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Analysis of Energy Performance Indicators Based on ISO 50001-2018 in Shopping Centers Using RET Screen Expert

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Abstract:
The ISO 50001 energy management system has been implemented by many organizations around the world, including in Indonesia. The purpose of this application is to sustainably improve energy performance to reduce energy consumption and energy costs. In determining the measurement of energy performance improvement, energy performance indicators and energy baseline are used. This study will analyze the energy performance indicators obtained from the energy audit results of one shopping center in Indonesia using RETScreen Expert software. Multiple linear regression is used to develop the energy baseline equation and examine the relationship between energy consumption and significantly influencing variables, such as Service Usage (person) and Cooling Degree Days (CDD). This baseline equation will be used to monitor energy performance after energy performance improvement measures are taken. From the results of this equation, the predicted value of energy consumption in 2023 after improving energy performance in 2022 is 7,014,081 kWh then from the actual measurement results obtained energy consumption value of 6,113,632 kWh the results of the calculation of energy savings obtained from the energy baseline equation using RETScreen Expert software is 900,449 kWh / year.

Keywords: Energy Audit, Energy Performance Indicator, Energy Baseline, ISO 50001, RETScreen Expert, Shopping Center.

1. Introduction

Energy sustainability and the impact of climate change are the main focus of energy users around the world [1]. Energy efficiency is the solution to these problems because energy efficiency has a direct impact on the environment and energy sustainability [2]. The increase in environmental problems that result in an increase in carbon dioxide emissions, causing global warming, is caused by inefficient use of energy [3], [4]. Nowadays, researchers in several countries have a great interest in energy conservation and energy benchmarking of buildings. Various policies, regulations and new methods have been used and become a substantial step for industrialized countries [5], [6]. Regulations that have been implemented by developing countries include energy taxes, energy benchmarking and feed-in tariffs to reduce their energy consumption [7]. In terms of gaining energy efficiency and reducing overall greenhouse gas emissions, energy performance assessment is one benchmark. This assessment will raise awareness for energy users from various levels, such as facility managers, company owners, and building users. The concept of energy efficiency of a building refers to reducing energy consumption without sacrificing the comfort and satisfaction of building occupants so as to eliminate energy waste [8]. In addition, in a building, the Heating, Ventilation and Air Conditioning (HVAC) system is the electrical equipment that consumes the most energy [9]. The large energy consumption of the HVAC system makes it one of the Significant Energy Use (SEU) equipment. Managing energy consumption in a building such as how to evaluate, monitor and improve energy performance in a management system is a point in eliminating energy waste [10].

One of the tools used worldwide to create an effective energy management system is ISO 50001-2018 [11], which is an international standard that focuses on improving the energy performance of organizations in a sustainable manner. In an effort to reduce energy use and increase sustainable energy including reducing greenhouse gas emissions, there are currently 127 companies in Indonesia that are ISO 50001-2018 certified.

The application of ISO 50001-2018 is carried out to measure the effectiveness of the energy management system in order to improve sustainable energy performance. This standard compares changes in energy performance indicators (EnPI) with the associated energy baseline (EnB) at the level of significant energy use (SEU) equipment or organizational level to measure energy performance improvement [12]. EnPI is a value or measure that quantifies results related to energy efficiency, energy utilization and energy consumption in facilities, systems, processes and equipment, while EnB is a reference that characterizes and quantifies an organization's energy performance over a specified time period. EnB allows organizations to assess changes in energy performance between selected timeframes. EnB is also used for the calculation of energy savings, as a reference before and after the implementation of energy performance improvement measures [1], [12]. [2], [13] stated that the difficulty that occurs when wanting to implement an energy management system is in determining EnB and EnPI due to complex data variables and limited availability of such data to get a high correlation with energy consumption. [14] has identified that integrating ISO 50001-2018 in organizations to support the implementation of supply chains to be environmentally friendly. One of the several methods used in the study of determining the Energy Baseline (EnB) is the statistical method [9]. By knowing the benchmark for energy consumption, building users will know and monitor their energy performance status and the value of energy savings obtained. This paper will analyze a sample of shopping centers in Indonesia with the aim of developing an energy baseline as a benchmark for monitoring energy performance status using RETScreen Expert software.

2. Literature Review

2.1 Energy Audit

An energy audit consists of various tasks that can be performed, which depend on the type of energy audit and the purpose of the energy audit facility. An energy audit can start with a review of secondary data such as historical energy consumption data for the last 2 to 3 years. Energy audits that have been carried out by various researchers in different ways for energy consumption have been presented in [15] for the energy can be used in proper utilization, which can also reduce the tariff in their electricity bill [16]. An energy audit is an energy investigation of a specific area or building to determine the current energy performance of an organization, system, process or significant energy-using equipment. The whole investigation process will look for potential savings in energy consumption without affecting the working of the device or equipment and maintaining comfort levels. Consumer behavior can be considered as an important factor affecting energy consumption, besides the age of the building and climatic factors. The data collected from the local weather station helps to design the thermal power structure model of the building, whether a large number of variables can affect the energy consumption whether it increases or decreases. A good energy management system starts with energy saving, this can be done by using adequate device ratings, using high-efficiency devices, and changing habits that cause huge energy waste through energy audits [17].

2.2 Energy Audit Phase

In [18] conducting an energy audit, several things should be done in accordance with the following principles:

a) The audit is consistent with the agreed energy audit scope, boundaries and audit objectives:
b) Measurements and observations are appropriate to energy use and consumption;
c) The energy performance data collected is representative of the activities, processes, equipment, and systems;
d) The data used to measure energy performance and identify improvement opportunities is consistent and unique;
e) The data collection, validation, and analysis processes are traceable;
f) The energy audit report provides energy performance improvement opportunities based on appropriate technical and economic.

3. Research Method

The use of energy performance indicators with an energy baseline is used to measure and monitor changes in the energy performance of shopping center buildings after energy saving measures are taken to meet the goals and targets set in energy planning.

3.1 Energy audit to determine SEU

An energy audit was conducted to analyze the characteristics of energy use from past to present to assessing its energy performance. The energy audit was also conducted to determine the significant energy use (SEU) equipment and assess its current performance and look for energy saving opportunities that could be made to improve the energy performance of the shopping center building. The determination of SEUs was aimed at considering substantial energy consumption and the potential for large energy performance improvements. Historical data collection of energy use for 2 years starting from January 2022 to December 2023 was conducted during the energy audit. On-site measurements of the shopping mall on energy-using equipment to determine SEU and analyze its energy performance were conducted for 5 days. To determine the effect of weather conditions on the energy use of the shopping center, the Cooling Degree Days (CDD) value of the shopping center site will be temporarily considered as a relevant variable affecting energy consumption, This data is obtained from the National Aeronautics and Space Administration (NASA) database through RETScreen Expert software [19]. Another data that will also be used as a relevant variable is the occupancy/service usage (person) data of visitors to the shopping center. Both CDD and occupancy/service usage (person) data will be taken with the same period as the energy consumption data.

3.2 Determine relevant variables

Once the collected data and all required information were analyzed, the next step was data preparation to determine relevant variables using RETScreen Expert software. The data is inputed into the RETScreen Expert software to determine the energy baseline equation from energy consumption and relevant variables using the following linear regression equation.

$$Y = C_0 + C_1 * X_1 + C_2 * X_2 \ldots\ldots + C_n * X_n \quad (1)$$

Where:

Y = Energy consumption
$X_1, X_2 \ldots . X_n$ = Relevant variable 1,2….n
C_0 = Intercept coefficient value
$C_1, C_2 \ldots . C_n$ = Coefficient value relevant variable 1,2,…n

To see the results of this analysis, graphs will be created to visualize the data qualitatively. The energy baseline equation results obtained will be used to calculate the predicted energy consumption which will be compared with the actual energy consumption. This will eventually lead to the formation of a cumulative sum (CUSUM) of the difference between predicted energy consumption and actual energy consumption to obtain the energy saving value. Measurement and Verification (M&V) is made in the form of a bifurcated graph of the entire dataset of the period before the implementation of energy-saving measures and the period after their implementation [19].

4. Result and Discussion

This case study was conducted at a shopping center located on the island of Sumatra, Indonesia with a total area of 29,218.16 m².

4.1 Energy audit for SEUs identification

From the results of the energy audit, the energy consumption data of each equipment during the period January-December 2022 is shown in Table 1.

Table 1. Energy consumption for shopping center in 2022

No	Load	Energy consumption (kWh/year)	% Load
1	HVAC system	2,355,597	40.4%
2	Lighting	1,585,227	27.2%
3	Electric socket	1,084,812	18.6%
4	Compressor	247,470	4.2%
5	Fan	228,636	3.9%

6	Pump	78,906	1.4%
7	Lift & Escalator	10,600	0.2%

In Table 1. Pareto analysis was used to determine the SEUs from the energy consumption data for the period of the energy audit, January-December 2022. HVAC systems, lights and electric sockets consisting of electrical loads used by tenants and playgrounds were selected as the top three SEUs, accounting for more than 80% of the total energy consumption so that they fall into the category of significant energy users (SEU).

4.2 Identification of relevant variables

Relevant variables were identified by determining the factors that most influence energy consumption by analyzing the correlation of each variable with simple linear regression equations with RETScreen Expert software. Table 2. Shows the variables to be tested for correlation with energy consumption

Table 2. Relevant variable and energy intensity of shopping center building in 2022

Month	Energy Consumption (kWh)	Variables		Static Factor	SEC
		Service Usage (person)	CDD	Usage Area (m^2)	kWh/m^2
January	640,000	390,605	83.5	29,218	21.9
February	579,200	271,695	71.1	29,218	19.8
March	630,400	278,366	109.9	29,218	21.6
April	611,200	272,393	101.4	29,218	20.9
May	620,800	237,203	114.5	29,218	21.2
June	643,200	458,166	88.1	29,218	22.0
July	612,448	310,992	102.4	29,218	21.0
August	584,352	204,056	92.6	29,218	20.0
September	566,400	195,946	87.7	29,218	19.4
October	550,400	172,350	83.4	29,218	18.8
November	518,560	125,043	82.7	29,218	17.7
December	572,640	380,084	67.4	29,218	19.6

Assessment of the level of energy performance can use EnPI and EnB, can also be with energy intensity (kWh/m^2) [11],, The choice of this method depends on the availability of data owned by the company, Table 2, shows the data that will be used as variables relevant to energy consumption to calculate EnB using RETScreen Expert software, In addition, Table 2, also shows the results of energy intensity calculations that compare monthly energy consumption with the area of the shopping center, From the results of linear regression calculations with RETScreen Expert software, it shows that the value of R^2 service usage (person) = 0.53, R^2 Cooling Degree Days (CDD) = 0.24, From the results of this calculation, it shows that the correlation of each variable with energy consumption does not meet the requirements of the International Performance Measurement and Verification Protocol (IPMVP) protocol to be used as the EnB equation [20]. Because one variable still cannot find a good correlation with energy consumption, so a multivariable linear regression model will be created by combining the service usage and CDD variables to become the energy baseline equation, the calculation will be carried out with RETScreen Expert, the results of the calculation analysis can be seen in Table 3,

Table 3, Summary EnB model of shopping center in 2022

Model Summary	Baseline	Status	IPMVP
Intercept t stat	12.4	Pass	T, stats > 2
Slope Service Usage stat	5.93	Pass	T, stats > 2
Slope CDD stat	7.92	Pass	T, stats > 2
R^2	0.90	Pass	R^2 > 0.75

Cvrmse	0.002	Pass	Cvrmse < 0.2

The EnB equation generated from the multivariable linear regression calculation with RETScreen Expert software is as follows:

$$Y = 357{,}916{,}24 + 1{,}632{,}16 * X_1 + 0{,}322 * X_2 \quad (2)$$

Where:

$X_1 = service\ usage$ (SU)

$X_2 = Cooling\ Degree\ Days\ (CDD)$

With an R^2 value of 0.90, indicating that the variables included have a large correlation with energy consumption, Table 3, shows that all parameters also meet the requirements of the IPMVP statistical validation standard, so this equation will be used as an energy baseline for monitoring energy performance. To prove the correlation of the equation, it can be seen in Figure 1, where the comparison between the predicted energy consumption calculated by equation (2) and the actual energy consumption will be seen.

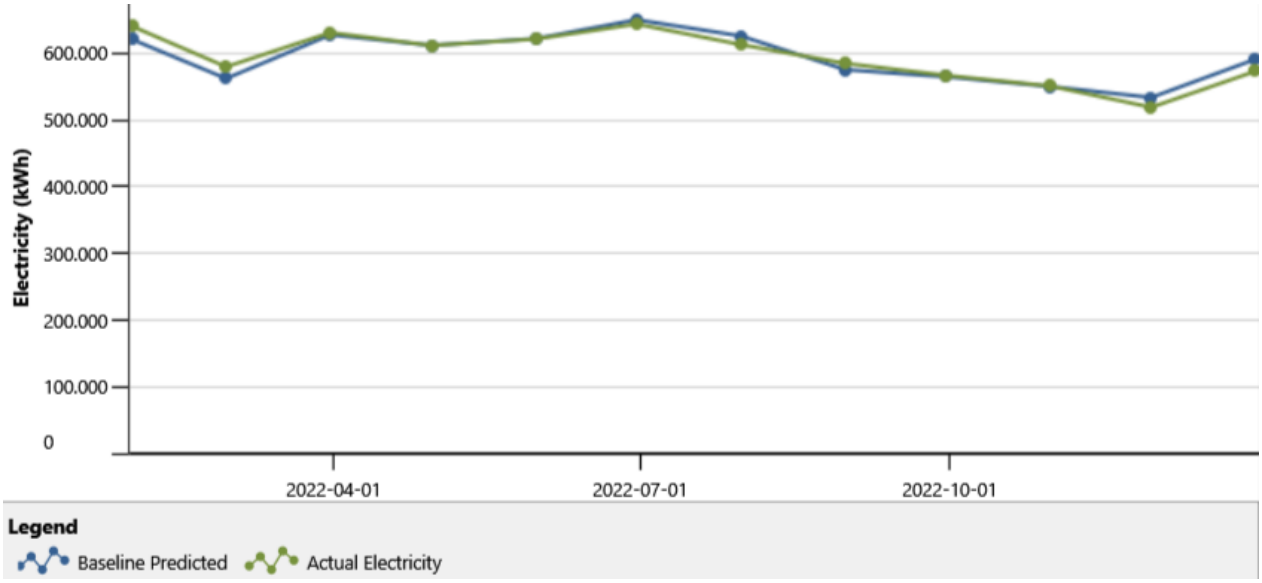

Figure 1. Comparison of predicted energy consumption with actual energy consumption in 2022

From Figure 1. it can be seen that the results of the calculation of energy consumption predictions using the EnB equation (2) compared to actual energy consumption have almost the same value, so the EnB equation can be used as a reference in measuring the energy performance of shopping centers.

4.3 Energy Conservation Measure

From the results of the energy audit conducted in October 2022, there are several energy saving recommendations on several SEU equipment that can improve the energy performance of the shopping center building shown in Table 4.

Table 4. Energy conservation measure in 2022

No	Energy Conservation Measures	Energy Saving (kWh/thn)
1	Operational control chiller, kitchen water intake vents and parking access doors	583,276
2	LED lighting replacement	125,765
Total energy saving (kWh)		709,041

The audit recommendations in Table 4. show that the HVAC system which is SEU equipment number 1 has a large energy saving potential.

The recommendations in Table 4. were implemented in the period November-December 2022. To calculate and prove the energy savings obtained, an energy savings calculation analysis will be carried out with the EnB equation (2) using RETScreen Expert software. Energy consumption data for the period January-December 2023, service usage data (person) and CDD with the same time period will also be entered into RETScreen Expert software for calculation analysis. The calculation results with equation (2) are shown in Table 5.

Table 5. Monitoring & Verification (M&V) energy performance shopping center in 2023

Month	Energy Consumption (kWh)	Relevant Variables		Difference	CUSUM (kWh)
		Service Usage (person)	CDD	Actual-EnB (kWh)	
January-23	552,128	390,605	65.6	- 38,941	- 38,941
February-23	479,904	177,944	74.3	- 56,720	- 95,661
March-23	552,672	237,235	78.8	- 10,435	- 106,096
April-23	538,688	219,488	101.5	- 55,741	- 161,837
May-23	536,160	190,107	125.7	- 88,283	- 250,120
June-23	539,552	380,696	115.9	- 130,416	- 380,536
July-23	517,216	215,864	114.1	- 96,608	- 477,144
August-23	495,456	154,541	99	- 73,928	- 551,072
September-23	471,616	141,782	110.9	- 113,072	- 664,144
October-23	473,152	132,031	104.8	- 98,433	- 762,577
November-23	470,112	136,907	90.4	- 79,543	- 842,120
December-23	486,976	180,566	79.1	- 58,329	- 900,449

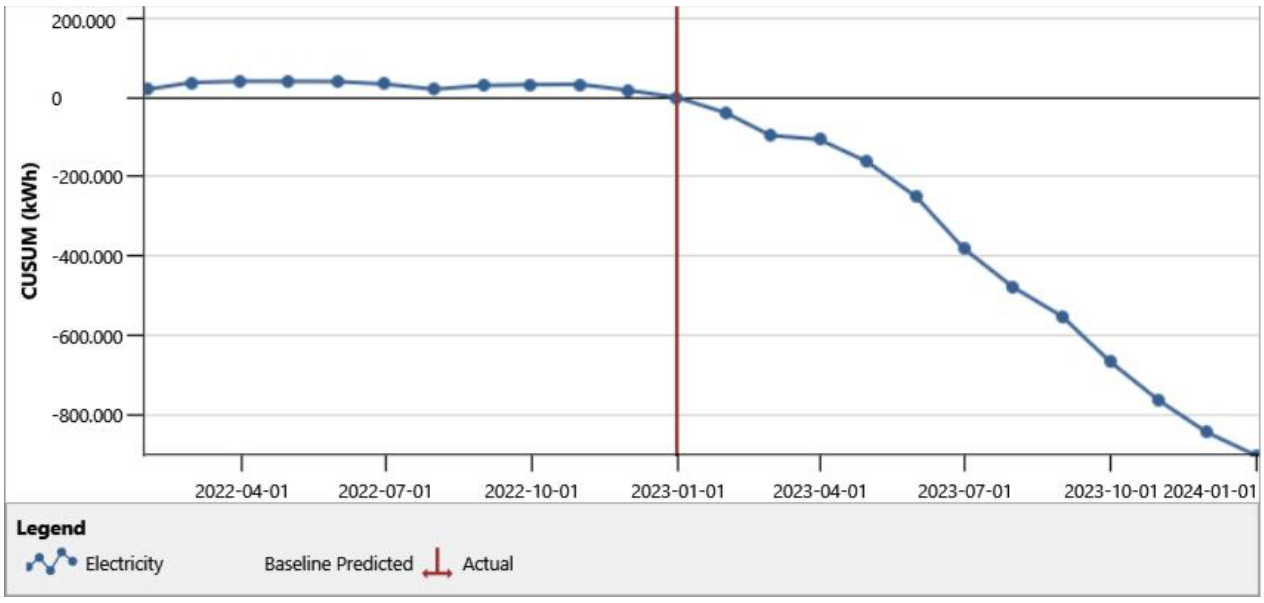

Figure 2. Energy Saving CUSUM

Table 5. shows the difference between the predicted energy consumption using the EnB equation and the actual energy consumption, where the actual energy consumption is lower than the predicted energy consumption. This shows that there are energy savings that occur after the implementation of energy savings as recommended during the energy audit. The graph in Figure 2. shows the CUSUM value of energy savings which began to see a decrease in energy consumption from January 2023 to December 2023, where the implementation of energy savings has been carried out since the November-December 2022 period. The amount of energy savings obtained can be seen in Figure 3 below.

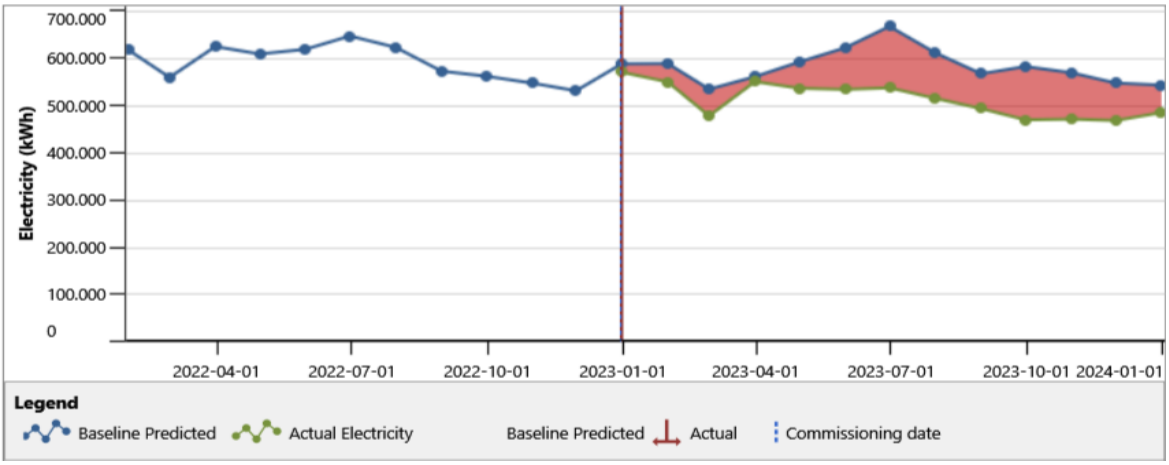

Figure 3. M&V chart for measuring energy performance after implementing energy efficiency in the shopping center in 2023.

Figure 3. shows the measurement and verification (M&V) graph from the period of 2022 when the energy audit and the implementation of energy efficiency were conducted as the baseline period until the period of 2023. The blue line in Figure 3 shows the predicted energy consumption calculated by equation (2) of the energy baseline while the green line shows the actual energy consumption, where in the Figure 3. shows the actual energy consumption is lower than the predicted energy consumption. The red area is the amount of energy savings obtained, where in Table 5. shows, the total CUSUM value of energy savings obtained for one year in 2023 is 900,449 kWh.

The results of this study can be used as tools for monitoring energy use after energy efficiency measures are taken for the following years as a measurement and verification (M&V) step for energy performance in shopping centers.

5. Conclusion

This study was conducted starting with the collection of energy consumption data for the period of 2022 and 2023, where in 2022 energy audit activities were carried out by producing several energy saving recommendations. Measurement of energy performance after the implementation of energy efficiency measures is carried out by setting energy performance indicators (EnPI) and energy baseline (EnB) as comparison and monitoring parameters using measurement and verification (M&V). In addition to energy consumption data, data on other variables that affect energy consumption such as service usage data (person) and Cooling Degree Days (CDD) are entered into RETScreen Expert software for multi-variable liner regression analysis. RETScreen Expert is also used to analyze the amount of energy savings and determine the energy performance.

With the EnB equation that has been established, the amount of energy savings obtained from the application of energy efficiency measures is 900,449 kWh in one year during 2023. This EnB equation can be used as a tool to monitor energy performance after implementing energy efficiency measures using RETScreen Expert software. Future research can be done by looking for other variables that can make the R^2 correlation value with energy consumption higher than the value of the variables used today.

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