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Comparative Analysis of Energy Efficiency Measurement in Building with Manual Calculation and RETScreen Expert

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Abstract

Energy efficiency is a crucial aspect of energy saving efforts. Energy efficiency is an important factor in reducing energy consumption and environmental impacts. One of the important steps that can be taken in achieving energy efficiency is to conduct an energy audit. This research aims to analyze the comparison between manual calculations and calculations using RETScreen Expert software on building energy efficiency. The parameters used to analyze energy efficiency are air conditioning systems, room lighting systems, and the use of other electronic devices, during an annual period. The analysis results show that there is a difference in calculation between the manual method (816,010.8 kWh/year) and RETScreen Expert (1,113,453 kWh/year). The difference between manual calculation comparison with RETScreen Expert is 297,442.2 kWh/year with a percentage of calculation difference of 15.42%. With this difference, it is assumed that manual calculations and calculations using RETScreen Expert are quite different. However, both methods are reliable for conducting energy audits in buildings. Based on the EUI value obtained in the manual calculation of 122.4 kWh/m²/year, while the EUI value in the calculation with RETScreen Expert is 167.08 kWh/m²/year. It can be concluded that energy use in the building is relatively efficient with an annual EUI value of 102 ≤ IKE < 168 kWh/m2 /year. The results of the energy audit also show that the rungan cooling system (HVAC) is a major contributor to the building's energy consumption.

Keywords: Energy, efficiency, audit, comparison, EUI, RETScreen expert.

INTRODUCTION

Energy efficiency programs are a problem for many countries today. The International Energy Agency (IEA) states that 30% of energy consumption in the world today comes from the building sector or buildings that are still operating today, and it is also undeniable that the effects of greenhouse gas emissions have also increased along with the increase in energy consumption [1]. If this continues, the significant impact of CO2 emissions in the future will have a negative impact on the environment. This problem certainly cannot be ignored, there needs to be appropriate action and solutions to deal with these problems [2]

Energy efficiency efforts have become a global concern and a major topic in national and international energy policy discussions [3]. This is because energy over the next 20 years in the built environment will increase by 34%, or an average of 1.5% per year [4]. Indonesia's forecasted energy consumption over the next 20 years shows a sharp increase. The National Long-Term Development Plan (RPJPN) 2025-2045 projects that Indonesia's energy needs will increase along with economic expansion, urbanization, and rising national living standards [5]. Therefore, there is a need for energy saving or energy efficiency efforts to meet future energy supplies [6].

One important step to achieve energy use efficiency is to conduct an energy audit [7]. An energy audit is a systematic process to evaluate, analyze, and identify the energy use of a building, or system [8]. The purpose of an energy audit is to understand how energy is used in a place and find ways to optimize energy use, improve efficiency, and reduce energy costs [9]. Energy audits are also used to find energy leaks or wastage in a building that can be addressed with corrective measures or known as retrofitting [4].

Energy efficiency can be done by using various platforms available today, one of the platforms that offers to perform energy efficiency and audits is RETScreen Expert [10]. RETScreen Expert is a software program developed by Natural Resource Canada and is available for public use for feasibility analysis of clean energy projects, including energy-efficient technologies and renewable energy systems, such as wind energy, small hydropower plants, photovoltaics, biomass heating, solar space heating, solar water heating, passive solar heating, ground source heat pumps, and combined heat and power projects. The software was developed in the Microsoft Excel program [11]

This study aims to analyze and compare the results of energy efficiency measurements using manual calculation methods and RETScreen Expert software. This research also compares annual energy consumption and Energy Use Intensity (EUI) values.

RESEARCH METHODS

The method used in this research is a quantitative method by calculating the total energy use in the building in a one-year period manually and using RETScreen Expert software. Measurements are made by monitoring electrical energy consumption, heating, ventilation and air conditioning (HVAC), and lighting systems.

One of the efforts to determine the energy efficiency of the building is by looking at the Energy Use Intensity (EUI) value. EUI is the most important factor in energy audits [12]. EUI serves as a standard for categorizing the energy use of a building, whether it is wasteful or in accordance with the Indonesian National Standard (SNI) regulations. Lower EUI values indicate more efficient energy use and vice versa.

This research also aims to identify the potential for energy savings through analyzing the difference in results between the manual method and RETScreen Expert, as well as providing recommendations for improving energy efficiency in the Integrated Laboratory building of Padang State University.

In general, EUI is calculated by dividing the total energy consumption by the total output produced. The general formula is:

$$\boldsymbol{EUI} = \frac{\text{Annual Total Energy Consumption}}{\textit{Building Area}} \quad (1)$$

The lower the EUI value, the more efficient a system or process is in using energy to achieve its goals. A decrease in IKE is often considered an indicator of improved energy efficiency. EUI can be applied in various contexts, such as industry, transportation, or buildings.

In the context of this research, a decrease in the EUI value of the Integrated Laboratory building of Universitas Negeri Padang will indicate an increase in energy efficiency and compliance with relevant Indonesian National Standards (SNI). EUI analysis will be an important instrument in evaluating the effectiveness of the energy saving strategies proposed in the study [13]. In the Indonesian Ministry of Energy and Mineral Resources regulations, there are several categories of EUI values that benchmark the energy use of a building can be said to be efficient or wasteful, as in **Tables 1** and **2**.

Table 1. EUI Criteria for Unconditioned Buildings According to Indonesian Minister of Energy and Mineral Resources Regulation No.13 Year 2012

Criteria	**Specific Energy Consumption (kWh/m^2/year)**
Highly Efficient	EUI < 40,8
Efficient	40,8 ≤ EUI < 67,2
Moderately Efficient	67,2 ≤ EUI < 88,8
Wasteful	EUI ≥ 88,8

Table 2. EUI Criteria for Air Conditioned Buildings According to Minister of Energy and Mineral Resources Regulation No.13 Year 2012

Criteria	Specific Energy Consumption ($kWh/m^2/year$)
Highly Efficient	EUI < 102
Efficient	102 ≤ EUI < 168
Moderately Efficient	168 ≤ EUI < 222
Wasteful	EUI ≥ 222

2.1 Research object

In the energy efficiency research conducted, the Integrated Laboratory building of Padang State University became the object of research. The Integrated Laboratory Building of Padang State University is a building consisting of four floors located on Jalan Prof. Dr. Hamka, Air Tawar Padang, West Sumatra. It is located at 0.90° latitude and 100.35° longitude, at an altitude of 3 m above sea level and located 113° north. Figure 1 shows the place of the research object carried out in the integrated laboratory building of the State University of Padang.

Fig. 1. Integrated Laboratory Building of Padang State University

2.2 Data collection techniques

This research procedure begins with the collection of building data that wants to be audited for energy. Data collection in this study utilizes historical data on the use of electrical energy in the UNP Integrated Laboratory building, building area data, building documentation, electricity account payments for the past year, the type of cooling system used in each room, and the type of lighting used in each room in the UNP Integrated Laboratory building.

Calculation of the amount of Energy Use Intensity (EUI) in the building before the audit, to find out the extent of the efficiency of the use of electrical energy in the building. At this stage, an initial audit is carried out on the air conditioning system and the room lighting system. To find out the EUI value can be obtained from the amount of electrical energy use in one month (kWh) divided by the total building area (m2) [14]. To find out the AC capacity requirements of each room can use the following equation.

$$Ac\ Requirements = \frac{\text{Room Area x Room Coeffisient}}{AC\ capacity\ 1\ PK} \quad (2)$$

Data processing using RETScreen Expert software provides a five-step standardized analysis, we can find out the energy savings made, costs associated with energy use, gas emission reduction, risk analysis, and building energy analysis data. RETScreen Expert makes it easier for users to analyze the potential of renewable energy projects, energy audits and energy efficiency [15]. The stages used in RETScreen Expert analysis can be seen in **Fig. 2.**

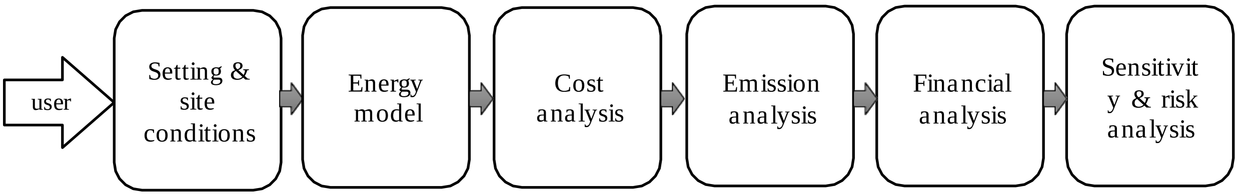

Fig. 2. RETScreen Expert software model flow chart: a five-step standard analysis [16]

RETScreen Expert provides energy saving solutions with a standard five-step analysis procedure. Each of these five-step procedures is interlinked with each other in an Excel spreadsheet. The five-step procedure allows users to analyze building energy use, starting with the Energy Model worksheet, cost analysis, greenhouse gas emissions, sensitivity and risk analysis, financials and an executive summary of annual energy savings.

Energy efficiency analysis in buildings is influenced by various aspects, including air conditioning systems, lighting systems, building insulation, and other energy uses [17]. The energy saving opportunities in this study focus on the air conditioning system and the lighting system. After completing the energy audit, identify areas where energy savings can be achieved, identify the air conditioning capacity used in each room, record the operating hours of the chiller, the type of lighting used, record the time of light usage in each room. The stages of the research conducted can be seen in **Fig. 3.**

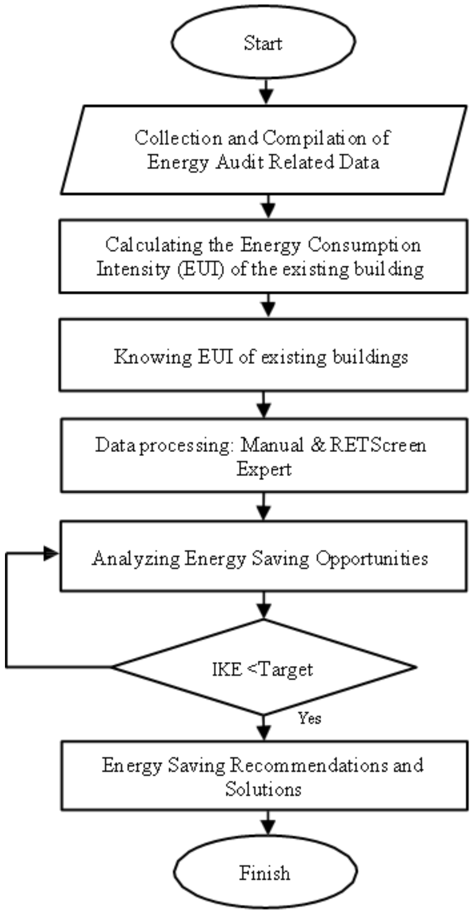

Fig. 3. Flow chart of Research

This research procedure begins with the collection of building data that wants to be carried out efficiency. Data collection in this study utilizes historical data on the use of electrical energy in the UNP Integrated Laboratory building, building area data, building documentation, electricity account payments for a month, the type of cooling system used in each room, and the type of lighting used in each room in the UNP Integrated Laboratory building.

Calculation of the amount of Energy Use Intensity (EUI) in the building, to find out the extent of the efficiency of the use of electrical energy in the building. At this stage, an initial audit is carried out on the air conditioning system, room lighting system and other electronic components.

Data processing was carried out using two methods, the first by manual calculation and the second by using RETScreen Expert software. RETScreen Expert provides a standard five-step analysis. The analysis of energy saving opportunities in buildings is affected by various aspects, including air conditioning systems, lighting systems, building insulation, and other energy use.

If the EUI value after the energy audit is still above the target or has not reached the desired energy optimization, it is necessary to re-evaluate at the energy saving opportunity analysis stage. But if the EUI value is below the target or achieves the desired energy optimization, the research continues by providing recommendations and solutions for energy saving opportunities in the building.

RESULTS AND DISCUSSION.

This report presents energy use data over a one-year period and also breaks down the data by total building area, as well as conditioned building area. Conditioned building area refers to the total area or space in a building that is actively controlled or conditioned by an HVAC (Heating, Ventilation, and Cooling) system. This includes spaces where the temperature, humidity, and air quality are regulated according to the needs of the occupants. Table 3 shows the data of the building area studied.

Table 3. Building Area [18]

	Area (m^2)
Total Building Area	9.173
Conditioned Building Area	6.664
Unconditioned Building Area	2.509

3.1 Analysis of building energy consumption calculation with manual method

Electrical energy use in buildings is distributed across 3 types of components, site air conditioning, lighting systems, and other electrical equipment. In general, the HVAC system or air conditioning system is a major contributor to building energy consumption. Recording AC operating hours is done to monitor energy consumption in the cooling system, also used to calculate AC power consumption in a room [8]. To calculate the power consumption (kWh) of an air conditioner, it is necessary to consider several factors, such as AC power, usage time, and electricity price. For Panasonic CS-PN18SKP type air conditioner, it has an electric power consumption of 1660Watt, using refrigerant type R-32. **Tables 4** and **5** show the energy consumption of air conditioners during weekdays and Saturdays

Tabel 4. Energy Consumption in Cooling System (AC) on Weekday

Building floor	Operating Hours	Total Operating hours (Hours)	AC Type	Number of AC Running	Total kWh
Floor 1	07.00-17.00	10	Panasonic CS-PN18SKP	19	315,4
Floor 2	07.00-20.00	13	Panasonic CS-PN18SKP	34	733,72
Floor 3	07.00-20.00	13	Panasonic CS-PN18SKP	36	776,88
Floor 4	07.00-18.00	12	Panasonic CS-PN18SKP	18	358,56
Total				107	2.184,56

Tabel 5. Energy Consumption in Cooling System (AC) on Saturday

Building floor	**Operating Hours**	**Total Operating hours (Hours)**	**AC Type**	**Number of AC Running**	**Total kWh**
Floor 1	08.00-12.00	4	Panasonic CS-PN18SKP	4	26,56
Floor 2	08.00-16.00	8	Panasonic CS-PN18SKP	12	159,36
Floor 3	08.00-16.00	8	Panasonic CS-PN18SKP	10	132,8
Floor 4	08.00-16.00	8	Panasonic CS-PN18SKP	4	53,12
Total				29	371,84

In one working day, based on the results of data analysis, the cooling system uses 2,184.56 kWh of energy per day. Meanwhile, on Saturday the energy consumed by the building in the cooling system only amounted to 371.84 kWh. The calculation of air conditioning usage for one year is 594,572.16 kWh.

The recording of lamp operating hours is carried out for monitoring energy consumption in the room lighting system, also used to calculate the power consumption of lamps in a room. in the building under study using the lighting system TL LED T8 18w Philips has an electric power consumption of 18Watt or equal to 0.018 kW. In **Tables 6** and **7** shows the energy consumption of lights during weekdays and Saturdays.

Tabel 6. Energy Consumption of Weekday Lighting System

Building floor	Operating Hours	Total Operating hours (Hours)	Lamp Power (Watt)	Number of Lamp Running	Total kWh
Floor 1	07.00-18.00	11	18	90	17,82
Floor 2	07.00-21.00	12	18	100	21,6
Floor 3	07.00-20.00	13	18	129	30,18
Floor 4	07.00-18.00	11	18	84	16,63
Total				403	86,23

Tabel 7. Energy Consumption of Saturday Lighting System

Building floor	Operating Hours	Total Operating hours (Hours)	Lamp Power (Watt)	Number of Lamp Running	Total kWh
Floor 1	08.00-12.00	4	18	20	1,44
Floor 2	08.00-18.00	8	18	40	5,76
Floor 3	08.00-18.00	8	18	28	4,03
Floor 4	08.00-18.00	8	18	32	4,60
Total				120	15,83

In the building, from data collection obtained on weekdays the lights use 86.23 kWh of energy per day, while on Saturdays the energy consumed by lights in the building is only 15.83 kWh. The calculation of lamp usage for one month is 1,960.38 kWh.

Energy consumption in the building by manual calculation is 816,010.8 kWh/year. The energy consumption is obtained by summing up the total energy consumption in the cooling system, the total energy consumption in the lighting system and the total energy consumption in other electronic devices in a one-year period.

The EUI value obtained from manual calculations on the building is 122.4 kWh/m^2/year. EUI Criteria for Air Conditioned Buildings According to Minister of Energy and Mineral Resources

Regulation No.13 Year 2012, the building is classified as a building with efficient energy use with an annual EUI value of $102 \leq$ EUI < 168 kWh/m^2/year.

Although classified as efficient, energy efficiency efforts are still being made. One of the efforts that can be made to reduce energy consumption in the building being studied is to adjust the capacity of the air conditioner to the room area, conduct routine checks on the cooling system, and also on the lighting system. The lighting system can use natural lighting from windows. **Fig. 4** shows the details of energy use in the building on weekdays and Saturdays.

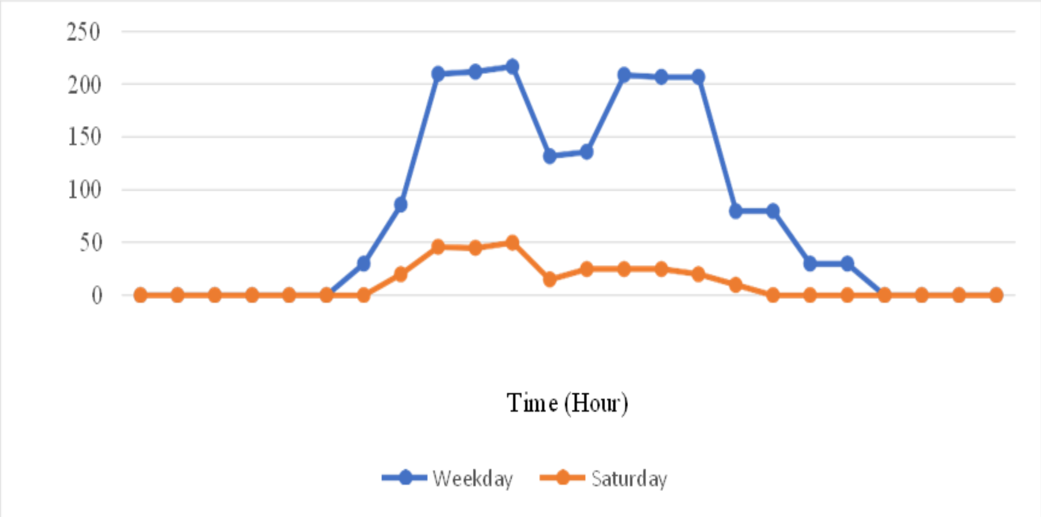

Fig. 4. Graph of electric power consumption in the building on weekdays and Saturdays

Power consumption measurements were taken from 7:00 am to 9:00 pm. The graph of power consumption on Monday-Friday (weekday) shows that 10:00-11:00 is the peak energy usage of 217 kW, this is because at this time is the peak time of activity in the building. When the break time is clearly visible on the graph there is a decrease at 12.00 and an increase again after the break, starting from 13.00 to 16.00. While on Saturdays do not use too much electricity, the average electricity usage is only around 28.1 kW on Saturdays.

3.2 Analysis of building energy consumption calculation with RETScreen Expert

Calculations using RETScreen Expert software are carried out to determine the energy use of **buildings** in the last one-year period quickly and efficiently. Users simply input data related to energy consumption in the building they want to make efficient [19]. RETScreen Expert displays data related to energy use, ranging from reference cases, proposed cases, how much savings can be made, cost analysis, CO2 gas emission reduction, and risk analysis.

Climate data on the research area is also included in the RETScreen Expert software. This climate data aims to determine the climatic conditions for each month in the region over a one-year period [20]. **Table 8.** Shows the climate data of the study area with RETScreen Expert in 2023.

Table 8. Climate data of the study area with RETScreen Expert in 2023

Month	Air Temperature (°C)	Air Humidity (%)	Precipitation (mm)	Daily solar radiation (kWh/m2/d)	Wind Speed (Km/h)	Cooling degree-day(°C-d)
January	26,8	80,9	277,14	4,85	3,6	521
February	27,0	79,6	233,52	5,23	3,6	476
March	27,0	81,7	290,47	5,15	3,6	527
April	27,2	82,9	279,90	5,13	3,2	516
May	27,3	81,7	220,10	5,03	3,2	536
June	27,0	80,4	216,60	4,97	3,2	510
July	26,5	81,5	235,60	4,87	3,2	512
August	26,4	80,9	248,00	4,85	3,6	508
September	26,2	83,7	290,10	4,87	3,2	486

October	26,2	84,1	355,88	4,88	3,2	502
November	26,2	85,2	412,80	4,53	3,2	486
December	26,5	83,4	354,02	4,58	3,2	512

Climate data processed through software also affects energy use in buildings. RETScreen Expert software utilizes climate data to provide a more accurate analysis of energy consumption. This climate data includes air temperature, rainfall, solar radiation, wind rate, cooling degree days, and atmospheric pressure.

These factors are critical in determining the energy requirements for heating, ventilation and air conditioning (HVAC) in buildings. For example, higher air temperatures in the study area will increase energy use for air conditioning systems, as the air conditioners have to work harder to maintain a comfortable temperature. Conversely, lower temperatures may reduce energy requirements for cooling but may increase energy requirements for heating.

In addition, high solar radiation may reduce the need for artificial lighting during the day, while the wind rate may affect the efficiency of the ventilation system. By considering all these variables, software such as RETScreen Expert can assist in planning and managing energy use more efficiently, as well as identifying significant energy saving opportunities. The simulation results of energy efficiency calculations with RETScreen Expert can be seen in **Table 9.**

Table 9. Energy consumption and savings in buildings with RETScreen Expert

	Fuel Consumption (kWh)	**Fuel Cost ($)**	**GHG Emissions (tCO_2)**
Base Case	1.113.453	111.345	911
Proposed Case	933.894	93.389	764
Saving	179.559	17.956	147
%	16,1%	16,1%	16,1%

The results of the analysis using RETScreen Expert software show that the building's energy consumption in a one-year period amounted to 1,113,453 kWh/year. The difference between the reference case and the proposed case shows energy savings of 179,559 kWh/year, with a savings percentage of 16.1% of the total energy. The gas emission generated after the savings are made is 764 tCO2. The EUI value of the building according to RETScreen Expert software is 167.08 kWh/m²/year. The energy use of the building in the annual period is detailed in **Fig. 5.**

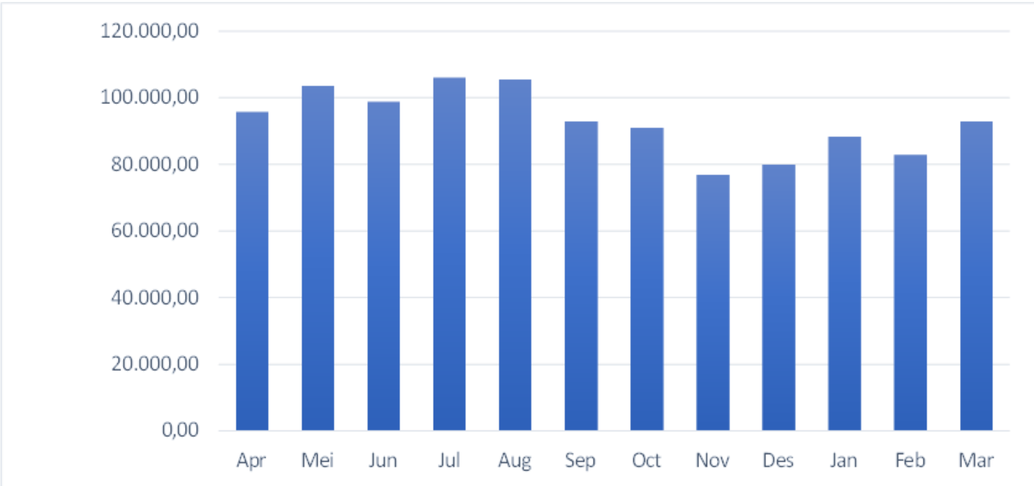

Fig. 5. Forecast-Electricity

The calculation of building energy use starts from April 2023 to March 2024. The largest energy consumption occurred in July 2023 at 108,463 kWh, and the lowest energy consumption occurred in November 2023 at 78,216 kWh. This happens because RETScreen Expert software also considers several factors such as weather changes, full load efficiency, energy leakage rate and other factors.

Occupancy data and annual energy consumption are also contained in the data base of RETScreen Expert. **Fig. 6**. Shows an overview of energy use for the past few years, according to the data base of RETScreen Expert.

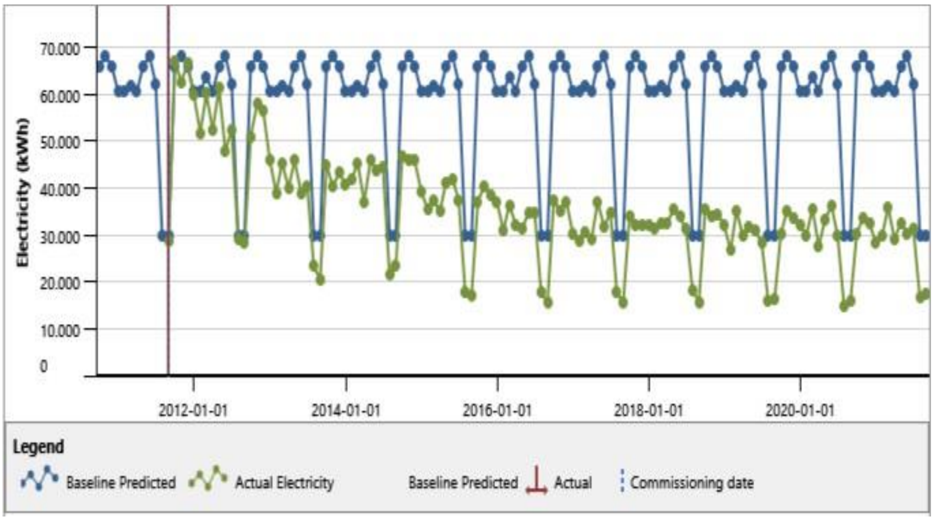

Fig. 6. Measurement and verification (Electricity Consumption -occupancy)

The occupancy rate will affect the energy use of the building. The higher the occupancy rate in the building, the greater the energy used. This is due to the increased use of electrical equipment, lighting, and air conditioning and heating systems needed to maintain occupant comfort. As seen in Figure 7, there is a direct correlation between occupancy and energy consumption. When the building is at full occupancy, energy consumption increases significantly, while during periods of low occupancy, energy consumption tends to decrease. These factors need to be considered in the energy efficiency analysis to get an accurate picture of the actual energy consumption.

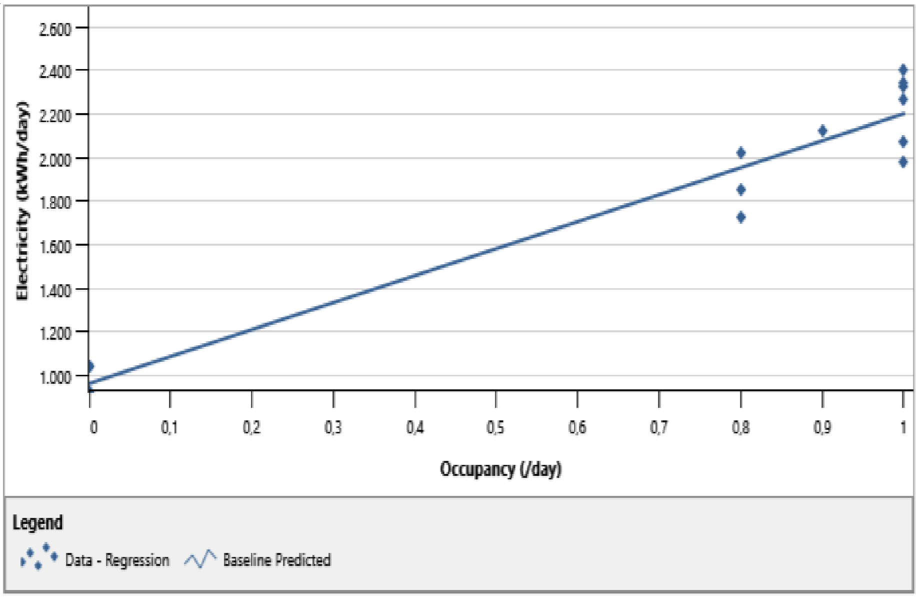

Fig. 7. Regression (Electricity Consumption -occupancy)

Fig.8 shows that energy savings are greatest in mechanical components, such as air conditioning. This is done by adjusting the operating hours of the air conditioner and adjusting the temperature to the comfort temperature of the occupants of the room at 27°C, savings are also made on electrical components, and also on the lighting system.

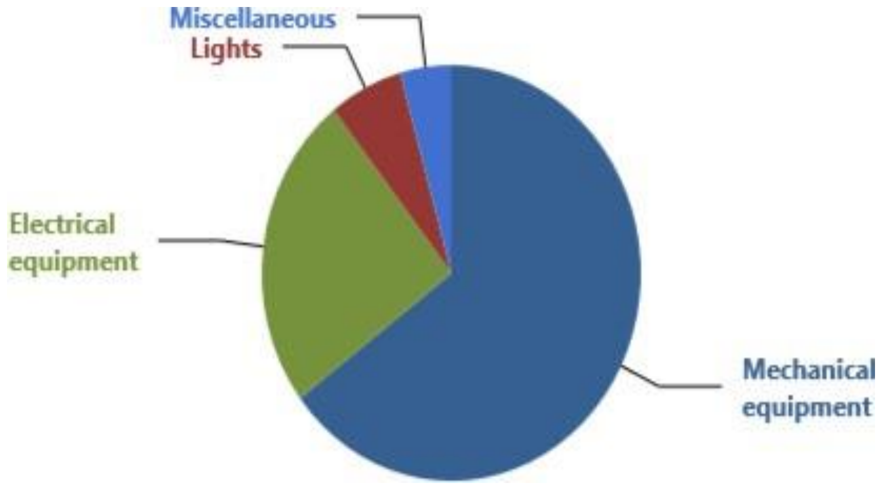

Fig. 8. Energy saved

From the savings efforts made, the energy savings data obtained in the building amounted to 179,559 kWh over a one-year period. The greatest energy savings occur in mechanical components such as air conditioning, saving energy of 116,214 kWh/year, with a percentage of 64.7%. Electrical components save energy by 44,208 kWh/year, with a percentage of 24.6%, and lights save energy by 11,295 kWh/year with a percentage of 6.3%. The data is detailed in **Table 10**.

Table 10. Energy Savings Details

Section	Energy Saved	
	kWh	%
Mechanical Equipment	116.214	64,7%
Electrical Equipment	44.208	24,6%
Lights	11.295	6,3%
Miscellaneous	7.842	4,4%

These savings not only have an impact on reducing energy consumption, but also on reducing carbon emissions generated by the building. In addition, these energy savings can also reduce the overall operational costs of the building, providing long-term economic benefits.

The implementation of energy efficiency measures, such as the optimization of air-conditioning systems, the use of more efficient electrical appliances, and the application of energy-efficient lighting technologies, have proven effective in achieving substantial energy savings. This savings data demonstrates the importance of energy audits and the use of software such as RETScreen Expert to identify and maximize energy saving opportunities.

3.3 Comparative results of energy consumption calculation with manual method and RETScreen Expert

The results of the analysis show that there are differences in calculations between the use of manual methods (816,010.8 kWh/year) and RETScreen Expert (1,113,453 kWh/year). The difference between manual calculation comparison with RETScreen Expert is 297,442.2 kWh/year with a calculation difference percentage of 15.42%. With this difference, it is assumed that manual calculations and calculations using RETScreen Expert do not have too much difference. The comparison of these calculations can be seen in **Fig. 9.**

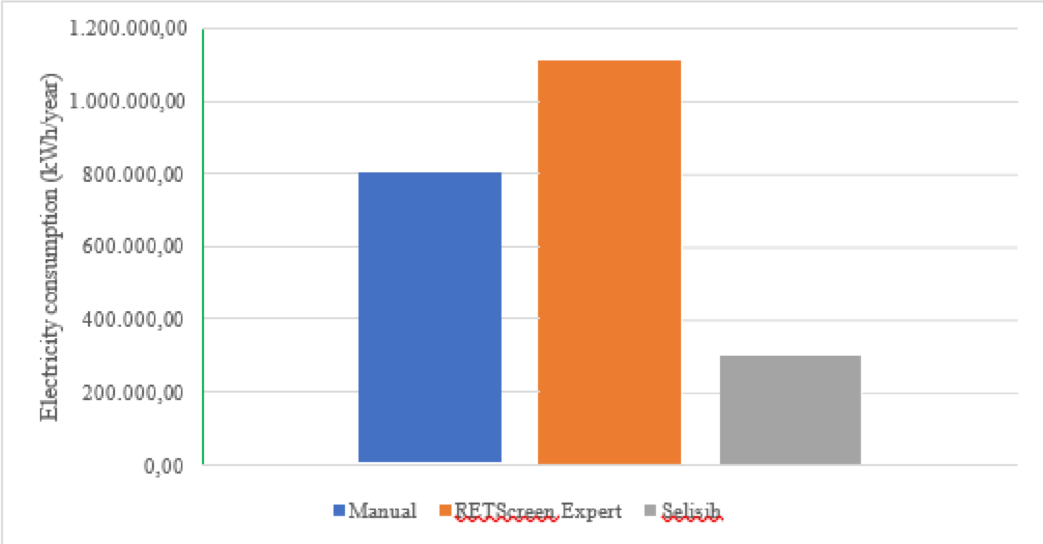

Fig. 9- Energy consumption in annual period

The difference in calculations can occur due to the factor of recording different working operating hours between manual calculations and RETScreen Expert, and is also influenced by several other factors such as full load efficiency, energy leakage rate, weather factors, and other factors in the RETScreen Expert software.

CONCLUSIONS.

Energy saving opportunities that can be implemented include several strategic actions. First, adjust the capacity of the air conditioner (PK) in each room and carry out regular checks and checks of the air conditioner. regulate the operating hours of the air conditioner and adjust the temperature to the comfort temperature of the occupants of the room, namely 27°C. Secondly, in the room lighting system, energy savings can be made by adjusting the operating hours of lights in each room and utilizing natural light from windows as additional lighting.

Energy consumption in a one year period in the Integrated Laboratory building at Padang State University using the manual calculation method is 816,010.8 kWh/year, with an Energy Use Intensity (EUI) value of 122.4 kWh/m²/year. Meanwhile, energy consumption using RETScreen Expert is 1,113,453 kWh/year, with an EUI value of 167.08 kWh/m²/year. The energy that can be saved reaches 179,559 kWh/year, with a savings percentage of 16.1% of the total energy. The gas emissions produced after saving are 764 tCO_2. It can be concluded that energy use in the building is classified as efficient with an annual EUI value of $102 \leq EUI < 168$ kWh/m² / year.

The difference in results between manual calculation and using RETScreen Expert shows a considerable difference, but both methods are reliable in calculating energy efficiency in buildings. RETScreen Expert provides more comprehensive and accurate results by considering various factors that affect energy consumption. Therefore, it can be concluded that RETScreen Expert software is excellent for use in building energy audits to achieve optimal energy efficiency.

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