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A Novel of Energy Consumption Profile of a Shopping Center

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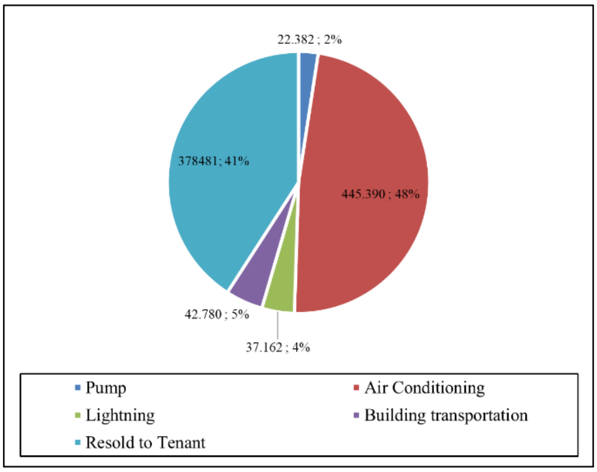
ABSTRACT



Energy conservation in Indonesia is the primary choice made by the government of the Republic of Indonesia. It is undeniable that the highest consumption of a building is air conditioning energy, especially in a tropical environment like Indonesia. Air conditioning consumes between 40% and 80% of power in a high-rise building. The problem is how to find out the electricity usage profile and energy consumption index in a building that has been in operation for more than 20 years. This research aims to find the energy profile and calculate the energy consumption of a shopping center building. The method used is an Energy Audit according to SNI 6196. The energy consumption profile is an anomaly where the energy consumption for the air conditioning system is only 48%, while the average value in shopping centers in Indonesia is 62.9%. Meanwhile, the GFA energy consumption index is 23.11 kWh/m2/month or 277.3 kWh/m2/year. According to SNI 03-0196, the result is classified as an energy-intensive building. This value is close to the SNI 03-0196 standard for very energy-intensive building levels, which has values between 23.75 and 37.5 kWh/m2/month. Energy-saving opportunities are calculated by calculating the difference in the ECI value with the target ECI value. To increase the efficiency of energy consumption, this can be done by replacing the chiller unit which still uses a step type compressor. Apart from that, improving air conditioning insulation is very significant to overcome energy consumption problems. Adding green plants around buildings can also increase electrical efficiency.

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1. INTRODUCTION

Energy conservation in Indonesia is the primary choice made by the government of the Republic of Indonesia to address the current state of energy in the world. The success of this activity certainly requires support from various parties [1]. The activity is related to the increasing demand for energy in Indonesia. The problem is that management is more focused on production levels than energy efficiency [2][3].

In Indonesia, environmentally friendly buildings are a must to anticipate environmental damage and global climate change. Compared to the growth rate of buildings in Indonesia, the number of environmentally friendly buildings is relatively small (less than 5%) [4]. Worldwide, 30-40% of all energy is used in buildings. Most of this energy is used for heating, cooling, lighting, and operating equipment. In contrast, active methods refer to automated systems that enable convenience applications such as heating, cooling, lighting, elevators, and others [5]-[8]. Buildings constitute 32% of the total final energy consumption in the world [1]. They are the largest emitters of carbon emissions in nature, so businesses in the building sector are responsible for contributing to reducing carbon emissions [9]. The concept of green building is one of the solutions for the following sustainable development [2]. One of the most significant barriers to investing in green buildings is the perception that the costs incurred are more significant than conventional buildings, such as increasing the initial investment cost of the building [3].

Currently, for the need for energy conservation, the development of green buildings is a necessity. Using environmentally friendly building materials can help improve indoor air quality (Indoor Air Quality or IAQ) and meet consumer demand. Currently, the property market trend is to accept more products that apply the green concept. One of the indicators is that property market prices are higher than properties that do not apply the Green Development concept [6]. Assets that maintain value through higher occupancy and more accessible maintenance are easier to sell and have a higher market valuation. The Indonesian Property Management Association estimates that the green project will bring added value. Rental prices can go up 6.4 percent, while selling prices can go up 19.6 percent. Companies with an image of being an 'environmentally friendly company' can attract more consumers to buy their products.

Conventional buildings consume more energy sources than necessary and generate various emissions and waste. To overcome this problem, build green and intelligent buildings or green and smart buildings. Using renewable energy is a crucial component of the intelligent and green building concept. Solar energy and wind energy are energy sources that are not sustainable, so these sources must be combined with other energy sources or storage devices [10]-[12]. Practical and systematic architectural design adapted to environmental conditions is expected to help minimize energy consumption and improve building performance [13]. Table 1 shows energy consumption in Indonesia based on building functions [14].

Table 1. Building energy consumption in Indonesia [14]

Building	Value (kWh/m^2/Year)
Office	180.95
Hotel	208.15
Hospital	180.81
Shopping Centre	286.54

Most buildings in Indonesia still need to refer to green buildings. One of them is Cijantung Mall, a shopping center in Jakarta. This building began operating in 1998 and has been operating for more than 20 years. When it was first built, energy conversion was not implemented. The building equipment used still uses old model equipment which has not implemented efficient electricity consumption. The air conditioning system used is still the old model which uses R22. This futuristic building does not yet have an ECI (Energy Consumption Index). For this reason, it is necessary to carry out an initial audit to obtain the ECI value. Furthermore, steps can be taken toward energy-saving conditions under applicable standards.

The purpose of this study is to obtain a measurement value of energy use in a shopping center building. The method used in this research is a short energy audit [15]. The contribution that can be made in this study is the value of Energy Consumption Intensity and recommendations that can be taken by building management to achieve energy efficiency [12],[16]. The benefit of this research is that stakeholders can decide on the most appropriate and effective steps in making decisions so that this building is energy efficient.

2. METHODS

From the data from the questionnaire results of 204 buildings, the distribution of total energy use in the building was obtained [14]. It can be seen that 35 building objects consume energy of more than 500 TOE (Ton Oil Equivalent), or around 17.2%, dominated by hotels and shopping centers. At the same time, buildings that consume energy below 250 TOE are around 139 objects or around 68.1%. Of the 204 buildings surveyed, the total Gross Floor Area (GFA) is 3.782.547.50 m², and the total annual energy consumption is 67.507.08 TOE which has contributed to the benchmarking survey.

The ECI of a conditioned building is calculated from the annual consumption of electrical energy divided by the area of the conditioned building. Meanwhile, GFA (Gross Floor Area) Building ECI is the total energy consumption divided by the total building area, excluding the parking area. This distribution has almost the same pattern between conditioned ECI and GFA ECI [14]. Calculating the intensity of energy consumption can be found in Equation (1) [17]. The energy consumption intensity in buildings/buildings is defined in terms of energy per unit area of buildings served by energy, which can be calculated by Equation (1) [22],[23]. SNI (Indonesian National Standard) number 03-0196: 2010 has classified the ECI of air-conditioned buildings as shown in Table 2.

$$ECI = \frac{Energy\ Consumption\left(\frac{kWh}{Month}\right)}{Building\ Area(m^2)} \quad (1)$$

Where ECI is the Energy Consumption Index and GFA is the building area.

In Equation (1), the calculation for one month is given to obtain the ECI value of 1 year multiplied by 12 months. The multiplier also applies to Table 2, all values are multiplied by 12. Following applicable Indonesian standards, old buildings are not required to follow energy efficiency standards. However, stakeholders must be able to understand that efficiency is a requirement to obtain optimal company performance. The energy audit is the main parameter in implementing energy conservation. There are quite a lot of standards that apply. In Indonesia, we can refer to the Indonesian National Standard number SNI 6196:2011. However, this standard refers to other existing standards [18],[19]. In this study, we use the short energy audit method. The steps include preparation, data collection, analysis, and report preparation. We provide the steps in our research in a flow chart according to Figure 1. Because the building we are studying has been in operation for more than 20 years, the calculation of energy use uses direct measurement results, not based on an existing single-line diagram.

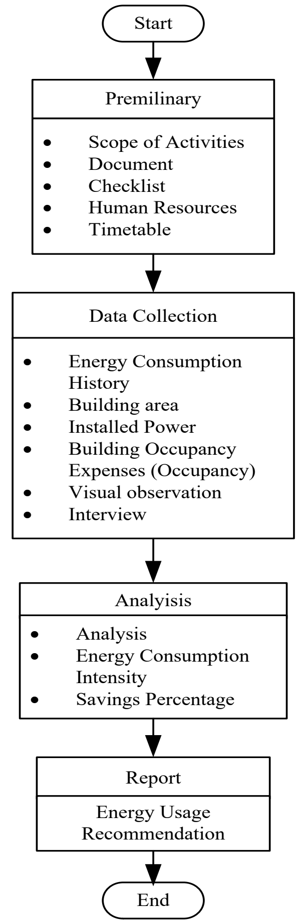

Figure 1. The Simple energy audit flow chart [15]

Table 2. Classification of the ECI value of air-conditioned buildings SNI: 03-0196-2010

Value	ECI (kWh/m²/month)
Very Wasteful	23.75 – 37.5
Wasteful	19.2 – 23.75
A bit wasteful	14.58 – 19.2
Quite efficient	12.08 – 14.58
Efficient	7.93 – 12.08
Very efficient	4.17 – 7.93

Preparing for an energy audit includes preparing resources and supporting documents and preparing an activity schedule. In addition, from the administration side, permits are also issued to access all existing documents, especially the Single Line Diagram of buildings [20]. An activity schedule is required to calculate energy consumption for at least one month of energy measurement on equipment that consumes electricity. However, in this preparatory stage, it is a list of equipment that works in a building.

The second step in the research is data collection. We collect data in the form of historical data consisting of the total floor area of the building along with the area covered, payment of the building's monthly electricity bill for the past 1 (one) to 2 (two) years, and fuel oil purchase accounts, the occupancy rate for the last 1 (one) to 2 (two) years. We compare the data with the installed power in the building. To complete the data, we conducted interviews and visual observations of all the equipment in the building.

The third step in this research is to perform calculations using the available data obtained based on the second step. This calculation is expected to obtain a building's profile and energy efficiency, including the calculation of energy consumption intensity (kWh/m^2/year) and energy consumption index. Based on direct observation and the results of brief interviews with operators regarding matters related to the operation of the energy use of the object under study and the energy needs of the entire building [21].

The energy audit report is prepared by including a portrait of energy use, recommendations that include energy conservation steps that can be implemented, and options to proceed to a more detailed audit. The selection of primary and secondary equipment for the HVAC system, as well as determining their specifications, is an essential step in determining the level of efficiency in use and the level of energy savings. In general, primary, and secondary equipment is not made specifically for the needs of the planned building. For this reason, it is necessary to make engineering compromises by choosing equipment with specifications that are closer to planning, with the best efficiency that can be obtained.

3. RESULT AND DISCUSSION

Based on the data we obtained, the Cijantung Mall shopping center building has a total area of 53.059 m^2. This building consists of 7 floors; besides the ground floor, this shopping center building has two basements and four floors above. The parking area is on the two basement floors. Table 3 provides a detailed area of the shopping center. In commercial buildings, the use of electricity is grouped, the first is used alone, and the second is that electricity is resold to tenants.

The electricity in the building is used to provide lighting and equipment to serve public facilities. This electricity is paid by building tenants as one of the service charge components every month. The results are given in Table 4.

Table 3. Total area of the building

Floors	Net Area (m²)	Common Area (m²)	Service Area (m²)	AC Room (m²)	Total (m²)
B2	45	733	300	250	7680
B1	3648	3732	300	4580	7680
Ground	4300	1911	300	6211	6511
1st	6547		300	6247	6547
2nd	6547		300	6247	6547
3rd	6547		300	6247	6547
4th	6547			3547	6547
Outdoor				1500	5000
		Total		34829	53059

Table 4. Measurement of energy consumption of electrical equipment in a month

Equipment	Energy (KWH)
Fan	20404
Pump	22382
Chiller	230482
Lamp	37162
Air Handling Unit	89516
Building Transportation	42780
Total	442727

By adding the value of the total electrical energy used by the tenants, the electricity consumption profile in the building can be presented in Table 4 [22],[23]. The total electricity usage used by tenants is referred to as shared electricity usage. The result of this value is the total use of electricity used by the building. Based on Table 4, the fan equipment, AHU (Air Handling Unit), and chiller are part of the air conditioning system. Combining the energy shows that the amount of electrical energy consumption for the HVAC system is 77%.

The amount of electrical energy used by tenants is 483.469 kWh. Based on the recapitulation of electricity bills issued by shopping centers, we record that 14 large tenants use an independent air conditioning system separate from the building's air conditioning system [18],[24]. These tenants are restaurants that require cooler air temperatures [15],[18],[21],[22]. Apart from restaurants, there are cinemas and karaoke rooms, and the total electricity usage for the 14 tenants is 166.912 kWh. Even though the number of tenants using independent air conditioning is only 14, it accounts for 34.55% of the total energy used by all tenants.

We perform calculations assuming that the amount of electrical energy used for air conditioning is 62.9%, then the actual power used by tenants can be calculated [14]. So of the 166.912 kWh consumed by tenants, 104.988 kWh is used for air conditioning. This figure significantly changes the data in Table 5. We can provide new data that of the 483.469 kWh of energy used by tenants, 104.988 kWh is used for the air conditioning system. The results of energy use in buildings can be presented in Table 6.

Table 5. Measuring the electricity consumption of shopping centers in a month

Equipment	Energy (kWh)
Fan	20.404
Pump	22.382
Chiller	230.482
Lamp	37.162
Air Handling Unit	89.516
Building Transportation	42.780
Resold to Tenant	483.469
Total	926.196

Table 6. Final Electricity consumption of shopping centers profile

Equipment	Energy (kWh)
Pump	22.382
Air Conditioning	445.390
Lightning	37.162
Building transportation	42.780
Resold to Tenant	378.481

Because shopping centers resell the electricity received from the state electricity company to tenants, based on Table 6, the electricity consumption of shopping centers profile will be generated. From these results, the energy consumption for the air conditioning system is only 48%. These results are very different from the results of measurements in previous studies.

Based on Figure 2, the amount of electricity consumption for air conditioning in this building is only 48%. This energy ratio is far from the average value of energy consumption used in other shopping centers in Indonesia, which has an average value of 62.9% [14]. This anomaly occurs with several possibilities. The first possibility is an efficient air conditioning system in the building—the possible by keeping the environment around the building cooler by planting plants as shade. The second possibility is more energy use for the air conditioning system.

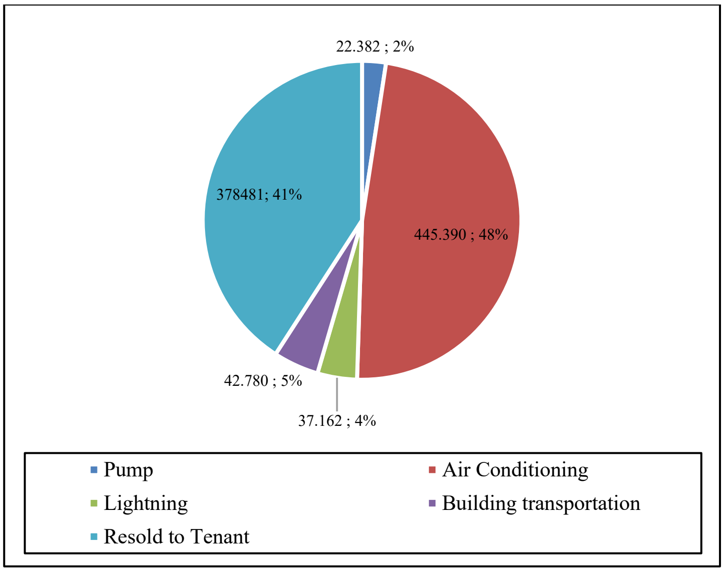

Figure 2. Electricity consumption of shopping centers profile

The energy consumption index can be calculated using Equation (1). Based on Table 3, the total area of the building is 53059 m^2. The total energy used for one month of measurement can be seen in Table 6, with a value of 926.196 kWh. This calculation gives a result of 17.46 kWh/month/m^2 or the equivalent of 209.47 kWh/m^2/year for the GFA value. However, according to reference [14], the amount of ECI does not include the vehicle parking area, which is 286.54 kWh/m^2/year for shopping centers. If the area of the parking area is not included, the ECI will be 23.11 kWh/m^2/month or 277.3 kWh/m^2/year. According to [17], the use of 23.11 kWh/m^2/month is classified as an energy-intensive building. This value is close to the SNI 03-0196 standard for very energy-intensive building levels, which have values between 23.75 to 37.5 kWh/m^2/month.

Energy-saving opportunities are calculated by calculating the difference in the ECI value that occurs with the target ECI value. Many methods can be done to increase the ECI value. According to [26], we must conduct an energy audit assisted by monitoring the internet of things. Considering that the building has been operating for over 20 years, much infrastructure is needed. According to [27], Energy saving opportunities through Variable Frequency Drive for Commercial Air Conditioners. This choice could be made by gradually replacing the air conditioning system with an inverter.

Meanwhile, high-efficiency refrigerants have been started [28],[29]. All devices that still use R22 will soon be replaced with more efficient ones such as R32 or the like. Another step that can be taken is to minimize leaks and air infiltration from outside the room in the air conditioning system [30]. Another step that can be taken is to minimize leaks and the entry of hot air from outside the room in the air conditioning system. We can audit all air-conditioned rooms, so they do not experience infiltration from the outside air. These actions will be able to reduce the waste of energy. Keeping the ambient temperature of the building cooler can reduce the burden of air conditioning. Cooling can be done by planting as many green plants that can dampen the sun's heat.

Variable speed control can also be applied to escalator devices. Variable speed control can adjust the rotational speed of the motor according to the speed we want. The motor's rotational speed will be lowered or even totally dead when there is no user. To increase the efficiency of energy consumption, this can be done by replacing the chiller unit which still uses a step type compressor. Apart from that, improving air conditioning insulation is very significant to overcome energy consumption problems. Adding green plants around buildings can also increase electrical efficiency.

4. CONCLUSIONS

An energy audit to determine the energy consumption profile in a building using a brief audit method can be carried out effectively according to SNI 6196 standards. The energy consumption profile is an anomaly where the energy consumption for the air conditioning system uses only 48%, while the average value in shopping centers in Indonesia is 62.9%. Meanwhile, the GFA energy consumption index has a value of 23.11 kWh/m^2/month or 277.3 kWh/m^2/year. According to SNI 03-0196, 23.11 kWh/m^2/month use is classified as an energy-intensive building. This value is close to the SNI 03-0196 standard for very energy-intensive building levels, which has values between 23.75 to 37.5 kWh/m^2/month. Energy-saving opportunities are calculated by calculating the difference in the ECI value that occurs with the target ECI value. Many methods can be done to increase the ECI value. Energy saving opportunities through Variable Frequency Drive for Commercial Air Conditioners. This choice could be made by gradually replacing the air conditioning system with an inverter. All devices that still use R22 will soon be replaced with more efficient ones such as R32 or the like. Another step that can be taken is to minimize leaks and air infiltration from outside the room in the air conditioning system. Adding green plants around buildings can reduce the workload on the air conditioning system. Furthermore, replacing lights with LEDs (Light Emitting Diodes) can gradually reduce the electrical load.

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