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Improving Military Facility Energy Efficiency Through Preliminary Audit and Conservation Strategies

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Abstract

Energy efficiency and conservation are critical global issues due to rising energy demand, escalating electricity prices, and the environmental impacts of energy generation, including greenhouse gas emissions. This study aimed to develop energy conservation measures to improve energy efficiency in a Philippine government military facility through a preliminary energy audit. A walkthrough audit was conducted to identify potential energy wastage, while electricity billing records from January 2019 to December 2023 were analyzed to observe trends and project future energy consumption and electricity prices. Prioritization techniques were employed to develop energy conservation measures. The results showed a consistent increase in energy consumption, with a noticeable surge in electricity costs after the end of the COVID-19 pandemic. The audit revealed that cooling, office equipment, other loads, and lighting accounted for 63.34%, 24.49%, 8.97%, and 3.19% of the total energy consumption, respectively, with cooling loads being notably higher than in similar studies. This suggests a need to improve the efficiency of air conditioning and fan systems. Additionally, 48.2% of lighting loads still use outdated, inefficient fluorescent lamps. The study also highlighted that energy consumption patterns varied across different buildings and floors, indicating that tenant behavior and demand significantly influence energy use. This research provides valuable insights and opportunities for improving energy efficiency in government military facilities, offering a framework for similar institutions seeking to optimize energy consumption.

Keywords
Electricity Consumption, Energy Audit, Energy Conservation Measures, Energy Efficiency, Military Facility.

1. Introduction

There is a growing global push to promote energy efficiency and conservation due to rising energy demand, increasing electricity prices, and the harmful effects of greenhouse gas emissions, especially carbon dioxide (CO_2), from burning fossil fuels for power generation. This movement is aligned with the United Nations' priority agenda, particularly Goal 7 – Affordable and Clean Energy, which aims to improve access to electricity and increase energy efficiency (Walsh et al. 2022). It emphasizes that energy efficiency and conservation are vital for achieving green and sustainable economic growth across all sectors of society, including government institutions. In the Philippines, all government agencies are required to submit and justify their annual budgets, which include line items for personnel salaries and benefits, capital outlay (for building projects and equipment), and Maintenance and Other Operating Expenses (MOOE)—where funds for utilities like water and electricity are allocated. Most savings within a government agency are typically derived from cost-cutting in MOOE, and these savings often go toward employee incentives and benefits through the Collective Negotiation Agreement (CNA) at the end of the year. The rising electricity consumption and fuel prices have put pressure on government budgets. Many agencies risk overspending on electricity, forcing them to reallocate funds from other critical areas. While this challenge doesn't affect all agencies equally, especially those with unique operational demands like military institutions, the impact on budget planning is real. Military facilities, being crucial to national defense and security, operate differently from civilian agencies. Recognizing the importance of sustainable energy use, Republic Act 11285, or the Energy Efficiency and Conservation Act, mandates all government agencies to adopt energy-saving practices. This is especially relevant because MOOE accounts for significant electricity costs in most institutions. Yet, despite their high energy needs, many military facilities have not yet adopted formal energy efficiency or conservation strategies. This lack of action highlights the need for structured and targeted initiatives to manage energy use better, reduce electricity expenses, and support national goals for lower carbon emissions and environmental sustainability. To help address this gap, this study aims to develop energy conservation measures that can improve energy efficiency in a Philippine government military facility, using a Preliminary Energy Audit as the foundation. Specifically, the study seeks to: assess the facility's electricity load profile, analyze energy consumption patterns and utility cost trends, identify areas where energy is being wasted, and propose a comprehensive energy conservation policy for the facility. By taking a data-driven approach to energy management, this research offers practical solutions that can be applied not only in this military facility but also in other government institutions seeking to reduce costs and operate more sustainably.

1.1 Problem Statement

Despite the critical role of energy efficiency in reducing operational costs and promoting sustainability, many government military facilities in the Philippines lack data-driven approaches to manage and conserve energy. This study addresses this gap by seeking to develop energy conservation measures grounded in empirical evidence. Specifically, the study aims to answer the following questions:

1. What is the current electricity load profile of the selected military facility?
2. What patterns can be observed in the facility's energy consumption and utility cost trends?
3. Which areas within the facility exhibit significant energy inefficiencies and wastage?
4. What comprehensive and actionable energy conservation policy can be proposed based on the findings?

Through these questions, the study intends to contribute to more efficient energy use and informed policy-making in public-sector facilities.

1.2 Objectives

The study aims to design practical energy conservation strategies to improve energy efficiency in a Philippine government military base. In particular, it seeks to:

1. To conduct a comprehensive inventory of all electrical loads across seven buildings and sixteen floors within the government military facility, including lighting, HVAC systems, office and ICT equipment, and other electrical appliances.
2. To perform a preliminary energy audit through a walkthrough inspection and occupant interviews, aimed at identifying operational inefficiencies and sources of energy wastage such as outdated equipment, poor insulation, and suboptimal usage behaviors.
3. To analyze historical electricity consumption and cost data from January 2019 to December 2023 using statistical methods such as linear regression and interpolation to determine usage trends and predict future energy demands and costs.

4. To categorize and quantify the contribution of various electrical loads (e.g., cooling, lighting, ICT equipment) to the overall energy consumption of the facility, with detailed disaggregation by building and floor.
5. To develop targeted Energy Conservation Measures (ECMs) based on the audit findings, addressing issues such as inefficient cooling and lighting systems, and proposing both behavioral and technical interventions.
6. To evaluate the projected impact of recommended ECMs on energy savings, operational efficiency, and sustainability, considering short-term implementable solutions and long-term investments like renewable energy integration.
7. To support decision-making for energy management policies in similar institutional settings by providing insights on high-consumption zones and identifying feasible, cost-effective strategies for reducing energy use and promoting sustainable practices.

2. Literature Review

The literature suggests that energy audits are crucial for identifying inefficiencies, improving energy performance, and reducing CO2 emissions in various sectors. They range from preliminary walk-through audits to comprehensive diagnostic and investment-grade audits. In the Philippines, the Department of Energy (DOE) promotes energy audits through initiatives like the Government Energy Management Program (GEMP) and the Energy Efficiency and Conservation Act, aiming to enhance energy efficiency in both the public and private sectors. While civilian offices focus on optimizing basic systems like lighting and HVAC, non-civilian offices, such as military and research facilities, prioritize energy security and renewable energy integration. Despite challenges such as budget constraints, the government supports energy conservation through incentives, training, and regulations, aligning with global trends in improving energy efficiency and reducing emissions. Energy audits and conservation measures are essential for improving energy efficiency, reducing costs, and minimizing environmental impact. While energy audits are widely implemented in civilian offices, studies on non-civilian institutions, such as military facilities, remain limited. Given the unique energy demands of these facilities, there is a need for tailored conservation strategies to enhance efficiency without compromising operational requirements. This study addresses this gap by conducting a preliminary energy audit in a Philippine government military facility to develop targeted energy conservation measures that align with national sustainability goals.

2.1 Energy Audit and Conservation Measures

An energy audit is a systematic approach to evaluate a facility's energy consumption, identify inefficiencies, recommend improvements, and ultimately reduce CO2 emissions by improving energy efficiency and minimizing wastage (Mbaye 2022). Energy audits range in complexity from preliminary audits, which provide a general assessment, to comprehensive audits, which involve detailed data analysis, equipment testing, and financial evaluations. Audits are essential for pinpointing energy-saving opportunities and prioritizing actions that offer the highest impact on energy conservation and cost reduction (Unnikrishnan et al. 2018). Energy audit methodologies include walk-through audits, detailed (diagnostic) audits, and investment-grade audits, each providing different levels of insight into energy performance. Energy Conservation Measures (ECMs) are specific actions or technologies implemented to reduce energy use and enhance efficiency (Duan et al. 2024). These measures vary based on context, ranging from low-cost solutions, like adjusting operational practices, to capital-intensive upgrades, like retrofitting buildings with efficient insulation or upgrading equipment to energy-efficient models. ECMs may include improvements in lighting systems, HVAC upgrades, installation of renewable energy sources, and optimization of building envelope insulation (Duan et al. 2024).

2.2 Energy Audit in Civilian Offices

In the United States, federal mandates require government buildings and facilities, including civilian offices, to perform regular energy audits and meet specific energy-saving targets as part of their Energy Policy Act. Similarly, civilian offices in many parts of the world often conduct detailed or diagnostic audits, involving comprehensive data collection and analysis to identify deeper, systemic inefficiencies in energy use. These audits provide insights that help organizations prioritize energy-saving investments, such as advanced HVAC systems, LED lighting, and automated energy management systems. In the local context, the Philippine Government, through the Department of Energy (DOE), has increasingly recognized the value of energy audits to reduce energy consumption, lower operating costs, and contribute to national sustainability goals. As such, DOE has issued regulations that encourage energy audits across various sectors to promote energy efficiency and conservation. A few research works on energy audits have been published and conducted in the Philippines, and often perform preliminary or walk-through audits that focus on identifying immediate, low-cost energy-saving opportunities, such as optimizing air conditioning schedules, improving lighting systems, and promoting energy-saving behaviors among employees such as in the case of universities (Alba and Santiago 2019), (Lopez et al. 2017) These audits typically assess the efficiency of common systems like lighting, HVAC, and office equipment, providing recommendations for energy-saving upgrades or modifications. Additionally, the DOE has launched initiatives, such as the Government Energy Management Program (GEMP), which mandates energy conservation practices and regular audits in government facilities, aiming to achieve a significant reduction in energy use within public offices. However, challenges remain, including limited budgets for implementing more comprehensive audits and energy-efficient retrofits

2.3 Energy Audit in Non-Civilian Offices, Trends, and Efforts in Energy Conservation

In non-civilian offices like military bases and government research facilities, energy audits are often more advanced, focusing on both operational efficiency and energy security. (Abdelaziz and Mekhilef 2011) For example, the U.S. The Department of Defense uses audits to strengthen energy resilience and explore renewable energy options such as solar and microgrids, reducing dependence on the grid. (Schleich and Fleiter 2019) In the Philippines, however, there is little to no public research on energy audits in non-civilian agencies like the Philippine National Police (PNP), Armed Forces of the Philippines (AFP), or Philippine Navy. (Fleiter et al. 2012) These audits, if conducted, are likely confidential due to security concerns. (10) They typically cover critical infrastructure and equipment that must operate 24/7 (Rashdi et al. 2021). Globally, energy audits are common in industries, businesses, banks, schools, and universities (Samira and Nurmammad 2018). Countries like Germany and the UK follow strict standards such as the Energy Efficiency Directive and ISO 50001, offering incentives and training to encourage energy conservation in both civilian and non-civilian sectors. In the Philippines, energy audits are part of the national effort to improve efficiency and reduce fuel imports. Under Republic Act 11285, the DOE requires audits in both the public and private sectors. Government buildings follow the Government Energy Management Program (GEMP), while large businesses must conduct regular audits and assign Certified Energy Conservation Officers. Common conservation measures include switching to LED lights, improving air conditioning schedules, and installing solar panels. Although cost and lack of expertise remain challenges, the DOE supports organizations with incentives, training, and awareness programs.

3. Methods

This paper presents a case study conducted at a government military facility in the Philippines. For confidentiality and security reasons, the name of the facility is not disclosed. The study covered seven (7) buildings with a total of sixteen (16) floors, each with varying activities and functions. A site inspection was carried out to inventory all lighting and signage, office and ICT equipment, machinery, ventilation, and air conditioning units. All operational units were recorded along with their power ratings (in watts) from the nameplates. For unreadable or missing nameplates, equipment specifications were sourced online. Electricity consumption data for the entire facility was based on monthly electric bills provided by the local utility, covering the period from January 2019 to December 2023.

3.1 Preliminary Energy Audit

The study started with the creation of an inventory of all electrical loads, followed by a walkthrough audit. The audit will involve a combination of direct interviews and on-site inspections with building occupants to uncover any energy wastages like unnecessary equipment usage, inefficient lighting technologies, inefficient ventilation and cooling systems, poor insulation and envelope issues, inadequate power management, and lack of energy-efficient office equipment.

3.2 Energy Conservation Measures (ECMs)

To develop the Energy Conservation Measures, the study first conducted a thorough energy audit to identify key areas of energy wastage within the office environment, including inefficient lighting, equipment usage, HVAC systems, and insulation. ECMs were crafted following the walkthrough audit by evaluating each identified issue and developing targeted solutions aimed at reducing energy consumption. The prioritization process was done considering both short-term and long-term benefits to create an overall strategy for energy conservation that could be easily adopted.

4. Data Analysis

The study used linear regression and interpolation analysis to project the future trends in energy consumption and electricity cost through best-fit line estimates at a 95% confidence interval. Descriptive statistics were used to obtain the general information of each building and floor according to the category of the electrical load. GraphPad Prism 9.0 (USA) was used for the whole analysis, including the generation of the visualization graphs. Figure 1 shows the energy consumption trend and the interpolated values for projections. Figure 1 presents the energy consumption trend and interpolated projections for the military facility. The data indicates a slight but consistent increase in energy consumption, peaking during the mid-year months (April to June) and declining towards the end of the year (November to December). This pattern suggests higher demand during the hotter months and lower usage during the holiday season when staff are on leave. The linear regression analysis shows a steady increase in energy consumption, with an average rise of 237 kWh per month. However, the R-squared value of 0.06714 indicates a weak correlation, suggesting that the linear model does not fully capture the complex factors influencing energy usage, particularly human behavior.

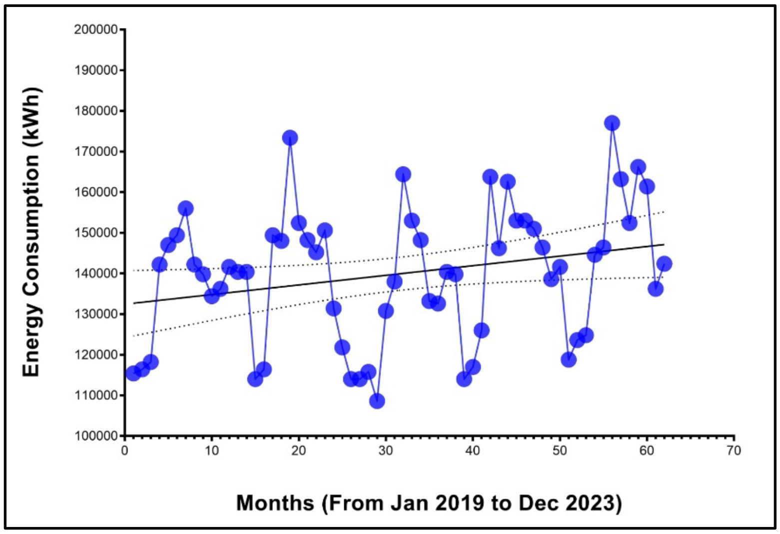

Figure 1. Energy Consumption Trend and Interpolation

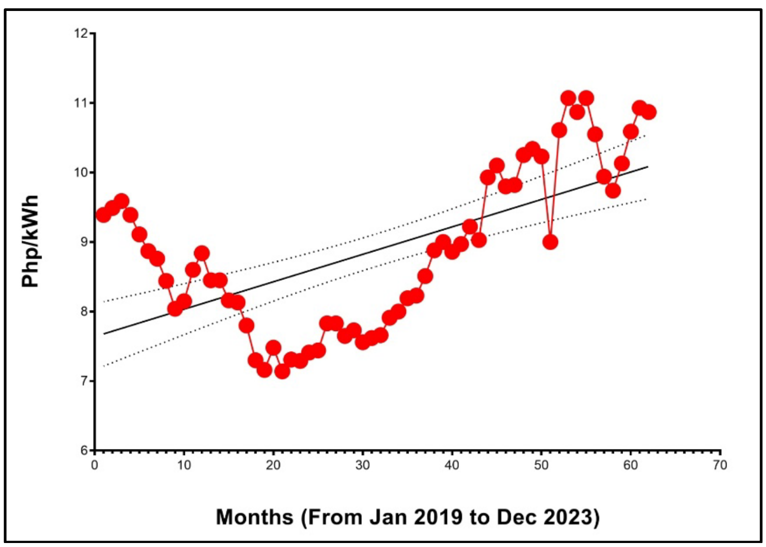

Figure 2. Electricity Cost Trend

Figure 2 illustrates the electricity cost trend, revealing a general increase in costs with some fluctuations. The significant drop in electricity prices during the COVID-19 pandemic due to reduced demand is evident in the early months of 2020, with a rise in prices as onsite work resumed in 2022. The regression analysis shows a modest increase of Php 0.03947 per month in electricity costs, with an R-squared value of 0.3770, suggesting that while the model captures some of the trends, other external factors may be influencing price variations. Projections for 2025, 2030, and 2040 predict energy consumption at 173,608.4 kWh, 169,349.6 kWh, and 163,671.2 kWh, respectively, while electricity costs are expected to rise to Php 12.85/kWh, Php 13.80/kWh, and Php 14.51/kWh, respectively. Figure 3 shows the summary of electrical loads per category of the whole military facility. The cooling loads (air conditioning units and fans) account for 63.34% of total energy consumption, significantly higher than the typical 51-57% observed in similar studies in the Philippines and Malaysia. Lighting loads make up 8.97% of the total, with 48.2% of the lighting still using outdated fluorescent lamps. Other electrical loads, including water heaters, cooking appliances, and specialized equipment, account for 24.49%. Figures 4 through 7 provide a detailed breakdown of cooling loads, lighting loads, office equipment, and other electrical loads by building and floor.

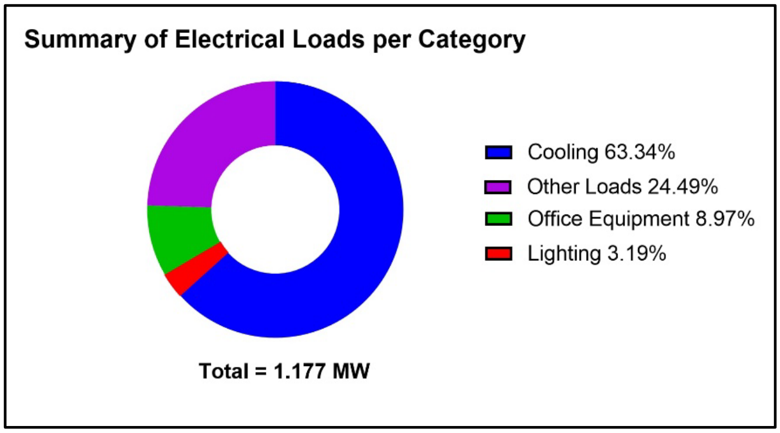

Figure 3. Summary of Electrical Loads

Cooling loads were highest in Building 4, Floor 2 (B4F2), while lighting loads were most prominent in Building 3, Floor 2 (B3F2), reflecting the nature of each building's use. Office equipment, primarily desktop computers, contributed significantly to energy consumption, especially in buildings with high occupancy, such as B3. Other electrical loads, particularly from kitchen appliances, were most significant in B3F1 and B3F2 due to the presence of a large pantry area.

As shown in Figure 4. B4F2 got the highest number of power requirements in terms of cooling, followed by B3F4 and B4F1. Due to the nature of confidentiality, the study is limited to providing specific details as to the nature of work. Nevertheless, cooling is the highest consuming load in most of the research found in the literature, and cooling expenditure emerged as one of the new indicators of energy poverty as the climate warms (Wang et al. 2024). In terms of lighting loads, B3F2 has the highest number of lighting loads, followed by B3F1. Building 3 in this study accommodates a large number of people, like conference and meeting places (see Figure 5). However, it is still important to note that 48% of the lighting loads are using the old FL technology. Furthermore, Figure 6 below shows the summary for office equipment. number of "other loads," largely due to the presence of kitchen appliances, since this building includes the pantry and receiving area that serve many people. Load characteristics vary across buildings and floors depending on the nature of work, tenant behavior, and energy demand. The data showed that air conditioning units (ACUs) and fans account for 63.34% of total power use, highlighting the need for optimization. One key solution is to replace current ACUs with energy-efficient inverter-type units, which adjust output based on demand. However, since this requires funding, implementing temperature control guidelines(e.g., setting thermostats to 24–26°C) is a practical first step. As shown in Figure 7, floors B3F1 and B3F2 had a high. Installing smart thermostats (Fakhr et al. 2024) and conducting regular maintenance can also improve efficiency and reduce energy waste. For lighting, 48.2% still use outdated fluorescent lamps. Replacing these with LEDs, which are more energy-efficient and longer-lasting, is a priority. Adding motion sensors and timers in low-traffic areas will further cut energy use. Maximizing natural daylight and using daylight sensors can also reduce the need for artificial lighting during daytime hours. A clear policy to transition to 100% LED lighting should be adopted as soon as possible. Desktop computers are a major energy load in the office. Replacing them with mini-PCs or all-in-one units, enabling power-saving settings, and adopting server virtualization can significantly reduce electricity use (DellaValle 2019), (Randazzo et al. 2019). A policy should require all new equipment to meet Energy Star or equivalent standards, with power-saving features activated by default.

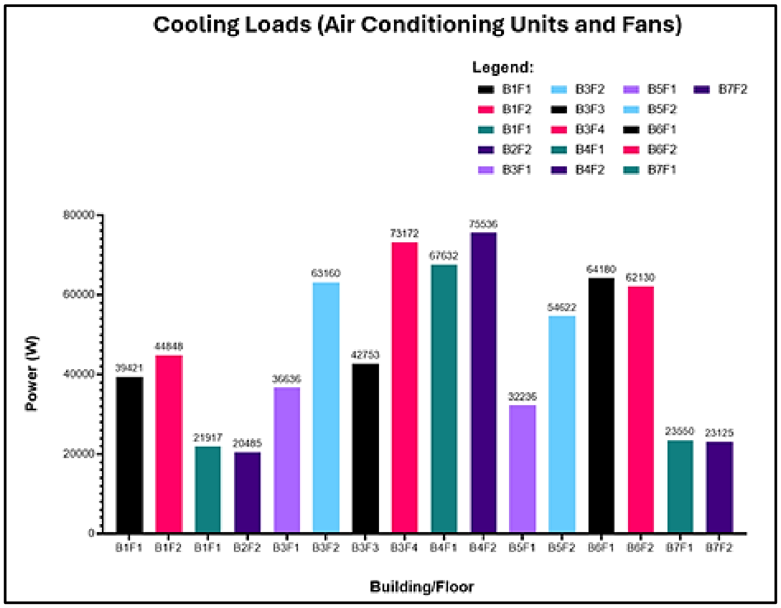

Figure 4. Cooling Loads per Building/Floor

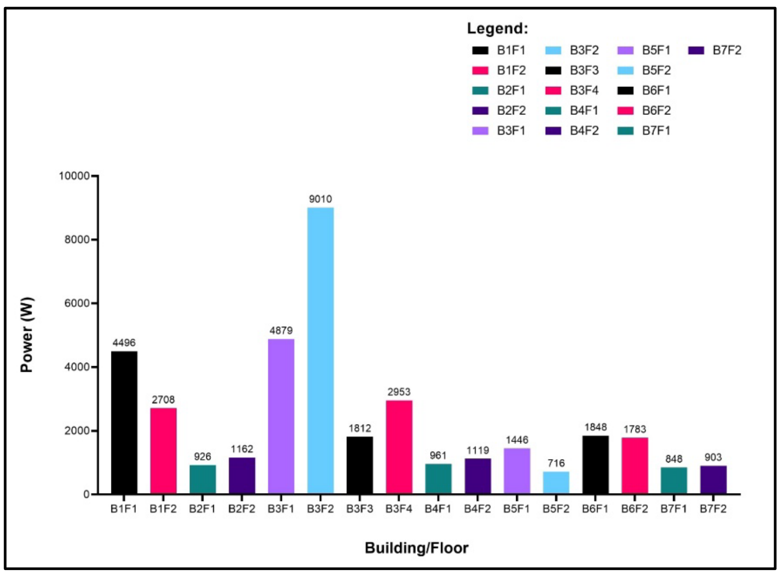

Figure 5. Summary of Lighting Loads

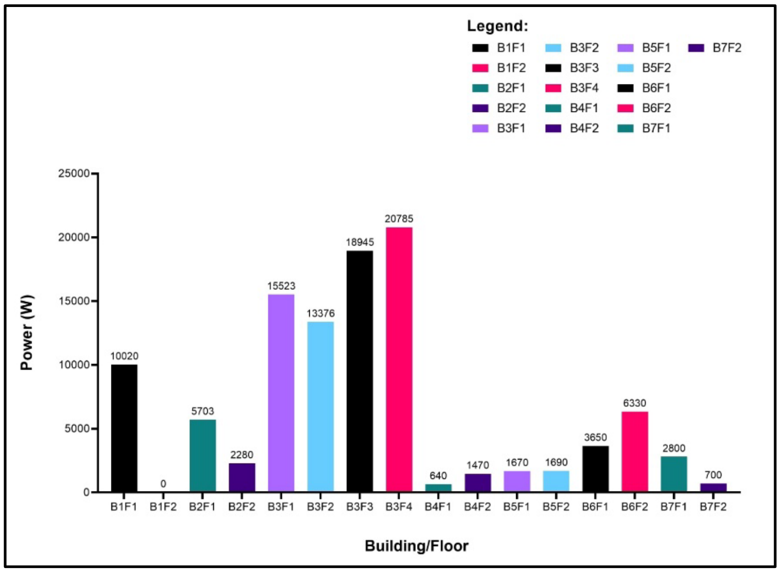

Figure 6. Summary of Office Equipment

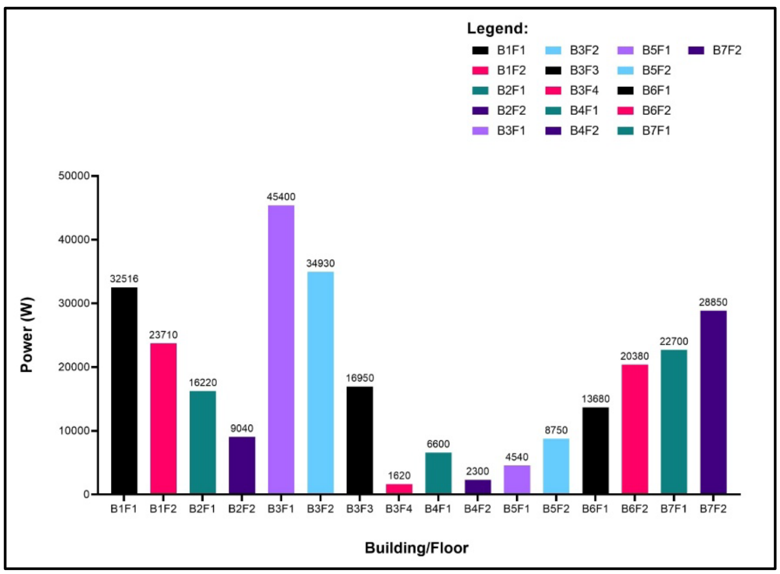

Figure 7. Summary for Other Electrical Loads

An energy awareness campaign can further cut consumption by encouraging simple actions, like turning off lights and unused devices. Real-time energy monitoring will help identify high-usage areas for targeted improvements. Adding renewable energy sources, such as solar panels, will reduce grid reliance and long-term costs. Pursuing green building certifications like LEED can enhance overall energy performance. To address the facility's high energy use—especially from cooling (63.34%) and lighting (48.2% using fluorescent lamps)—key ECMs include upgrading to inverter ACs, setting temperature guidelines, using smart thermostats, and conducting HVAC maintenance. Switching to LED lighting, combined with motion sensors, timers, and daylight sensors, will enhance efficiency. These ECMs—including equipment upgrades, behavioral changes, and renewable integration—can reduce costs, improve efficiency, and advance the facility's sustainability goals.

5. Results and Discussion

The focus of the discussion centers on identifying and addressing the factors influencing energy consumption at a military facility, with a focus on the integration of relevant theories and the development of effective energy conservation strategies. The discussion covers three key areas: electricity consumption and price trends, energy audit findings, and recommended energy conservation initiatives.

5.1 Electricity Consumption and Price Trend

The study's findings on energy consumption trends at the military facility can be linked to theories in energy management and human behavior. According to Energy Consumption Behavior Theory, energy use is shaped not just by equipment but also by occupant routines and habits. Seasonal patterns—such as higher energy use during hot months due to air conditioning and drops during holidays—support this, reflecting both environmental and behavioral influences (Randazzo et al. 2019). The weak R^2 value (0.06714) from the regression model further shows that energy consumption is complex and not solely driven by temperature or systems. This aligns with studies highlighting that inefficient human actions, like leaving equipment running, contribute significantly to energy waste (Zhang et al. 2022). These insights suggest that effective conservation strategies must be tailored and adaptive. Optimizing systems like HVAC for seasonal use and integrating dynamic energy-saving technologies are essential (Yun et al. 2016). Additionally, energy awareness programs targeting occupant behavior can reduce unnecessary consumption, especially during off-peak times or periods of excessive cooling (Islam et al. 2022).

5.2 Energy Audit

The study's findings align with Energy Efficiency Theory, which targets high-consumption systems like cooling, lighting, and office equipment (Hafez et al. 2022). Cooling, mainly from air conditioners and fans, accounts for 63.34% of energy use, higher than India and Hong Kong but lower than the Middle East and Australia (Vakiloroaya et al. 2014), reflecting tropical climate demands. Lighting makes up 3.19%, with 48.2% still using inefficient fluorescent lamps, highlighting an easy upgrade to LEDs for energy savings. Other loads, such as kitchen appliances in high-occupancy areas like Building 3, Floor 1 (B3F1), contribute 24.49% of consumption and offer further efficiency opportunities. These results suggest focusing on cooling optimization, lighting upgrades, and managing high-power appliances to maximize energy savings. Understanding energy use by building and floor can guide targeted conservation efforts tailored to the facility's needs.

5.3 Energy Conservation Initiatives

Optimizing energy use by focusing on high-consumption areas and adopting advanced technologies can greatly improve efficiency and sustainability. Key steps include replacing outdated air conditioners with energy-efficient inverter systems, using smart thermostats, and setting clear temperature guidelines to reduce overcooling. Switching 48.2% of fluorescent lamps to LEDs, along with installing motion sensors, timers, and daylight sensors, cuts lighting energy use and peak demand. For office equipment, upgrading to energy-efficient devices and enforcing standards like Energy Star ensures lasting savings. Real-time energy monitoring and promoting an energy-conscious culture help identify waste and drive continuous improvement. Integrating renewables, especially solar panels, lowers costs and emissions. Together, these measures reduce the facility's carbon footprint and operational costs, supporting national energy goals and serving as a model for others.

6. Conclusion

The military facility's load profile shows that 63.34% of energy is used for cooling, followed by 24.49% for office equipment, 8.97% for other loads, and 3.19% for lighting. Energy use has steadily increased each year. Major inefficiencies were found in office equipment, mainly due to widespread desktop computer use, and in lighting, with 48.2% of fixtures still using outdated fluorescent lamps. Improving air conditioning practices, such as setting thermostats properly, could reduce waste. A proposed energy conservation policy includes replacing desktops with Mini-PCs, upgrading to LED lighting, installing smart thermostats, and promoting energy-saving behaviors through education. These measures could cut energy use and costs while supporting sustainability. The study recommends further research on behavioral factors and evaluating the real-world impact of these energy-saving strategies.

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Declaration of Conflict of Interest and Declaration of the use of AI

The authors confirm no conflicts of interest related to this manuscript. The authors confirm that no generative AI or AI technologies were used to develop ideas, though AI was employed to improve readability and language. Afterward, the text underwent thorough human editing and review to ensure accuracy and organization.

Authorship Contribution Statement

Jovie Latade authored the paper and conducted the preliminary energy audit and analysis. Jaypy Tenerife provided expert guidance throughout the study, drawing on his expertise in both quantitative and qualitative research methods. He also reviewed and edited the manuscript for publication. Ferdinand Milan served as the Technical Adviser, offering specialized expertise in electrical engineering, particularly in energy auditing and management

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Biographies

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Ferdinand Milan is a retired Program Chair of the Electrical Engineering Program at the Technological Institute of the Philippines, College of Engineering and Architecture. Currently serving as a lecturer in the same program.