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Development of Kilowatt-hour Consumption Monitoring System for a State University: Real-time Tracking with Sub-meter

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ABSTRACT

The study detailed the development of a real-time kWh consumption monitoring system that aims at tracking electrical energy usage within the Main Campus of Don Honorio Ventura State University. Using sub-metering technology, the system captures more detailed data than conventional utility meters, enabling monitoring at the departmental or building level. An IoT-based platform was integrated with digital sub-meters to collect, transmit, and present real-time data through a web-based dashboard, providing stakeholders with clear insights into usage trends, peak demand periods, and historical consumption. The system was implemented in selected campus buildings to assess its reliability, usability, and overall performance. Findings showed that the monitoring system enhances energy usage visibility, supports efforts to reduce costs, encourages energy-efficient practices, and contributes to the university's broader sustainability and smart campus initiatives.

Keywords: Kilowatt-hour Monitoring; Sub-metering; Real-time Energy Tracking; IoT-based Platform; Power Consumption Monitoring; Smart Energy Management; University Energy System; Energy Efficiency; Internet of Things; Sustainable Campus Solutions.

1. Introduction

Electricity is an essential part of modern society, driving both industrial and daily activities. In the Philippines, electricity consumption reached around 118,000 gigawatt-hours, a clear sign of increasing demand [1]. At Don Honorio Ventura State University (DHVSU), energy usage has also continued to rise, influenced by climate-related factors such as the aftermath of the Mount Pinatubo eruption, which led to increased reliance on cooling systems [2]. These conditions have contributed to higher energy costs, underscoring the need for more efficient energy monitoring and conservation practices.

According to the Autonomous and Cyber-Physical Systems (ACPS) Research Group (2023), smart electronic systems such as combining sensors, microcontrollers, and real-time connectivity enable users to gather accurate energy data and make informed decisions. Sub-metering, in particular, has evolved from a billing tool to a strategic energy management solution, offering facilities the ability to monitor usage patterns and detect inefficiencies.

Currently, DHVSU lacks individual metering per building, limiting visibility of electricity use across departments. This research addresses that gap by developing a real-time kilowatt-hour consumption monitoring system using a smart sub-meter and a cross-platform application. The system allows detailed tracking of energy consumption at the building level, enabling administrators to identify peak usage periods, improve operational efficiency, and support the university's energy-saving initiatives. It also aligns with national policy goals stated in the Energy Efficiency and Conservation Act (RA 11285), which mandates energy-saving efforts in government institutions.

The study aimed to support efficient energy management by designing, testing, and implementing a low-cost sub-metering solution at the College of Engineering and Architecture. It includes analysis of daily consumption patterns, development of a mobile-friendly application, and recommendation of actionable insights based on

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real-time data. The results are expected to benefit not only university personnel but also students and future researchers by providing a scalable model for sustainable energy practices within educational institutions.

Therefore, it is crucial to investigate the potential effects of these substances on human health, particularly their impact on hematological parameters in healthy individuals. This study evaluated the influence of selected preservatives and food processing substances, namely calcium carbide, bifenthrin, ethanol, ethylene, potassium carbonate and sodium glutamate on oxy-hemoglobin levels and oxidation of hemoglobin.

1.1. Study Objectives

(1) To analyze the daily and seasonal electricity consumption in the buildings in order to determine the peak hours and days, the low usage hours and days, and the overall trends.

(2) To develop an application that will help the stakeholders to monitor energy consumption in real time.

(3) To provide practical measures concerning energy saving, as well as to analyze the data concerning the campus to improve its sustainability and efficiency.

2. Materials and Methods

The researchers used descriptive design methods as a scientific approach, wherein data were gathered through continuous observation and documentation to help establish accurate conclusions.

2.1. Conceptual Framework

Figure 1 shows the conceptual framework of the study using the Input-Process-Output (IPO) Model. The input phase involved data collected from a smart electric submeter. The process included monitoring, observation, and data assessment. The output was the development of a smart electric submeter prototype, intended for installation at the Don Honorio Ventura State University – CEA Main Building. Researchers evaluated the electrical usage data and used it to guide the design of the prototype's electrical and electronic components.

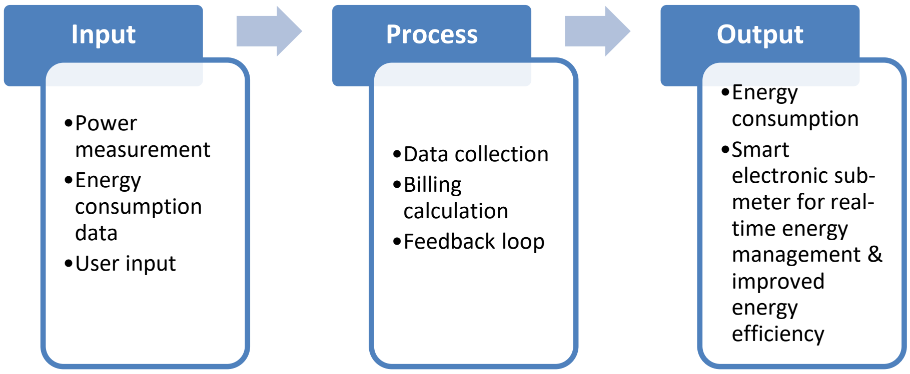

Figure 1. Conceptual framework of the study

2.2. System Flow

The kWh monitoring system at Don Honorio Ventura State University's College of Engineering and Architecture enables real-time tracking of electricity consumption. A smart sub-meter installed on the third-floor panel board wirelessly transmits energy data, which is processed through a design analytics platform and converted into visual graphs. These are then displayed in a cross-platform mobile application, allowing users to conveniently monitor energy usage.

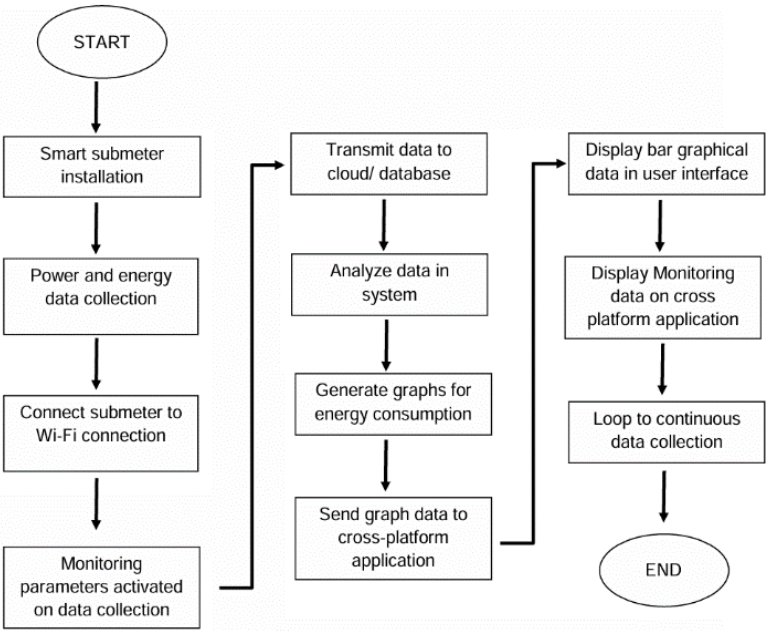

Figure 2. System flow chart

2.3. Architecture Diagram

Using a smart submeter setup, the proponents were able to leverage a controlled testing through a plug in outlet in pursuit to simulate real-world loads. This enabled the proponents to measure voltage, current, power, and energy usage in real time, ensuring accurate performance before deployment. Initial testing was done in a residential setting, comparing the smart submeter to an existing main meter. Over a three-hour period, the smart submeter recorded slightly lower energy readings with deviations ranging from -0.03 kWh to -0.09 kWh, likely due to calibration differences.

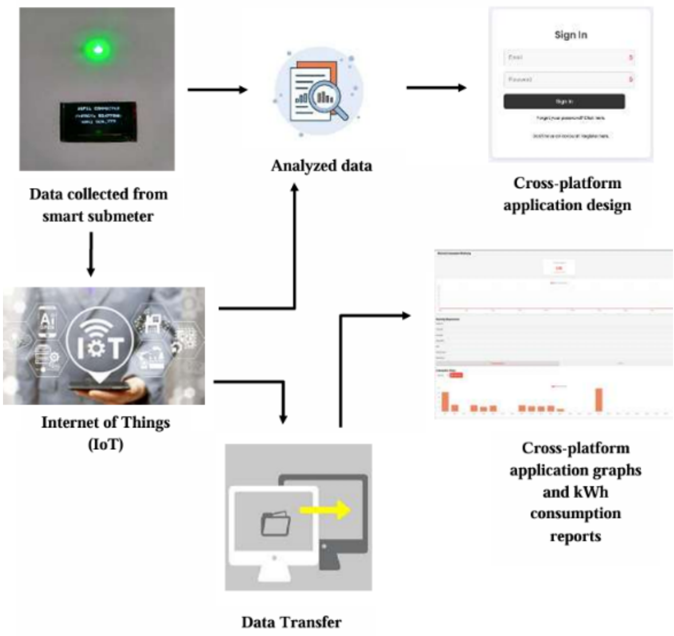

Figure 3. Architectural diagram

Instrumentation included usability testing across iOS, Android, and computer platforms; accuracy validation via manual readings; and data analysis using Python, R, Excel, or Tableau. Project documentation and version control were managed using tools like GitHub, Trello, or Jira for organized and transparent development.

3. Results and Discussion

3.1. Energy consumption per department

The results of the study provided a comprehensive overview of the energy consumption patterns across the various facilities within the College of Engineering and Architecture, highlighting the differences in usage among departments.

Table 1. Total energy consumption per day across CEA departments

Group	Energy Consumption
EE faculty	10.61
ECE faculty	19.34
Architecture faculty	38.96
2F CEA-M & Hallway	15.69
3F CEA-M & Hallway	15.51
Total	**100.11**
Total with 80% Demand factor	80.084

The total daily energy consumption across the listed CEA facilities was 100.11 kWh, with Architecture consuming the most at 38.96 kWh. When adjusted using an 80% demand factor to reflect more realistic usage, the estimated daily consumption dropped to 80.084 kWh.

3.2. Actual bar consumption per day

Table 2. Total actual bar consumption per day

Date	Bar Power Consumption
May 6	71.98
May 8	68.56
May 9	50.54
May 10	63.80

The comparison between estimated and actual energy usage shows that applying an 80% demand factor gives a realistic approximation of daily consumption. While the unadjusted estimate was 100.11 kWh, the adjusted estimate of 80.084 kWh closely matched actual sub-meter readings from May 6 to 10, which ranged from 50.54 to 71.98 kWh. These findings confirm the practicality of using a demand factor, accounting for varying occupancy and equipment use.

4. Conclusion

The development of a low-cost smart electronic sub-meter integrated with a cross-platform application marks a significant step forward in energy monitoring technology. This system offers a user greater insight and control over their electricity consumption with sub-meter kWh readings that closely match actual daily usage in the College of Engineering and Architecture Main Building. Such accuracy and consistency emphasize the system's reliability and its potential to support more efficient energy management. Looking ahead, integrating advanced analytics and machine learning could further enhance predictive capabilities and optimize energy use.

5. Future Suggestions

1) Future studies should include in vivo experiments to evaluate the systemic hematological effects of chronic, low-level exposure to these preservatives and ripening agents in animal models.

2) Implement a memory feature that allows the device to save data offline, ensuring continued functionality and access to historical data anytime and anywhere. Researchers should examine potential additive or synergistic interactions by testing mixtures of two or more of these substances at concentrations relevant to real-world exposures.

3) Explore a feature that will automatically shut down the device when it overheats, ensuring safety and preventing potential damage.

4) Implement standardized evaluation criteria and periodic reviews to ensure the validity, and reliability of assessment tools and its alignment with project goals.

5) Develop a regular schedule for system updates, bug fixes, and feature enhancements to maintain system efficiency and relevance.

6) Conduct thorough technical risk assessments during the planning phase and allocate resources for proactive troubleshooting and technical support.

7) Create a flexible budgeting model with contingency funds and prioritize features to ensure the core system can function effectively within financial limitations.

8) Design and test a robust prototype that allows for scalability and user feedback integration, ensuring its adaptability to evolving needs and technologies.

Declarations

Source of Funding

No internal or external funding was obtained for this study.

Competing Interests Statement

The authors declare that they have no competing interests related to this work.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

Availability of data and materials

Authors are willing to share data and material on request.

Institutional Review Board Statement

This study was approved by the Institutional Review Board of Don Honorio Ventura State University, Philippines.

Informed Consent

Not applicable for this study.

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