SEESDGJ
Social, Ecology, Economy for Sustainable Development Goals Journal
SEESDGJ 1(1): 1–17
ISSN 3025-3942

Research

Energy auditing and electricity saving opportunities in BPOM laboratory of Manokwari

Asril Yanto Musa[1], Adelhard Beni Rehiara[2,*] and Jamius Bin Stepanus[3]
[1,2,3] Electrical Engineering Department, University of Papua, Indonesia
* Correspondence: a.rehiara@unipa.ac.id

Received Date: March 27, 2023 Revised Date: June 24, 2023 Accepted Date: July 18, 2023

Cite This Article:
Musa, A. Y., Rehiara, A. B. & Stepanus, J. B. (2023). Energy auditing and electricity saving opportunities in BPOM laboratory of Manokwari. *Social, Ecology, Economy for Sustainable Development Goals Journal, 1*(1), 1-17. https://doi.org/10.61511/seesdgj.v1i1.2023.22

Abstract
Energy auditing is a method of increasing energy efficiency. An energy audit is conducted to provide an overview of energy use, analyze the electrical system, and determine potential cost savings. The laboratory of the national food and drug agency (BPOM) in Manokwari has problems with electricity that often cause interruptions, power outages, and expensive bills. Therefore, this research was conducted to audit the energy used in the laboratory of the BPOM of Manokwari, with a building area of 1,484 m^2 and an installed power of 105 kVA. In this laboratory building, a diesel generator with capacity of 5 kVA is installed as a backup energy source and the generator has its own installation line. According to the calculation results before auditing, the energy consumption intensity (IKE) value obtained per month is 10.18 kWh. Energy audit through lighting loads and air conditioning systems. Then the recommendation through energy savings for lights and air conditioners is 274.12 kWh/month and 639.32 kWh/month, respectively. Therefore, total savings are 913.44 kWh/month, or about IDR 1,541,886.72/month.
Keywords: BPOM; energy auditing; energy consumption intensity; energy saving

1. Introduction

Electrical energy is an important factor in the operations of an industry, company, or other agency because it has a high degree of dependence on energy needs for its business operations. Most of the electrical energy producers in Indonesia use fossil fuel energy sources such as coal and oil. Fossil energy sources are non-renewable, causing energy reserves to decrease. One of the methods used to efficiently use electrical energy is energy conservation (Atiba et al., 2019).

The energy conservation must consider the comfort and function of energy use so that, if done correctly, it should not reduce the comfort and performance of reducing energy use. The company's efforts to be able to meet this increased level of production certainly increase the level of energy demand. Meeting the increasing demand for energy can be done by building new power plants as an additional source of energy, which requires a lot of money, time, and land to be able to meet the increasing demand from time to time, or companies can carry out energy conservation to improve energy efficiency (Bergero & Chiari, 2021). The Indonesian government has issued a policy regarding energy conservation in an effort to increase the efficiency of the energy used. This process ncludes an energy audit, which is a method for calculating the level of energy consumption of a building or buildings (Choir & Irawan, 2023).

An energy audit is an effort or activity to identify the type and amount of energy used in the operating parts of an industry, factory, or building and identify possible energy savings. The goal of an energy audit is to find ways to reduce energy consumption per unit of output and reduce operating costs (Abdurrachim et al., 2022). The research in energy auditing has been carried out in some buildings in Indonesia, such as in Gresik (Choir & Irawan, 2023), Banten (Anagra, 2020), Denpasar (Surya Ganesputra et al., 2022), and Semarang (Agus, 2007).

The energy audit aims to determine the energy use profile of a building and seek efforts to increase energy efficiency without reducing the comfort level of the building. An energy audit is a technique used to calculate the amount of energy consumed and identify ways to save it. Through an energy audit, we can find out patterns of energy distribution so that the part that consumes the most energy can be identified and can provide opportunities for energy savings if it is increased efficiently. The benefit that can be obtained from this energy audit research is to know the profile of energy use and energy saving opportunities in buildings to increase energy use efficiency, which causes energy use in these buildings to be more effective and efficient so as to save costs (Mulyadi & Yudha, 2019).

The national food and drug agency (BPOM) is a non-ministerial government agency responsible for drug and food control. As a government agency that continues to grow and experience an increase in quantity and quality. To be able to carry out its functions in public health, BPOM requires adequate facilities and infrastructure to support drug and food control (BPOM, 2017).

The increase in the number of employees and the development of facilities and infrastructure will result in increased utilization of electrical energy. Electrical problems arise because an increase in the use of electrical energy will result in increased bill costs. Another problem is that people are using more electricity, but the amount of electricity available isn't growing at the same rate. This will cause problems like blackouts, blown fuses, unstable power, and other things. In carrying out the audit process on buildings that are more than 11 years old, it is suspected that there has been a decrease in the efficiency of electrical equipment and an increase in energy consumption. If this is allowed, it will affect building safety and comfort, energy efficiency, and drug and food testing processes (Sönmez et al., 2022; Norhisham et al., 2022).

Another reason why research is done in the BPOM laboratory of Manokwari is because of the office environment and the electricity. There are often interruptions and power outages, so it is important to figure out how much electricity is being used to see if it is still being used efficiently and to find other ways to save money. The results of the energy audit can be used as a point of reference for the program to help the lab use electricity more efficiently.

2. Literature Review

Energy auditing conducts the process of assessing and evaluating energy usage and efficiency in a building, facility, or industrial process (Atiba et al., 2019). It involves a systematic analysis of energy consumption patterns, equipment performance, and energy conservation opportunities with the goal of identifying areas for improvement and cost savings (Adewale et al., 2018). Therefore, the objectives of energy auditing revolve around understanding energy usage (Chan et al., 2021), identifying inefficiencies (Bergero & Chiari, 2021), and providing recommendations to optimize energy consumption (Abdallah et al., 2021), reduce costs (Adewale et al., 2018), and improve environmental sustainability (Darshan et al., 2022a).

One of the key objectives of energy auditing is to determine the current energy consumption patterns and identify the major sources of energy usage within a facility. This involves gathering data on energy consumption from utility bills, sub-metering, and other measurement devices. In identifying energy consumption, energy auditors collect data on energy usage, including electricity, gas, water, and other energy sources, to establish a baseline of current consumption patterns. This data is typically obtained through utility bills, sub-metering, and on-site measurements (Chan et al., 2021; Merabtine et al., 2018; Nkwaze et al., 2019; Thakur et al., 2018).

Energy efficiency assestment is conducting to identify inefficiencies in buildings. Energy auditing aims to identify cost-saving opportunities by reducing energy consumption and improving energy efficiency. By implementing energy conservation measures, organizations can lower their energy bills and operational costs, resulting in significant cost savings over time (Bergero & Chiari, 2021; Čajčíková, 2016; Egwunatum & Akpokodje, 2019; Ghadi & Baniyounes, 2018).

The recommendations to optimize energy consumption are given after identifying energy conservation opportunities. Energy auditors look for opportunities to reduce energy consumption and improve efficiency. This may involve recommending equipment upgrades or replacements, operational changes, behavior modifications, or implementing energy-saving technologies such as LED lighting, energy management systems, or renewable energy systems. They also consider the financial viability and payback periods of these measures (Abdallah et al., 2021; Chisale & Mangani, 2021; Hassan et al., 2022; Muhammad et al., 2018),

In order to reduce the operational cost, it is needed to quantify the potential energy savings. Another objective of energy auditing is to estimate the potential energy savings that can be achieved by implementing the identified energy conservation measures. This helps organizations understand the financial and environmental benefits of energy efficiency improvements and prioritize the most impactful measures costs (Adewale et al., 2018; Assimakopoulos et al., 2018; Azizul et al., 2023; Hafiz et al., 2018).

Environmental Sustainability is the other objectives of energy auditing. Energy audits contribute to environmental sustainability by helping organizations reduce their carbon footprint and energy-related environmental impacts. By optimizing energy usage and promoting the use of renewable energy sources, energy audits support organizations in their efforts to achieve sustainability goals and comply with environmental regulations (Darshan et al., 2022a; Darshan et al., 2022b; Deo & Rajput, 2021; Kumar & Kumar, 2020).

3. Methods

2.1. Energy Conservation

Energy is a quantity that is conceptually related to the transformation, process, or change that occurs. This quantity is often associated with the transfer of a force or a change in temperature, making it possible to determine the units of joules which is the transfer of 1 Newton of force per meter as well as specific heat that is the energy required to raise the temperature by 1 degree per unit mass of material. For practical purposes, energy is often associated with the amount of fuel or electricity consumed (Darshan et al., 2022b). Energy is the ability to do work, which can be in the form of heat, light, mechanics, chemistry, or electromagnetics (Karmiathi & Putra, 2022).

Every substance actually contains a certain amount of energy in it, which is called internal energy. In a process, a substance can release some of its internal energy (in the combustion process) or store energy that comes from the environment (heating a substance). In conducting energy analysis, In a system, various calculation processes must be carried out involving the amount of material, substance, and energy (Bin Norhisham et al., 2022).

One of the most economical, easy, and safe ways to transmit energy is through electrical energy. At the power plant, primary energy resources such as fossil fuels (oil, natural gas, and coal), hydro, geothermal, and nuclear are converted into electrical energy. The synchronous generator converts the mechanical energy generated by the turbine shaft into three-phase electrical energy. Through step-up transformers, this electrical energy is sent through high-voltage transmission lines to load centers. The increase in voltage is intended to reduce the amount of current flowing through the transmission line. Thus, the high-voltage transmission line will carry a low current flow, which means reducing the heat loss that occurs, which is equal to I2 R. When the transmission line reaches the load center, the voltage is again lowered to medium voltage with a step-down transformer (Supriyo et al., 2022).

Conservation of energy resources is the management of energy resources that guarantees their utilization and supply while maintaining and increasing their quality, value, and diversity. Energy conservation is a systematic, planned, and integrated effort to preserve domestic energy resources and increase the efficiency of their usage. The implementation of energy conservation includes all stages of energy management (BAKOREN, 1994).

The country of Indonesia is rich in energy sources, but its utilization so far has not been balanced because it is too dependent on petroleum energy sources. Even though the energy source of petroleum today is the most important source of income and the supply is limited, Dependence on one source of energy, namely oil and its derivatives, cannot be allowed to continue because energy demand will continue to increase, both due to increased industry and population growth as well as an increase in people's welfare. Therefore, besides having to quickly develop energy sources from non-fossil fuels such as biomass, biogas, and so on, it must also try to be able to optimize the use of petroleum energy in a more precise, careful, economical, and efficient manner in the context of implementing an energy conservation program (Santika & Ruslan, 2022).

Reducing GHG emissions through energy savings is the policy step that is the easiest to implement and has the lowest cost, so that it can be widely applied to all levels of society. This energy policy is aimed at making the best use of available energy sources, and reducing dependence on petroleum, with the understanding that energy conservation should not become an obstacle to operational plans or development work (BAKOREN, 1994).

According to Indonesian standard (SNI) 03-6196-2000 concerning energy audit procedures in buildings, the definition of energy conservation is an effort to make energy use efficient for a need so that energy waste can be avoided. The success rate of efficient use of energy is strongly influenced by behavior, habits, discipline, and public awareness of the importance of saving energy. In addition to energy efficiency, another thing that can be done is to maintain and repair electrical equipment so that control over energy use can be monitored (Energy, 2007).

Policies regarding energy conservation are regulated in more detail in Energy Law No. 30 of 2007, article 25, which regulates energy conservation, namely (Energy, 2007):

- National Energy Conservation is the responsibility of the government, regional governments, authorities, and the community.
- Energy users and producers of energy-saving equipment that implement energy conservation are provided with facilities and/or incentives by the government and/or regional governments.
- Users of energy sources and energy users who do not carry out energy conservation are given disincentives by the government and/or regional governments.
- Further regulations regarding energy conservation will be set forth in a government regulation.

2.2. Energy Audits

Through an energy audit, one can find out the energy distribution pattern of a building so that the part that consumes the most energy can be identified. From the results of an energy audit, it can also be seen that there are large opportunities for potential energy savings if efficiency is increased (Abdurrachim et al., 2002).

Energy audit activities are periodic checking activities to ensure that energy is used appropriately, efficiently, and rationally. With an energy audit, indications of energy leaks can be tracked and traced, which can then be determined by corrective steps. The scope of energy activities includes:

- Identifying energy use, especially with regard to the type of energy, usage system, and energy costs
- observation of the level of energy use in accordance with the conditions of the type of use of the building.
- Know where the greatest potential for improving efficiency of use can be made.
- How to improve efficiency

Energy audits can be carried out at any time or according to a predetermined schedule. There are three types of energy audits:

A. Short energy audit

A brief energy audit is the initial process of an energy audit activity, which includes the collection of historical data on energy consumption, building area, installed capacity, building occupancy load, and visual observations. The difference between a brief energy audit and an initial energy audit is that a brief energy audit does not require measurements on electrical equipment. The results of a brief energy audit activity are a portrait of the building's energy use and recommendations for energy savings opportunities.

B. Initial Energy Audit

The purpose of the initial energy audit is to measure productivity and efficiency in energy use and identify possible energy savings. As part of the first steps of an energy audit, data about a building's energy use are collected using data that is already available. The data includes:

- The required building documentation is a building technical drawing according to the construction implementation, consisting of:
    - Sites, plans, and sections of the entire floor of the building.
    - Floor plan of the building's lighting installation.
    - A diagram of one electricity line, complete with an explanation of the use of electric power, the amount of connection to PLN's electricity, and the amount of reserve electricity for backup generators.
- payment of the building's monthly electricity bill for the last one year.
- Calculate the energy consumption intensity (IKE) of a building with the equation 1 (Choir & Irawan, 2023).

Energy Consumption Index (IKE) is a term used to determine the level of energy consumption in a building where measured monthly. The value of the energy consumption index is important to use as a benchmark for calculating potential energy savings that may be applied to each room or the entire building area. By comparing the building energy consumption index with national standards, it can be seen whether a room or the entire building is efficient or not in using energy. The IKE value was obtained from an initial audit of electrical energy at a facility of the agency concerned. The following is the formula for calculating the IKE (Choir & Irawan, 2023).

$$IKE = \frac{\sum Energy\ consumption\ (kWh)}{Building\ width\ (m^2)} \quad (1)$$

Each building has IKE standards according to the function of the building. The following is the standard IKE value of a building according to the Guidelines for Energy Conservation and Monitoring of the Environment of the Ministry of National Education (Regulation No. 13, 2012):

Table 1. IKE criteria for Buildings

Criteria	Full AC Building (kWh/m²/Month)	Building Without AC (kWh/m²/Month)
Very Efficient	<8.5	<3.4
Efficient	8,5-14	3.4-5.6
Efficient Enough	14-18.5	5.6-7.4
Wasteful	>18.5	>7.4

Electricity energy consumption intensity (IKE) is the division between electricity consumption in a certain period of time by a unit area of a building. Sectors that can be counted include:

- Specify the area of the building and the total area of the building (m^2).
- Building energy consumption per year (kWh/year)
- Energy consumption intensity (IKE) of buildings per year (kWh/m^2/year).
- building energy costs (Rp/kWh).

According to the results of research conducted by ASEAN-USAID in 1987, whose report was only issued in 1992, the target for the size of the energy consumption intensity (IKE) of electricity for Indonesia is as follows (Choir & Irawan, 2023):

Table 2. IKE Value of Asean-USAID 1992 Standards

No	Building Type	Average IKE (kWh/m²/tahun)
1	Office	240
2	Shopping center	330
3	Hotels / Apartments	300
4	Hospital	380

C. Detailed Energy Audit

A detailed energy audit is an energy audit that uses measuring instruments specially installed in the facility to determine the amount of energy consumed (Agus, 2007).

A detailed energy audit is carried out to determine the profile of the building's energy use so that it can be identified which energy-using equipment uses a large amount of energy. The activities carried out in a detailed energy audit are:

- Efficiency of Using Electric Loads

Steps taken to realize efficiency through the use of electrical loads include (Surya Ganesputra et al., 2022):

a. Indoor loads that can be turned off without disrupting room functions are an opportunity for energy savings; for example, turning off lights in the exterior daytime zone if natural lighting is sufficient and turning off electronic loads when not in use,
b. At cooling loads, in general, infiltration of outside air needs to be prevented because it will be difficult to control room conditions to the maximum limit within the

comfort zone. "On-off" systems are generally not recommended for energy conservation because they are less able to adjust the capacity of the air conditioning system to accommodate changes in load.

- Identification of Energy-Saving Opportunities

Identification of energy-saving opportunities is carried out in the following steps (Mulyadi & Yudha, 2019):

a. The results of data collection are then followed up by calculating the amount of IKE and compiling a building's energy use profile.
b. If the calculated IKE is equal to or less than the target IKE, then the detailed energy audit can be stopped or continued to obtain an even lower IKE.
c. If the results are higher than the IKE target, it means there is an opportunity to continue the next detailed energy audit process in order to obtain energy savings.

- Analysis of Energy-Saving Opportunities

When energy-saving opportunities have been identified, then it must be followed up with an analysis of energy-saving opportunities, namely by comparing the potential for energy-saving gains with the costs to be paid for implementing the recommended energy-saving. Analysis of energy-saving opportunities can also be carried out using a computer program that has been designed for that purpose and is recognized by the professional community. Energy savings in buildings must still pay attention to the comfort of occupants. Analysis of energy saving opportunities is carried out with efforts including (BAKOREN, 1994):

a. Reducing energy usage to a minimum (reducing installed and used power and operating hours);
b. improving equipment performance; and
c. Using a cheap energy source.

2.3. Energy usage in buildings

A. Light Intensity

This lighting is defined by the amount of irradiation in a work area that is needed in order to effectively carry out these activities. The Indonesian National Standard for light intensity is shown in Table 3 (Surya Ganesputra et al., 2022).

Table 3. Room Light Intensity Standards

No	Room Functions	Lighting Level (Lux)
1	Corridor	100
2	Canteen	200
3	Meeting Room	300
4	Library	300
5	Workspace/Office	300
6	Classroom	350
7	Laboratory	500
8	Drawing Room	750

Referring to Table 3, it shows the Light Intensity Standards at offices. In this study, the light intensity standards used were between 100 and 750 lux because the existing rooms at BPOM could consist of office and laboratory rooms.

B. Temperature and Humidity

The comfort of a room is influenced by temperature and humidity. Based on the Indonesian National Standard, to increase the potential for energy savings but not reduce comfort at work, room temperature is set at a minimum range of 24°C to a maximum of 26°C and with humidity between 50% and 70% (Surya Ganesputra et al., 2022).

2.4. Energy Auditing Procedures

Energy auditing can be performed by in-house energy managers or external energy consulting firms with expertise in energy efficiency and conservation. It is an essential step in developing effective energy management strategies, reducing energy costs, and meeting sustainability goals. Additionally, energy audits may be required by regulatory bodies or for compliance with energy efficiency standards or certification programs (Patel et al., 2023).

Energy auditing involves a systematic approach to assess energy consumption, identify inefficiencies, and recommend energy-saving measures. Here is a general outline of the steps involved in conducting an energy audit (MAUL, 2018):

- Pre-Audit Preparation
  Define the scope and objectives of the energy audit. Gather historical energy consumption data, utility bills, and other relevant information. Obtain building plans, equipment specifications, and operational data.
- Site Visit and Data Collection
  Conduct a walkthrough survey of the facility to observe energy-related systems, equipment, and operational practices. Collect detailed information on energy-consuming systems such as HVAC, lighting, motors, appliances, and processes. Record measurements of key parameters such as temperatures, flow rates, operating hours, and equipment ratings.
- Energy Consumption Analysis
  Analyze historical energy consumption data to understand consumption patterns, peak demand, and seasonal variations. Break down energy usage by system, equipment, and end-use to identify major energy consumers. Compare energy consumption against industry benchmarks or similar facilities to identify areas for improvement.
- Energy Performance Assessment
  Evaluate the efficiency and performance of energy-consuming systems and equipment. Review maintenance records, equipment age, and condition to identify potential efficiency losses. Perform measurements, inspections, and tests to assess energy losses, air leaks, insulation, and other efficiency-related factors.
- Identify Energy Conservation Opportunities
  Analyze the collected data and observations to identify energy-saving measures and opportunities. Consider low-cost or no-cost measures such as behavioral changes, optimizing equipment settings, and implementing preventive maintenance practices. Explore equipment upgrades, retrofit options, and technology improvements to achieve greater energy efficiency. Evaluate the feasibility, costs, and potential savings associated with each identified opportunity.
- Quantify Potential Savings and Financial Analysis
  Estimate the energy and cost savings achievable by implementing the identified measures. Conduct a financial analysis, considering factors such as implementation costs, payback period, return on investment (ROI), and lifecycle cost analysis. Prioritize measures based on their energy savings potential, financial viability, and alignment with organizational goals.
- Reporting and Recommendations
  Prepare a comprehensive report summarizing the audit findings, analysis, and recommendations. Present the report to stakeholders, including management, building owners, or relevant departments. Provide clear and actionable recommendations, including specific measures, implementation steps, and potential benefits. Suggest an energy management plan for continuous monitoring, measurement, and verification of energy savings.

It's important to note that the specific methods and procedures for energy auditing may vary depending on the type of facility, industry, or regulatory requirements. Engaging experienced energy auditors or energy management professionals can help ensure a comprehensive and accurate assessment of energy usage and potential savings.

4. Results and Discussion

3.1. Electrical System

The BPOM laboratory of Manokwari is classified as a P1 customer with a power contract >200 kVA and a tariff category of IDR 1,688/kWh. Payment for electricity consumption is made every month based on the amount of energy used (kWh) recorded on the installed kWh meter. The difference in usage between last month and the following month is the number of kWh that must be paid by consumers. From the historical data on the use of electrical energy in the BPOM laboratory of Manokwari, the number of kWh used in the years 2020–2021 can be calculated, along with the total cost that must be paid for the use of electrical energy in that period. The total kWh for the 2021 period is 227,240 kWh/year, and this is equivalent to IDR 383,581,120 with the average tariff charged by government electrical company (PLN) in the P1 tariff group (6.6–200 kVA), which is IDR 1,688/kWh.

The demand of electricity in the BPOM laboratory of Manokwari is supplied from the PLN distribution network. As a medium-voltage customer, this system is equipped with a 200 kVA step down transformer. With an installed power capacity of 105 kVA to serve the entire load in the BPOM laboratory of Manokwari. In accordance with its needs, most of the energy is used for lighting, room cooling, and to meet the needs of activities in the laboratory building at BPOM laboratory of Manokwari. In addition to the electricity source from PLN Manokwari, to maintain the availability of electricity when the power goes out, a genset unit with a capacity of 450 kVA is used as a backup energy source.

3.2. Loads Grouping

The procedure of auditing energy starts by identifying the loads in a building as given by (Karmiathi & Putra, 2022; Santika & Ruslan, 2022). The electrical load in the BPOM laboratory of Manokwari consists of lights, air conditioners, and several other electronic devices. According to the survey, the electrical equipment at the building is not used throughout the day; therefore, those equipments will be categorized into six groups, which can be seen in the following table.

Table 3. Load Group

Group	Operation/day (hour)	Load (kWh)
1	24	282.96
2	12	3.45
3	8	154.33
4	6	156.78
5	4	24.88
6	2	18.46
∑		640.86

Based on the calculation of electric power consumption above, the total power from load usage in one day for Monday to Friday is 640.86 kWh. On the other hand, there is a special load that is operated on Saturdays and Sundays with a total power of 286.41 kWh. Thus, energy and weekly and monthly costs can be shown in Table 4, with a basic rate of IDR 1,688/kWh and under assumption there are 4 weeks in a month.

Table 4. Enegy and Cost

Category	Energy (kWh)	Cost (IDR)
Weekly	3777.12	6,375,778.56
Monthly	15108.48	25,503,114.24

3.3. Energy Consumption

The consumption of electrical energy in the BPOM laboratory of Manokwari from January to December 2021 is rewritten from PLN, as shown in Table 5.

Table 5. Energy and payment

Month	Energy (kWh)	Payments (IDR)
Jan-21	18,022	26,046,382.99
Feb-21	16,724	24,171,162.96
Mar-21	16,112	23,287,005.87
Apr-21	19,926	28,797,091.91
May-21	19,288	27,875,373.90
Jun-21	19,261	27,836,366.96
Jul-21	19,148	27,673,115.97
Aug-21	17,986	25,994,373.88
Sep-21	18,426	29,801,158.93
Oct-21	18,691	31,462,563.86
Nov-21	20,745	35,574,067.99
Des-21	21,055	35,537,949.86
∑	225,384	344,056,615.08

From the data shown in Table 5, maximum energy consumption was reached in December 2021 at 21,055 kWh and minimum energy consumption was reached in March at 16,112 kWh. The lowest payment in March 2021 is IDR 23,287,005.87 while the highest electricity bill payment will be in December 2021, about IDR 35,537,949.86.

3.4. Initial Energy Audits

Energy consumption intensity (IKE) in buildings is a value or quantity that can be used as an indicator to measure the level of energy utilization in a building. The intensity of energy consumption in buildings is defined in terms of the amount of energy consumed per unit area of the building served by energy in kWh/m^2/month (Bergero & Chiari, 2021; Čajčíková, 2016; Egwunatum & Akpokodje, 2019; Ghadi & Baniyounes, 2018).

The building area of the BPOM laboratory of Manokwari is about 1,484 m^2. Meanwhile, the consumption of electrical energy in a month is 15,108.48 kWh. Thus, the calculation of IKE per month for the BPOM laboratory of Manokwari can be calculated as follows:

$$IKE = \frac{15{,}108.48}{1{,}484} = 10.18$$

From the results of the calculation of the IKE value above, based on the standard IKE value of a building according to the guidelines for energy conservation and supervision within the Ministry of National Education (Choir & Irawan, 2023), the IKE value of the BPOM laboratory of Manokwari, as an air-conditioned office or laboratory building, is included in the efficient category. Based on the IKE value in Table 1, then the value of 10.18 kWh/m^2/month is within the range of the efficient criteria.

Table 6. Energy and payment

Month	Energy (kWh)	IKE (kWh/m^2/month)
Jan-21	18,022	12.14
Feb-21	16,724	11.27
Mar-21	16,112	10.86
Apr-21	19,926	13.43
May-21	19,288	13,00
Jun-21	19,261	12.98
Jul-21	19,148	12.90
Aug-21	17,986	12.12
Sep-21	18,426	12.42
Oct-21	18,691	12.60
Nov-21	20,745	13.98
Des-21	21,055	14.19
Total	225,384	151.88
Average	18,782	12.66

Based on Table 5, the IKE calculation is taken from the electricity bill every month and the area of the BPOM laboratory of Manokwari, using Equation 1. In Table 6, the energy consumption from January to November is 225,384, while the total IKE is 151.88 kWh/m^2/year, which is within the standard in Table 2. Therefore, energy usage in BPOM can be categorized as the "efficient" category. However, the IKE was in the quite efficient category in December, which is already below the standards set by ASEAN and USAID (Karmiathi & Putra, 2022).

3.5. Energy Saving

The process of saving energy plays an important role in the electrical energy audit of a building. For this reason, it is necessary to take advantage of opportunities to achieve an efficient level of use in the future (Mulyadi & Yudha, 2019; Karmiathi & Putra, 2022; Surya Ganesputra et al., 2022). Based on observations in the field, energy saving opportunities in the laboratory building at Balai POM Manokwari can be done in 2 ways:

A. Lamp Replacement

In the BPOM laboratory of Manokwari, most of the lighting uses Neon type TL lamps with a power rating of 36 Watt and 2,600 lumens. To improve energy efficiency, it is better if in the future these lamps can be considered to replace the lighting using LED type TL lamps, because LED lamps can produce higher lumens with lower power.

From the power comparison table, namely between incandescent, CFL, and LED lamps, to produce 2,600 lumens with LED lamps, the electric power consumption is about 25–28 watts. Compared to CFL or Neon lamps, which require more power about 30 to 55 watts, the LED lamp is more efficient. The following is a table of lamp power consumption before and after replacement.

Table 7. Lamps power consumption

<table>
<tr><th rowspan="2">No</th><th rowspan="2">Amount (unit)</th><th rowspan="2">Operation (hour)</th><th colspan="3">Existing</th><th colspan="3">Recommendation</th></tr>
<tr><th>Lamp type (W)</th><th>Power (W)</th><th>Energy (Wh)</th><th>Lamp type (W)</th><th>Power (W)</th><th>Energy (Wh)</th></tr>
</table>

1	130	8	TL (36)	4680	37440	LED (26)	3380	27040
2	6	8	CFL (14)	84	672	LED (7)	42	336
3	16	12	CFL (18)	288	3456	LED (9)	144	1728
∑				5052	41568		3566	29104

Table 7 shows that the lamps will consume approximately 41568 Wh of energy in their current state; after replacement, the lamps will consume approximately 29104 Wh of energy per day. Therefore, about 12464 Wh per day or about 274208 Wh per day per month in 22 working days can be saved by the replacement of the lamps.

B. AC Scheduling

When using air conditioners (AC) in rooms, especially offices, there is a possibility of forgetting to turn the AC off after using the room so that the air conditioning system continues to work even though there are no activities being carried out in the room. Based on the results of interviews with employees in the laboratory building at Balai POM Manokwari, this sort of thing often happens in the office. Since the electric power used for air conditioners is quite large, if things like that continue to happen, of course there will be losses, both due to wastage of energy and electricity bill payment accounts in the BPOM laboratory of Manokwari. The data of the AC usage at the laboratory is provided in Table 8.

It can be seen in Table 8 that the amount of energy used by the AC will be multiplied by a duty cycle value of 50% or 0.5 because, in an AC machine, when the room temperature is reached as desired, the AC machine will automatically stop; in this condition, the air conditioner does not absorb electrical energy and will return to operation after the room temperature starts to rise again. So that the energy calculation is the amount of AC power multiplied by the number of hours of use and the value of the duty cycle.

Table 8. AC power consumption

No	AC Type	Amount (unit)	Operation (hour)	Existing		Recommendation	
				Operation (hour)	Energy (Wh)	Operation (hour)	Energy (Wh)
1	1 HP	2	745	24	17880	24	17880
2	2 HP	7	1490	24	125160	24	125160
3	1 HP	1	745	8	2980	6	2235
4	2 HP	19	1490	8	113240	6	84930
∑					259260		230205

Based on Table 8, there is an air conditioner that runs 24 hours a day because, in the laboratory, there are chemicals that need to be maintained at a certain temperature and humidity, so they cannot be turned off during operation. Savings on AC can be made in administrative offices by making an appeal to turn off the AC during office breaks and turn off the AC 30 minutes before breaks and before working time ends so that there is a reduction in AC operating hours by 2 hours, with details of 1 hours break and 1 hour rest. Thus, there is a reduction of 29055 Wh per day or 639210 Wh per month for 22 working days.

3.5. Benefits of Energy Saving

Based on the calculations made, energy savings have occurred through scenarios A of 274208 Wh/month and B of 639210 Wh/month, for a total savings of 913418 Wh/month or 913.44 kWh/month. With a basic electricity rate of IDR 1,688/kWh, the expenditure savings are IDR 1,541,886.72 per month. The findings are then used to make some adjustments to IKE in Table 6, as given in the following table.

Table 9. IKE Adjusments

Month	Energy (kWh)	IKE ($kWh/m^2/month$)
Jan-21	17,108.56	11.52867925
Feb-21	15,810.56	10.65401617
Mar-21	15,198.56	10.24161725
Apr-21	19,012.56	12.81169811
May-21	18,374.56	12.38177898
Jun-21	18,347.56	12.36358491
Jul-21	18,234.56	12.28743935
Aug-21	17,072.56	11.50442049
Sep-21	17,512.56	11.80091644
Oct-21	17,777.56	11.97948787
Nov-21	19,831.56	13.36358491
Des-21	20,141.56	13.57247978
Total	214,423	144.49
Average	17,869	12.04

In case of the scenarios is undertaking on the building consistently, some benefits can be taken i.e. 1). No month is out of the efficient category, 2) IKE total per year will be drop from 151.88 $kWh/m^2/year$ to be 144.49 $kWh/m^2/year$, and 3) Money saving about IDR 18,502,640.64/year can be collected as given in Table 9.

Based on the initial investigation of the electrical system at bPOM, it can be concluded that the availability of power in the laboratory is sufficient. Frequent electricity interruptions and power outages can occur because the power grid often shuts down at these locations. While the power outages that occur can be caused by the installation of mini circuit breakers that are no longer in accordance with the load characteristics existing in the rooms of the laboratory, the appropriate circuit breaker replacement also needs to be done.

Overall, energy use at BPOM is quite efficient. However, based on the data collected, in certain months there is still inefficient energy use. For this reason, the best recommendation that can be given to make energy use more efficient is to replace TL and CFL lamps with more efficient LED lamps. Besides that, the use of AC also needs to be maximized by turning off the AC about 30 minutes before break time. With the implementation of strict recommendations, electricity bills can be reduced.

5. Conclusions

Based on electricity consumption, which can be calculated, in a month, the BPOM laboratory of Manokwari consumes 15,108.48 kWh. From the BPOM laboratory of Manokwari building of 1,484 m^2, it can be determined that the Energy Consumption Intensity (IKE) value is 10.18 $kWh/m^2/month$, thus the building is included in the efficient category.

The results of energy audits, energy use, based on historical usage of electricity bills in the BPOM laboratory of Manokwari, are still categorized as efficient after several energy saving opportunities have been carried out, with an IKE value obtained each month of 10, 24 $kWh/m^2/month$. This result is not much different from the results of previous calculations and is still in the efficient category. And the yearly IKE value is 112.89 kWh/m^2/year.

Skenario A's Energy Saving Opportunity, the total number of lamps used is 41.568 kWh. After being replaced with LED lamps, the daily lamp savings were obtained, which were 29.104 kWh, and within a month the savings opportunities were obtained, which were 274.12 kWh. On the other hand, in scenario B, the total AC used is 259.26 kWh. After setting the use of air conditioning, the daily air conditioning savings were obtained, which were 29.06 kWh, and within a month the savings opportunities were obtained, which were 639.32 kWh. Therefore, the total savings are 913.44 kWh/month, or about IDR 1,541,886.72/month.

This paper only provides recommendations for steps that need to be taken to save energy and money. However, the effectiveness of these recommendations has not been discussed, so further research is needed to evaluate their implementation of these recommendations.

References

Abdallah, A. S. H., Makram, A., & Nayel, M. A. A. (2021). Energy audit and evaluation of indoor environment condition inside Assiut International Airport terminal building, Egypt. Ain Shams Engineering Journal, 12(3), 3241-3253. https://doi.org/10.1016/j.asej.2021.03.003

Abdurrachim, H., Pasek, D. A., & Sulaiman. (2002). Audit Energi, Modul 2, Energi Conservation Efficiency And Cost Saving Course. PT. Fiqry Jaya Mandiri.

Adewale, A. A., Adekitan, A. I., Idoko, O. J., Agbetuyi, F. A., & Samuel, I. A. (2018). Energy audit and optimal power supply for a commercial building in Nigeria. Cogent Engineering, 5(1), 1546658. https://doi.org/10.1080/23311916.2018.1546658

Agus, R. (2007). Audit Energi dan Analisis Peluang Penghematan Konsumsi Energi pada Sistem Pengkondisian Udara di Hotel Santika Premiere Semarang [Universitas Negeri Semarang]. http://lib.unnes.ac.id/id/eprint/1209

Anagra, F. (2020). Audit Energi dan Analisis Peluang Penghematan Konsumsi Energi Listrik di Unit 1 PLTU Banten 3 Lontar. Jurnal Teknologi Elektro, 11(1), 32-38. https://doi.org/10.22441/jte.2020.v11i1.005

Assimakopoulos, M. N., De Masi, R. F., Papadaki, D., Ruggiero, S., & Vanoli, G. P. (2018). Energy audit and performance optimization of a residential university building in heating dominated climates of Italian backcountry. Tema: Technology, Engineering, Materials and Architecture, 4(3), 19-33. https://www.researchgate.net/profile/Dimitra-Papadaki-2/publication/330082068_Energy_audit_and_performance_optimization_of_a_residential_university_building_in_heating_dominated_climates_of_Italian_backcountry/links/5c2c87da299bf12be3a76b58/Energy-audit-and-performance-optimization-of-a-residential-university-building-in-heating-dominated-climates-of-Italian-backcountry.pdf

Atiba, O. E., Efemwenkiekie, U. K., Olatunji, R. O., Ohunakin, O. S., Adelekan, D. S., & Oyeleke, O. A. (2019, December). Walk-through energy audit of an institutional building. *In Journal of Physics: Conference Series* (Vol. 1378, No. 3, p. 032051). IOP Publishing. https://doi.org/10.1088/1742-6596/1378/3/032051

Azizul, M. H., Salim, F., & Adnan, S. Z. S. (2023, May). Energy audit exercise at commercial building. A case study and analysis of the 10 years old office building located at Cyberjaya, Selangor Darul Ehsan. In *AIP Conference Proceedings* (Vol. 2530, No. 1). AIP Publishing. https://doi.org/10.1063/5.0129347

BAKOREN. (1994). Buku Pedoman tentang Cara-Cara Melaksanakan Konservasi Energi dan Pengawasannya. Direktorat Jenderal Listrik dan Pengembangan Energi Departemen

Pertambangan dan Energi. https://pustaka.pu.go.id/biblio/buku-pedoman-tentang-cara-cara-melaksanakan-konservasi-energi-dan-pengawasannya/JKLJJ

Bergero, S., & Chiari, A. (2021, November). Validation and calibration of dynamic energy models: energy audit of a public building. In *Journal of Physics: Conference Series* (Vol. 2116, No. 1, p. 012107). IOP Publishing. https://doi.org/10.1088/1742-6596/2116/1/012107

Bin Norhisham, M. A. M., Bin Razali, M. A., Bin Manshoor, B., Bin Mohd Amin, M., & Bin Abdul Hadi, N. (2022). Preliminary Energy Audit for 27 Years Old Building at Kemaman Terengganu, Malaysia. *Bukhari and Bin Mohd Amin, Makeen and Bin Abdul Hadi, Norhadiman, Preliminary Energy Audit for, 27*. https://dx.doi.org/10.2139/ssrn.4020933

BPOM, Pub. L. No. 80 / 2017, 80 / 2017 24 (2017).

ČAJČÍKOVÁ, J. (2016). Energetický audit polyfunkčního objektu. https://core.ac.uk/download/pdf/44396257.pdf

Chan, M., Arriola, E., Cuevas, R., & Reyes, J. G. (2021). Development of an Energy Audit Working Procedure for an Academic University Office Building in the Philippines. *ASEAN Eng. J*, *11*, 88-95. https://doi.org/10.11113/aej.v11.16669

Chisale, S. W., & Mangani, P. (2021). Energy audit and feasibility of solar PV energy system: Case of a commercial building. *Journal of Energy*, *2021*, 1-9. https://doi.org/10.1155/2021/5544664

Choir, Y. N., & Irawan, D. (2023). Audit Energi Listrik Gedung Baru Universitas Muhammadiyah Gresik. *Power Elektronik: Jurnal Orang Elektro*, *12*(1), 8-11. http://dx.doi.org/10.30591/polektro.v12i1.4699

Darshan, A., Girdhar, N., Bhojwani, R., Rastogi, K., Angalaeswari, S., Natrayan, L., & Paramasivam, P. (2022a). Energy audit of a residential building to reduce energy cost and carbon footprint for sustainable development with renewable energy sources. *Advances in Civil Engineering*, *2022*. https://doi.org/10.1155/2022/4400874

Darshan, A., Girdhar, N., Bhojwani, R., Rastogi, K., Angalaeswari, S., Natrayan, L., & Paramasivam, P. (2022b). Energy audit of a residential building to reduce energy cost and carbon footprint for sustainable development with renewable energy sources. *Advances in Civil Engineering*, *2022*. https://doi.org/10.1155/2022/4400874

Deo, A., & Rajput, S. K. (2021). Improving Energy Efficiency and Reducing CO 2 Emission of Institutional Building: An Energy Audit Case Study. In *Latest Trends in Renewable Energy Technologies: Select Proceedings of NCRESE 2020* (pp. 137-146). Springer Singapore. https://doi.org/10.1007/978-981-16-1186-5_11

Energy, Pub. L. No. Law No. 30 2007, No.30/2007 (2007).

Egwunatum, S. I., & Akpokodje, O. I. (2019). Economic aspects of building Energy audit. In *Zero and Net Zero Energy*. IntechOpen. https://books.google.com/books?hl=en&lr=&id=UKf8DwAAQBAJ&oi=fnd&pg=PA119&dq=audit+energy+building+audit+energy+building&ots=9XpYostOYp&sig=8-extAxqpLbNx5I8tM2F8YDGagg

Ghadi, Y. Y., & Baniyounes, A. M. (2018). Energy audit and analysis of an institutional building under subtropical climate. *International Journal of Electrical and Computer Engineering (IJECE)*, *8*(2), 845-852. https://www.academia.edu/download/63959248/24_29Dec17_7Non_9701-12056-3-ED20200718-1517-loecba.pdf

Hafiz, M. I. M., Sulaima, M. F., Razak, J. A., Tahir, M. M., Bohari, Z. H., Nor, M. K. M., ... & Omar, S. R. (2018). Energy audit in public higher learning institution: A case for chancellery building. *Proceedings of Mechanical Engineering Research Day*, *2017*, 165-166. https://books.google.com/books?hl=en&lr=&id=MsZaDwAAQBAJ&oi=fnd&pg=PA165

&dq=audit+energy+building+audit+energy+building&ots=NaTYKcQUvl&sig=6ANWvVpWj9ZOqwtTdiJJn6b1UJ0

Hassan, M. T., Abdelgeliel, M., & Hamad, M. S. (2022, September). ENERGY audit and management on residential and commercial building: A case study. In *2022 11th International Conference on Renewable Energy Research and Application (ICRERA)* (pp. 424-429). IEEE. https://doi.org/10.1109/ICRERA55966.2022.9922771

Karmiathi, N. M., & Putra, I. K. A. (2022). Technical analysis of power factor improvement using ETAP 12.6 at Regent Resort & Holiday Inn Canggu. *Matrix: Jurnal Manajemen Teknologi dan Informatika*, *12*(1), 38-50.https://doi.org/10.31940/matrix.v12i1.38-50

Kumar, A., & Kumar, V. (2020). Energy Audit of an Engineering College Building for Energy Cost Reduction and Power Conservation. *Int. J. Recent Trends Eng. Res*, *6*, 11-14. https://scholar.archive.org/work/wcfkjei7fzbpheidv7q7kjlxge/access/wayback/https://www.ijrter.com/papers/volume-6/issue-6/energy-audit-of-an-engineering-college-building-for-energy-cost-reduction-power-conservation-2.pdf

Maul, M. I. (2018). *Audit Energi Dan Perancangan Building Energy Management System Untuk Ruang E5 Dan E6 Departemen Teknik Elektro Dan Teknologi Informasi Universitas Gadjah Mada* (Doctoral Dissertation, Universitas Gadjah Mada). http://etd.repository.ugm.ac.id/penelitian/detail/164693

Merabtine, A., Maalouf, C., Hawila, A. A. W., Martaj, N., & Polidori, G. (2018). Building energy audit, thermal comfort, and IAQ assessment of a school building: A case study. *Building and Environment*, *145*, 62-76. https://doi.org/10.1016/j.buildenv.2018.09.015

Muhammad, J. Y. U., Adamu, A. A., Alhaji, A. M. I., & Ali, Y. Y. (2018). Energy Audit and Efficiency of a Complex Building: A Comprehensive Review. *Engineering Science*, *3*(4), 36-41. https://doi.org/10.11648/j.es.20180304.11

Mulyadi, A. D., & Yudha, D. A. (2019). Audit energi listrik pada gedung analis kesehatan Bandung. Jurnal Teknik Energi, 9(1), 79-86. https://doi.org/10.35313/energi.v9i1.1649

Nkwaze, D. C., Aruwajoye, J. B., Aderoju, P. A., Shitta, M. B., Ogedengbe, E. O., & Odumuyiwa, V. T. (2019). Development of a Renewable Energy Sizing Calculator for Building Energy Audit and Appliance'Performance Assessment. In *AIAA Propulsion and Energy 2019 Forum* (p. 4407). https://doi.org/10.2514/6.2019-4407

Norhisham, M. A. M., Razali, M. A., Amin, M. M., & Hadi, N. A. (2022). Review on Preliminary Energy Audit for 27 Years Old Building at Kemaman Terengganu, Malaysia. *Journal of Complex Flow*, *4*(1), 8-11. http://fazpublishing.com/jcf/index.php/jcf/article/view/43

Patel, V. B., Padhya, H. J., & Mevawala, J. P. (2023). Introduction to Green Building. *Journal of Sustainable Construction Engineering and Project Management*, *6*(1), 15-18. http://hbrppublication.com/OJS/index.php/JSCEPM/article/view/3108

Regulation No. 13, Pub. L. No. No. 13/2012 (2012). https://peraturan.bpk.go.id/Home/Details/142561/permen-esdm-no-13-tahun-2012

Santika, M. E., & Ruslan, W. (2022). CASE STUDY OF ENERGY AUDIT IN CV MANNA ANUGERAH SEJAHTERA BUILDING (INDONESIA). https://ijaer.com/admin/upload/01%20Maria%20Enggar%2001186.pdf

Supriyo, S., Margana, M., Purwati, W., Suwarti, S., & Mulyono, M. (2022). Energy Audit of Flouresen Lights at School Building C III Floor Politeknik Negeri Semarang. *Eksergi*, *18*(3), 196-200. http://dx.doi.org/10.32497/eksergi.v18i3.3890

Surya Ganesputra, I., Janardana, l., & Budiastra, I. (2022). STUDI MANAJEMEN ENERGI LISTRIK DAN ANALISIS PELUANG PENGHEMATAN KONSUMSI ENERGI LISTRIK PADA GEDUNG PENGADILAN NEGERI DENPASAR. Jurnal SPEKTRUM, 9(2), 120-127. https://doi.org/10.24843/SPEKTRUM.2022.v09.i02.p14

Sönmez, T., Neşe, S. V., Uslu, B. Ç., Akpolat, A. N., & Dursun, E. (2022). Energy saving potential and energy audit of a faculty building at Marmara University in Türkiye. *Turkish Journal of Electromechanics and Energy*, *7*(2). https://sloi.org/urn:sl:tjoee72236

Thakur, N., Prasath Kumar, V. R., & Balasubramanian, M. (2018). Comparative Energy Audit of Building Models Using BIM for the Sustainable Development. *J. Adv. Res. Dyn. Control Syst*, *10*, 986-992.