MEASUREMENT AND VERIFICATION OF ENERGY PERFORMANCE AT THE RECTORATE BUILDING OF UNSOED: STAGE 1 – BASELINE ENERGY ASSESSMENT AND SAVING POTENTIAL

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Abstract. This research aims to conduct a Measurement and Verification (M&V) of the energy performance at the Central Office and Rectorate Building of Universitas Jenderal Soedirman (Unsoed). Energy efficiency in office buildings is crucial for reducing operational costs and supporting environmental sustainability. M&V is a method for assessing the extent to which implemented energy-saving measures have reduced energy consumption and achieved the desired energy-efficiency targets. This study will involve collecting energy consumption data, mapping energy use across building sectors, and analysing changes in energy consumption before and after the implementation of energy efficiency policies. The methodology adheres to ISO 50001 and the International Performance Measurement and Verification Protocol (IPMVP) standards, which enable objective, transparent verification of the results of energy-efficiency program implementation. The findings of this research are expected to provide a clear picture of the energy performance at the Unsoed Central Office and Rectorate Building, as well as offer strategic recommendations for further improving energy efficiency. Furthermore, this study aims to contribute to efforts to achieve carbon emission reduction targets and to promote more sustainable energy management within the Universitas Jenderal Soedirman environment. This research is also expected to serve as a reference for developing energy management policies and to support the implementation of energy efficiency policies in the higher education sector in Indonesia.

Keywords: Measurement, verification, energy performance, M&V, Unsoed

1. Introduction

Energy conservation programs were mandated by Law No. 30 of 2007 on Energy, followed by the issuance of Government Regulation No. 33 of 2023 on Energy Conservation. This regulation requires energy users that consume more than 6,000 TOE (Tonnes of Oil Equivalent) to implement energy conservation and management programs [1]. The implementation of this energy management is further regulated in the Minister of Energy and Mineral Resources Regulation No. 14 of 2012 concerning Energy Management [2].

Energy efficiency in buildings of higher education institutions is critical to supporting sustainable resource management and reducing operational costs. The Central Office and Rectorate Building of Universitas Jenderal Soedirman (Unsoed) is a vital facility with substantial energy consumption, supporting lighting, cooling, and other electronic equipment. However, the building's energy efficiency has not been systematically measured, leaving potential energy savings unrealised.

Measurement and Verification (M&V) of energy performance is a standard method for evaluating the success of energy-efficiency program implementation. This method refers to international protocols, such as the International Performance Measurement and Verification Protocol (IPMVP), which enable accurate and objective analysis of energy performance [3]. M&V is also related to the application of the SNI ISO 50001 standard on Energy Management Systems, which provides a structured framework for improving energy performance through systematic management [4]. At Universitas Jenderal Soedirman, the application of M&V and an SNI ISO 50001-based approach is expected to identify energy-efficiency opportunities, reduce carbon emissions, and support environmental sustainability. This is also in line with the national strategic plan for sustainable energy management from the Ministry of Environment and Forestry [5].

The objective of this institutional research is to assess the energy-efficiency performance of the Unsoed Central Office and Rectorate Building, measure energy savings, and determine whether the program achieves the expected level of savings. The objects of this research consist of two buildings: the two-story central office building and the three-story rectorate building. The electricity supply from PLN is provided by two three-phase distribution transformers, with an installed capacity of 60 kVA at the central office and 48 kVA at the rectorate building. In addition to PLN, there are two backup power sources: 60 kVA generators, providing contingency for PLN power outages.

This research will also calculate the Energy Consumption Intensity (ECI), a building energy performance indicator that quantifies the amount of energy used in a building. ECI is expressed in kWh/m²/month [4]. Performance testing of the AC in this study will be conducted in accordance with the Indonesian National Standard SNI 6390:2011 [6], while lighting system testing will follow the Indonesian National Standard SNI 6197-2011 [7].

As a reference, similar research has been conducted within the DKI Jakarta Provincial Government. This M&V-related research is ongoing as part of the Energy Conservation program in Indonesia [8]. Ultimately, this study is expected to serve as a reference to support sustainable energy policies in the higher education sector and to directly benefit the operational efficiency of Universitas Jenderal Soedirman.

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2. Methods

2.1 Preparation Stage

The preparation stage was undertaken systematically to ensure methodological rigor and compliance with international standards. Initially, the specific data requirements related to institutional energy consumption were identified, encompassing electricity, air conditioning, and lighting systems. This step ensured that the scope of the research was comprehensive and relevant to the operational characteristics of the buildings under study. Subsequently, appropriate measuring instruments and supporting software were selected to guarantee accuracy, reliability, and replicability of the data acquisition process. A detailed work plan was then developed in accordance with the International Performance Measurement and Verification Protocol (IPMVP) and the SNI ISO 50001 framework, thereby establishing a structured methodological foundation.

2.2 Data Collection

During the data collection phase, both real-time and historical records of energy consumption were compiled. Operational data from building systems were complemented by archival records of past energy use, providing a robust dataset for empirical evaluation. This dual approach ensured that the dataset captured both current operational dynamics and long-term consumption trends.

2.3 Analysis and Verification

The analysis and verification stage involved a systematic examination of consumption patterns, culminating in the establishment of a baseline of energy use over the preceding year. Measurement results were empirically verified against this baseline to ensure consistency, validity, and methodological transparency. This process provided a reliable foundation for subsequent evaluation and recommendation formulation.

2.4 Recommendation Formulation

Building upon the verified findings, recommendations were formulated by identifying energy-saving opportunities (ESOs) and developing strategies to enhance efficiency in alignment with the SNI ISO 50001 standard. These recommendations were designed to strengthen institutional energy management practices, improve operational performance, and contribute to long-term sustainability objectives.

2.5 Expected Outcomes

The expected outcomes of this research include the identification of energy consumption patterns at the Unsoed Central Office and Rectorate Building, the establishment of a 2024 energy baseline as a reference for performance evaluation, and the formulation of strategic recommendations for improving energy performance. Moreover, the study is expected to facilitate the implementation of energy efficiency policies guided by the IPMVP protocol and the SNI ISO 50001 framework.

2.6 Achievement Indicators

To evaluate the success of the research, several achievement indicators were established. These include the availability of a comprehensive measurement and verification report on energy performance, the attainment of a targeted 2% reduction in energy consumption relative to the baseline, and the development of an UNSOED energy management guide based on SNI ISO 50001. In addition, the dissemination of research findings through publication in a reputable journal is anticipated to contribute to the broader academic and professional discourse on energy management. Collectively, these indicators underscore the significance of the study in advancing institutional energy efficiency, reinforcing evidence-based strategies, and supporting sustainable development within higher education infrastructure.

3. Results And Discussion

3.1.Description

In-Depth Explanation of Energy Performance Research Findings

This research project was initiated to rigorously apply the scientific principles of **Measurement and Verification (M&V)** to assess and validate the energy performance and savings achieved at two critical facilities at Jenderal Soedirman University: the Central Office Building and the Rectorate Building. The fundamental goal was to move beyond mere estimation and provide **quantifiable, data-driven proof** of the efficacy of energy management initiatives.

Phase I: Establishing the Energy Baseline (Year 1: 2024)

The entire first year was dedicated to establishing a precise and reliable **Energy Baseline**. This baseline serves as the "control group" or the pre-intervention consumption level, against

which all future savings would be measured. Without an accurate baseline, claims of energy savings are impossible.

Methodology for Baseline Establishment

We meticulously collected monthly electricity consumption data (in kilowatt-hours, kWh) for both buildings throughout2024. However, raw total consumption alone is an inadequate measure of efficiency, as it fails to account for differences in building size and function.

To overcome this, we calculated the industry-standard metric known as **Energy Consumption Intensity (ECI)**. The ECI is defined as the total annual energy use divided by the building's gross floor area, as is expressed in Fig. 1.

$$\text{EUI} = \frac{\text{Total Annual Energy Consumption (kWh)}}{\text{Total Gross Floor Area (m}^2\text{)}}$$

Figure 1 EUI Formula

This normalization factor ensures a **fair and comparative assessment** of efficiency, allowing us to accurately benchmark the performance of the buildings.

Key Baseline Findings

The ECI analysis provided a clear differentiation in building performance:

- **The Central Office Building:** This facility exhibited a **relatively high ECI**. This finding was critical, as it immediately signalled a **significant opportunity for energy conservation measures (ECMs)**. The high intensity suggested that investments in optimising lighting, HVAC (Heating, Ventilation, and Air Conditioning), or operational scheduling would likely yield substantial returns and justify the subsequent M&V efforts.
- **The Rectorate Building:** Conversely, this building performed well from the outset, exhibiting a **very low ECI**. According to national benchmarking standards, this ECI placed the Rectorate in the **"Very Efficient" category**. The challenge identified for this building was not to find massive savings, but rather to establish best practices for **maintaining this existing excellence** and preventing "efficiency drift" over time.

By the end of Year 1, we had a validated, data-driven foundation and a targeted action plan for the implementation phase.

Phase II: Measurement and Verification (Year 2: 2025)

Following the identification of opportunities, various energy conservation measures were implemented in the Central Office Building. The second year focused entirely on **measuring the impact** of these changes and officially verifying the savings.

Methodology for Verification

The same data collection protocol was repeated throughout 2025 to track new monthly kWh consumption. The core of the M&V process involved a direct comparison:

{Energy Savings} = {Baseline Consumption (2024) - \text{Measured Consumption (2025)

This comparison was adjusted for any necessary changes in "non-routine" factors (such as major renovations or significant changes in operating hours), ensuring that the calculated savings were genuinely attributable to the implemented ECMs.

Verified Outcomes and Performance

The verification process confirmed the success of the program with highly encouraging results:

- **Overall Reduction in Energy Consumption:** Across both facilities, there was a **quantifiable and significant decrease** in total electricity use when comparing 2025 to the 2024 baseline. This confirmed that the energy conservation measures were technically sound and operationally effective, translating into real, measurable savings and reduced operating costs for the university.
- **The Central Office Building's Success:** As expected and targeted, the Central Office Building's **ECI improved noticeably**. This improvement directly correlates with the successful implementation and effectiveness of conservation strategies (e.g., replacing inefficient equipment and installing smart controls). This outcome proves that the initial identification of a high-ECI building correctly indicated a large, recoverable energy waste.
- **Sustained Excellence at the Rectorate Building:** A particularly important finding was the confirmation that the Rectorate Building successfully **maintained its extremely low ECI**. While no drastic savings were expected, the sustained performance is crucial. It validates the building's **sustainable operational standards** and demonstrates that even a highly efficient building requires continuous monitoring and operational diligence to prevent performance degradation—a phenomenon often overlooked in energy management.

3.2. Figures and Tables

3.2.1 Measurement of the Electrical Load of the Rectorate Building

Figures, graphs, and tables contain the measurements and verifications that we carried out for 1 month, where in this section, we provide images when we carried out the measurements and also the verifications, which are shown in the table of electrical loads used in the rectorate building, where the verified loads are still limited to lights and air conditioning.

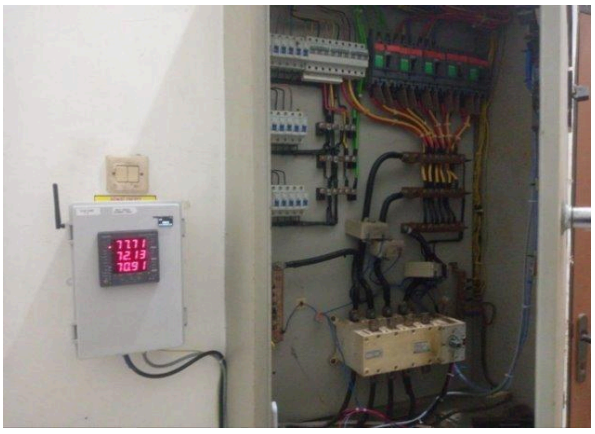

Figure 2 Measurement Using Schneider PM-2100

Figure 3 Manual Measurement Using Clamp Multimeter

1. Real-Time (Automated) Monitoring

The first method involved continuous, real-time monitoring utilising the installed Schneider PM-2100 digital power meter. This device serves as the primary energy-monitoring system, automatically recording critical electrical parameters, including voltage (V), current (A), active power (kW), energy consumption (kWh), and power factor (PF).

The main advantage of this method is the dynamic nature of the data. All measurement results from the PM-2100 are constantly updated and sent to a server, which can then be accessed via the provided website portal. This enabled us to analyse historical energy usage patterns (load profiles), identify peak-load hours, and monitor load fluctuations over a full 24-hour period without being physically present on-site.

2. Manual Measurement (On-Site Validation)

The second method, complementary, involved manual measurements conducted directly at the site. This method was crucial for validating and verifying the data reported by the PM-2100, as well as for obtaining a more detailed instantaneous "spot check."We performed these measurements using a portable multimeter (tang ampere). The process involved carefully taking readings at the output points of the main electrical distribution panel of the Rectorate Building. Specifically, we measured the electrical quantities (primarily current and voltage) for each phase (R, S, and T). This per-phase measurement is essential for analysing the load-balancing condition of the building's installation system.

3.2.2 Verification of Electrical Load Rectorate Building

The second step is to verify the electrical usage of the Unsoed Rectorate Building that we measure. We make a table about the usage of electrical load, as shown below, we get the three most used electrical loads that the Rectorate Building use that is lamp, AC 2 Pk, and AC 5 Pk. The data we verified are presented in Table 1.

Table 1. Electrical Load Of Rectorate Building

1st Floor					
Room	Lamp 15 Watt	Ac 2 Pk	Ac 5 Pk	Total Hour/week	Total KWh
4 Administration	40	4	0	40	272
Meeting	20	2	2	8	105,12
Hall	25	0	2	50	505,75
Toilet dan Pantry	5	0	0	40	3
Total KWh					885,87
2nd Floor					
Room	Lamp 15 Watt	Ac 2 Pk	Ac 5 Pk	Total Hours/week	Total KWh
Field	50	9	0	40	588
Secretariat	10	1	0	40	68
Hall	25	0	1	50	262,25
Toilet dan Pantry	5	0	0	40	3
Total KWh					921,25
3nd Floor					
Room	Lamp 15 Watt	Ac 2 Pk	Ac 5 Pk	Total Hours/week	Total KWh
Headship	60	10	0	40	651,2
Meeting	40	2	3	8	145,84
Hall	25	0	2	50	503,25
Toilet dan Pantry	5	0	0	40	2,6
Total KWh					1302,86

This table outlines a weekly electrical energy consumption audit for a three-story building, segmented by Floor 1 (Lantai 1), Floor 2 (Lantai 2), and Floor 3 (Lantai 3). For each floor, it breaks down electricity usage by specific rooms ("Ruang"), quantifying the primary electrical loads: 15-Watt lamps ("Lampu 15 Watt"), 2 PK air conditioning units ("Ac 2 Pk"), and 5 PK air conditioning units ("Ac 5 Pk"). The table also specifies the total weekly operating hours ("Total Jam/minggu") for the equipment in each area, which is then used to calculate the "Total KWh" (Total Kilowatt-hours) consumed by that room per week. Each floor section concludes with a subtotal of its weekly energy usage, showing 885.87 kWh for Floor 1, 921.25 kWh for Floor 2, and 1302.89 kWh for Floor 3.

4. Conclusion

In conclusion, the M&V project successfully transitioned the university's energy management from a hopeful initiative to a matter of scientific certainty. The project not only achieved quantifiable financial savings by reducing overall consumption and improving the efficiency of the lower-performing Central Office Building, but also provided robust evidence of the sustainability and operational integrity of the high-performing Rectorate Building. This validated data serves as a critical tool for future budgeting, capital investment planning, and ongoing institutional energy policy.

5. Acknowledgement

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