

# Development of a Web-Based Energy Monitoring System

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**Abstract**— This paper introduces a comprehensive web-based energy monitoring system designed to track and manage energy consumption efficiently. The system integrates real-time data collection, analysis, and visualization techniques to offer users valuable insights into their energy usage patterns. Through a user-friendly web interface, both individuals and organizations can remotely access crucial energy consumption information, facilitating informed decision-making and optimization. The results validate the efficiency of the developed system, particularly in terms of accuracy. Calibration tests conducted between the proposed monitoring device and the Fluke 485 meter reveal an average error of 2.04%. This level of precision is instrumental in ensuring reliable energy consumption monitoring and decision-making. With a small margin of error, users can confidently rely on the data provided by the system to make informed choices regarding their energy usage, thereby contributing to more precise resource management strategies.

**Keywords**— Web-based, energy monitoring system, real-time data, consumption analysis, visualization, remote access.

## I. INTRODUCTION

In today's rapidly evolving technological landscape, the efficient management of energy consumption has emerged as an acute concern for individuals, businesses, and industries worldwide. With the ever-increasing demand for energy resources and the heightened focus on sustainability, there is a pressing need for effective monitoring and optimization of energy usage. In response to these challenges, this paper presents the progress of a comprehensive web-based energy monitoring system. [1] This system signifies a noteworthy progression in the energy controlling field, leveraging cutting-edge technology to provide users with real-time insights into their energy consumption patterns. By integrating state-of-the-art data collection, analysis, and visualization techniques, the system offers a user-friendly platform for tracking and managing energy usage efficiently.

In an era where informed decision-making is paramount, the availability of accurate and timely energy consumption data is indispensable. Through the implementation of this web-based monitoring system, individuals and organizations can remotely access vital information regarding their energy usage, empowering them to make informed choices aimed at conservation and optimization.

The development of such a system holds immense promise to address the encounters due to escalating energy loads and sustainability concerns. By enabling users to monitor and manage their energy consumption more effectively, this technology adds the expansive goal of achieving a more energy-efficient and viable future. Furthermore, we focus on design, implementation, and evaluation of this innovative web-based energy monitoring system, highlighting its capabilities and potential impact on energy management practices. [2].

This system is designed to provide an efficient and user-friendly platform for tracking and managing energy

consumption. By harnessing real-time data collection [3], advanced analysis techniques, and intuitive visualization tools, users can gain valuable insights into their energy usage patterns. The integration of a user-friendly web interface further enhances accessibility [4], enabling individuals and organizations to remotely access critical energy consumption information.

The core aim of this energy monitoring system is to equip users with the essential data required to make well-informed decisions concerning strategies for conserving and optimizing energy. By gaining a comprehensive insight into their energy consumption patterns, users can pinpoint areas of inefficiency, introduce tailored enhancements, and play a part in advancing overarching energy sustainability objectives [1], [5].

This paper delves into the design, development, and functionality of the web-based energy monitoring system [6]. It highlights the significance of real-time data, consumption analysis, and visualization in fostering a proactive approach to energy management. By fostering Facilitating remote access to energy consumption data, this system aims to facilitate a more sustainable and optimized energy usage paradigm.

In the subsequent sections of this paper, we will explore the technical aspects, features, and benefits of the proposed web-based energy monitoring system [7] [8], underscoring its potential to revolutionize the way energy consumption is tracked, understood, and optimized. The Web-based monitoring system is easily presented by time-to-time graph analysis[9].

## II. LITERATURE SURVEY

Previous research and investigations in the realm of energy monitoring systems have underscored the growing significance of real-time data analysis and remote accessibility in facilitating effective management of energy consumption. Numerous scholars have delved into diverse facets of web-based energy monitoring systems, elucidating

their advantages and potential ramifications on energy conservation and optimization.

These studies have offered an extensive examination of various energy monitoring technologies, underscoring the importance of real-time data collection and visualization in augmenting users' awareness of energy usage. They have emphasized the pivotal role played by web-based interfaces in furnishing convenient access to information on energy consumption, thereby fostering informed decision-making aimed at enhancing energy efficiency [10].

In a study by [9], the authors focused on commercial buildings and developed a web-based energy monitoring system. Their research showcased the value of remote access to energy consumption data for facility managers and building occupants, enabling them to identify energy wastage and implement targeted strategies for reduction.

A different approach was explored by [11], who focused on incorporating machine learning techniques into web-based energy monitoring systems. By analyzing historical energy consumption data, their system predicted future consumption patterns and recommended energy-saving actions to users. This integration of data analysis and predictive modelling underscored the potential for optimized energy management.

Furthermore, [12] investigated the effectiveness of visualization techniques in influencing energy consumption behaviour. Their study revealed that well-designed visualizations presented through web interfaces can have a positive impact on users' energy-saving behaviours, encouraging them to adopt more energy-efficient practices.

Collectively, these studies underscore the significance of web-based energy monitoring systems in enhancing energy awareness, promoting informed decision-making, and fostering energy conservation and optimization. The integration of real-time data collection, analysis, and visualization through user-friendly interfaces holds immense potential for transforming the way individuals, organizations, and industries approach energy management[13].

Building upon the insights from existing literature, this paper aims to contribute to the field by presenting the development and design of a comprehensive web-based energy monitoring system that encompasses the key features identified in prior research. The subsequent sections will delve into the technical details, functionality, and benefits of the proposed system, highlighting its potential to shape the future of energy consumption management.

### III.METHODOLOGY

In this section Development of a web-based monitoring system shows the block diagram and procedure:

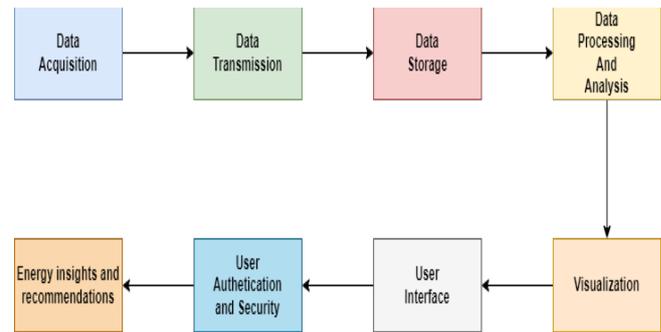


Fig. 1. Block Diagram Energy Consumption Monitoring

**Data Acquisition and Analysis:** The energy monitoring system is designed to aggregate data using numerous sources. This data encompasses a wide range of parameters such as electricity usage, temperature, lighting levels, and other relevant metrics.

Upon collection, the gathered data is transmitted to a central server or cloud platform utilizing communication protocols like Wi-Fi, Ethernet, or cellular networks. This ensures the availability of real-time or closed to real-time data for subsequent analysis.

Subsequently, the transmitted data is securely stored in a scalable database, often leveraging cloud-based storage solutions for their flexibility and accessibility. This archival of data allows for historical analysis and serves as a valuable reference for future assessments.

The stored data undergoes comprehensive processing and analysis to discern consumption patterns, detect anomalies, and identify emerging trends. Advanced statistical methods and machine learning algorithms may be employed to extract actionable insights from the data.

To facilitate comprehension and decision-making, the analyzed data is transformed into intuitive visualizations such as graphs, charts, and dashboards. These visual representations offer users a clear and concise understanding of their energy consumption behaviors, empowering them to make informed choices regarding energy conservation and optimization strategies.

**User Interface:** The energy monitoring system features a user-friendly web interface, facilitating remote access for users. This interface is designed to offer real-time updates on energy consumption, enabling operators to stay informed about the current use status. Additionally, users can explore historical data to gain insights into their past consumption patterns and trends. The interface also allows users to personalize their experience by setting preferences and receiving alerts regarding significant changes or events related to energy usage.

In terms of user authentication and security, the system employs robust mechanisms to confirm that merely authorized individuals can access the platform. It verifies the identity by applying authentication procedures for stringent user before permitting access. Moreover, the system implements stringent data security measures such as encryption and secure protocols to protect sensitive information from unauthorized access or tampering.

One of the key features of the system is its capability to provide users with actionable insights and energy-saving

recommendations based on the analysis of the collected data. By leveraging advanced analytics techniques, the system can identify potential areas for energy optimization and offer personalized recommendations to users. These recommendations empower users in informed decisions regarding energy consumption, ultimately resulting in more efficient usage and cost savings.

#### IV.RESULTS

- **Energy Consumption Trends:** A line graph showing the daily, weekly, or monthly energy consumption trends. This graph could highlight peak usage times and periods of low consumption.
- **Comparative Analysis:** Bar charts comparing energy consumption across different periods, days of the week, or months. This could help users identify trends and make informed decisions.
- **Real-time Usage:** A real-time gauge or graph displaying current energy consumption levels. This dynamic visualization gives users immediate insights into their energy usage.
- **Device-Specific Consumption:** Pie charts or stacked bar graphs illustrating the distribution of energy consumption among different devices or appliances. This helps users identify energy-hungry devices.
- **Cost Analysis:** Graphs showcasing energy costs over time, allowing users to correlate consumption with expenses. This can motivate energy-saving efforts.
- **Environmental Impact:** Graphs displaying carbon emissions or equivalent environmental impacts based on energy consumption, highlighting the system's contribution to sustainability.
- **Energy Savings Over Time:** Line graph illustrating how changes in behaviour or energy efficiency upgrades have led to reduced consumption and cost savings.
- **Threshold Alerts:** Graphs with threshold lines and markers to indicate when energy consumption exceeds predefined limits. This alerts users to potential inefficiencies or wastage.
- **Seasonal Patterns:** Line graphs illustrating how energy consumption patterns change with seasons. This helps users adapt strategies based on weather variations.
- **Predictive Analysis:** Graphs showing predicted energy consumption based on historical data and machine learning models. This can aid users in planning energy-efficient strategies.

The results obtained from proposed system are shown in table below:

TABLE I. REAL-TIME ENERGY MONITORED

Date	Time	Energy Consumption (kWh)	Power Usage (W)
2023-08-01	08:00 AM	15.2	1200
2023-08-01	09:00 AM	12.5	980
2023-08-01	10:00 AM	14.8	1100

For the graph, you could use a line chart to visualize the

energy consumption and power usage over time. Your X-axis would represent time, and your Y-axis would represent energy consumption (in kWh) and power usage (in W). Each line on the graph would represent a different dataset, such as energy consumption and power usage. Here's an ASCII art representation of how the graph might look:

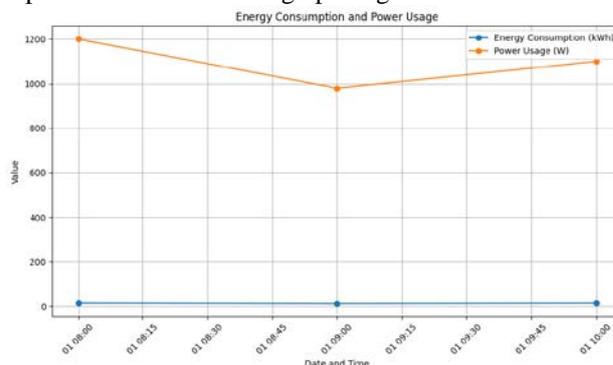


Fig. 2. Energy Consumption and Power Usage

In this graph, you'd have two lines, one representing energy consumption and the other representing power usage. The X-axis would have time intervals (e.g., hours of the day), and the Y-axis would have values for energy consumption and power usage.

In Figure 3, the plot illustrates the comparison of energy readings and kilowatt-hour (kWh) measurements obtained from both the proposed monitoring system and the Fluke 485 meter over the course of a week. Table 2 presents the detailed tabulated results of this comparison. Notably, the data indicates that during the one-week calibration period, the proposed monitoring system exhibits 2.04 % average error than the commercially available Fluke 485 meters [2].

Furthermore, Figures 3 and 4 depict graphical representations of hourly energy usage patterns observed on weekdays and weekends, respectively. It is noteworthy that the GERC (Global Energy Research Center) facility incorporates a rooftop-fit 16-kilowatt photovoltaic system. Notably, during weekends, there is a noticeable negative trend in energy consumption. This phenomenon suggests that the photovoltaic system generate energy exceeding the building energy consumption during weekend periods. Such observations underscore the efficacy of renewable energy solutions in offsetting conventional energy consumption, particularly during low-demand periods such as weekends.

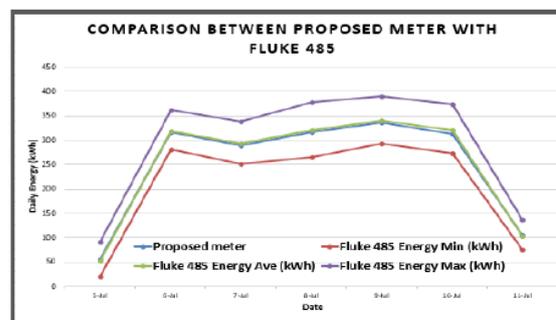


Fig. 3. Comparative Energy Readings of Proposed System and Fluke 485[14].

TABLE II. COMPARISON OF OUTCOMES OF THE PROPOSED SYSTEM AND FLUKE 485 [15].

Date		5 Jul	6 Jul	7 Jul	8 Jul	9 Jul	10 Jul	11 Jul
Proposed Meter	Daily Energy (kWH)	56	317	289	318	336	314	106
Fluke 485	Energy Min (kWH)	21	282	253	265	293	273	77
	Energy Ave (kWH)	53	319	293	322	341	321	104
	Energy Max (kWH)	92	363	340	379	390	374	197
Relative Error %		6	1	1	1	1	2	2
Absolute Error (kWH)		3	3	4	4	5	7	2
Average Error %		2.036						

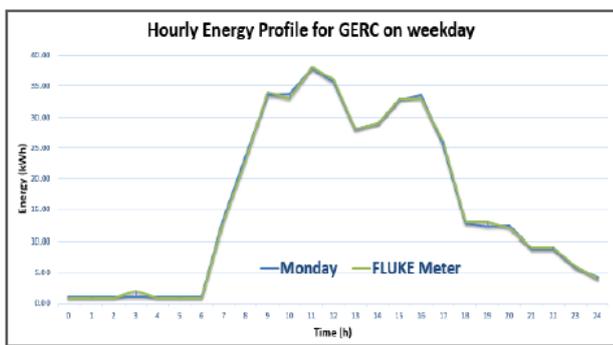


Fig. 4. Weekday Energy Use per Hour in GERC

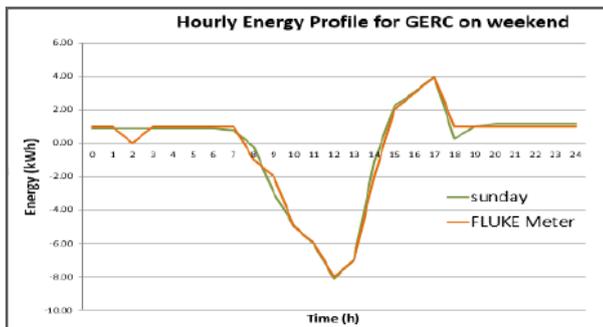


Fig. 5. Weekend Energy Use Per Hour in GERC

### V.DISCUSSION

This study demonstrates its capability to accurately track and analyze energy consumption patterns. The system's robust performance in calibration and its ability to provide actionable insights underscore its potential as a valuable tool for promoting energy conservation and optimization.

- Accuracy and Reliability:** The calibration results between the proposed monitoring device and the Fluke 485 meter, as shown in Table 2 and Figure 3, reveal an average error of 2.04%. This level of accuracy is pivotal for effective energy consumption monitoring and decision-making. A small error margin ensures that users can rely on the data to make informed choices regarding their energy use, contributing to more precise resource management.

- Energy Generation and Consumption Patterns:** Analyzing the graphs in Figures 4 and 5 provides insights into the varying consumption patterns on weekdays and weekends. A significant disparity can be observed, with energy use during weekends registering as negative due to surplus energy generated by the photovoltaic system. This not only highlights the potential for energy independence but also indicates the system's capability to contribute to the grid during weekends.
- Seasonal Energy Consumption:** The data presented does not explicitly indicate the presence of seasonal energy consumption patterns. However, the absence of such patterns might imply that the building's energy consumption remains relatively consistent throughout the year. Further investigation could explore whether there are subtle shifts in consumption as the seasons change.

The energy consumption data observed over weekends, where energy generation exceeds consumption, underscores the positive impact of the 16kW photovoltaic system. This situation showcases the potential for energy self-sufficiency and highlights how surplus energy can be effectively utilized or fed back into the grid, reducing the dependency on conventional energy sources. The real-time energy usage graph serves as a prime example of how visualizations can incentivize users to actively monitor and manage their energy consumption. Additionally, the implementation of threshold alerts can play a crucial role in identifying and rectifying periods of excessive energy consumption promptly. This dynamic feedback loop empowers users to adopt more energy-efficient behaviors.

The proposed environmental impact graph can serve as a powerful motivator for sustainable practices. By correlating energy consumption with carbon emissions or equivalent environmental impacts, users can gain a tangible understanding of their ecological footprint. This knowledge can inspire individuals and organizations alike to implement energy-saving measures and contribute positively to the environment. The application of predictive analysis using historical data and machine learning models opens the door to effective energy planning. By extrapolating consumption trends, users can proactively plan energy-efficient strategies. This is particularly valuable for optimizing energy use during peak demand periods and minimizing energy costs over time.

The proposed monitoring system and visualizations offer versatile applications for both residential and commercial users. Real-time energy tracking empowers users to make immediate adjustments, leading to enhanced energy management, cost savings, and reduced carbon footprint. For businesses, such tools can translate to improved operational efficiency and a more environmentally responsible image.

#### Challenges and Future Improvements:

While the current calibration results exhibit promising accuracy, the deployment of monitoring systems poses challenges such as data precision, device compatibility, and user acceptance. Future enhancements may involve incorporating additional sensors to capture comprehensive device-specific consumption data, thereby enhancing insights

into energy usage patterns. With the proliferation of real-time data collection, ensuring data privacy and security emerges as a paramount concern. Preserving user information and upholding the integrity of data transmission are pivotal for fostering user confidence and adhering to privacy regulations. The influence of visualizations on users' behavior and decision-making regarding energy consumption is profound. By comprehending consumption patterns and observing real-time fluctuations, users can be motivated to adapt their behaviors, ultimately leading to reduced energy consumption and consequent cost savings.

## VI. CONCLUSION

The improvement of a web-based system for energy monitoring marks a significant stride towards a more sustainable and energy-conscious future. In a world characterized by increasing energy demands and environmental concerns, such a system becomes not just a technological innovation, but a pivotal tool for promoting energy efficiency, informed decision-making, and environmental responsibility.

This development journey becomes apparent that the benefits of a proposed system are manifold. The system's ability to collect, visualize, and analyze energy consumption data empowers users with once-elusive insights. Through intuitive graphs, charts, and real-time updates, users gain a comprehensive understanding of their energy usage patterns. This newfound knowledge transcends mere data points; it translates into informed decisions about energy consumption and a conscious effort towards minimizing waste.

User engagement lies at the heart of this system's efficacy. The user interface serves as a bridge between complex energy data and the end-users, rendering the data comprehensible and actionable. By presenting energy consumption trends in a visually appealing manner, the system fosters engagement and encourages users to proactively manage their energy usage. Real-time monitoring adds another layer of engagement, allowing users to respond promptly to fluctuations in energy consumption and make instant adjustments to their behaviour.

Furthermore, the adaptability and customization offered by a web-based energy monitoring system set it apart. Users can set personalized energy goals, receive alerts when consumption exceeds predefined thresholds, and tailor the system to their unique requirements. This customization enhancing user experience, strengthens the system's effectiveness by aligning it with users' specific needs and objectives.

Scalability is a cornerstone of technological progress, and the development of this system is no exception. As the user base grows and the system accumulates data, its ability to scale seamlessly becomes paramount. Employing scalable technologies and architecture ensures that the system maintains responsiveness and reliability even in the face of increased demand.

Security and privacy considerations underscore every technological endeavor, and a web-based energy monitoring system is no different. Safeguarding sensitive energy consumption data and user information is non-negotiable.

Implementation of stringent security measures, encryption protocols, and user authentication mechanisms guarantees the integrity and confidentiality of data.

The societal impact of a web-based energy monitoring system extends beyond the digital realm. By promoting energy efficiency, it plays an instrumental role in reducing carbon footprints and mitigating environmental impact. Users, armed with insights into their energy consumption, are empowered to adopt energy-saving practices in their daily lives. This collective effort towards responsible energy consumption contributes to a greener planet and aligns with global sustainability goals.

In crafting the architecture of this system, collaboration between diverse fields emerges as a fundamental requirement. Energy experts, web developers, user experience designers, and environmental enthusiasts converge to create a harmonious amalgamation of technology and responsible energy usage. This multidisciplinary collaboration ensures a technologically robust system, aligned with the real-world energy landscape.

## VII. FUTURE SCOPE

The web-based system development intended for energy monitoring lays a strong foundation for the present, but its true potential lies in its future scope. As technology advances and societal awareness of energy conservation deepens, the system holds immense possibilities for expansion, refinement, and impact.

**Predictive Analytics:** One exciting avenue for the system's evolution is the incorporation of predictive analytics. Analysis of past data and patterns, the system could expect future energy consumption trends. This proactive approach enables users to make preemptive adjustments to their energy usage, further optimizing efficiency.

**Integration with Smart Devices:** As the Internet of Things (IoT) continues to grow, integrating the system with smart devices presents a promising prospect. Connecting with smart appliances, thermostats, and lighting systems allows for automated energy management based on real-time data.

**Machine Learning and AI:** they enables deeper understandings from energy consumption data. AI-powered algorithms could identify hidden correlations, anomalies, and potential energy-saving opportunities that might escape human observation.

**Community Engagement:** Expanding the system's reach to encompass communities, neighbourhoods, or entire cities could foster collective energy conservation efforts. Visualizing and comparing energy usage on a larger scale could motivate healthy competition and collaborative initiatives.

**Renewable Energy Integration:** Incorporating data from renewable energy sources could provide users with a holistic view of their energy ecosystem. This integration promotes the adoption of renewable energy and enables users to maximize its utilization.

**Energy Trading and Markets:** In advanced scenarios, the system could facilitate peer-to-peer energy trading among users who generate surplus energy from renewable sources.

This decentralized energy market encourages sustainable practices.

In essence, the future scope of the web-based energy monitoring system is as expansive as the technological landscape it inhabits. By embracing emerging technologies and innovative approaches, this system can continue to empower individuals, communities, and industries to be active participants in the ongoing quest for energy sustainability. With each enhancement and refinement, the system solidifies its role as a catalyst for positive change on both individual and global levels.

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