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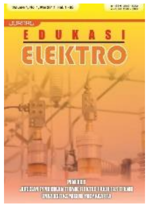

Analysis of Electrical Energy Consumption in Office Buildings of the Institute Technology of Sumatra in Energy Conservation and Efficiency Efforts

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Abstract— Electrical energy is one of the basic human needs in carrying out various activities or daily activities, especially in office buildings such as office buildings of state higher education institutions, namely the Sumatra Institute of Technology (ITERA). Office buildings are the third highest consumer of electrical energy after shopping centers and hotels. The high demand for electrical energy requires the user sector to make efficiency in energy use. Before making efficiency, it is necessary to know the profile of electrical energy consumption including energy consumption intensity (ECI) and significant energy users. Therefore, in this study, an analysis of electrical energy consumption in each ITERA office building was carried out, through observation and interviews according to SNI / ISO 50002: 2018 energy audit procedures. The results obtained show that the total energy use of the 6 largest buildings (A, B, C, D, E, and F) in May 2023 is 144768 kWh and from the calculation of the ECI value is in the very efficient category (7.44 kWh/m^2/month). From 6 existing buildings, there are 3 buildings that are very efficient, 1 building is efficient, and 2 buildings are quite efficient. Then, significant energy users were found by 83% in building C AC. Recommendations for saving energy in the effort of energy conservation and efficiency that can be done include, making changes in habits / patterns of use of electrical energy user equipment, especially in air conditioners and dispensers, so as to save electricity 2-21%, and retrofitting refrigerant AC types of split ducts and cassettes that still use R-22 with MC-22 which can save electricity 15-25%.

Keywords: sumatra institute of technology, electrical energy consumption, energy conservation

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1 Introduction

Electrical energy is one of the basic human needs that has an important role in sustainable national economic development. The intensity of electrical energy consumption increases along with the increase in population growth and economic growth. High energy intensity is one of the problems in the national energy sector because of changes in people's lifestyles influenced by projected increases in GDP and increasingly efficient technology. The trend of electrical energy utilization from 2018-2050 is dominated by electrical energy by 35% caused by the increasing use of electronic devices and the substitution of the use of generators in the industrial and commercial sectors fueled by oil to the use of electricity *on grid* [1]. This means that electricity is one of the important factors that support the production activity of goods/services, especially those that have a high dependence on electrical energy needs.

Based on data from the Ministry of Energy and Mineral Resources (ESDM), Indonesia's per capita electricity consumption reached 1,173 kilowatt-hours (kWh) in 2022, representing a 4.45% increase compared to the previous year when it stood at 1,123 kWh. These figures clearly indicate a consistent annual increase in electricity consumption [2]. The high demand for electricity necessitates energy users to focus on energy efficiency through energy conservation activities. For this reason, based on Presidential Regulation No. 79 of 2014 on the National Energy Policy and Presidential Regulation No. 22 of 2017 on the General National Energy Plan (RUEN), the government has set a national energy conservation target of 17% by 2025 [3]. This energy-saving target encompasses all sectors, including the building sub-sector. Surveys and studies have indicated that energy savings potential in buildings can range from 10% to 30% of their energy consumption. Moreover, according to statistical data, the building sector consumed approximately 43.15 million barrels of oil equivalent (BOE) in 2018, equivalent to around 4.82% of the national final energy consumption [4].

Despite some buildings making efforts to improve energy efficiency, such as replacing energy-efficient equipment and operating efficiently while implementing energy conservation programs, there are still many implementation challenges. These challenges include issues related to funding, problem identification (energy audits), and execution. Given the significant energy savings potential identified and the substantial benefits that can be obtained by implementing these opportunities, energy conservation programs need to be continuously promoted. Additionally, the President has instructed office buildings, including government offices, to enhance energy efficiency [5]. Government Regulation No. 33 of 2023 on Energy Conservation also states that any activity with permits issued by the central government must implement and manage energy conservation activities [6]. This includes the Office Building of the State University of Sumatera Institute of Technology (ITERA), owned by the Ministry of Education, Culture, Research, and Technology.

Research related of electricity consumption has been conducted in various university buildings in Indonesia, with some buildings falling into the category of very efficient [7], [8], [9], [10], [11], efficient [12], [13], [14], [15], [16], [17], [18], [19] and some still inefficient [20], [21], [22], [23]. In line with these previous research efforts, initial surveys have revealed that since ITERA building operations began in South Lampung from 2014 to 2023 (9 years), no energy conservation and efficiency activities have been conducted through energy audits. The only activities carried out were the placement of energy-saving stickers on light switches at a few points, limited information regarding energy usage, and a lack of kWh meters in the building (only 1 kWh meter for 6 office buildings). Consequently, the baseline of electricity usage in each building, including electricity usage patterns and significant energy users, remains unknown. Most of the energy sources used come from electricity supply. Unlike shopping centers and hotels, the amount of energy used in offices is influenced by the number of employees and the working hours of office staff. In interviews with several employees, it was mentioned that the operation of electronic equipment in the rooms depends on employee habits, such as operating the air conditioning at 18-20°Celsius, leaving lights on during working hours and forgetting to turn them off after work hours, and having dispensers running 24 hours a day, as well as printers occasionally being on standby for 24 hours. If these usage habits continue among all employees, it will lead to higher electricity consumption and increased electricity costs. Therefore, research on energy usage in ITERA's building structures is urgently needed to understand the electricity usage patterns in each building, identify significant energy users, and provide opportunities and recommendations for energy savings in the context of conservation and efficiency.

2 Methods

In this study, an analysis of the intensity of electrical energy consumption in all ITERA buildings will be carried out using the Energy Audit method according to ISO 50002: 2018. The flow chart of this research plan can be seen in Figure 1. This research activity began with the identification of problems found in ITERA buildings, namely since the operation of the ITERA building in South Lampung from 2014 – 2023 (9 years), namely the building has never carried out conservation and energy efficiency efforts / activities through energy audits, the lack of kWh meters in the building (only 1 kWh meter for the 6 office buildings), so that the baseline for the use of electrical energy in each building is not yet known. Then, continued with literature studies from various references both journals and books.

After that, energy audit preparation was carried out starting from determining the scope of activities, namely level 1 energy audits on all ITERA office building buildings consisting of A, B, C, D, E, and F, then the necessary documents including energy use history, energy consumption intensity standards [24], policies related to energy conservation [6], [25], [3] and survey form documents. The next preparation is the implementation team, consisting of the team leader and members from the Energy System Engineering Study Program, Sumatra Institute of Technology. The last preparation is the implementation schedule which will be carried out from May – June 2023.

After that, primary and secondary data collection. Primary data include electrical energy user equipment and the length of use of energy equipment in each room contained in each ITERA office building, and room observation. Then, for secondary data, namely room area plan data, and a history of energy use of 5 months. After all the data is collected, a descriptive statistical data analysis is carried out including analysis of the value of energy consumption intensity (ECI) and benchmarking against ECI standards from the Minister of Energy and Mineral Resources No.13 of 2012, significant energy users, and energy saving opportunities in each room. Then, this study ended with drawing conclusions and providing suggestions / recommendations from research on ITERA office buildings to optimize energy use without reducing comfort and productivity.

2.1. Energy Consumption Intensity (ECI)

Energy consumption intensity is the primary indicator used to calculate the energy consumption in buildings in unit area and identify ways to achieve energy savings. The calculation of ECI (kWh/month/m^2 or kWh/m^2/year) within the building follows the SNI standard, involving the division of total energy consumption by the duration of electricity equipment usage in unit area, per month or year. The calculation of the ECI value for office building is adjusted based on the building type, whether it falls into the categories of AC buildings, Non-AC building, or with both AC and Non-AC building [26]. Therefore, the calculation of the ECI/Specific Energy Consumption for the building can be seen in equations (1), (2) and (3) [26]. Equation 1 is used for office buildings with AC or without AC area >90% of the total floor area. Equations 2 and 3 are used for office buildings with AC and without AC area comprising 10-90% of the total floor area (Equation 2 is used to calculate the AC floor area, and Equation 3 is used to calculate the non-AC floor area).

$$ECI = \frac{Total\ Energy\ Consumption\ (kWh/month)}{Large\ detail\ of\ building\ (m^2)} \quad (1)$$

$$ECI = \frac{Energy\ Consumption\ from\ AC\ \left(\frac{kWh}{month}\right)}{AC\ Area\ (m^2)} + \frac{Total\ Energy\ Consumption - Energy\ Consumption\ from\ AC\ (kWh/month)}{Total\ Area - AC\ Area\ (m^2)} \quad (2)$$

$$ECI = \frac{Total\ Energy\ Consumption - Energy\ Consumption\ from\ AC\ (kWh/month)}{Total\ Area - Non\ AC\ Area\ (m^2)} \quad (3)$$

The results derived from computing the Electricity Consumption Intensity (ECI) serve as a reference point for categorizing the electricity usage in the building, determining if it aligns with established standards or not. The standard values of ECI (Energy Consumption Intensity) as per Regulation of the Minister of Energy and Mineral Resources Number 13 of 2012 for office buildings are divided into 4 criteria/categories, which can be seen in the Table 1.

Table 1. Standard ECI

Criteria	AC Building (kWh/m^2/month)	Non-AC Building (kWh/m^2/month)
Very Efficient	<8,5	<3,4
Efficient	8,5 – 14	3,4-5,6
Sufficiently Efficient	14 – 18,5	5,6-7,4
Wasteful	>18,5	>7,4

2.2. Significant Energy User (SEU)

A Significant Energy User (SEU) is an energy user in a facility, section, or process that utilizes energy significantly. Significance, in this context, means its total energy usage is ≥80% of the total energy consumption [27]. SEUs are identified through a ranking method using a graph that displays energy usage for each equipment/process section along with its percentage of the total. SEUs are selected based on a cumulative energy usage of at least 80% of the total in that facility. Once SEUs are identified, the focus of subsequent actions (measuring energy performance and identifying energy-saving opportunities) is solely on these SEUs.

2.3. Energy Savings Opportunities

Energy savings involve reducing electricity consumption while maintaining productivity and work efficiency. The primary approach is to compare the current ECI value with the ECI target value [28]. Energy-saving options can be grouped into three categories [29]:

1. No-cost options are energy-saving measures implemented without incurring any expenses, typically in the form of in-kind contributions.
2. Low-cost options are energy-saving measures that require relatively modest expenses and can be budgeted by the organization itself without the need for external funding (such as loans or banks).
3. Medium-high-cost options are energy-saving measures that involve significant expenses, which can be self-funded or require external funding for implementation, or may involve collaboration with third parties (ESCO).

The cost categorization limits can be adjusted based on the policies and financial conditions of each organization, for example: low-cost options <50 million, medium-cost options <1 billion, and high-cost options >1 billion.

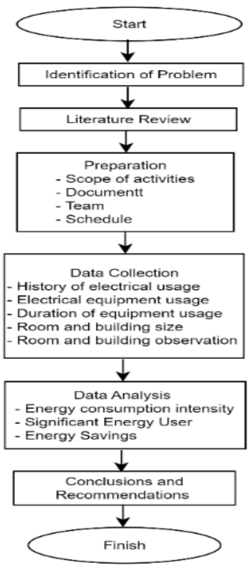

Fig.1. Research flow chart

3 Result and Discussion

Buildings A, B, C, D, E, and F at ITERA are oriented differently. Building A is oriented towards East, benefiting from the rising sun, and having the second-largest solar radiation factor, ensuring ample sunlight. In contrast, Buildings B, D, and E face West, capturing the setting sun's intense solar radiation, providing both sunlight and increased heat. Then buildings C and F are oriented towards North, which has a solar radiation factor that is not large enough but can still get enough light. The front view of buildings A, B, C, D, E, and F ITERA can be seen in Figure 2.

The function of the entire building is basically to function as an office building. However, due to the limited number of classrooms at ITERA, several rooms in buildings D, E, and F function as classrooms. Building A is a rectorate office building, building B is an office building for ITERA academic and financial services, building C and D is an office building of the Department of Production and Industrial Technology, building E is a building with various room functions, then building F is an office building of the Department of Science and the Department of Infrastructure and Regional Technology and several rooms function as lecture classrooms. The building name, function, and building area can be seen in Table 2.

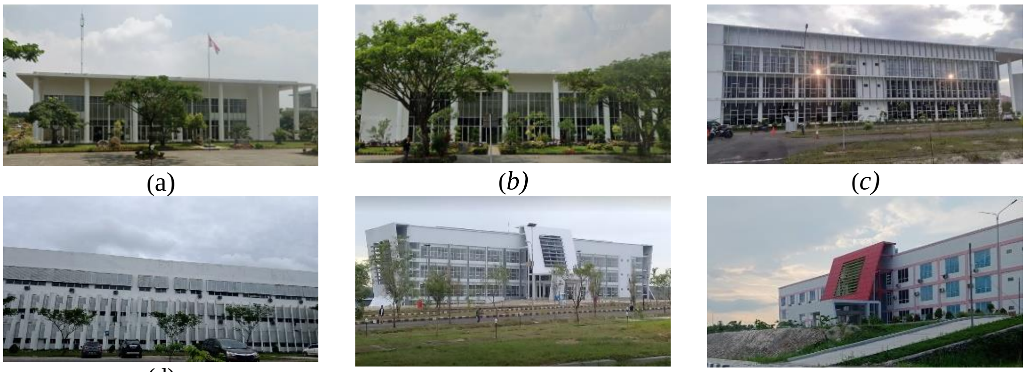

Fig. 2. Front view of building (a) building A, (b) building B, (c) building C, (d) building D, (e) building E, (f) building of ITERA

Table 2. Building name, function, and building area of building A, B, C, D, E, F ITERA

Building	**Building Type**	**Function Building**	**Number of Floor**	**Number of rooms**	**Area (m^2)**
A	Air-conditioned building	Office	2	13 workspaces, 2 toilets, 4 other rooms, and a lobby	1022
B	Air-conditioned building	Office	2	11 workspaces, 2 toilets, 1 prayer room, 1 panel room, and lobby	1022
C	Air-conditioned building	Office	3	21 workspaces, 1 hall, 6 toilets, 3 corridors, and a lobby	3340
D	Air-conditioned building	Office	3	17 workspaces, 8 seminar rooms, 6 toilets, 3 prayer rooms, 1 warehouse, 1 logistics workshop, 3 corridors, and lobby	3147
E	Air-conditioned building	Office + Library + Lectures	4	29 lecture halls, 12 workspaces, 4 library rooms, 3 sports halls, 2 lab rooms, 2 warehouses, 9 toilets, 6 prayer rooms, 6 wifi corner areas, 1 hall, 8 corridors, and lobby	5967

Building	Building Type	Function Building	Number of Floor	Number of rooms	Area (m^2)
F	Air-conditioned building	Office + Lecture	4	33 workspaces, 16 lecture halls, 1 hall, 9 toilets, 3 prayer rooms, 1 warehouse, 6 wifi corner areas, 8 corridors, and a lobby	4968
Total					19466

In research conducted in May-June 2023, a hybrid lecture scheme has been implemented so that classrooms have begun to be used for lectures and student activities but not for long, and for lecturer rooms and administrative services to be used every day and working hours, namely Monday-Friday from 08.00-16.00 WIB.

3.1. Energy Consumption Intensity (ECI)

The intensity of energy consumption shows the amount of electrical energy consumption (kWh) per square meter (m^2) of the area of the room/floor/building of the building every month or every year. Customer ID at ITERA State University is only available 2 Customer IDs or 2 kWh meters. Customer ID 1 is included in Group S3 with an electrical power capacity of 1110000 VA serving buildings A, B, C, D, E, F, and GKU 2. However, the GKU2 building will only operate in the odd semester of 2023/2024 in August 2023. Data on the history of electrical energy consumption of buildings A, B, C, D, E, F in January – May 2023 can be seen in Figure 3. In the even semester period of the 2022/2023 academic year, namely January – May 2023, the largest is in May 2023 (144768 kWh) and the smallest in April 2023 (100240 kWh). Electrical energy consumption during campus operating hours or outside peak load time (LWBP) is highest at 123029 kWh/month in May 2023, then electrical energy consumption outside campus operating hours or at peak load time (WBP) is highest at 21739 kWh/month which is also in May 2023 (Figure 4). This is because May 2023 is the last month in the even semester of 2022/2023 and because April coincides with the Eid holiday so that office activities and lectures, especially substitute classes, are quite dense in May.

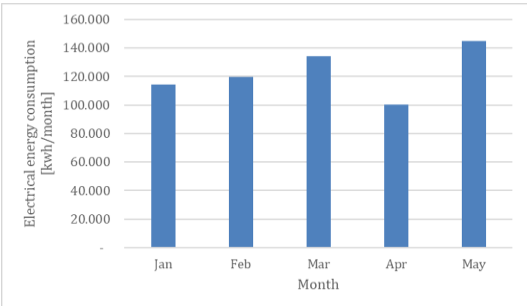

Fig. 3. History of electrical energy consumption on Customer ID 1 ITERA Campus

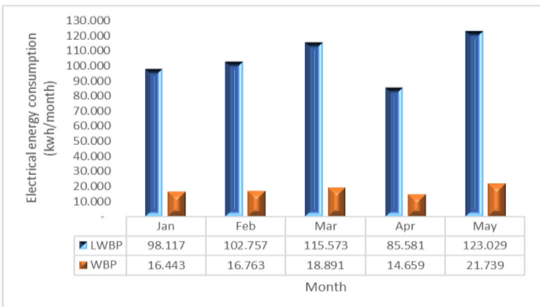

Fig. 4. Profile of electrical energy consumption in LWBP and WBP

Energy use per consumption in each building A, B, C, D, E, F is obtained through direct observation because there is only 1 kWh meter unit, so it cannot be known with certainty from historical data on energy use in each building. The profile of electrical energy use/consumption in each building can be seen in Figure 5. Building F is a building that has the greatest value of electrical energy consumption compared to other buildings, which is 36,647.92 kWh/month. This is because building F is an air-conditioned office and lecture building consisting of 4 floors and houses administrative and academic services of 2 majors at ITERA, so there are more types of electrical equipment used during working days and hours for activities. While the building that has the smallest electrical energy consumption value is in building B, which is 14728.83 kWh/month. This is because, in the 2-storey office building that provides academic and financial services, ITERA does not have many types of electrical equipment and there are 2 AC Split Ducts with a capacity of 12.5 PK each and 1 AC Cassette with a capacity of 6 PK which have long been damaged and not operated.

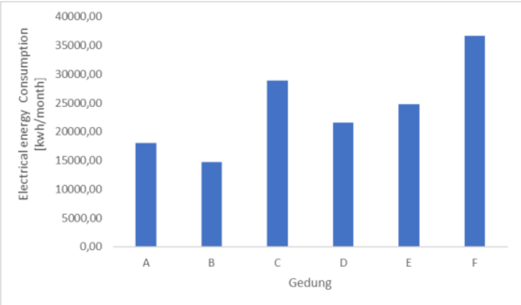

Fig. 5. Energy consumption profile of each building A, B, C, D, E, F ITERA

To determine the performance of each building, an analysis of the ECI calculation results shown in Figure 6 was carried out. Building A is a building that has the largest ECI value compared to other buildings, which is 17.68 kWh / m^2 / month. This high ECI value is influenced by the use of the type of AC used, namely 4 pieces of AC Split Duct with a capacity of 12.5 PK each, 2 AC Casettes with a capacity of 6 PK each, 1 AC Standing Floor with a capacity of 5 PK, 2 pieces of AC Standing Floor with a capacity of 3 PK, 6 pieces of AC Split Wall Standard Non-Inverter with a capacity of 2 PK, and 1 Standard Non-Inverter Split Wall AC with a capacity of 1 PK, while there are not many rooms or work areas (12 work rooms) and occupancy is not crowded and the use of Split Duct and Casette type air conditioners cannot be set the desired temperature in each use of the room. However, the ECI value is still included in the category of sufficiently efficient [24]. Even so, this value is almost in the category of wasteful, meanwhile, for other buildings there are 3 buildings including very efficient (building D, E, F), then 1 building including efficient (building C) and 1 building including sufficiently efficient (building B).

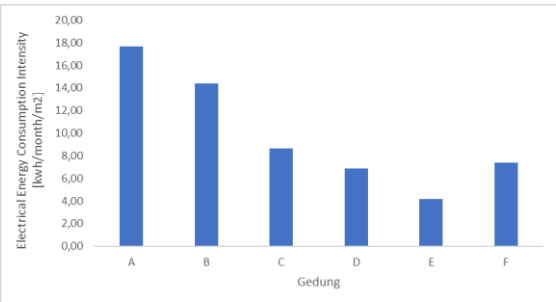

Fig. 6. The energy consumption intensity (ECI) of buildings A, B, C, D, E, F ITERA

Overall, for the total use/consumption of electrical energy in 6 buildings (A, B, C, D, E, F) ITERA can be seen in Table 2. From Table 3 the use/consumption of electrical energy in 6 buildings (A, B, C, D, E, F) ITERA is included in the category of Very efficient.

Table 3. Total consumption of electrical energy in 6 buildings (A, B, C, D, E, F) ITERA

Total Electrical Energy Consumption (kWh/month)	Total Area (m^2)	ECI (kWh/m2/month)	Category
144768,19	19466	7,44	Very Efficient

3.2. Significant Energy Users

The electrical energy users' profiles for different equipment types (lights, air conditioners, and other devices) are shown in Figure 7. In buildings A, B, C, and D, the primary energy consumers are air conditioners, other electronic equipment, and lights, respectively. Building E primarily comprised of lecture halls, so it doesn't have as much other electronic equipment, with air conditioners and lights being the main consumers. In the case of building F, both other electronic equipment and lights contribute significantly to electrical energy consumption, with only a 1% difference between them.

Significant electrical energy users are found by 83% in air conditioners found in building C. This can be caused by using 2 types of air conditioners in the building, namely AC Casette with a capacity of 2.5 PK and AC Split Wall 2 PK which is found almost in every room and is used every day and working hours for 9-10 hours. The Cassette-type air conditioners are centrally controlled, making it impossible to adjust individual room levels, and also still use R-22 type of refrigerant, thus contributing to the overall high energy consumption.

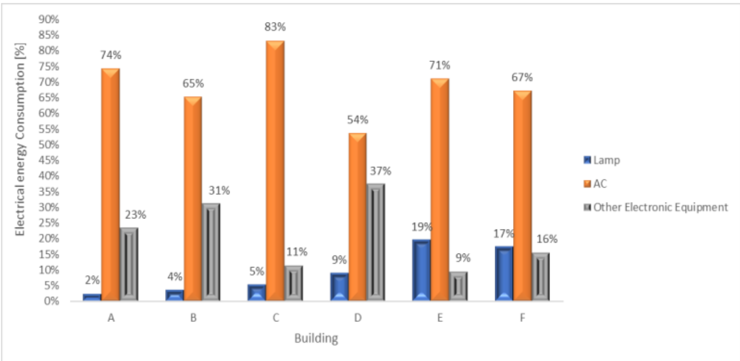

Fig. 7. Significant electrical energy user profile of each building A, B, C, D, E, F ITERA

Overall, for the total profile of electrical energy use/consumption of 6 buildings (A, B, C, D, E, F) ITERA in each type of electrical equipment (lights, air conditioners, and other equipment) can be seen in Figure 8. For the largest users of electrical energy, namely in air conditioning by 70%, then in other electronic equipment by 19%, and in lamps by 11%.

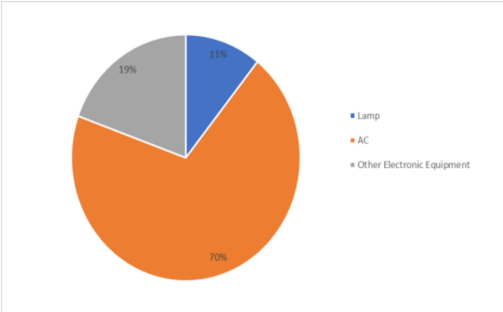

Fig. 8. Electrical energy user profile of a total of 6 buildings (A, B, C, D, E, F) ITERA

3.3. Energy Saving Opportunities

The main opportunity to save electrical energy is to calculate the comparison or difference between the current ECI value and the ECI target value [28]. Savings targets to be able to increase to efficient (buildings A and B) and highly efficient (building C) categories can be seen in Table 4. The savings target in Table 3 can be made with several efforts that must also consider the comfort aspect in activities, namely using electrical energy wisely (using enough electrical energy without having to sacrifice comfort in activities).

Tabel 4. Electrical energy saving targets

Building	**Before**		**Target (%)**		**After**	**Categry**
	Electrical energy consumption (kWh/month)	***ECI (kWh/month/m²)***		***Electrical energy consumption (kWh/month)***	***ECI (kWh/month/m²)***	
A	18073,38	17,68	21,00%	14277,97	13,97	Efficient
B	14728,83	14,41	2,88%	14304,64	14,00	Efficient
C	28896,39	8,65	7,55%	26714,71	8,00	Very Efficient

a. No cost – Change habits or actions on the pattern of use of electrical energy user equipment

Efforts to save energy involve changing habits and usage patterns of high-energy-consuming equipment like air conditioners, dispensers, and lights. This change is driven by self-awareness among building occupants, including employees, security personnel, and facility managers [28].

Based on our room observations in these buildings, we can implement changes to conserve energy. For air conditioners, we can utilize natural ventilation in the morning for 1-2 hours (e.g., 07:00-09:00 or 08:00-09:00) when the air is cool and can make the air in the room fresher because of good air circulation. This will reduce air conditioning usage from 8-10 hours to 6-8 hours per day. Dispensers are often running 24/7 in each room, significantly impacting energy consumption. To save energy, we should turn off dispensers when not in use and limit their operation to a maximum of 10 hours, typically from 07:00 to 17:00. Regarding lighting, we noticed that some rooms keep lights on after working hours, sometimes until 20:00, due to employees working overtime. Implementing a more efficient lighting usage pattern can lead to energy savings. These changes in electrical equipment usage can help us achieve our energy savings goals, as outlined in Table 3. The progress in energy usage reduction is detailed in Table 5.

Table 5. Achievement of electrical energy saving scenarios

Build-ing	**Before**		**Target**		**After**		**Achieve-ment**
	kWh/month	***Rp/month***	***kWh/month***	***Rp/month***	***kWh/month***	***Rp/month***	
A	18073,38	14.437.542,87	14306,25	11.304.596,07	14922,57	11.791.602,36	95,87%
B	14728,83	11.638.516,16	14304,64	11.303.326,89	14105,95	11.146.320,39	101,41%
C	28896,39	22.833.523,07	26714,71	21.109.592,08	25043,82	19.789.277,95	106,67%

b. Low/medium cost – Retrofitting Refrigerant R22

In addition, the results of identifying savings opportunities that can also be made are replacing refrigerant types for the use of AC Split Duct and AC Cassette in buildings A and B that still use R-22 to R-290. retrofitting the Split AC involves replacing R-290 with MC-22 musicool brand refrigerant. R-22 refrigerant contains chlorine and contributes to the depletion of the ozone layer in the atmosphere, so based on the decree of the Minister of Environment Number 08 of 2013 concerning the National Action Plan for the Utilization of HCFC Substitute Gas Substitution (HydroCloro-FluoroCarbon) to reduce HCFC by 35% in 2020 to 99.5% in 2040 [30]. Based on this, retrofitting the Split AC is carried out by replacing the use of R-290 refrigerant with the MC-22 musicool brand.

The selection of R-290 refrigerant due to its environmental friendliness and similar characteristics to R-22. It reduces greenhouse gas effects and cuts AC electrical consumption by 15% to 25% compared to R-22 [31], mainly because MC-22 refrigerant lowers AC compressor discharge pressure, resulting in reduced electricity usage [32].

Assuming a 15% savings (point 1 achieved), the total electrical energy savings for air conditioning in Buildings A and B amount to 15,549.97 kWh/month, equivalent to Rp 11,429,226.73 per month. This energy savings also leads to a 47-56% reduction in the ECI value, classifying it as very efficient (Figure 9). The investment cost for retrofitting R-22 with MC-22 includes equipment and refrigerant costs, totaling Rp 68,200,000. With a payback period of 6.23 months or 0.52 years, the retrofitting investment becomes profitable in the 7th month.

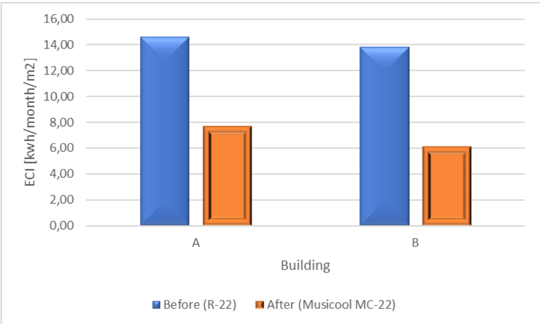

Fig. 9. Decreased ECI with retrofitting R-22 with MC-22

To conserve energy effectively, it's crucial to set AC temperatures within the thermal comfort range of 24-27°C and avoid exceeding 10% below the outdoor temperature [33]. However, in several rooms (C, D, E, and F) utilizing Split Wall AC units, temperatures as low as 18-20°C are observed. Lower AC temperatures result in higher energy consumption. In buildings A and B using AC Split Duct and Cassette types, temperature adjustments are limited due to on/off control from the panel, a drawback of these systems. To address this, users should practice disciplined AC operation by adhering to the recommended temperature range and ensuring windows and doors are properly sealed to prevent energy wastage.

Regular maintenance is crucial for indoor air conditioning units, including filter cleaning, refrigerant pipeline insulation, and monitoring evaporator output temperatures. These tasks should be performed every 3-4 months to ensure optimal AC performance [34]. Neglecting the indoor unit filter can lead to decreased AC performance [35], while inadequate pipeline insulation may cause refrigerant leaks. Additionally, if the evaporator output temperature doesn't match the remote AC settings, it's a sign that maintenance is required.

c. Commitment Organization

In addition, of course, it needs to be supported by the commitment of ITERA leaders in overseeing energy conservation and efficiency as well as a control system and monitoring of electrical energy consumption in each building. This commitment can be realized with the existence of energy conservation policies in the campus area. Currently, ITERA's energy management is at level 1, there is a lack of written policies, there are less energy management activities. Appointed employees have limited involvement in awareness training and information about energy usage is not easily accessible to all members of the institution. There are minimal programs and campaigns to raise staff awareness, and energy-saving initiatives like stickers are only present in a few buildings. Notably, there has been little investment in improving energy efficiency, with a focus on measuring small energy costs.

Therefore, with the commitment from the leadership, it can support ITERA to become an Energy Efficient campus category [36]. In the implementation of energy conservation efforts, it needs to be regulated in the form of SOPs and prepared based on scientific studies by the Campus Energy Conservation Development Agency with several policies directed at wiser and more efficient energy use. Also, always socialize about electrical energy-saving behavior to visitors who come, especially at ITERA activities that invite parties from outside ITERA [28]. This is because in general, carbon intensity is influenced by several components, one of which is the intensity of energy end users [37].

4 Conclusions

The conclusions of the research conducted includes the primary energy source used at ITERA is provided by PLN with one Customer ID (Group S3) having an electrical power capacity of 1,110,000 VA, serving multiple buildings (A, B, C, D, E, F, and GKU 2). In May 2023 the total energy consumption across these six buildings reached 144,768 kWh and obtained an ECI value of 7.44 kWh/m2/month (very efficient). Of the 6 buildings, building F had the highest energy consumption value (36,647.92 kWh/month) while building B had the lowest energy consumption value (14,728.83 kWh/month). Building F’s higher consumption was due to its use as accommodating administrative and academic services for 2 of 3 departments at ITERA, therefore more types of electrical equipment are used during working hours and on weekdays for various activities. Then, building A had the highest ECI value (17.68 kWh/m2/month), while Building E had the lowest (4.16 kWh/m2/month). Building A's high ECI was attributed to extensive air conditioner usage, limited workspace, low occupancy, and the use of centrally controlled air conditioning units, makes it impossible to make individual room level adjustments, contributing to the overall high energy consumption. Building C had significant energy usage, with 83% attributed to air conditioning. This was due to extensive air conditioning use, limited workspace, and the operation of two types of air conditioning (Split Wall and Cassette) for 9-10 hours per workday. The Cassette-type air conditioners are centrally controlled, making it impossible to adjust individual room levels, and still use R-22 type of refrigerant, thus contributing to the overall high energy consumption. So, there are 2 energy saving recommendations that can be done, namely changing the habits / patterns of using electrical energy user equipment, especially in air conditioners and dispensers, for potential savings of 2-21%, and retrofitting R-22 refrigerant AC units with MC-22 for potential electricity 15-25%.

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