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Electrical Energy Audit to Achieve Energy Use Efficiency in the Engineering Faculty Building, Hasanuddin University (Unhas) Gowa

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***Abstract*— Energy is a vital need in every aspect of life, increasing population causes energy demand to increase. Energy use in buildings such as offices and universities must be done effectively and efficiently, so as to minimize excessively large electricity bill payments. Therefore, it is necessary to carry out an energy audit to determine the Energy Consumption Intensity (IKE) value in order to obtain an IKE value that meets standards so that effective and efficient energy use is achieved. Energy audit is a technique used to obtain efficiency and calculate the amount of energy consumption in a building using certain methods. This research was conducted in the Electrical and Civil Building at Engineering Faculty, Universitas Hasanuddin. The aim of the research is to determine the value of energy consumption intensity through an energy audit process, as well as finding solutions for saving electrical energy. Based on the research results, it is known that in the initial energy audit, the IKE value produced in the Electrical Building and Civil Building is 233,436 kWh/m²/year. The IKE value is classified as "Wasteful" criteria. Then at the final energy audit stage, the IKE value produced in the Electrical building is 181.19 kWh/m²/Year, and in the Civil building is 175.75 kWh/m²/Year. The IKE value is classified as "Quite Wasteful" criteria. Energy savings can be done in various ways, such as; turning off electronic devices when not in use, changing the type of LED lights, arranging a good room layout, carrying out routine maintenance on the AC, etc.**

Keywords*— *Energy Audit; Energy Consumption Intensity; IKE Value; Energy Saving

I. INTRODUCTION

Electrical energy is a form of energy that most needed in everyday life. Projection for electrical energy load is increasing through out the years. However, on the other hand, the energy crisis and basic electricity tariff costs tend to risea and require us to make efforts to save electrical energy [1].

Energy conservation is an important way to overcome energy problems, because the results are usefull in a relatively short time [2].

An energy audit is the first step in implementing an energy conservation program. Energy audits can provide an overview of energy use, energy distribution, energy costs and energy conversion which can ultimately be used to identify sources of energy waste [3].

Engineering Faculty of Unversitas Hasanuddin has has 9 main buildings, and its load consist of lighting installations; air conditioning; computers; electrical machines; and others. The energy audit process is to calculate the level of energy use of a building, then the results are compared with energy use standards as a consideration for finding solutions to save energy use if the level of energy use exceeds existing standards.

The large amount of electrical energy used in buildings at Engineering Faculty is the reason for the author to conduct this research. Therefore the research aims to determine the Energy Consumption Intensity (IKE) value in order to obtain an IKE value that meets standards so that effective and efficient energy use is achieved.

II. LITERATURE REVIEW

A. Audit Energy

Energy audit is a technique used to obtain efficiency and to calculate the amount of energy consumption in a building using certain methods. Data analysis aims to obtain electrical energy efficiency and it is hoped that continuous research can identify electrical energy efficiency [4].

B. Energy Consumption Intensity

Energy Consumption Intensity (IKE) is a term used to express the amount of electrical energy used in a building. If the IKE value of a building has been obtained, the energy saving step could be taken and the solution could be achieved [5].

IKE can be expressed in units of kWH/m² per year and has been implemented in various countries (ASEAN, APEC). Based on research by ASEAN-USAID in 1987 which was only released in 1992, the magnitude of the electricity IKE for Indonesia itself can be seen in the following details [6]:

- IKE in offices : 240 kWh/m² per year.
- IKE at the shopping center : 330 kWh/m² per year.
- IKE on hotels / apartments : 300 kWh/m² per year.
- IKE at the hospital : 380 kWh/m² per year.

The calculation of the IKE value is as follows:

$$IKE = \frac{kWh\ Total}{Occ\ Rate\ \times Area\ Room}$$

The IKE value of a building based on the Guidelines for the Implementation of Energy Conservation and Supervision in the Environment of the Department of National Education can be classified into two criteria, namely the IKE of non-air-conditioned buildings and the IKE of air-conditioned buildings [7].

TABLE I. IKE CRITERION FOR AIR-CONDITIONED AND NON-AIR-CONDITIONED BUILDING

Criterion	Air-Conditioned Building (kWh/m^2/year)	Non-Air-Conditioned Building (kWh/m^2/year)
Very Efficient	50 – 95	-
Efficient	95 – 145	10 – 20
Quite Efficient	145 – 175	20 – 30
Quite Wasteful	175 – 230	-
Wasteful	230 – 285	30 – 40
Very Wasteful	285 – 450	40 – 50

C. *Energy Audit Stages*

The energy audit stages consist of two stages, namely initial energy audit and detailed energy audit. Carrying out the initial energy audit requires data on energy payment bills for the building and the building area. This can be done by the building manager. The results of calculating the IKE value can then be submitted to the owner or manager of the building as consideration, input or information in determining the new IKE [8].

- Initial Energy Audit

  The initial energy audit aims to measure the efficiency of energy use and identify whether there is a possibility of making energy savings [9].

  At this initial energy audit stage, building energy data is collected and compiled using available data. An initial energy audit can be carried out by the owner/manager of the building concerned based on bill data for energy payments incurred and the area of the building [3].

- Detailed Energy Audit

  A detailed energy audit carried out at the initial energy audit stage provides an overview of the IKE value which is greater than the target. A detailed energy audit also aims to find out the profile of energy use in the building, and also to find out and identify any electrical equipment that uses quite a lot of energy.

  Then, in energy research, the activities carried out are researching and collecting a number of inputs that can influence the amount of energy in the building, and from the results of the research and measurements a profile of energy use in the building is then created [10].

  The measurement results are then followed up by calculating the IKE value and preparing a profile of energy use in the building. Then the IKE calculation results are compared with the IKE standard or target.

  If the results are the same or even less than the standard thus the detailed energy audit activity can be stopped. However, if the results are greater than the standard IKE then there may be an opportunity to continue the detailed energy audit process to obtain energy savings results.

D. *Analysis of Energy Saving Opportunities*

If energy saving opportunities (PHE) have been identified, the next step needs to be followed up with an analysis of energy saving opportunities. The method is to compare the potential energy savings gains with the costs that must be paid for implementing the recommended energy saving plan without reducing occupant amenitied [11].

The efforts that can be made to analyze energy saving opportunities is given on the following activities [12]:

1) Reduce as little as possible energy use.
2) Improve equipment performance.
3) Use of cheap energy sources.

E. *Lighting Level*

Lighting level is the amount of light present in a room or certain area. This parameter is measured in lux units (lm/m²) which describes the intensity of light on a surface. The measuring instrument for measuring lighting levels is a Luxmeter [13].

Good lighting is useful for energy conservation and the well-being of room occupants by creating visual comfort. Meanwhile, poor lighting can cause health problems, especially eye problems.

Therefore, lighting design must consider and take into account the specific needs of the room and its use in order to create an optimal environment. Achieving good lighting levels can be obtained by utilizing natural lighting and artificial lighting [14].

It is recommended that the minimum good average lighting level in a particular room or area must be more than the standard lighting level that has been regulated. Lighting standards vary depending on the type of activity carried out in the room or area. The following is a lighting index table according to Indonesian National Standard number 6197 of 2020 concerning energy conservation in lighting systems [15].

TABLE II. STANDARD LIGHTING LEVEL BY ROOM OR UNIT

Room Function	Minimum Average of Lightning Level (Lux)
Office Room	
Reception	300
Director Room	350
Working Room	350
Commuter Room	150
Meeting Room	300
Drawing Room	750
Archive Building	150

Room Function	Minimum Average of Lightning Level (Lux)
Emergency Stairs Room	100
Education Building	
Class Room	350
Library Reading Room	350
Laboratory	500
Computer Laboratory	500
Laboratory Room	300
Teacher Room	300
Auditorium	300
Lobby	100
Stairs	100
Canteen	200

III. RESEARCH METHOD

A. Research Location and Time

The research was carried out in the Electrical Engineering and Civil Engineering Building at Engineering Faculty Universitas Hasanuddin, located on Jl. Malino Axis Km. 6, Romang Lompoa Village, Bontomarannu District, Gowa Regency. The time for carrying out this research starts from June 2023 to December 2023.

B. Research Tools and Materials

This research requires materials such as name plate data on installed loads, single line diagram building data, building area data, and building occupancy level data.

The tools used in this research include a lux meter to measure light intensity, a clamp meter to measure current, resistance and electrical voltage, one MSI GF63 laptop unit with an Intel Core i5 9300H 64 bit RAM 8 GB, and also Microsoft Excel software to analysis the data.

C. Data Collection Techniques

The data collection techniques used as methods to be carried out in this research include:

- Primary Data

  In this research, the primary data is data on building occupancy levels, as well as data on the use of electrical loads installed in the building.

- Secondary Data

  In this research, secondary data is single line diagram building data, building electricity bill data, building area data, name plate data on installed loads, and electricity quality data on certain electrical loads.

  The data that will be used in this research can be obtained using various methods, namely by carrying out observation techniques, interview techniques, and conducting literature studies related to this research.

D. Research Flow Diagram

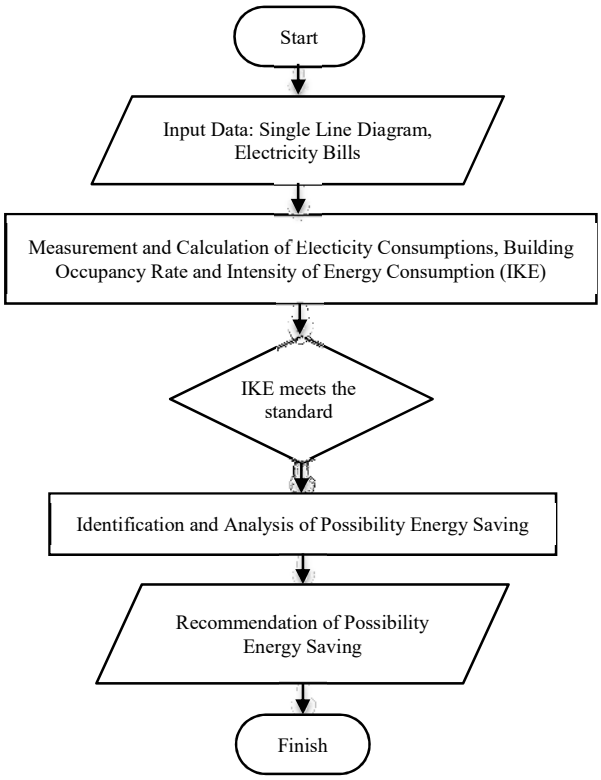

Fig. 1. Reseach Flow Diagram

IV. RESULTS AND DISCUSSION

A. Initial Energy Audit

The energy audit process begins by looking for the Energy Consumption Intensity (IKE) value in the Engineering Faculty, Universitas Hasanuddin

Data collection will be carried out in the Electrical Building and Civil Building as a comparison. This data collection utilizes historical data on energy use in each building, data on the building area and campus area which includes:

1) Building documentation
2) Monthly electricity bill payments for the last year
3) Building occupancy rate

- Building Area and Building Occupancy Level

  Occupancy rate is the percentage of space rented or used to the total space available. The occupancy rate for the Electrical & Civil building was obtained from the percentage between the number of rooms measured at 189 rooms and the total number of rooms at 313 rooms. So, the building occupancy rate is 60%.

TABLE III. DETAILS OF TOTAL AREA PER FLOOR

Building	Room Layout	Total Area (m^2)
Electrical	Ground Floor	2,509.74
	1st Floor	2,244.88
	2nd Floor	1,753.44
	3rd Floor	1,799.95
	Total	8,308.01
Civil	Ground Floor	1,910.04
	1st Floor	1,369.20
	2nd Floor	1,950.56
	3rd Floor	1,926.20
	Total	7,156.00

- Electrical Building & Civil Building Electricity Account

  The electricity profile of the Faculty of Engineering, Unhas Gowa, is that it has an S-3 electricity tariff category with an installed power of 1,110,000 VA. Maximum conditions (peak load) occur at 08.00 – 16.00 WITA. Electricity bills and electricity usage can be seen in (Table IV).

TABLE IV. ELECTRICITY BILLS DATA OF ENGINEERING FACULTY

Year	Month	Billing (IDR)	kWh/Month
2022	July	134,685,520	172,880
	August	120,355,960	154,112
	September	147,380,440	189,584
	October	160,392,880	206,912
	November	164,538,280	212,192
	December	161,398,360	208,416
2023	July	138,377,000	177,792
	August	107,802,160	138,192
	September	109,031,080	140,064
	October	154,330,600	199,328
	November	107,984,440	139,056
	December	174,934,120	227,392
TOTAL		1,681,210,840	2,165,920

- Initial Energy Audit IKE Calculation

  In the electricity bill data from the Faculty of Engineering, Hasanuddin University for 1 year, it is known that the total kWh per year is 2,165,920 kWh/year. Then the total area of the Electrical & Civil building with a building occupancy rate of 60% is a total of 15,464.01 m². The calculation of Energy Consumption Intensity (IKE) value is found with the amount of 233.43 kWh/m^2/year.

  According to the Guidelines for the Implementation of Energy Conservation and Supervision in the Environment of the Department of National Education, an air-conditioned building has an Energy Consumption Intensity (IKE) value as calculated has the **"Wasteful"** criteria because it is in the range of 230 – 285 kWh/m²/year.

  An energy audit needs to be considered in order to determine corrective steps so that energy waste can be avoided. To find out the details of energy use more clearly, it is necessary to carry out a detailed energy audit.

B. Detailed Energy Audit

A detailed energy audit is carried out if the initial energy audit stage provides an overview of the electricity IKE value is greater than the target. A detailed energy audit also aims to find out the profile of energy use in the building, and also to find out and identify any electrical equipment that uses quite a lot of energy. Detailed energy audit activities include detailed measurements of lighting, air conditioning, and electronic equipment.

- Calculation Results of Electrical Energy Consumption on Use of Equipment in the Electrical Building

  Table V shows the calculation of electrical energy consumption, which is in the air conditioning system*Cassette* consumes the largest electrical energy, namely 540,708.48 kWh/year, and using motor loads consumes the smallest electrical energy, namely 15,724.80 kWh/year.

TABLE V. ENERGY CONSUMPTION IN ELECTRICAL BUILDING

Equipment	Energy Consumption (kWh/year)
Lighting System	104,261.66
Air Conditioning System (Cassette)	540,708.48
Air Conditioning System (Split)	199,337.74
Electrinics	43,192.31
Motor Loads	15,724.80
TOTAL	903,224.99

- IKE Calculation Detailed Energy Audit of Electrical Building

  It is known that the total kWh of energy consumption used in the Electrical Building based on details of the

equipment used such as lighting loads, Cassette air conditioning systems, split air conditioning systems, electronic equipment and motor loads is 903,224.99 kWh/year. Then the total area of the Electrical Building with the building occupancy rate is assumed to be 60%, namely a total of 8308.01 m². The calculation of Energy Consumption Intensity (IKE) value is found with the amount of 181.19 kWh/m²/year.

Accordance with the Guidelines for the Implementation of Energy Conservation and Supervision in the Environment of the Department of National Education in an air-conditioned building (Table 1) the Electrical building has an Energy Consumption Intensity (IKE) value with the criteria**"Quite Wasteful"** because it is in the range of 175 – 230 kWh/m²/year. So it can be concluded that:

1) An energy audit should be considered to determine possible efficiency improvements.
2) Building design and maintenance and operation of buildings do not yet consider energy conservation.

- Calculation Results of Electrical Energy Consumption on Use of Equipment in Civil Buildings

Table VI gives the calculation of electrical energy consumption, which is in the air conditioning system *Cassette* consumes the largest electrical energy of 460,309.2 kWh/year, and using motor loads consumes the smallest electrical energy of 15,724.80 kWh/year.

TABLE VI. ENERGY CONSUMPTION IN CIVIL BUILDING

Equipment	Energy Consumption (kWh/year)
Lighting System	50,808.06
Air Conditioning System (Cassette)	460,309.20
Air Conditioning System (Split)	156,313.25
Electrinics	66,438.53
Motor Loads	15,724.80
TOTAL	754,593.84

- IKE Calculation Detailed Energy Audit of Civil Buildings

It is known that the total kWh of energy consumption used in Civil Buildings based on details of the equipment used such as lighting loads, Cassette air conditioning systems, split air conditioning systems, electronic equipment and motor loads is 754,593.84 kWh/year. Then the total area of the Civil Building with the building occupancy rate is assumed to be 60%, namely a total of 7156 m². The calculation of Energy Consumption Intensity (IKE) value is found with the amount of 175.75 kWh/m²/year.

Accordance with the Guidelines for the Implementation of Energy Conservation and Supervision in the Environment of the Department of National Education in an air-conditioned building (Table 1) civil buildings have an Energy Consumption Intensity (IKE) value with the criteria of **"Quite Wasteful"** because it is in the range of 175 – 230 kWh/m²/year. So it can be concluded that:

1) An energy audit should be considered to determine possible efficiency improvements.
2) Building design and maintenance and operation of buildings do not yet consider energy conservation.

C. Light Intensity Measurement

Light intensity measurements were carried out in the Electrical Building & Civil Building in November 2023. Measurements were carried out during the day when lecture activities were active, namely around 09.00-15.00 WITA. The following are the results of light intensity measurements in the Electrical building (Figure 2) and the Civil building (Figure 3). The light intensity average os 258.9 lux in Electical Building and 254.1 lux in Civil Building,

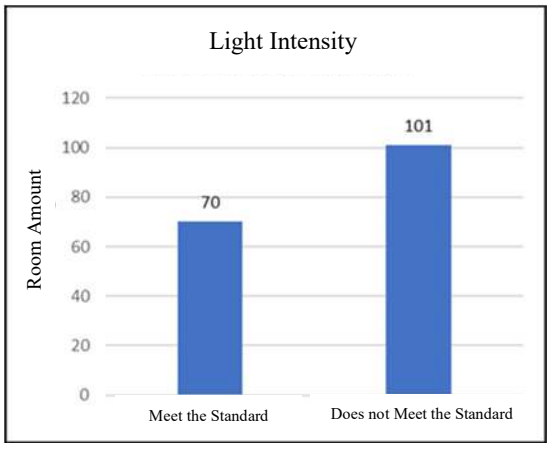

Fig. 2. Measurement of Light Intensity on Electrical Building

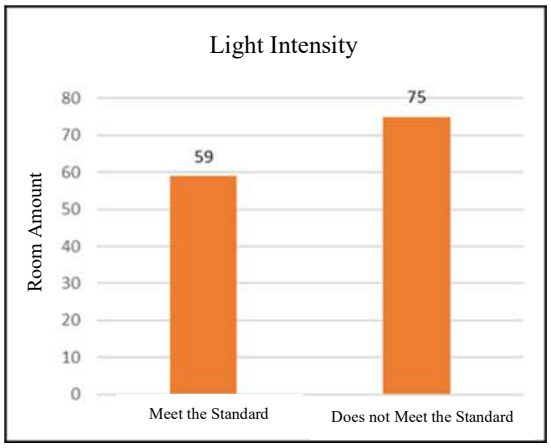

Fig. 3. Measurement of Light Intensity on Electrical Building

D. Analysis of Energy Saving Opportunities (PHE)

- PHE Analysis of Lighting Systems

  It can be seen that the electrical and civil buildings use lighting system equipment installed of 36 Watt fluorescent lamps and 18 Watt PLC lamps (Philips).

  The use of fluorescent lamps (Fluorescent) and PLC lamps (Philips) can be replaced with LED lamps which are more efficient and have a longer lifespan. Apart from that, it can produce brighter light but consumes less electrical power.

- PHE Analysis in Air Conditioning Systems

  It can be seen in electrical buildings and civil buildings that the largest use of electrical energy is the air conditioning system. Steps to increase the efficiency of energy use include:

  1) Perform routine maintenance on the AC,
  2) Set the AC room temperature wisely,
  3) Use window coverings and room ventilation covers,
  4) Turn off the AC when the room is not in use,
  5) Using or replacing a type of refrigerant that saves more electricity, such as refrigerant MC-22 (MUSICOOL); And
  6) Choose an AC that has a high level of energy efficiency.

- PHE Analysis of Electronic Equipment

  Steps in using electronic equipment to increase energy use efficiency include:

  1) Turn off the device when not in use;
  2) Use a power strip with a switch;
  3) Reduce screen brightness on electronic devices such as laptops and monitors; And
  4) Choose devices with a high energy rating and meet energy efficiency standards.

V. CONLUSIONS

In the initial energy audit stage, the IKE value produced in the Electrical & Civil Building was 233,436 kWh/m²/year. The IKE value is classified as **"Wasteful"** criterion |. Then at the final energy audit stage, the IKE value produced in the Electrical building was 181.19 kWh/m²/Year, and in the Civil building it was 175.75 kWh/m²/Year. The IKE value is classified as **"a bit wasteful"** criterion.

Energy savings can be done by; turn off electronic devices when not in use, change the type of LED lights, organize a good room layout, take advantage of natural lighting, carry out routine maintenance on the air conditioner, regulate the room temperature wisely, use window coverings and ventilation, change the type of refrigerant that saves more electricity, and use a power strip with a switch.

This research can make it easier for energy auditors to implement an information system that enables efficiency in the energy audit process, including monitoring energy consumption, identifying potential savings, and the results of electrical energy audits can be presented in more detail and supported by reliable data, enabling decision making. which is appropriate for optimizing energy management, as well as enabling faster and more accurate access to the required information.

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