Electrical Energy Intensity Analysis in Electricity Saving at the Faculty of Engineering UNG

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***Abstract*—The electrical energy use in government buildings seems to pay less attention to electrical energy-saving provisions. Many rooms still have the lighting on during the day although the room has enough of sunlight. Using many air conditioners (AC) does not comply with the room volume and the number of people in the room. It leads to electrical energy waste, which is a problem at Universitas Negeri Gorontalo (UNG). The UNG household has reported that the electricity consumption in March 2021 was 65,291,330 VA. It greatly burdened the university's operating costs budget (±60.30% of UNG's household operating funds). This study aims to analyze the electrical energy use intensity and establish electrical energy use saving policies. The study was conducted at the Faculty of Engineering of UNG. The employed research method was the audit analysis of energy use intensity (EUI). The room lighting level according to the lighting and sunlight entering the room was directly measured with a lux meter and analyzed following the provisions of Indonesian National Standard (Standar Nasional Indonesia, SNI) 6197-2011. Electrical energy use in air-conditioned and non-air-conditioned rooms was analyzed using the EUI method. The energy use level refers to efficiency standards following the Regulation of the Minister of Energy and Mineral Resources No. 13 of 2012. The results showed that, on average, 23.43% of the 233 rooms had lighting intensity exceeding the SNI standard. The electrical power use in an air-conditioned room for 26 working days was 14.73 kWh/m^2/mo. Based on the efficiency standards of the Minister of Energy and Mineral Resources Regulation, it falls into the moderately wasteful category. Electrical energy saving is conducted by implementing the room lighting system efficiency, and the use of AC with power complies with the standards of room coolness demands and the implementation of electrical energy saving life patterns.**

***Keywords*—Intensity, Consumption, Energy, Electricity, Energy Saving.**

I. INTRODUCTION

The majority of power plants in Indonesia still utilize resources from non-renewable energy sources. Furthermore, many people using electrical energy are inefficient in using electricity at the household scale, for office work, and industrial activities [1]. It is contradictory because, on the one hand, the government continues to try to meet the electrical energy demands of the community. Still, on the other hand, many people who use electrical energy in government buildings do not save electrical energy in their daily activities.

The Regulation of the Minister of Energy and Mineral Resources No. 13 of 2012 on the Saving of Electric Power Consumption states that government office buildings at the central and regional levels are required to implement the energy saving program both in the air and light management also electricity use [2]. The government has issued an energy conservation policy to reduce national energy use. Government Regulation No. 70 of 2009 on Energy Conservation states that energy conservation is a systematic, planned, and integrated effort to preserve energy sources and their use more efficiently [3]. It also states that the national energy policy requires users using energy greater than or equal to 6,000 tons of oil equivalent (TOE) per year to implement energy conservation provisions [3].

The Faculty of Engineering (Fakultas Teknik, FT), Universitas Negeri Gorontalo (UNG) is a faculty whose electrical energy use is relatively large compared to other faculties (FMIPA, FAPERTA, FSB) in the UNG's new campus, located in Bone Bolango Gorontalo Regency. Based on data from the UNG Household, the electrical energy use of the FT UNG in March 2021 was 65,291,330 VA. This electrical power use was the largest use of power compared to other faculties, with an average power of 2,180,000 VA per month.

Based on these data, the University Officers of UNG needs to make efforts to save electrical energy through lighting system efficiency and reduce the power of air conditioner (AC) loads and other electrical equipment following the government's established electrical power usage efficiency standards. Every individual in all work units must implement an electrical energy-saving life pattern.

Implementing an energy audit is one method to determine the use of electrical energy in a building, whether it is more consumed by the electrical equipment load (air conditioning, refrigerator, sound system) or consumed by the lighting system loads (lamps). In addition, an electrical energy audit shows that the part/unit that uses electrical energy is relatively high. It is important to know that savings measures can be effectively made. The electrical energy audit is carried out through the energy use intensity (EUI) analysis method.

Based on these problems, this study aims to conduct an audit analysis of the electrical energy intensity in the building of FT UNG and formulate strategies and policies to save electricity in FT UNG. This study conducted a case study of the use of electrical energy in FT UNG.

II. ENERGY USE INTENSITY (EUI)

EUI is a measure of energy employed to determine the energy use of a building per area of the conditioned area in one

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TABLE I
LIGHTING LEVEL STANDARDS FOR EDUCATIONAL INSTITUTIONS AND OFFICES

Room Functions	Light Levels (lux)
Classroom	250
Library	300
Laboratory	500
Drawing practice room	750
Canteen	200
Praying room	200
Workspace/office	350
Meeting room	300
Lobby/corridor	100

Source: SNI 03-6197-2000.

month or year [4], [5]. The EUI analysis method for lighting systems per month and year employed the comparison of the energy value used per month and year as written in (1) and (2).

$$IKE\ per\ month = kWh\ value\ per\ month/floor\ width \quad (1)$$

$$IKE\ per\ year = kWh\ value\ per\ year/floor\ width. \quad (2)$$

The National Standardization Agency (Badan Standardisasi Nasional, BSN) has set room lighting standards for a building. The room lighting standard for educational institutions and offices refers to Indonesian National Standard (Standar National Indonesia, SNI) 03-6197-2000 [6]. Based on these standards, whether the room lighting has met the room use function or not can be known. Table I indicates the standards of lighting levels in educational institutions and offices.

A. Room Lighting Power

The calculation as in (3) [7] can be used to calculate the power demand in a room lighting system based on the area of the room.

$$Pc = \frac{Pt}{A} \quad (3)$$

where

Pc = lighting power of the room (W/m^2),
Pt = the power that the lighting (W) uses,
A = room area (m^2).

The SNI 6197-2011 standard, as in Table II, is used to determine the maximum power demand of a room lighting system [8].

B. EUI for Air-Conditioned and Non-Air-Conditioned Rooms

The EUI calculation for air-conditioned rooms uses the method as in (4).

$$Air\text{-}conditioned\ EUI = \frac{AC\ Energy\ Consumption}{Area\ of\ air-conditioned\ floor\ (m^2)} + \frac{Energy\ Consumption\ Total - AC\ Consumption}{Entire\ Floor\ Area\ (m^2)}. \quad (4)$$

For non-air-conditioned rooms, the EUI method is used as in (5).

$$IKE = \frac{Energy\ Consumption\ Total(kWh) - \text{AC Energy Consumption}\ (kWh)}{Entire\ Floor\ Area\ (m^2)}. \quad (5)$$

TABLE II
POWER STANDARDS FOR LIGHTING

No.	Room	Maximum Lighting Power (W/m^2)
1.	Classroom	15
2.	Library	11
3.	Laboratory	13
4.	Computer room	12
5.	Workspaces	12
6.	Drawing room	20
7.	Canteen	8
8.	Praying room	10
9.	Lobby/corridor	12
10.	Toilet	7

Source: SNI 6197-2011.

TABLE III
EUI STANDARDS FOR AIR-CONDITIONED AND NON-AIR-CONDITIONED BUILDINGS

Air-Conditioned Building		Non-Air-Conditioned Building	
Highly efficient	4.17–7,92 kWh/m^2/mo	Highly efficient	0.84–1.67 kWh/m^2/mo
Efficient	7.92–12,08 kWh/m^2/mo	Efficient	1.67–2.50 kWh/m^2/mo
Moderately efficient	12.08–14,58 kWh/m^2/mo	Moderately efficient	-
Moderately wasteful	14.58–19.17 kWh/m^2/mo	Moderately wasteful	-
Wasteful	19.17–23.75 kWh/m^2/mo	Wasteful	2.50–3.34 kWh/m^2/mo
Highly wasteful	23.75–37.5 kWh/m^2/mo	Highly wasteful	3.34–4.17 kWh/m^2/mo

Source: Regulation of Minister of Energy and Mineral Resources No. 13 of 2012.

The determination of a building categorized as efficient or not in energy use refers to the EUI value standards enacted following the Regulation of the Minister of Energy and Mineral Resources No. 13 of 2012, as shown in Table III. The need for room air temperature and room design will determine the AC power used. AC power is determined based on room conditions, which include the volume of the room, the position of the room towards the sun, the position of the room affecting other rooms, and the insulation system of the room [9]. AC power units are BTU per hour or *paard kracht* (PK) or horsepower (HP).

Equation (6) [10], [11] are used to determine the AC power to be used in the room.

$$AC\ Power = \frac{L\ x\ W\ x\ H\ x\ I\ x\ E}{60}\ BTU/h \quad (6)$$

where L is the length of the room in ft (1 m = 3.28 ft); W states the width of the room (ft); H is the height of the room (ft); I is worth 10 for an insulated room (being on the lower floor or wedged with another room) and is worth 18 if the room is not insulated (it is upstairs); then E is worth 16 if the longest wall is facing north, is worth 17 if the wall is facing east, is worth 18 if the wall is facing south, and is worth 20 if the wall is facing west. The provisions for the room temperature are determined based on the Decree of the Minister of Health of the Republic of Indonesia No. 261 of 1998 [12] and the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia No. 14 of 2012 [13] regulating room temperature standards.

III. METHODOLOGY

The method used in this study was the observation and analysis of the EUI audit. Electrical EUI audit analysis was performed using a short energy intensity audit technique (walk-through audit) [14]. EUI analysis was carried out to determine the efficiency level of electricity use in the faculty. Measurements of lighting intensity and power usage of electrical equipment were carried out in all of the rooms in the FT UNG building. The flowchart of the implementation of the study is shown in Fig. 1.

A. Research Data and Data Collection Techniques

The required data and data collection techniques are described as follows. The area data of each room in the FT UNG Building was obtained through the building construction project drawings (IDB project) layout. The area of the room that was not contained in the project layout is obtained through direct measurements. Data collection of the area of the room was carried out for ten days. Then, the lighting intensity data of each room was measured directly using a lux meter. The light intensity measurement was carried out in the morning (at 8:30 a.m.), noon (at 1:30 p.m.) and evening (at 4 p.m.). Measurements were carried out in each room when there was activity or no activity in the room.

Room temperature data were measured using a thermometer in each air-conditioned room. AC power was measured using ampere pliers and power specification readings on indoor/outdoor AC. Data on the power usage of other electrical equipment (water pumps, dispensers, LCD projectors, refrigerators, computers, and sound systems) were obtained through direct review by looking at the power specifications of each electrical equipment. Meanwhile, data on the turn time of lamps and ACs was obtained through observation of working time when lights and ACs were turned on and off.

B. Research Stages

The flowchart in Fig. 1 indicates the stages of research activity. The research began with surveying the building and a study of the literature. Next, data collection was carried out for analysis. The analysis results were used as the basis for determining the category of the level of electrical energy use. Energy saving policies must be carried out if the electricity use is declared wasteful.

C. Data Analysis Technique

To analyze the lighting intensity of a room, whether it has met the light needs according to the volume of the room and the type of activities carried out indoors, the light intensity of the room was measured first using a lux meter. Considering that this research was carried out in a campus building, the room lighting standard used was SNI 03-6197-2000, which regulates light levels standards for educational institutions and offices.

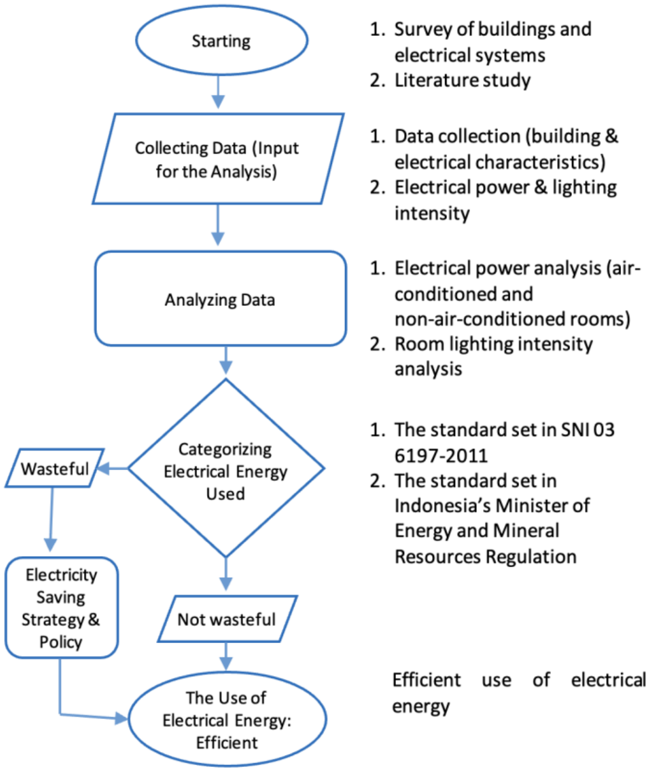

Fig. 1 Research flowchart.

Based on the comparison of the light intensity of the room with SNI 03-6197-2000, it can be known whether the room's lighting demand is up to standard.

The electrical power demand used in the room lighting system was analyzed using the calculations in (3). The maximum power demand of room lighting was set using the SNI 6197-2011 standard, as in Table II. Equation (4) was used to determine the EUI of a building based on an air-conditioned room, while (5) is used to determine the EUI of a non-air-conditioned room.

The energy use category, whether efficient or not, was determined by adjusting the results of the EUI calculation to the efficiency value of utilizing electrical energy according to the Regulation of the Minister of Energy and Mineral Resources No. 13 of 2012, as shown in Table III. Potential saving or the air-conditioned room air system's energy saving potential was analyzed using the calculations in (6).

D. Determination of Electrical Energy Use Saving Policy

Before providing recommendations that will be the basis for establishing an electrical energy saving policy, it is necessary to determine beforehand the factors causing the electrical energy waste. The following factors of energy waste were identified based on energy wastage data obtained from analysis results of EUI lighting and EUI power consumption of air-conditioned and non-air-conditioned rooms.

- The lighting and room temperature intensity do not comply with or exceed the standards established following the Ministerial Regulation and BSN.
- The condition of the placement of electrical equipment, such as light switches that are too far from the room

door, so that people who are going out or leaving the room have difficulty reaching the switch (to turn off the room light).

- The condition of the power outlet that has been loose or damaged causing the loss of contact, so that the electrical equipment works abnormally.
- The habit of leaving the room by not first turning off the lighting, AC, and other electrical appliances.
- The use of park lights that do not implement an automatic system (in the evening, the automatic lighting will turn on, and in the morning, the automatic lights will go out).
- The use of an automatic water pump working on and off when the water reservoir is almost empty or full.

The application of electrical energy saving based on the energy use intensity audit results is carried out to minimize or eliminate the factors that cause energy waste, namely by applying an electrical energy saving life pattern.

IV. Results and Discussion

A. Condition and Electrical Load of the Faculty of Engineering Building, UNG

The FT UNG building is located on Jalan B.J. Habibi, Tilongkabila Regency, Bone Bolango Regency, Gorontalo Province. This building consists of five sections (C2-C6) with a three-floor construction. Rooms C2-C6 serve as classrooms, library, laboratory, computer practice room, image practice room (study), work/office room, canteen, *musholla* (praying room), lobby/corridor, and toilet.

There are six study majors in the FT UNG building, i.e., the Department of Civil Engineering, Department of Electrical Engineering, Department of Informatics Engineering, Department of Industrial Engineering, Department of Architectural Engineering, and Department of Fine Arts and Design Education. The building was built in 2019 through the Islamic Development Bank (IDB) grants. The lighting arrangement in each room has generally been adjusted to the room lighting intensity demand standard according to its function. Likewise, the installation of AC in individual classrooms, offices, and laboratories. AC power, in general, has been adapted to the room's area and the space's function. The main power source used to supply the entire FT building, and other faculties on the new UNG campus comes from National Electricity Company (Perusahaan Listrik Negara, PLN), with a power of 2,180 kVA.

FT UNG has five buildings or five sections, namely Building C2 (for faculty and major administration activities), Building C3 (for lectures), Building C4 (laboratories), Building C5 (laboratories), and Building C6 (laboratories). Each building consists of three floors divided into several rooms. Fig. 2 shows the FT UNG building. Based on the results of the FT building electrical load measurement, the obtained electrical power is presented in Table IV.

Fig. 2 Building of FT UNG.

TABLE IV
LIGHTING, AC, AND OTHER ELECTRICAL EQUIPMENT LOAD POWER IN THE BUILDING OF THE FT UNG

Floor	Section	Lighting Power (W)	AC Power (W)	Other Equipment (W)
1st floor	C2	6,120	31,110	21,494
2nd floor	C2	7,221	32,155	2,427
3rd floor	C2	7,425	46,050	2,274
1st floor	C3	1,964	13,650	164
2nd floor	C3	1,913	16,380	0
3rd floor	C3	2,134	22,060	0
1st floor	C4	2,726	16,785	540
2nd floor	C4	2,713	14,450	14,450
3rd floor	C4	2,072	19,050	0
1st floor	C5	1,850	21,650	0
2nd floor	C5	2,760	15,285	3,439
3rd floor	C5	1,102	28,020	0
1st floor	C6	1,963	20,920	364
2nd floor	C6	2,140	19,585	14
3rd floor	C6	2,013	22,100	5,409

Source: Measurement results, 2021.
Note: Other electrical appliances: dispenser, refrigerator, computer, sound system, LCD, and water pump.

B. Electrical Power Consumption

Electrical power consumption in the FT UNG building is presented in Table V. The average electrical power consumption per day in the FT UNG building is 367.37 kWh. The graph of daily load characteristics in the use of electrical energy of the FT UNG building is shown in Fig. 3.

C. Energy Use Intensity (EUI) Analysis

Based on the project layout drawings and measurement results, the FT UNG building has a total area of 8,909.12 m². The room area that does not use AC is 2,775.16 m², and the room area that uses AC is 6,133.97 m².

1) EUI Analysis of Lighting Systems: The results of light intensity measurements carried out during working hours (morning at 8:30 a.m., noon at 1:30 p.m., and afternoon at 4 p.m.) are as follows.

Building C2 has three floors (1st, 2nd, and 3rd floors), consisting of 99 rooms with sunlight and lighting. The measurement results of the light intensity of the FT UNG building showed that there were twenty, thirty, and five rooms in the morning, midday, and afternoon, respectively, whose room lighting intensity exceeded the SNI 6197-2011 standard.

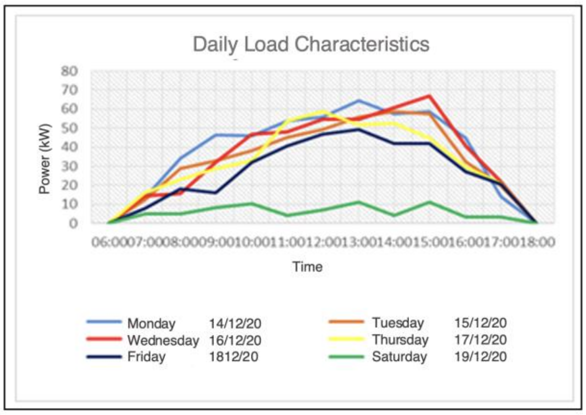

Fig. 3 Characteristics of electrical energy daily use loads of the FT UNG building.

TABLE V
TOTAL ELECTRICAL LOAD CONSUMPTION OF THE FT UNG BUILDING

Building Section	Lighting Power (kWh)	AC Power (kWh)	Other Equipment Power (kWh)
C2	114.25	718.96	58.09
C3	32.60	364.63	49.20
C4	33.15	289.00	25.11
C5	21.54	227.63	23.41
C6	31.36	402.24	41.22
Total	323.90	2,002.46	197.03
Total			2,523.39 kWh

Source: Results of analysis, 2021.

Building C3 also has three floors (1st, 2nd, and 3rd floors), consisting of 33 rooms with sunlight and lighting. The measurement results showed seventeen, seventeen, and seven rooms in the morning, midday, and afternoon, respectively, whose lighting intensity exceeded the SNI 6197-2011. standard.

Building C4 has three floors (1st, 2nd, and 3rd floors) consisting of 32 rooms with sunlight and lighting. The measurement results showed twelve, seven, and two rooms in the morning, midday, and afternoon, respectively, whose room lighting exceeded the SNI 6197-2011 standard.

Building C5 has three floors (1st, 2nd, and 3rd floors), consisting of sixteen rooms with sunlight and lighting. The measurement results showed six, eight, and zero rooms in the morning, midday, and afternoon, respectively, whose lighting intensity exceeded the SNI 6197-2011 standard.

Graph of the room numbers in the FT UNG building with lighting intensity that do not follow or exceed SNI 6197-2011 is shown in Fig. 4. Based on the results of the audit of the lighting system in the FT UNG building, there is an average of 23.43% of 233 rooms with lighting intensity that does not comply with or exceed the SNI 6197-2011 standard.

2) EUI Analysis of Air-Conditioned Rooms: Based on the analysis results, the area of the air-conditioned room is 6,133.97 m^2. The total electrical energy consumption of the FT building is 2,513 kWh, with a total energy consumption of air-conditioned rooms of 2,002 kWh. From the EUI analysis of air-conditioned rooms for one month (26 working days) using (4), the effective energy use of air-conditioned rooms was obtained at 14.73 kWh/m^2/mo. Based on the Regulation of the Minister of Energy and Mineral Resources No. 13 of 2012, as in Table III, the area of the room using AC with an EUI value of 14.33 kWh/m^2/mo is included in the moderately wasteful category.

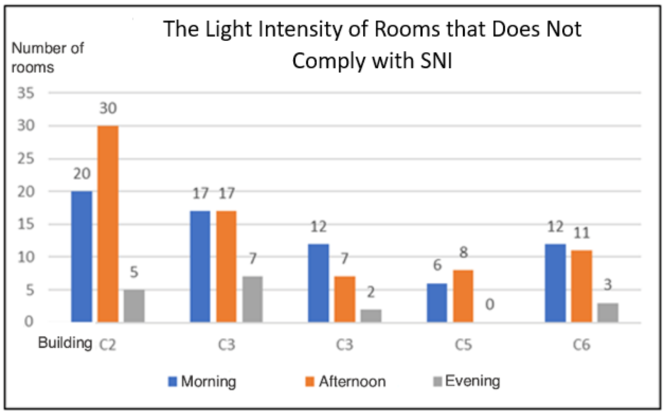

Fig. 4 Number of rooms with light intensity that does not comply with SNI.

3) EUI Analysis of Non-Air-Conditioned Rooms: Based on the analysis results, the area of rooms that do not use AC is 2,775.16m^2. The total electrical energy consumption of the FT building is 2,513 kWh, with the total energy consumption of the non-air-conditioned room amounting to 125 kWh. EUI analysis of the air-conditioned room for one month (26 working days) using (5) obtained the effective energy use of the air-conditioned room of 4.9 kWh/m^2/mo. Based on the Regulation of the Minister of Energy and Mineral Resources No. 13 of 2012 in Table III, the area of the non-air-conditioned room with an EUI value of 4.9 kWh/m^2/mo falls into the relatively efficient category.

4) EUI Analysis of the Air System according to AC Power: The energy audit of the air conditioning system is intended to determine the level of conformity of the installed AC power with the supposed AC power, according to the volume of the room and the number of people in the room. Based on the audit results in the FT building, the number of rooms whose AC power meets the provisions and does not meet the provisions stipulated in the Minister of Energy and Mineral Resources Regulation No. 13 of 2012 (Table III) is shown in Fig. 5.

The energy potential saving of air-conditioned rooms in the FT building was analyzed using the AC power unit equation as in (6). For example, potential saving was analyzed in the FT Quality Assurance Room located in Building C2. EUI analysis of the air system according to AC power was carried out in the FT Quality Assurance Room, with AC operated on average for seven hours per day for 26 days. The Quality Assurance Room uses two AC 1.5 PKs with a power of 2 × 1.365 = 2.730 kW.

Energy-saving potential analysis of the Quality Assurance Room air system is as follows.

- Installed AC power consumption = 2.730 × 7 × 26 = 496.86 kWh/mo.
- According to the provisions, AC power that should be installed for a room volume of 120 m^3 is 1.260 kW.

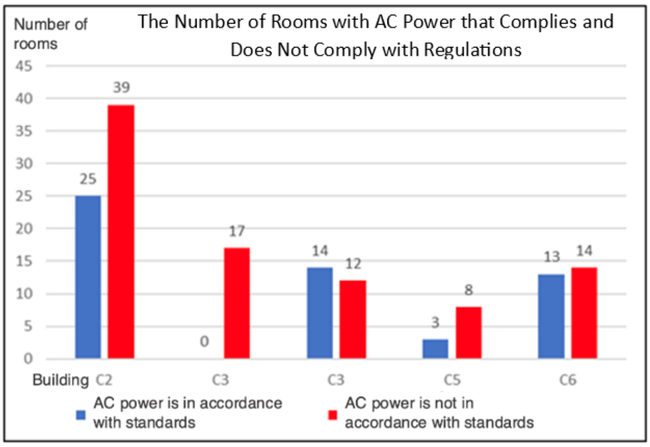

Fig. 5 Graph depicting the number of rooms with AC power that complies and does not comply with the regulations.

- AC power consumption according to the provisions = 1.260 × 7 × 26 = 229.32 kWh/mo.
- Potential saving = 496.86 – 229.32 = 267.54 kWh/mo.

The results of the potential saving analysis of electrical power for AC use in all rooms of the FT UNG building are as follows.

- Building C2 = 4,081 kWh/mo.
- Building C3 = 2,636 kWh/mo.
- Building C4 = 1,959 kWh/mo.
- Building C5 = 2,558 kWh/mo.
- Building C6 = 4,192 kWh/mo.

The potential saving total of AC electric power in the FT UNG building is 15,426 kWh/mo.

D. Saving Efforts in the Electrical Energy Use

Based on the results of the EUI analysis as discussed previously, there are 23.43% of rooms whose lighting system exceeds SNI standards. In addition, the EUI value for air-conditioned rooms of 14.33 kWh/m^2/mo is included in the moderately wasteful category. Several causes of electrical energy waste can be explained as follows. In some rooms, even though the room lighting has met standard demands, all lighting is switched on during the day. There is also a room where the lights are still turned on even if there is no activity in it. In terms of AC usage, AC power exceeds the capacity according to the room volume. The AC is also kept on even if there is no work activity in the room. In addition, room users have not consciously turned off the lights, AC, and other electrical appliances when there is no activity or when leaving the room.

Based on the formerly mentioned explanation, several important things were formulated as recommendations for saving electrical energy. First, the head of the faculty issues provisions or circulars on the order of the use of the room, which includes the following things.

- Room users must turn off lights, AC, and other electrical appliances when leaving the room.
- The AC is set in a cool mode according to the needs and room area. If an AC is not functioning properly, immediately report it to the equipment area for repair.
- In certain rooms (classrooms), a notice is attached to the use of the room so that if the room is illuminated less during the day, the room user can simply turn on the light whose switch has been marked/labeled.
- Lecturers, employees, and students are expected always to pay attention to the provisions of electrical energy saving and remind each other.

Second, users must be familiar with turning off room lights before leaving the room, except in corridors requiring nighttime lighting. Third, each room user must habituate themselves to turning off (unplugging) the computer, TV, and water heater (dispenser) before leaving the room.

V. Conclusion

The use of electrical energy in the UNG FT building has been analyzed using the EUI analysis method. The results of the analysis were compared with SNI standards and Ministerial Regulation. The results show an average of 23.43% of rooms whose lighting intensity exceeds or is not following SNI 6197-2011. In some rooms, the room lights are still turned on even though the room light intensity has been met as needed. Referring to the Regulation of the Minister of Energy and Mineral Resources No. 13 of 2012, the results of the EUI analysis of air-conditioned rooms, with a value of 14.73 kWh/m^2/mo, fall into a moderately wasteful category. The power potential saving total with the application of good air management (AC power installed according to the volume and coolness needs of the room) is 15,426 kWh/mo. The heads of the faculty can carry out electrical energy saving measures by issuing a decree on the order of electrical energy saving and implementing an electrical energy saving life pattern for all communities in the FT UNG environment.

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Conflict of Interest

No conflicts of interest are involved in this study's conduct, either individually or through organizations with particular messages.

Author Contribution

Conceptualization, Sardi Salim and Ade I. Tolago; methodology, Sardi Salim; software, Sardi Salim and Maharani R.P. Shafi; validation, Sardi Salim, Ade I. Tolago, and Maharani R.P. Syafii; formal analysis, Sardi Salim; investigation, Sardi Salim, Ade I. Tolago, and Maharani R.P. Syafii; resource, Sardi Salim; data curation, Sardi Salim and Ade I. Tolago; writing-drafting of the original draft, Sardi Salim and Ade I. Tolago; writing-review and editing, Sardi Salim; visualization, Sardi Salim; supervision, Sardi Salim and Ade I. Tolago; project administration, Ade I. Tolago; acquisition of funding, Sardi Salim; reporting, Sardi Salim and Ade I. Tolago.

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