real-Time Predictions: The web application provides real-time predictions of global active power consumption. By incorporating current data and considering factors such as weather conditions, time of day, and historical patterns, the application can generate up-to-date and accurate predictions. This real-time capability enables users to respond quickly to changes in energy demand and make proactive decisions. 3. Customizable Parameters: The application allows users to input various parameters such as date, time, and weather conditions to obtain predictions tailored to specific scenarios or regions. This flexibility enables users to explore "what-if" scenarios, evaluate the impact of different factors on energy consumption, and make data-driven decisions based on their unique requirements. 4. Machine Learning Techniques: The web application leverages machine learning techniques, such as regression or time series forecasting models, to predict global active power consumption. These models can capture complex relationships and patterns in the data, adapt to changing trends, and improve prediction accuracy over time. The use of advanced machine learning algorithms sets this application apart from traditional statistical methods. 5. Scalability and Performance: The web application is designed to handle large datasets and accommodate a high volume of user traffic. It is optimized for performance, ensuring efficient processing and delivery of predictions. The application can scale to support increased demand, making it suitable for use by energy management entities,

		policymakers, and stakeholders at various levels. 6. Continuous Model Updates: The application incorporates mechanisms for continuous model updates, ensuring that predictions remain accurate and reflect the latest data trends. Regular retraining of the models with updated data allows for adaptability to changing consumption patterns and improved prediction performance. By combining the global scope, real-time predictions, customization options, machine learning techniques, visualization capabilities, scalability, and continuous model updates, the web application offers a unique and valuable tool for energy planning, management, and decision-making on a global scale.
4.	Social Impact / Customer Satisfaction	The web application to predict Global Active Power has the potential to have a significant social impact and deliver high customer satisfaction. Here's how: 1. Energy Conservation: By providing accurate predictions of global active power consumption, the application enables energy management entities, policymakers, and stakeholders to plan and allocate resources more effectively. This promotes energy conservation by identifying peak demand periods, optimizing energy distribution, and implementing energy-saving measures. The application empowers users to make informed decisions that contribute to reducing energy waste and minimizing the environmental impact. 2. Sustainable Development: The web application supports sustainable development goals by promoting

		efficient energy usage and resource management. It aids in the development and implementation of renewable energy strategies, load forecasting, and infrastructure planning. By facilitating the transition to cleaner and more sustainable energy sources, the application contributes to a greener and more sustainable future. 3. Cost Savings: Accurate predictions of global active power consumption assist energy consumers in managing their energy usage and optimizing their consumption patterns. This can lead to significant cost savings by avoiding peak demand charges, optimizing energy intensive operations, and identifying opportunities for energy efficiency improvements. The application empowers users to take proactive measures to reduce their energy costs, benefiting both individuals and businesses. 4. Grid Stability and Reliability: The web application enhances grid stability and reliability by providing insights into energy demand patterns. By accurately predicting global active power consumption, energy management entities can ensure a balanced energy supply and demand, reducing the risk of blackouts, brownouts, and grid instability. This leads to a more reliable and resilient energy infrastructure. 5. Customer Satisfaction: The application's user-friendly interface, real-time predictions, and customizable parameters contribute to high customer satisfaction. Users can access intuitive visualizations, reports, and personalized insights, allowing them to understand energy consumption patterns better and make informed decisions. The application empowers users with actionable information, enhancing their

		ability to manage energy efficiently and meet their sustainability goals. 6. Stakeholder Collaboration: The web application promotes collaboration among energy management entities, policymakers, manufacturers, and consumers. By providing a common platform for accessing accurate energy consumption predictions, stakeholders can align their efforts, share insights, and collaborate on energy-saving initiatives. This fosters a collective approach towards sustainable energy practices and encourages innovation in energy management strategies. 7. Awareness and Education: The application raises awareness about energy consumption patterns, sustainability, and the importance of energy conservation. By providing visualizations and reports, it educates users about the impact of their energy usage and encourages behavioral changes towards more sustainable practices. Increased awareness and education around energy consumption contribute to a more energy-conscious society. Overall, the web application's social impact lies in promoting energy conservation, supporting sustainable development, delivering cost savings, enhancing grid stability, ensuring customer satisfaction, fostering stakeholder collaboration, and raising awareness about energy consumption. By empowering users with accurate predictions and actionable insights, the application facilitates the transition to a more sustainable and efficient energy future.

5.	Business Model (Revenue Model)	Revenue Model for a Web Application to Predict Global Active Power: 1. Subscription Model: Offer different subscription tiers with varying features and levels of access to the web application. Users can choose a plan based on their needs, such as the frequency of predictions, customization options, and access to advanced analytics. The subscription model can be offered on a monthly, quarterly, or annual basis, providing a recurring revenue stream. 2. Data Licensing: The web application generates valuable insights and predictions based on global active power consumption data. You can offer data licensing options to interested parties, such as energy management entities, research institutions, or policymakers, who can benefit from access to the historical and real-time data used in the application. Data licensing can be priced based on the volume of data, frequency of updates, and the purpose of use. 3. API Access: Provide an API (Application Programming Interface) that allows other businesses or developers to integrate the predictions and insights generated by the web application into their own systems or applications. Charge a fee for API access, based on usage, volume of requests, or API call limits. This revenue model allows for partnerships and integration opportunities with third-party platforms. 4. Consulting and Customization Services: Offer consulting services to assist organizations in leveraging the predictions and insights provided by the web application. This can include

		customization of the application to meet specific business requirements, analysis of energy consumption data, and guidance on energy management strategies. Charge a fee for these value added services based on the scope and complexity of the consulting engagement. 5. Partnerships and Sponsorships: Collaborate with energy management companies, utilities, or sustainability focused organizations to establish partnerships or sponsorships. This can involve promoting their products or services within the web application, featuring their branding, or co developing specific features or functionalities. Generate revenue through sponsorship fees or revenue sharing agreements with partners. 6. Advertisements: Incorporate targeted advertisements within the web application to generate revenue. Advertisements can be displayed strategically, considering user engagement and relevance to the energy industry, sustainability, or related products and services. Generate revenue through cost-per-click (CPC) or cost-per-impression (CPM) advertising models. 7. White-labeling and Licensing: Offer the web application as a white-label solution, allowing other companies or organizations to rebrand and customize it for their own use. License the application to interested parties who want to deploy it within their own infrastructure. Revenue can be generated through licensing fees or revenue-sharing agreements based on the number of deployments or user licenses.

		It is important to consider a combination of revenue models that align with your target market, customer segments, and the value proposition of the web application. Additionally, conducting market research and engaging with potential customers will help determine the pricing and viability of each revenue model for sustainable business growth.
6.	Scalability of the Solution	Scalability is a critical aspect of a web application to predict Global Active Power, as it needs to handle large datasets, increasing user traffic, and evolving data demands. Here are key considerations for ensuring the scalability of such an application: 1. Infrastructure Scalability: Design the application to operate in a scalable infrastructure environment, such as cloud-based platforms like AWS, Azure, or Google Cloud. Utilize scalable storage options for handling large datasets, and leverage auto-scaling capabilities to dynamically allocate computing resources based on demand. This ensures the application can handle increasing data volume and user traffic without performance degradation. 2. Distributed Computing: Employ distributed computing techniques to process and analyze large datasets efficiently. Utilize parallel processing, distributed file systems, and distributed databases to divide the workload across multiple nodes, enabling faster data processing and analysis. This approach allows the application to scale horizontally by adding more computing resources

		as the data volume and demand increase. 3. Load Balancing: Implement load balancing mechanisms to distribute incoming requests evenly across multiple servers or instances. Load balancers help optimize resource utilization and ensure high availability and responsiveness of the application, even during peak usage periods. Load balancing enables scaling out the application by adding more servers or instances as needed to handle increased traffic. 4. Caching: Implement caching mechanisms to store and serve frequently accessed data or results. Utilize in-memory caches or caching technologies like Redis to reduce the load on the backend systems and improve response times. Caching helps improve scalability by reducing the computational load and database queries, especially for repetitive or static data. 5. Asynchronous Processing: Utilize asynchronous processing techniques to offload time consuming tasks or heavy computations to background processes or worker queues. This allows the application to respond quickly to user requests and ensures that the main processing components remain available for new requests. Asynchronous processing helps scale the application by enabling efficient resource utilization and reducing response time bottlenecks. 6. Modular Architecture: Design the application with a modular architecture that allows for independent scaling of different

		components. Identify the components with the highest resource demands or potential bottlenecks and ensure they can scale independently. This approach allows for vertical scaling of specific components to handle increased load without affecting the overall application performance. 7. Monitoring and Performance Optimization: Implement robust monitoring and logging mechanisms to track the application's performance, resource utilization, and potential bottlenecks. Utilize monitoring tools and performance profiling techniques to identify performance issues and optimize critical parts of the application. Continuously monitor the application's scalability and performance to proactively identify and address potential scaling challenges. By considering these scalability factors and implementing appropriate techniques, the web application to predict Global Active Power can handle growing data demands, increasing user traffic, and evolving requirements. Scalability ensures that the application can effectively serve a large user base, process complex data analyses, and adapt to changing needs while maintaining optimal performance.

PROJECT DESIGN PHASE 2

Designing a reliable energy consumption analysis system for energy-efficient appliances involves multiple components and considerations. Here is a high level solution outline for such a project:

Identify the energy-efficient appliances to be monitored and analyze their power consumption.
Install energy meters or smart plugs for each appliance to measure power consumption accurately.
Connect the energy meters to a microcontroller or IoT device capable of data collection and processing.
Ensure proper connectivity (wired or wireless) between the energy meters and the microcontroller/IoT device.

Data Collection:

Configure the microcontroller/IoT device to read data from the energy meters periodically.
Collect relevant data such as real-time power consumption, voltage, current, and energy usage.
Store the collected data in a database or local memory for further analysis.

Data Processing and Analysis:

Implement algorithms to process and analyze the collected data. Calculate energy consumption over time, identify peak usage periods, and calculate average consumption.
Analyze the data to identify energy-efficient appliances based on their power consumption patterns.
Generate reports or visualizations to present the energy consumption data in a user-friendly format.
User Interface and Control:

Develop a user interface to display real-time energy consumption information and historical data.
Provide options for users to set energy consumption thresholds or goals for appliances.

Implement control mechanisms to enable users to remotely monitor and control appliances for energy efficiency.

Integrate the system with a mobile application or web portal for convenient access.

Alerts and Notifications:

Set up alert mechanisms to notify users about abnormal energy consumption or when appliances exceed set thresholds.
Send notifications via email, SMS, or push notifications to inform users about energy usage patterns or anomalies.

Energy Efficiency Recommendations:

Implement a feature to provide energy efficiency recommendations to users based on the analyzed data.
Suggest ways to optimize energy consumption, such as adjusting appliance usage schedules or replacing inefficient appliances.

Security and Privacy:

Implement security measures to protect user data and ensure secure communication between devices and the system.
Consider data anonymization techniques if necessary to maintain user privacy.
Testing and Validation:

Perform thorough testing of the system to ensure accurate data collection, processing, and analysis.
Validate the system's functionality by comparing the measured energy consumption with known values.
Solicit user feedback to identify any issues or areas for improvement.
Remember, this is a high-level solution outline, and the actual implementation details may vary depending on your specific project requirements, available resources, and technologies chosen.

Project Flow

· The user interacts with the UI to enter the input.
· Entered input is analyzed by the model which is integrated. · Once the model analyses the input the prediction is showcased on the UI

- Data collection
    - Collect the dataset or create the dataset
- Visualizing and analyzing data
    - Univariate analysis
    - Multivariate analysis
    - Descriptive analysis
- Data pre-processing
    - Drop unwanted features
    - Checking for null values
    - Remove negative data
    - Handling outlier
    - Handling categorical data
    - Handling Imbalanced data
    - Splitting data into train and test
- Model building
    - Import the model building libraries
    - Initializing the model
    - Training and testing the model
    - Evaluating performance of the model
    - Save the model
- Application Building
    - Create an HTML file
    - Build python code
    - Run the Application

SOLUTION ARCHITECTURE

Solution Architecture: A Reliable Energy Consumption Analysis System for Energy-Efficient Appliances is designed to provide project stakeholders with valuable insights into energy consumption patterns and efficiency metrics. Here's a description of its structure, characteristics, behavior, and other aspects that stakeholders would find relevant:

1. Structure: Data Collection: The system collects energy consumption data from energy-efficient appliances and may incorporate additional data sources such as weather data or building characteristics. ○ Data Storage: The collected data is stored in a database or data lake, along with relevant metadata. ○ Data Processing and Analysis: Preprocessing techniques are applied to clean and normalize the data. Analytical algorithms and statistical models are used to analyze energy consumption patterns and calculate efficiency metrics. ○ Visualization and Reporting: The system provides a user-friendly dashboard or visualization interface to present analysis results. It generates reports and alerts to communicate important findings to stakeholders.

2. Characteristics: Reliability: The system ensures reliable data collection and storage, minimizing data loss or corruption. It handles large volumes of data and maintains data integrity throughout the analysis process. ○ Scalability: The architecture is designed to handle increasing data volumes and accommodate potential growth in the number of appliances, buildings, or users. ○ Efficiency: The system efficiently processes and analyzes energy consumption data, leveraging optimization techniques and parallel computing if necessary. ○ Flexibility: The system is adaptable to different types of energy-efficient appliances, building structures, and data sources, allowing for customization based on project requirements. ○ Security and Privacy: The system incorporates robust security measures to protect sensitive data and ensures compliance with privacy regulations.

3. Behaviour: Data Processing and Analysis: The system applies preprocessing steps to clean and normalize the data. It performs statistical analysis and generates energy efficiency metrics such as energy usage intensity, load profiles, or peak demand analysis. ○ Predictive Analysis:If enabled, the system uses machine learning techniques to develop predictive models that forecast energy consumption based on historical data and external factors. ○ Visualization and Reporting: The system presents analysis results through intuitive visualizations, charts, and graphs. It generates reports and alerts to highlight energy usage anomalies, potential savings opportunities, and performance trends.

4. Other Aspects: ○ User Experience: The system focuses on providing a user friendly interface, allowing stakeholders to easily navigate through the dashboard, visualize data, and access relevant reports. ○ Integration: The system can integrate with external systems such as building management systems, energy monitoring platforms, or utility company APIs to gather data and provide seamless functionality. ○ Training and Support: Stakeholders are provided with appropriate training and support to effectively utilize the system's features and understand the insights it provides. ○ Long-Term Sustainability: The system is designed for long-term usage, with considerations for regular updates, maintenance, and adaptation to evolving energy efficiency standards and regulations.

- User Interface: The user interface is the front-end of the web application where users interact with the system. It provides a user-friendly interface to input parameters, view predictions, and access visualizations and reports.

- Application Backend/API: The application backend handles user requests, performs necessary data processing, and interacts with the machine learning model for predictions. It serves as the middleware between the user interface and the data storage and processing components.

- Data Storage and Processing: This component includes the storage and processing infrastructure for handling the global active power consumption data. It may consist of a database or data warehouse for storing historical and real-time data, as well as data preprocessing and feature engineering pipelines to prepare the data for model training.

- Machine Learning Model Training and Predictive Analysis: This component encompasses the machine learning algorithms and processes involved in training the predictive model. It leverages historical and real-time data to train the model and generate predictions for global active power consumption. The model may employ regression, and it can be periodically retrained with updated data to improve accuracy. Here are some additional considerations for designing a web application to predict global active power:

- The data source should be reliable and up-to-date.

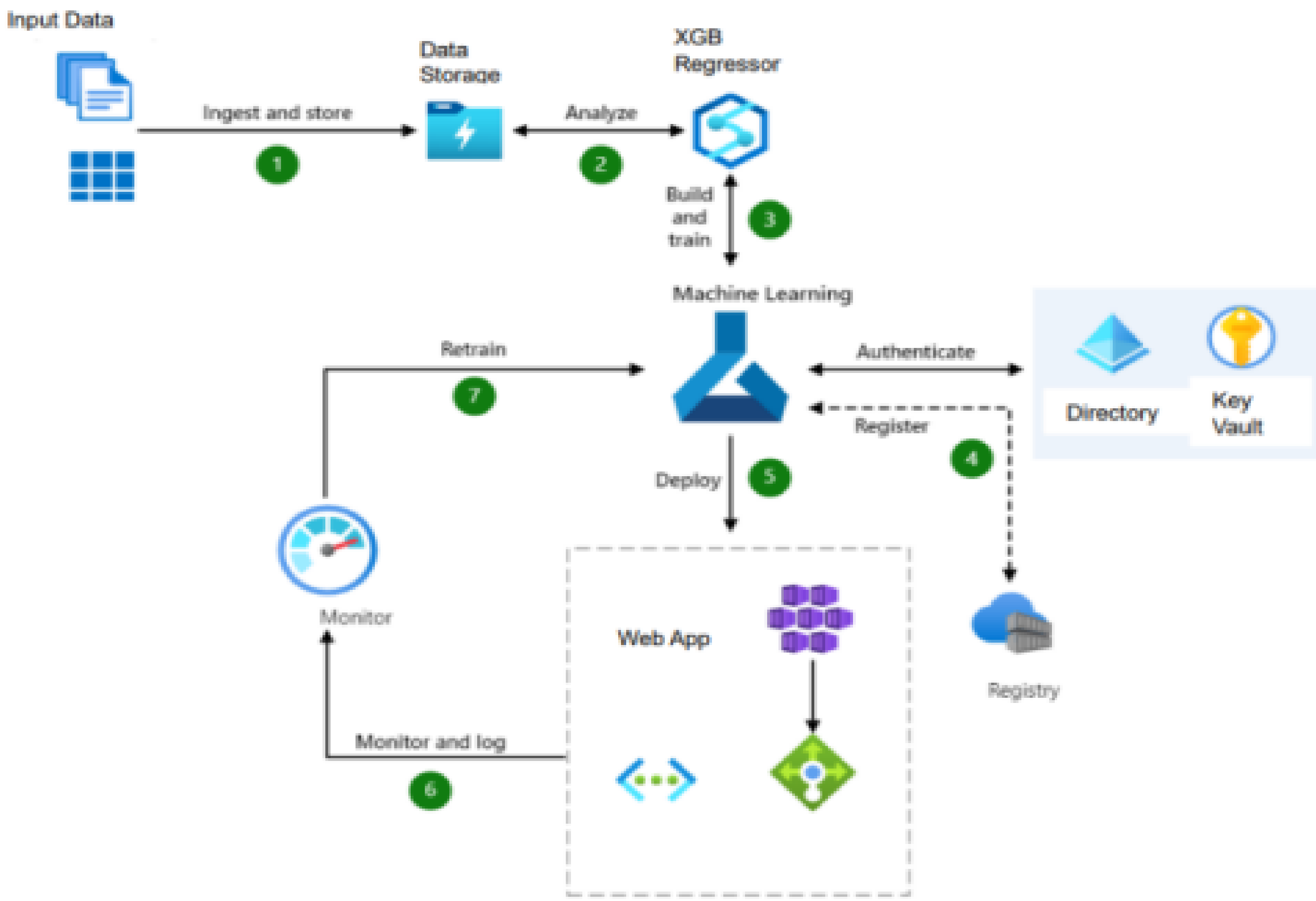
- The data processing component should be scalable to handle large amounts of data.

- The model training component should be able to train a variety of models.

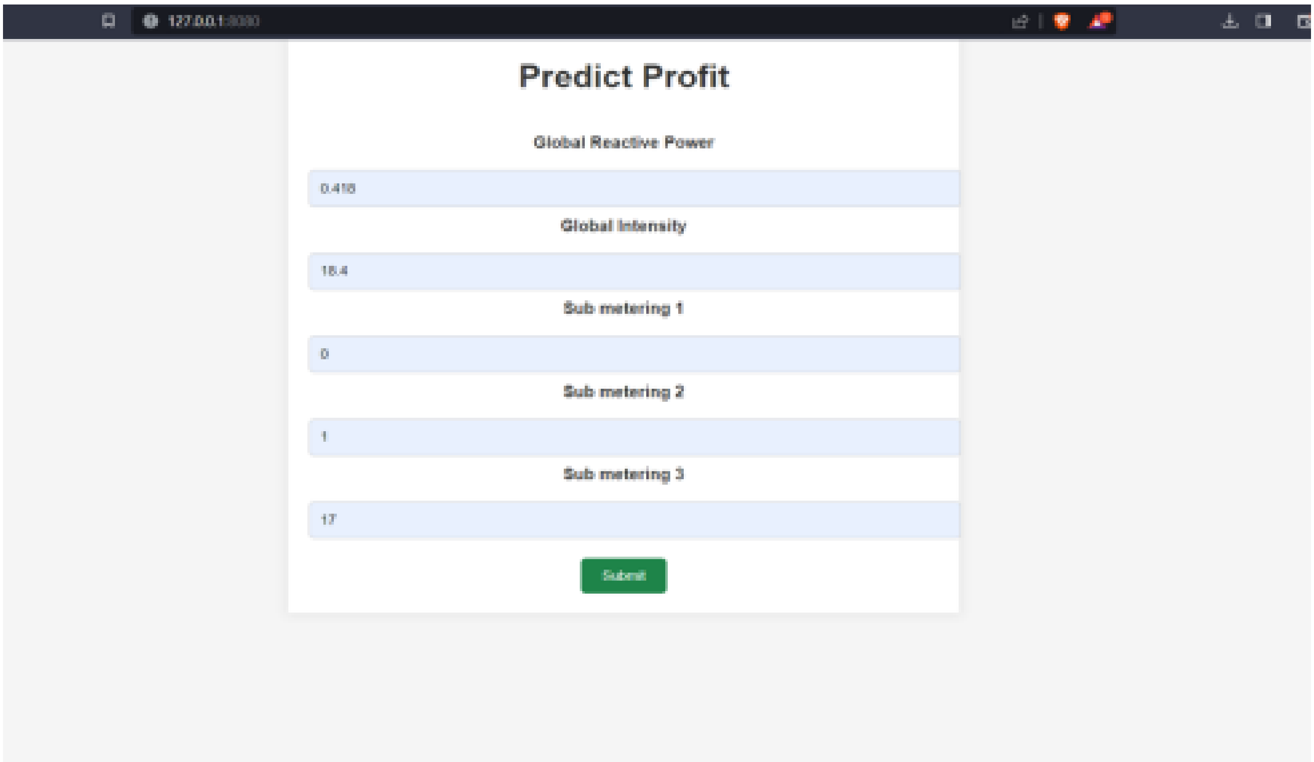
- The model deployment component should be secure and easy to manage.

- The web application should be user-friendly and easy to use.

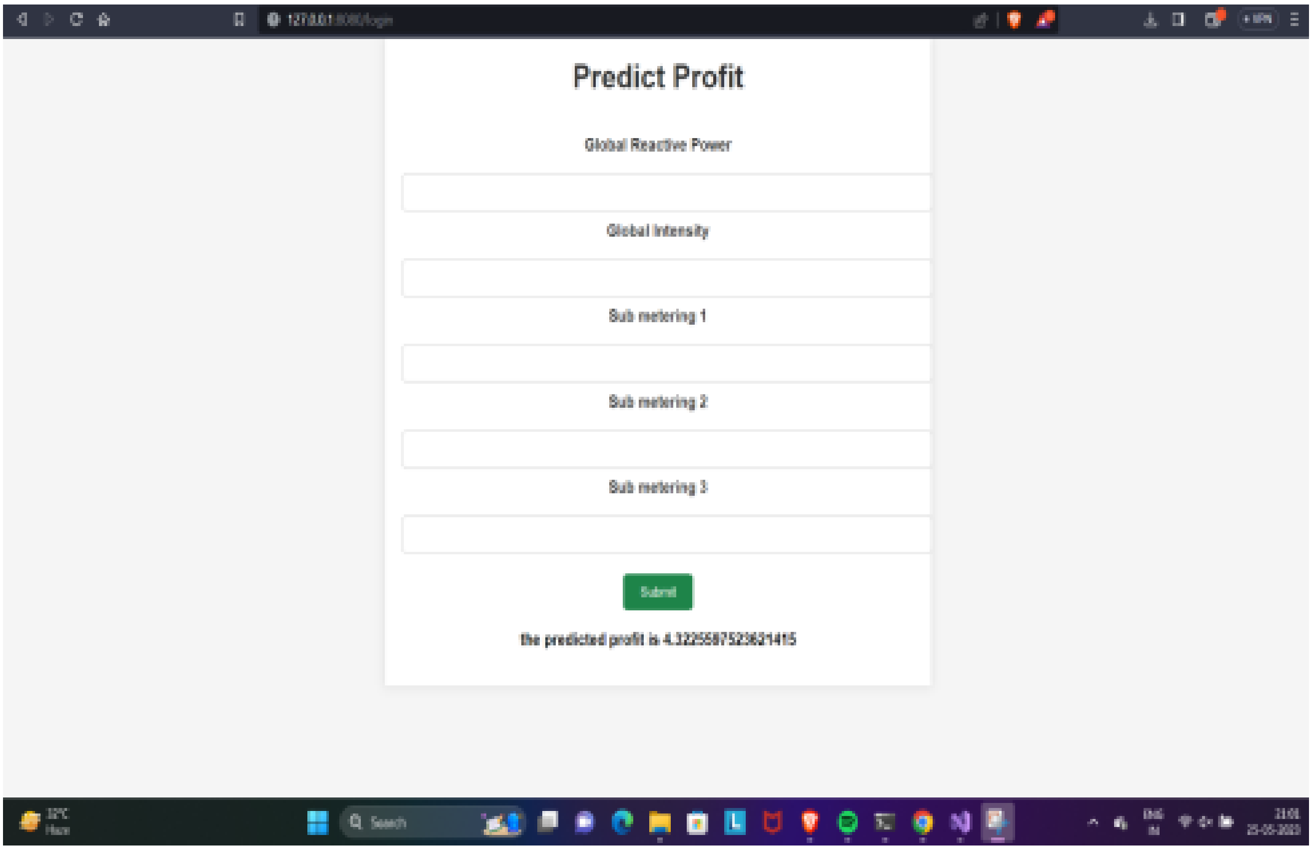
BLOCK DIAGRAM



OUTCOMES



Predict Profit
Global Reactive Power
0.418
Global Intensity
18.4
Sub metering 1
0
Sub metering 2
1
Sub metering 3
17
Submit



Predict Profit
Global Reactive Power
Global Intensity
Sub metering 1
Sub metering 2
Sub metering 3
Submit
the predicted profit is 4.3225587523621415

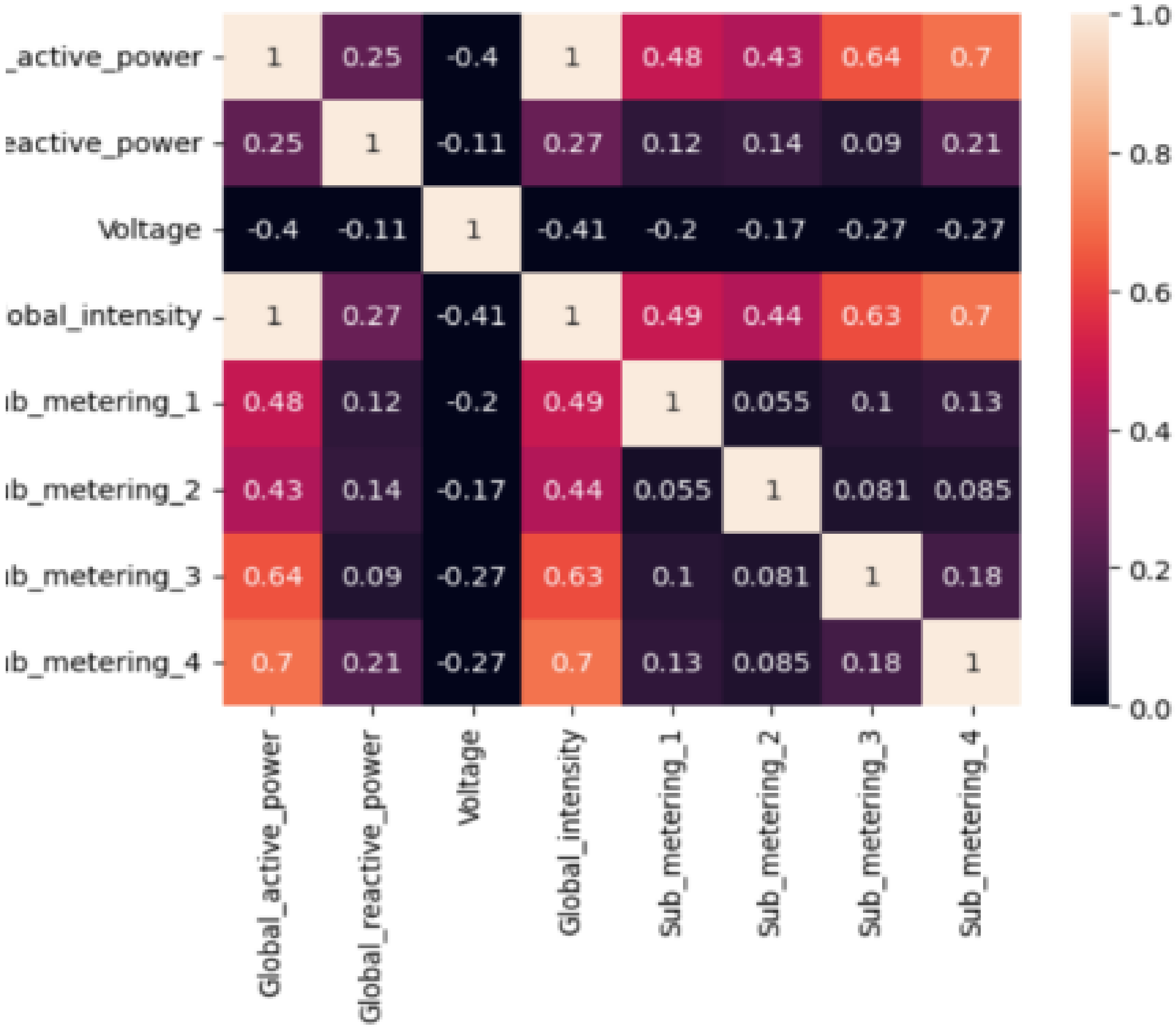
Performance

```
In [50]: #Linear Regression model Evaluation
         from sklearn import metrics
         print("MAE:",metrics.mean_absolute_error(y_test,Linear_predictions))
         print("MSE:",metrics.mean_squared_error(y_test,Linear_predictions))
         print("RMSE:",np.sqrt(metrics.mean_squared_error(y_test,Linear_predictions)))
         print("RSquarevalue:",metrics.r2_score(y_test,Linear_predictions))

         MAE: 0.027117467602869 49
         MSE: 0.0017725325026184174
         RMSE: 0.04210145487531776
         RSquarevalue: 0.9984104542302936
```

```
In [51]: #XGBRegressor model Evaluation
         from sklearn import metrics
         print("MAE:",metrics.mean_absolute_error(y_test,y_predict2))
         print("MSE:",metrics.mean_squared_error(y_test,y_predict2))
         print("RMSE:",np.sqrt(metrics.mean_squared_error(y_test,y_predict2)))
         print("RSquarevalue:",metrics.r2_score(y_test,y_predict2))

         MAE: 0.020571071765353 67
         MSE: 0.0011083153110183221
         RMSE: 0.03329136991801813
         RSquarevalue: 0.9990061012074376
```

```
In [53]: #Ridge Regression model Evaluation
         from sklearn import metrics
         print("MAE:",metrics.mean_absolute_error(y_test,y_predict3))
         print("MSE:",metrics.mean_squared_error(y_test,y_predict3))
         print("RMSE:",np.sqrt(metrics.mean_squared_error(y_test,y_predict3)))
         print("RSquarevalue:",metrics.r2_score(y_test,y_predict3))

         MAE: 0.027117476647276557
         MSE: 0.0017725324897610276
         RMSE: 0.042101454722622444
         RSquarevalue: 0.9984104542418236
```

```
In [57]: #hyperparameter tuning
         from sklearn.model_selection import cross_val_score

In [55]: cv = cross_val_score(lm,X,y,cv=5)

In [59]: np.mean(cv)

Out[59]: 0.9983250762524924

In [68]: cv1 = cross_val_score(model3,X,y,cv=5)

In [70]: np.mean(cv1)

Out[70]: 0.9983250760493775
```



_active_power
eactive_power
Voltage
obal_intensity
ib_metering_1
ib_metering_2
ib_metering_3
ib_metering_4
1
0.25
-0.4
1
0.48
0.43
0.64
0.7
0.25
1
-0.11
0.27
0.12
0.14
0.09
0.21
-0.4
-0.11
1
-0.41
-0.2
-0.17
-0.27
-0.27
1
0.27
-0.41
1
0.49
0.44
0.63
0.7
0.48
0.12
-0.2
0.49
1
0.055
0.1
0.13
0.43
0.14
-0.17
0.44
0.055
1
0.081
0.085
0.64
0.09
-0.27
0.63
0.1
0.081
1
0.18
0.7
0.21
-0.27
0.7
0.13
0.085
0.18
1
Global_active_power
Global_reactive_power
Voltage
Global_intensity
Sub_metering_1
Sub_metering_2
Sub_metering_3
Sub_metering_4
1.0
0.8
0.6
0.4
0.2
0.0

FUTURE WORK

In summary, future enhancements for a reliable energy consumption analysis system for energy-efficient appliances could include integrating with smart home technology, incorporating machine learning algorithms for improved accuracy, expanding appliance compatibility, enabling comparative analysis and benchmarking, incorporating energy cost analysis, implementing gamification and incentives, improving data visualization and the user interface, integrating with renewable energy sources, providing personalized energy-saving recommendations, and conducting long-term data analysis. These developments would enhance user experience, promote energy efficiency, and contribute to a sustainable future.