A Novel Green Building Energy Consumption Intensity: Study in Inalum Green Building

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***Abstract*—The need for a building with a green building concept is now very important for environmental conservation. The concept of green building is to design a building that has a more efficient consumption of electrical energy. The Energy Consumption Intensity (ECI) of a building in Indonesia with a tropical climate is regulated in SNI no 03-0196: 2010. In this standard, the ECI of an air-conditioned building is said to be efficient if it has a consumption of 7.93-12.08 kWh/M2/month. Meanwhile, according to the Indonesian Green Building Council (GBCI), the ECI in Green Building is 50% of a conventional building. In this study, electrical energy consumption was measured for at least 1 year. The research location is the Head Office Building of PT Indonesia Asahan Aluminium (Persero), a State-Owned Enterprise located in Batubara Regency, North Sumatra, Indonesia. According to the results of the analysis of existing data, it can be concluded that the Inalum Building has an efficient electricity consumption intensity according to SNI standards, with a value of 78.34 kWh/m2/year or 6.53 kWh/m2/month. However, as a green building, the existing air-conditioned space still has an ECI value that exceeds the specified standard. According to the SNI standard classification, this building is still considered energy-intensive because the ECI value of an air-conditioned room is 243.56 kWh/m2/year or 20.29 kWh/m2/month. The novelty that we get in this research is the actual Energy Consumption Intensity (ECI) indexes of this green building.**

Keywords—green building, energy intensity, standard, energy consumption

I. Introduction

In Indonesia, environmentally friendly buildings are a must to anticipate environmental damage and global climate change. The institution that certifies environmentally friendly buildings in Indonesia is GBCI (Green Building Council Indonesia) with green building certification. Compared to the growth rate of buildings in Indonesia, the number of environmentally friendly buildings is relatively small (less than 5%) [1][2]. Worldwide, 30-40% of all energy is used in buildings[3]. Most of this energy is used for heating, cooling, lighting, and operating equipment. Energy savings in buildings can have a faster and greater impact on CO_2 emissions than switching to cleaner energy sources. Methods that can be used to save energy in buildings are grouped into two methods, namely active and passive. Passive measures include permanent methods on the building envelope or facade such as insulation, glazing, ventilation while active methods refer to automated systems that allow comfort applications such as heating, cooling, lighting, elevators, and others [4][5][6][7]. Buildings constitute 32% of the world's total final energy consumption [1] and are the world's largest emitters of carbon, so building businesses have a responsibility to contribute to reducing carbon emissions. The concept of green building is one solution for the next sustainable development [2]. One of the biggest barriers to investing in green buildings is the perception that the costs incurred are greater than conventional buildings, such as an increase in the initial investment cost in the building.

Conventional buildings consume more energy sources than necessary and produce a wide range of emissions and wastes. To overcome this problem the solution is to build green and smart buildings or green and smart buildings[8]. One of the important components in the smart green building concept uses renewable energy. Solar energy and wind energy are unsustainable energy sources, so these sources must be combined with other energy sources or storage devices [9][10][11][12]. In a broader sense, green buildings include buildings that are built, operated, maintained, and reused considering maximum energy conservation in all phases. The first goal of green buildings is related to human health, maximum use of natural resources, reduction of electrical energy consumption, maximum utilization of renewable energy and reduction of environmental pollutants. Effective and systematic architectural design adapted to environmental conditions is expected to help minimize energy consumption and improve building performance [13].

PT Indonesia Asahan Aluminium (Persero) often abbreviated as Inalum is a State-Owned Enterprise having its address in Kuala Tanjung, Batubara Regency, North Sumatra Province, Indonesia has completed building an office building with a green and smart building concept. The concept of "Green and Smart Building" in this building has an ethnic Malay architecture, thus the concept of the building prioritizes aspects of sustainability development.

The problem that then arises is that the building with the green building concept which was inaugurated by the Minister of SOEs a (State-Owned Enterprise Republic of Indonesia) on

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January 6, 2021, is really a green building concept? Meanwhile, there is the Indonesian National Standard No. 03-0196: 2010 concerning the energy consumption level of air-conditioned buildings of 7.93 -12.08 kWh/M2/month.

The purpose of this study is to audit the use of electrical energy in the building[14]. Researchers collect empirical data that will be used to determine the index value of the Energy Consumption Intensity in this building. The measurement results will be compared with the standards issued by SNI (Indonesian National Standard) and GBCI. With these results, a conclusion will be obtained whether the building is worthy of being called a Green Building.

The novelty that we get in this research is the actual Energy Consumption Intensity (ECI) indexes of this green building.

II. THE COMPREHENSIVE THEORETICAL BASIC

The concept of smart building is the implementation of technological developments in the construction sector. The purpose of smart building is to integrate systems within the building in an appropriate coordination to manage resources efficiently [8][15][16]. Smart building operations utilize ICT (Information and Communication Technology) to achieve efficiency, comfort, and safety.

The concept of the smart building has an initial investment value that is not small and not cheap, but there are also many benefits that can be obtained by applying the concept [17]. In addition, the application of the smart building concept can provide building energy efficiency. Electrical energy efficiency can be obtained by optimizing the use of natural lighting during the day and using artificial lighting (lamps) as needed. This is done by integrating natural lighting and artificial lighting with control devices/sensors with a smart building concept, so that energy efficiency in buildings can be obtained [12], [18].

A. Energy Efficiency and Conservation

Energy Efficiency and Conservation **(**EEC**)** was born and became important because the need for energy use in new buildings varies from the construction stage to operation and maintenance. The operation of air conditioning, escalator/elevator facilities, and artificial lighting is the largest energy consumption among other facilities[19].

Not only having an impact on wasting costs due to excessive consumption of electrical energy, but the inefficient operation of the system can also have a major impact on climate change and global warming due to the large amount of CO_2 carbon dioxide emissions in power plants which causes the greenhouse effect. EEC on new buildings is divided into 5 assessment criteria with 2 prerequisite assessments as follows:

1. EEC P1, Electrical Submetering or Sub-meter Installation
2. EEC P2, OTTV Calculation
3. EEC1, Energy Efficiency Measures
4. EEC2, Natural Lighting
5. EEC3, Ventilation or Ventilation
6. EEC4, Climate Change Impact
7. EEC5, On-Site Renewable Energy.

B. Measuring Energy Savings

Indonesia's dependence on fossil energy encourages the presence of the EEC 1 criteria for new buildings. As we know, fossil energy which is the primary energy source to produce electrical energy is non-renewable energy and has many negative impacts[3]. The negative impacts are air pollution, solid waste, and global warming due to CO2 gas emissions[20].

In the operational and building maintenance phases, building users still waste electrical energy to meet their daily needs, as has been briefly explained in the previous discussion regarding prerequisite EEC criteria 2. To overcome this, an energy management plan is needed for a building. Energy management is an activity to manage energy use efficiently, effectively, and rationally without disturbing work comfort, aesthetics, health, safety, and productivity of building users.

C. Energy Consumption Intensity (ECI)

The energy consumption indicator parameter used in this study is ECI (Energy Consumption Intensity)[21]. ECI in buildings is a value/quantity that can be used as an indicator to measure the level of energy utilization in a building. The intensity of energy consumption in buildings/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 1 below.

$$ECI = \frac{Energy\_Consumption(\frac{kWh}{Month})}{Building\_Area(m^2)} \quad (1)$$

TABLE 1. 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

The Minister of Energy and Mineral Republic of Indonesia Resources No. 03: 2012 also classifies the use of electrical energy in air-conditioned buildings as shown in Table 2 below.

TABLE 2. CLASSIFICATION OF THE ECI VALUE OF AIR-CONDITIONED BUILDINGS [4]

Value	ECI
Very efficient	ECI < 8,5
Efficient	8,5 < ECI < 14
Quite Efficient	14 < ECI < 18,5
Wasteful	18,5 < ECI

III. METODE

In this study, several stages of the research process were carried out. The initial stage is collecting initial data from the research location. Data collection in the form of the architecture of the building to obtain the building area. Furthermore, the researchers conducted a survey of the electrical distribution system to obtain a Single Line Diagram (SLD) in the building.

A. The Inalum Building

To find out the amount of electrical energy consumption, data collection on electricity usage for a period of a minimum of 1 year was carried out. On the ground floor (1st floor) there are several existing tenants such as Bank and Coffee Shop. Figure 1 shows the layout of the 1st floor. The 1st floor has an area of 4,664 M2 which consists of an air-conditioned room and a non-air-conditioned room. However, not all floors have different sizes, the area of each room is given in Table 3.

TABLE 3 LIST OF ROOM AREAS IN INALUM BUILDING

Layers	AC (M^2)	Non-AC (M^2)	VOID (M^2)	Total (M^2)
1st Layer	1532	2412	720	4664
2nd Layer	1822	1810	1032	4664
3rd Layer	2338	2142	784	5264
4th Layer	2338	2142	784	5264
5th Layer	2338	2142	784	5264
6th Layer	2536	1944	784	5264
7th Layer	2536	1944	784	5264
8th Layer	2938	1606	720	5264
Total	18378	16142	6392	40912

Fig. 1. The 1st Floor Layout

With a green building concept, this building utilizes strong winds to cool non-AC areas in the building. Meanwhile, the void area is used for lighting in the building, especially in non-AC areas and corridors. Based on Table 3, the area of the AC room is 45%, the outside non-AC space is 39% and the remaining 16% is void that cannot be used. Void is used as natural lighting from the glass roof.

B. Single Line Diagram

This building's electricity comes from 3 sources. The main source comes from the aluminum smelter owned by Inalum. As a backup power, a generator set with a capacity of 1,250 kVA is provided. As a green building, the electricity source is also obtained from a solar panel generator with a capacity of 10 kW which is located on the roof top of this building[14][24]. The electrical single line diagram (SLD) system of this building is shown in Figure 2.

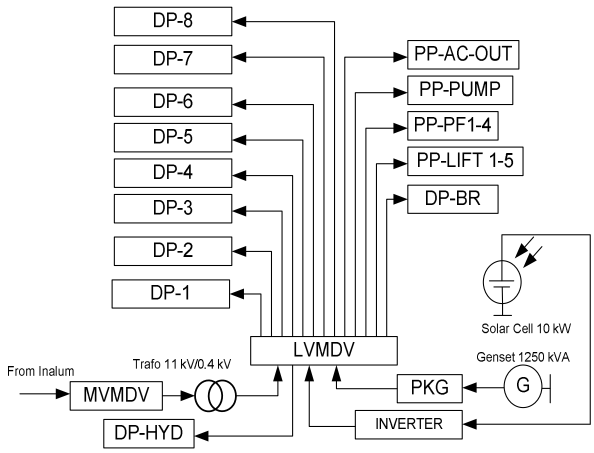

Fig. 2. Single Line Diagram

C. Building Energy Consumption

In this study, data on electricity usage with a single tariff was obtained. However, it is possible for the building to operate beyond the specified time. The operating hours also adjust to the needs. Even so, on weekdays, it officially operates every Monday to Friday. By special request Saturday or Sunday, the building remains partially operated. Table 4 shows data on the electricity usage for the period November 2020 to November 2021.

TABLE 4. THE USE OF ELECTRICITY DATA

Periods	Energy (kWh)	Periods	Energy (kWh)
Nov-20	167800	Jun-21	135400
Dec-20	147480	Jul-21	95000
Jan-21	137210	Aug-21	83390
Feb-21	129390	Sep-21	116600
Mar-21	142800	Oct-21	135500
Apr-21	121700	Nov-21	134010
May-21	103200		

IV. RESULT AND DISCUSSION

A. Room Area

The room area in the building according to Table 5 is 40,912 m^2. However, occupancy is not yet 52%. Based on the measurement data, the occupancy rate is given in Table 5.

TABLE 5. BUILDING OCCUPANCY RATE

Floors	AC (m^2)	Non-AC (m^2)	VOID (m^2)	Total (m^2)	Vacant (m^2)	Occupancy (m^2)
1st Layer	1532	2412	720	4664	429	72%
2nd Layer	1822	1810	1032	4664	1307	28%
3rd Layer	2338	2142	784	5264	2338	0%
4th Layer	2338	2142	784	5264	2338	0%
5th Layer	2338	2142	784	5264	2338	0%
6th Layer	2536	1944	784	5264	0	100%
7th Layer	2536	1944	784	5264	0	100%
8th Layer	2938	1606	720	5264	0	100%
Total	18378	16142	6392	40912	8750	52,39%

The data in Table 5 does not include the State Savings Bank which is located on the 1st floor with an area of about 200 m^2, because in December 2021 the renovation has been completed but not yet operational. From the table, it is found that the area of the air-conditioned room used is 9628 m^2 and the non-AC room (assuming the 3rd, 4th, and 5th floors are not counted) is 9716 m^2. The total area is 19,344 m^2.

B. Measurement

According to Equation 1, and electrical energy consumption in Table 5, the ECI can be calculated. For example, for November 2020, the amount of electrical energy consumption in that month is 167,800 kWh and the building area is 19,344 m^2, then the intensity of electrical energy consumption is 8,67 kWh/m^2/month.

With the above calculation, it is possible to calculate the ECI for the following months. Table 6 provides the results of the calculation of ECI per month from November 2020 to November 2021. According to Table 6, a monthly ECI graph of the Inalum Building can be made. Figure 3 shows the ECI graph of the Inalum building compared to SNI 03-0196. While in Figure 4 is ECI compared to the Minister of Energy and Mineral Resources No. 3 of 2012.

TABLE 6. DATA OF ECI PER MOTH

Periods	Monthly Energy Consumption (kWh)	Intensity (kWh/m2/month)
Nov-20	167,800	8.67
Dec-20	147,480	7.62
Jan-21	137,210	7.09
Feb-21	129,390	6.69
Mar-21	142,800	7.38
Apr-21	121,700	6.29
May-21	103,200	5.33
Jun-21	135,400	7.00
Jul-21	95,000	4.91
Aug-21	83390	4.31
Sep-21	116,600	6.03
Oct-21	135,500	7.00
Nov-21	134,010	6.93

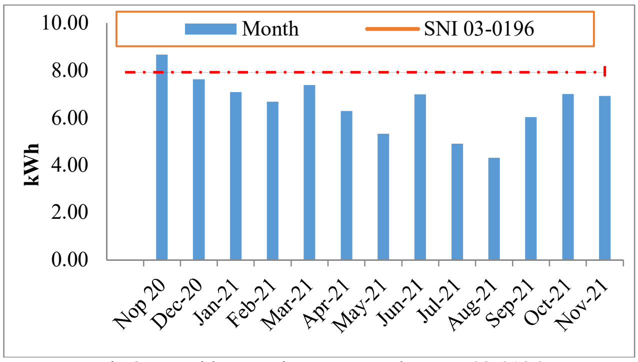

Fig.3. Monthly ECI chart compared to SNI 03-0196

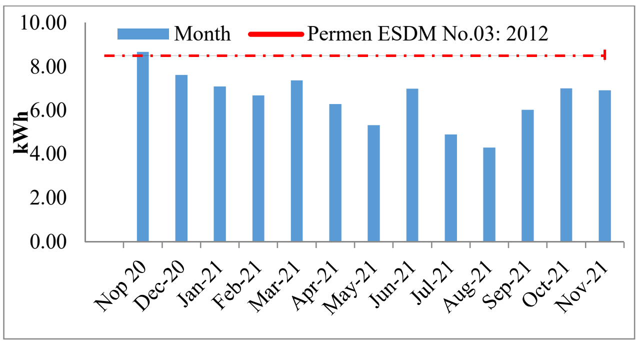

Fig. 4. Monthly ECI chart compared to Minister Regulation No. 3: 2012

Furthermore, the amount of ECI is based on [15], where the amount of ECI at the Commercial Office per year is 240 kWh/m2/year, then for the period November 2020 to October 2021, the amount of ECI is 78.34 kWh/m^2/year, and this is still far from the value limit. waste and still included in the value very efficient.

C. Green Building ECI Measurement

To comply with EEC 1 concerning Optimized Efficiency Building Energy Performance or Optimal Energy Efficiency Performance in Buildings, it is necessary to use electricity efficiently. The largest use of electricity in a building is for the air conditioning system. Referring to the Decree of the Minister of Energy and Mineral Resources number 3 of 2012 and SNI No. 03-0196: 2010 concerning air-conditioned buildings, it is necessary to evaluate the ECI calculation in Sub Chapter 4.2. According to the measurement results, data on the electricity usage of the building is obtained as given in Table 7.

TABLE 7. LIST OF PANELS OUTSIDE AIR-CONDITIONED ROOM

Panel	Locations	Energy
PP R. Pump Room & STP	Basement	11%
PP Ballroom	Ballroom	1%
Panel Lift	Roof	1%
PL/PP Indoor	Every Layers	4,65%
PL/PP Outdoor	Outdoor	2,68%
PP Electronic	Control Rooms	0,20%
PP Pump Room	Roof	1,40%
Total		22,63%

With Table 7 above, to measure the intensity of an air-conditioned room, monthly electricity usage is reduced by 22.63% of the total energy used. This approach was taken because data on electricity usage per kWh meter in the existing distribution subpanel was not obtained. Researchers perform calculations based on total meters recorded in digital meters in each sub-panel. Table 8 provides data on the estimated monthly energy use of the air-conditioned room in the building each month in the period November 2020 to November 2021. This data is obtained from the monthly value of the total energy used minus the energy used outside the air-conditioned room which is 22.63%.

TABLE 8. DATA ON THE USE OF AIR-CONDITIONED SPACE ENERGY CONSUMPTION

Periods	Energy Consumption	
	Total (kWh)	Air-conditioned Space (kWh)
Nov-20	167.800	129.827
Dec-20	147.480	114.105
Jan-21	137.210	106.159
Feb-21	129.390	100.109
Mar-21	142.800	110.484
Apr-21	121.700	94.159
May-21	103.200	79.846
Jun-21	135.400	104.759
Jul-21	95.000	73.502
Aug-21	83.390	64.519
Sep-21	116.600	90.213
Oct-21	135.500	104.836
Nov-21	134.010	103.684

Furthermore, to measure the amount of energy consumption in an air-conditioned room, it can be done using Equation 1 and the data for an air-conditioned room in Table 5 as shown below, an example for the calculation for November 2020 gives the value of 13,48 kWh/m^2/month.

With the same calculation as above, the ECI of the air-conditioned room in the building can be made a table for energy use in the following months. Table 9 the ECI data for the air-conditioned room, while Figure 5 is the ECI graph for the air-conditioned room at Inalum Building.

TABLE 9. ECI DATA OF AIR-CONDITIONED ROOM

Periods	**ECI (kWh/m²/month)**
Nov-20	13,48
Dec-20	11,85
Jan-21	11,03
Feb-21	10,40
Mar-21	11,48
Apr-21	9,78
May-21	8,29
Jun-21	10,88
Jul-21	7,63
Aug-21	6,70
Sep-21	9,37
Oct-21	10,89
Nov-21	10,77

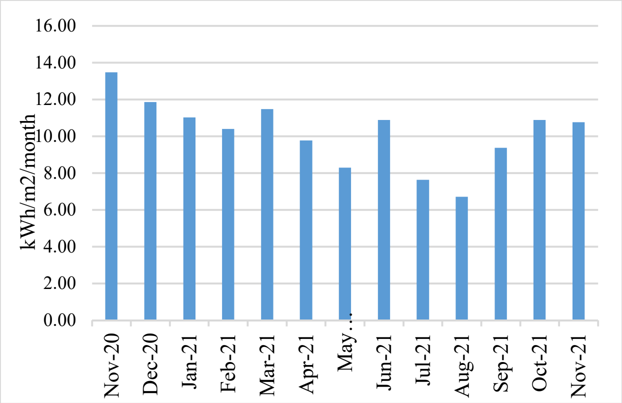

Fig. 5. The AC room ECI chart

D. Discussion

As a conventional office building, the building has very efficient use of electricity based on the reference to SNI 03-0196: 2010 which is 7.93 kWh/m^2/month and according to Ministerial Regulation No. 3 of 2012 which is less than 8.5 kWh.m2/month except in November 2020. In that month it is categorized as efficient. According to [16], the ECI of a green building is 50% of the standard for a conventional building. If the annual data for the building is in other words, the annual ECI value of 78.34 kWh/m^2/year has a value of 156.68 kWh/m^2/year or 13.05 kWh/m2/month. This means that the building is still classified as Efficient according to Ministerial regulation Republic of Indonesia number 3 of 2012 and Fairly Efficient according to SNI.

When viewed as an air-conditioned room based on green building criteria, using Table 4.5, the ECI is 121.78 kWh/m^2/year. If we refer to [25] that the actual value is 243.56 kWh/m^2/year or 20.29 kWh/m^2/month. This value indicates that the air-conditioned room in the building consumes electrical energy with a wasteful classification for green buildings.

Based on the observations of researchers at the Inalum Building, the causes of the high consumption of electrical energy are as follows:

1. Air conditioning operating hours are carried out long before operating hours (07.00 West Indonesia Time or WIT), according to data in the control system, the air conditioning system is turned on manually at 06.00 WIT to 06.30 WIT
2. The operating hours of the air conditioner which should be until 17.00 WIB often operate until 21.00 WIB or even more while no one is working in the room
3. On Saturdays when the number of workers is small, almost all the air conditioners are operated
4. Due to the COVID-19 pandemic that is still engulfing Indonesia, the air-conditioned room is opened to reduce the occurrence of touching hands on the door between the building communities.

V. CONCLUSION

The Inalum Building has an efficient electricity consumption intensity according to SNI standards, with a value of 78.34 kWh/m^2/year or 6.53 kWh/m^2/month. However, as a green building, the existing air-conditioned space still has a higher ECI value. The SNI standard classification is still energy-intensive because the ECI value of an air-conditioned room is 243.56 kWh/m^2/year or 20.29 kWh/m2/month.

Further research is recommended to assess green building standards for the Inalum Building. This can help accelerate the green building certification process from GBCI. Recording of building utilities is very important for green buildings, existing digital meters have been installed on all distribution panels and distribution sub-panels. As a smart and green building, electricity consumption, especially air conditioning, must be controlled regularly in the control room to get an ECI value that meets the standard.

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