Analysis of energy efficiency in the Krueng Raya TBBM Pertamina building using the energy audit method

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Abstract. Energy audit is a technique to determine anytime, according to, and how to use energy in its facilities, and to take advantage of opportunities to improve efficiency. In this study an audit was conducted in the Pertamina TBBM Krueng Raya office building. This study discusses calculating the Energy Consumption Intensity (IKE) of a building, the thermal comfort level of a building so that it can realize a green building and be applied to other BBM terminal installations. The results of survey data, the pattern of electric energy use combined with Krueng Raya TBBM is 42.617 kWh/year in which the building area is 259.18 m². The results of study, obtained IKE at the Krueng Raya TBBM building amounted to 164.43 kWh/m²/year. Although by default the category of saving building criteria, but the visual comfort aspect questions SNI 03-6197-2000 and thermal SNI 03-6390-2000 is not allowed.

1. Introduction
Energy has a very important role in the industrial sector, transportation, mining, and commercial buildings. The problem of global warming makes us make efforts to prevent artificial warming, extreme climate change, and environmental degradation. The use of fossil fuels in the production process in excessive power generation will increase the amount of carbon emissions by up to 60%. Emissions from carbon itself will produce global warming. Excessive use of electricity will also emit heat waves that can cause global warming. Basically, it is known that energy efficiency is part of energy conservation [1]. In the context of efficient energy use, the government has issued a national energy policy that refers to policies for providing effective and efficient energy, as well as implementing energy conservation and environmental preservation. One way to reduce the impact of global warming is to save energy, including in the building sector. Energy audits are recommended to be carried out in buildings such as office buildings, schools, hotels, apartments, shopping centers and hospitals [2]. The industrial building is the second largest natural resource consumption sector after the food industry. Therefore, industrial buildings have a very important role to be able to reduce the environmental impact that causes global warming [3]. The use of lighting in buildings can be influenced by the purpose of the building, daytime use, lighting levels and hours of usage by occupants [4].

Pertamina as an oil and gas company engaged in the upstream to downstream oil and gas sectors in the country and is responsible for the distribution of fuel. Pertamina seeks to manage energy consumption and minimize energy use in the context of energy conservation activities. Since the issuance of Law Number 22 Year 2001 concerning oil and gas, hence since then Pertamina as a state company engaged in the oil and gas industry is no longer a single company in the downstream oil and gas sector [5]. Saving energy use is a very wise action and is very important to reduce production costs, so that the effective and efficient use of energy is expected to increase the productivity and
competitiveness of the products or services produced. Increasing the performance of the company can be done with efficiency, both in the form of cost efficiency / fuel distribution costs and efficient use of energy in one fuel distribution installation, including energy efficiency in buildings / buildings of BBM terminal installations.

Energy efficiency in buildings was introduced popularly in Indonesia around the 2000s, and quickly became a trend. The government issued more than 10 regulations and SNIs related to building energy efficiency [6-15]. Energy Audit methods are used to determine the level of energy use in buildings, Energy audit is the first step to find out the use of energy to be able to create energy conservation measures in accordance with Government Regulation No. 70 of 2009 concerning energy conservation which requires energy use to be done sparingly and efficiently. Audits have a level of detail based on the object being audited based on the energy used, energy consumption and resources available for audits. Audits have 3 types including: Preliminary energy audits, Details of energy audits, and Comprehensive energy audits. Energy audits make it possible to build specific energy models that have been used to analyze the impact of various energy saving measures on major energy consumption [16]. By conducting energy audits, it is expected to save energy and non-energy and evaluate the use of electrical energy in buildings [17-20]. This study aims to calculate the Energy Consumption Intensity (IKE) from buildings / buildings, the thermal comfort level of the building so that it can realize a green building and be applied to other BBM terminal installations.

2. Method

2.1. Data Collecting

Data collection techniques used to determine energy consumption in TBBM facilities require a survey and data collection stage, while the data needed includes:

a. Primary Data is data obtained through surveys and measurements directly to the field. Primary data needed includes electrical measurements in the main panel (main panel) and distribution panel (main distribution panel), measurement of each energy user equipment, in this case the motor and pump in the process of fuel distribution, specifications of each major energy user equipment, equipment operational mechanism, hours of use of equipment and technological systems used, and energy management systems that have been implemented;

b. Secondary data is, supporting data obtained from the study site. Secondary data is required as shown in table 1.

| No. | Secondary Data Requirements                                      | Period         |
|-----|----------------------------------------------------------------|----------------|
| A   | Public Facilities                                               |                |
| a   | Office Building Layout Plan                                     | updated        |
| b   | Figure Single line electrical diagram at the office             | updated        |
| c   | AC Equipment Data and specifications                            |                |
| d   | Data of room lighting equipment and its specifications           | updated        |
| e   | Regional lighting equipment data                                 | 1 Week         |
| f   | Data of other electrical equipment in the building and its specifications | updated        |
| g   | Number of people (total employees) different in the building    | 2016 - 2018    |
| h   | Electricity usage data (kwh / month)                            | 2016 - 2018    |

c. Energy audit process flow chart in the Krueng Raya-Aceh Pertamina TBBM building as shown in figure 1.
3. Results and discussions

3.1. Description of the research object

In the current energy audit activity, supporting facilities that are the object of detailed Audit are several buildings that represent offices and visiting facilities that have significant energy use. The supporting facilities for the assessment in this case are office buildings. The Krueng Raya TBBM building functions as an office building. The TBKM Krueng Raya building is located on Jalan Admiral Malahayati Km 32. The assessment here is intended to assess the current condition of the building based on the above criteria. To meet the criteria of a building that is Safe, Comfortable and Energy Saving. The following are the Assessment parameters that will be carried out including: electrical system for office buildings, energy consumption intensity of buildings / buildings in Krueng Raya TBBM, electricity usage patterns in Krueng Raya TBBM building, lighting system measurement, air system measurement.
3.2. Electrical system in office buildings

The electricity system in office buildings in TBBM Krueng Raya is supplied by PLN electricity. Based on the results of measurements made in the office Sub Distribution Panel (SDP) (main office load), it is known that the maximum office load is 21.66 kW, a minimum of 1.94 kW and an average load of 8.86 kW. The following is the load profile of the load measurements as shown in Figure 2. While the quality of the electricity in the office SDP is shown in table 2.

![Load profile SDP office](PROFILE_OFFICE SDP_KRUENG RAYA TBBM)

**Figure 2.** Load profile SDP office.

### Table 2. The quality of electricity in the Krueng Raya TBBM office building.

| Observation          | Max     | Min     | Average  | SPD Office |
|----------------------|---------|---------|----------|------------|
| Volt (V) Phase R     | 236.27  | 195.64  | 222.32   |            |
|         Phase S     | 243.48  | 217.63  | 226.13   |            |
|         Phase T     | 244.95  | 221.62  | 228.25   |            |
| Current (Ampere)     |         |         |          |            |
| Phase R             | 83.41   | 5.83    | 27.53    |            |
| Phase S             | 17.04   | 2.12    | 9.75     |            |
| Phase T             | 12.73   | 0.00    | 3.67     |            |
| Phase N             | 70.89   | 3.59    | 20.48    |            |
| Apparent Power (kVA)| 21.81   | 2.02    | 8.98     |            |
| Active Power (kW)   | 21.66   | 1.94    | 8.86     |            |

From the profile of the use of electricity in offices as shown in figure 2, it can be seen that the building has implemented the principle of saving energy, where there are visible fluctuations in the load or decrease in electricity load between office operating hours (daytime) and at night. The load at night is only used on street lighting and building area lights.

3.3. Pattern of energy use and building energy consumption intensity

The pattern of energy use and intensity of building energy consumption based on measurement data (load survey) in the Krueng Raya TBBM building is distributed for lighting systems, air systems and receptacle systems. The amount of power used to the air system, lighting system and receptacle is as in table 3. Below:
Table 3. Total electric energy in the Krueng Raya TBBM building.

| Distributed       | Power (kW/day) | Percentage |
|-------------------|----------------|------------|
| Air Condition     | 18.58          | 92 %       |
| Lighting          | 0.778          | 4 %        |
| Receptacle        | 0.825          | 4 %        |
| Total             | 20.17          | 100 %      |

The total electrical energy consumed in the Krueng Raya TBBM building is 20.17 kWh or 161.43 kWh/day or 42.617 KWh/year.

3.4. The intensity of energy consumption in the Krueng Raya TBBM building

The results of the Krueng Raya TBBM building area survey are shown in table 4.

Table 4. Extensive area of the Krueng Raya TBBM building.

| Type of room       | Long (m) | Width (m) | Large (m²) |
|--------------------|----------|-----------|------------|
| Workspace          |          |           |            |
| Administration     | 15.9     | 6.9       | 109.71     |
| Supervisor RSD     | 3.8      | 2.9       | 11.02      |
| Archive            | 3.8      | 2.3       | 8.74       |
| Financial          | 3.9      | 2.9       | 11.31      |
| Maintenance service| 3.9      | 2.9       | 11.31      |
| Meeting            | 8.8      | 3.8       | 33.44      |
| Marine             | 3.0      | 2.8       | 8.4        |
| Staff marine       | 3.0      | 1.8       | 5.4        |
| living marine      | 4.8      | 3.0       | 14.4       |
| Server             | 3.6      | 2.4       | 8.64       |
| Head of operation  | 4.8      | 3.6       | 17.28      |
| Lobby              | 6.3      | 3.1       | 19.53      |
| Warehouse          | 5.9      | 4.0       | 23.6       |

Based on table 4, the measured area in the building area is 259.18 m². Where the energy usage pattern is seen in table 3 where the total electrical energy is 42.617 KWh/year. To calculate the IKE per year in a building, it must first be known the estimated energy consumption and equipment available in each room using equation 1.

\[
IKE = \frac{\text{Total Electric Energy Consumption (kWh)}}{\text{Building area (m}^2\text{)}}
\]  

Thus the IKE value of the Krueng Raya TBBM building is:

\[
IKE = \frac{42.617 \text{ (kWh/year)}}{259.18 \text{ (m}^2\text{)}} = 164.43 \text{ kWh/m}^2\text{/year}
\]

3.5. Lighting System

Work activities indoors require light and the light is generated with artificial lighting and also from natural lighting. Specifically for artificial lighting generated by a lighting system (lights), it should follow the references that have been made in an SNI standard [21]. To be able to meet the aforementioned effects, an engineering layout or room layout is needed to meet the standard lighting strength and also to meet the energy-saving effect by using energy-efficient lighting technology. The
The lighting technology used in the Krueng Raya TBBM building lighting system is already largely using LED lights. The following are the results of measurements of the quality of lighting or lighting strength as in table 5 and the distribution value of the lighting specifications of table 6 in the work area of the Krueng Raya TBBM building.

Table 5. Strong distribution of lighting in the Krueng Raya TBBM building.

| Room Name                 | Large (M²) | Type | 1   | 2  | 3  | Average | Standard | Information |
|---------------------------|------------|------|-----|----|----|---------|----------|-------------|
| OFFICE SPACE              |            |      |     |    |    |         |          |             |
| Workspace                 |            |      |     |    |    |         |          |             |
| Administration            | 109.71     | LED  | 149 | 172| 174| 165.0   | 350      | Not meet    |
| Supervisor RSD            | 11.02      | LED  | 206 | 223| 585| 338.0   | 350      | Meet        |
| Archive                   | 8.74       | TL   | 170 | 151| 217| 179.3   | 350      | Not meet    |
| Financial                 | 11.31      | LED  | 84  | 76 | 102 | 87.3    | 350      | Not meet    |
| Maintenance service       | 11.31      | LED  | 126 | 176| 593| 298.3   | 350      | Not meet    |
| Meeting                   | 33.44      | LED  | 88  | 102| 96  | 95.3    | 350      | Not meet    |
| Marine                    | 8.4        | LED  | 172 | 186| 164| 174.0   | 350      | Not meet    |
| Staff Marine              | 5.4        | LED  | 28  | 33 | 41  | 34.0    | 350      | Not meet    |
| Living Marine             | 14.4       | LED  | 69  | 85 | 80  | 78.0    | 350      | Not meet    |
| Server                    | 8.64       | TL   | 70  | 64 | 68  | 67.3    | 350      | Not meet    |
| Head of Operation         | 17.28      | LED  | 149 | 172| 174| 165.0   | 350      | Not meet    |
| Lobby                     | 19.53      | LED  | 70  | 64 | 68  | 67.3    | 100      | Not meet    |
| Warehouse                 | 23.6       | LED  | 132 | 195| 179| 168.7   | 300      | Not meet    |

Table 6. Distribution of lighting power specification values in the Krueng Raya TBBM building.

| Room Name                 | Large (m²) | Type | Watt | Unit | Total Watt | specific lighting power [watt/m²] |
|---------------------------|------------|------|------|------|------------|----------------------------------|
| Workspace                 |            |      |      |      |            | Actual   | Standard | Information |
| Administration            | 109.71     | LED  | 20   | 10  | 200        | 1.82     | 15       | Meet        |
| Supervisor RSD            | 11.02      | LED  | 10   | 4   | 40         | 3.63     | 15       | Meet        |
| Archive                   | 8.74       | TL   | 40   | 2   | 80         | 9.15     | 15       | Meet        |
| Financial                 | 11.31      | LED  | 7    | 4   | 28         | 2.48     | 15       | Meet        |
| Maintenance service       | 11.31      | LED  | 7    | 4   | 28         | 2.48     | 15       | Meet        |
| Meeting                   | 33.44      | LED  | 7    | 5   | 67         | 2.00     | 15       | Meet        |
| Marine                    | 8.4        | LED  | 7    | 2   | 14         | 1.67     | 15       | Meet        |
| Staff Marine              | 5.4        | LED  | 7    | 2   | 14         | 2.59     | 15       | Meet        |
| Living Marine             | 14.4       | LED  | 7    | 2   | 14         | 0.97     | 15       | Meet        |
| Server                    | 8.64       | TL   | 20   | 3   | 60         | 6.94     | 15       | Meet        |
| Head of Operation         | 17.28      | LED  | 40   | 4   | 160        | 9.26     | 15       | Meet        |
| Lobby                     | 19.53      | LED  | 32   | 1   | 39         | 2.00     | 15       | Meet        |
| Warehouse                 | 23.6       | LED  | 32   | 1   | 32         | 1.36     | 15       | Meet        |

From table 5 it can be seen that the illumination strength does not meet the standard values required by SNI 03-6197-2000, while table 6 shows that the lighting power has fulfilled the standard values required by SNI 03-6197-2000.

3.6. Air conditioning System

Same is the case with the lighting system. In the air system, the evaluation parameters are the aspects of Thermal Comfort (workspace) and the technology level (COP / Coefficient of Performance) of the AC unit used for the Air Conditioning system. Based on SNI 03-6390-2000 "Energy Conservation in the
Air System. Thermal comfort for work space is a room that has a temperature or room temperature between 22°C to 26°C and a relative humidity value of 50% to 70% and it is stated that the AC unit used should have the COP value required for example, for the AC unit split is required to use an AC unit that has COP > 2.6. The description of the air system in the work area of the Krueng Raya TBBM building is: An assessment of the thermal comfort of the room and an assessment of air conditioning technology.

a. Assessment of thermal comfort

The results of measurements of temperature and relative humidity in rooms in the Krueng Raya TBBM building area as shown in Table 7.

| Room Name     | Weight (m) | Width (m) | Large (m²) | Relative Humidity (% RH) | Temperature (°C) | Actual | Standard | Information | Actual | Standard | Information |
|---------------|------------|-----------|------------|--------------------------|------------------|--------|----------|-------------|--------|----------|-------------|
| Workspace     |            |           |            |                          |                  |        |          |             |        |          |             |
| Administration| 15.9       | 6.9       | 109.71     | 60                       | 50 to 70         | Meet   | 25 to 26 | Not meet    | 25     | 25 to 26 | Meet        |
| Supervisor RSD| 3.8        | 2.9       | 11.02      | 55                       | 50 to 70         | Meet   | 25 to 26 | Meet        | 26     | 25 to 26 | Meet        |
| Archive       | 3.8        | 2.3       | 8.74       | 56                       | 50 to 70         | Meet   | 25 to 26 | Meet        | 26     | 25 to 26 | Meet        |
| Financial     | 3.9        | 2.9       | 11.31      | 57                       | 50 to 70         | Meet   | 25 to 26 | Meet        | 24     | 25 to 26 | Meet        |
| Maintenance service | 3.9 | 2.9 | 11.31 | 53 | 50 to 70 | Meet | 25 to 26 | Not meet |
| Meeting       | 8.8        | 3.8       | 33.44      | 53                       | 50 to 70         | Meet   | 25 to 26 | Meet        | 25     | 25 to 26 | Meet        |
| Marine        | 3.0        | 2.8       | 8.4        | 45                       | 50 to 70         | Not meet | 25 to 26 | Meet        | 25     | 25 to 26 | Meet        |
| Staff Marine  | 3.0        | 1.8       | 5.4        | 45                       | 50 to 70         | Not meet | 25 to 26 | Meet        | 25     | 25 to 26 | Meet        |
| Living Marine | 4.8        | 3.0       | 14.4       | 42                       | 50 to 70         | Not meet | 25 to 26 | M Meet      | 25     | 25 to 26 | Not meet    |
| Server        | 3.6        | 2.4       | 8.64       | 56                       | 50 to 70         | Meet   | 25 to 26 | Not meet    | 27     | 25 to 26 | Not meet    |
| Head of Operation | 4.8 | 3.6 | 17.28 | 60 | 50 to 70 | Meet | 25 to 26 | Meet |
| Lobby         | 6.3        | 3.1       | 19.53      | 56                       | 50 to 70         | Meet   | 28 to 26 | Not meet    | 25     | 25 to 26 | Not meet    |
| Warehouse     | 5.9        | 4.0       | 23.6       | 55                       | 50 to 70         | Me     | 25 to 26 |            | 25     | 25 to 26 |            |

Based on table 7, it can be seen that the thermal comfort in the working area of the Krueng TBBM building still has several rooms that do not meet the required standards.

b. Assessment of air condition technology

Based on observations in the field, the air conditioning technology used in the Krueng TBBM building uses a Split Air Conditioning type. The AC unit technology used in TBBM Krueng Raya complies with SNI requirements with a COP value > 2.6 as shown in Figure 3. The AC units used in some rooms exceed their capacity or the installed capacity exceeds the cooling load required as shown in Table 8. Below:

![COP: 3.01](image1.png)

![COP: 2.61](image2.png)

**Figure 3.** AC technology (a) and (b) used in The Krueng Raya TBBM Building.
### Table 8. Cooling capacity needed.

| Type of room                  | Survey Cooling Load |
|-------------------------------|---------------------|
|                              | Large \( (m^2) \) | Unit AC Needs | Installed | Information |
| Workspace                     |                     |               |           |             |
| Administration               | 109.71              | 5.49          | 4         | Less        |
| Supervisor RSD               | 11.02               | 0.55          | 1.5       | Exceed      |
| Archive                      | 8.74                | 0.44          | 2         | Exceed      |
| Financial                    | 11.31               | 0.57          | 1.5       | Exceed      |
| Maintenance service          | 11.31               | 0.57          | 2         | Exceed      |
| Meeting                      | 33.44               | 1.67          | 2         | Exceed      |
| Marine                       | 8.4                 | 0.42          | 1         | Exceed      |
| Staff Marine                 | 5.4                 | 0.27          |           |             |
| Living Marine                | 14.4                | 0.72          | 1         | corresponding |
| Server                       | 8.64                | 0.43          | 1         | Exceed      |
| Head Of Operation            | 17.28               | 0.86          | 2         | Exceed      |
| Lobby                        | 19.53               | 0.98          | 1         | corresponding |
| Warehouse                    | 23.6                | 1.18          |           |             |

### 4. Conclusions

From the results of research conducted using the energy audit method, the Energy Consumption Intensity (IKE) value of the Krueng Raya TBBM building is 164.43 kWh/m²/year when compared to the 2011 IFC Study Reference. Although categorically the energy saving building criteria, but aspects of visual comfort and thermal abandoned. For the aspect of visual comfort referring to the standards required by SNI 03-6197-2000 with lighting specifications <15 watts/m² as shown in Tables 5 and 6. Whereas for the quality of the air system is based on SNI 03-6390-2000 namely: the aspect of thermal comfort the workspace at temperature 22°C-26°C and relative humidity of 50%-70% are shown in Table 7, while the Split AC unit with a COP value > 2.6 as shown in Figure 3 and Table 8.

There are also recommendations for savings opportunities from the lighting system at the Krueng Raya TBBM support facility:

a. Retrofit street lighting / regional lights from 250 watt HPL-N / Mercury to 80 Watt LEDs.

b. Maintain the COP value (performance) of Split AC units with regular routine maintenance.

c. Setting a comfortable room temperature based on benchmarks in Indonesia around 23°C-25°C.

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