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Energy Conservation and Energy Audit as an Energy Saving Effort at MSTP UNDIP (case study of MSTP Undip Jepara)

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Abstract. Conservation and energy saving audits on the consumer side are carried out to reduce the rate of energy use so that energy is not wasted. The MSTP Undip Jepara building was chosen as the object of the audit due to the absence of an energy audit report as a form of energy saving plan. Energy audits are carried out using the energy consumption intensity method to determine the efficiency level of the building based on the Minister of Energy and Mineral Resources Regulation No. 13 of 2012 and the significant energy users method to determine the distribution of energy consumption on installed equipment so that energy saving opportunities can be saved. Based on the calculation results, the MSTP Building is in the category of efficient energy consumption with the energy consumption intensity of air-conditioned and non air-conditioned buildings in 2021 with value 9.0 kWh/m^2/month and 4.9 kWh/m^2/month. Energy saving opportunities savings in the no/low cost category, the resulting savings are Rp. 31,963,190, medium cost Rp. 18,490,311, and high cost Rp. 582,503. Savings include setting air-conditioned temperature, reducing air-conditioned operating hours, replacing TL Neon and Spiral lamps with LEDs, as well as replacing conventional PCs with All-in-one PCs

1. Introduction

The Electrical energy in the current era is a very fundamental need for everyday life. Most human activities can be carried out because of the presence of electrical energy, ranging from the industrial, economic, educational, commercial and other sectors. The growth of electricity consumption in Indonesia is increasing every year based on data from the Central Statistics Agency [1]. The increasing use of electrical energy is also influenced by the development of electronic equipment such as computers, televisions, power supplies, air conditioners and other electrical equipment. These electronic equipment can cause several problems in the electrical system and waste electrical energy if good energy management is not carried out.

Buildings as one of the country's infrastructures have a total energy consumption of up to 23% of the total energy consumption of all infrastructure[2]. The government through PP no. 22 of 2017 concerning the General National Energy Plan states that conservation for national energy use has a target of energy saving opportunities of up to 17% for 2025 and 38% in 2050[3]. The targeted energy saving opportunities that have been proclaimed apply to all sectors, including the building sub-sector.

With this government program, users of electrical energy can participate in helping to realize electrical energy savings in every sector with good energy energy management.

In previous research conducted by Wafid Hudaya and Alif Prasetyo have created a web-based energy audit application. The app using the PHP programming language, but there is no preparation yet baseline level of energy efficiency expressed in the value of Consumption Intensity Energy, implementation of significant energy users, along with details on Energy Saving Opportunities[4]. Based on the previous research, the authors conducted an energy audit research with the value of energy consumption intensity, significant energy users, and energy saving opportunities.

The focus of research in this final project discusses the analysis of energy consumption intensity (ECI) and significant energy users (SEU) at MSTP Undip Jepara. Based on a survey conducted in the field, it shows that at MSTP Undip Jepara there has been no energy audit report as a form of electrical energy saving plan. In addition, according to data from the Undip electricity account, the electricity consumption of the Jepara MSTP Building from 2019-2021 continues to increase every year. Therefore, an energy audit at the Undip Jepara MSTP is needed so that the criteria for efficiency in electricity consumption and energy saving opportunities (ESO) can be known based on the reference to the Minister of Energy and Mineral Resources No. 13 of 2012[5]. These criteria and ESO are the basis for the report on recommendations for saving electrical energy for better energy management in order to achieve efficient energy use and reduce the cost of electricity consumption.

2. Theoretical Background

2.1. Energy Conservation

Energy conservation based on PP no. 70 of 2009 concerning Energy Conservation is a systematic, planned, and integrated effort to conserve domestic energy resources, and increase the efficiency of their use[5]. In its implementation in Indonesia, the government has provided detailed and structured regulations related to energy conservation, from the basic things listed in government regulations and laws to in-depth studies described in more specific ministerial regulations.

2.2. Energy Audit

Energy Audit is a technique for calculating the amount of energy consumption in a building area by calculating ECI (energy consumption intensity) which is adjusted to certain standards and then identifying possible energy savings that can be done. The purpose of conducting an energy audit is to determine the best option for energy savings so as to reduce energy consumption per unit output and reduce operational costs in buildings which can then be invested in other sectors[7].

2.3. Energy Audit Level 2

Secondary data processing is carried out during the initial energy audit based on data on total electricity bill rates and building power consumption until the ECI value is obtained[7].

Table 1. ECI Standard Regulation of the Minister of Energy and Mineral Resources No. 13, 2012

Criteria	AC Room Energy Consumption ($kWh/m^2/month$)	Non-AC Room Energy Consumption ($kWh/m^2/month$)
Very Efficient	< 8,5	< 3,4
Efficient	8,5 – 14	3,4 – 5,6
Quite Efficient	14 – 18,5	5,6 – 7,4
Wasteful	≥ 18,5	≥ 7,4

While the primary data collection is carried out directly during a field survey on electrical equipment installed with a case study in the Undip Jepara MSTP building. This level 2 energy audit which includes surveys and energy analysis has several outputs. The following is an illustration of the output:

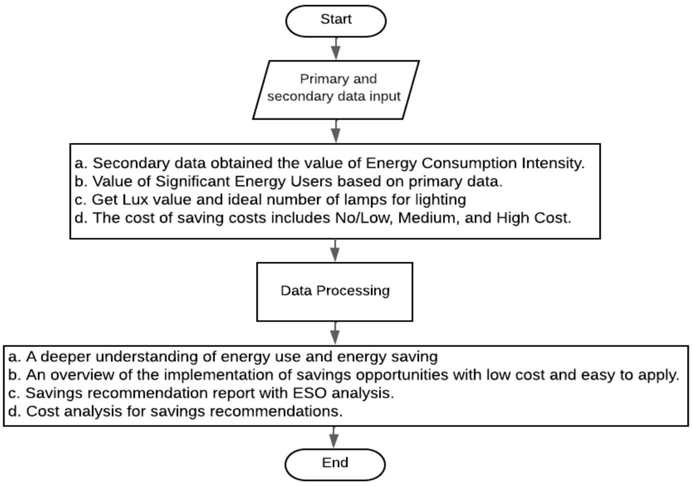

Figure 1. Energy audit output flowchart

2.4. Lighting Intensity Analysis

In the retrieval of light intensity (Lux) data, lux meter is used. Measurement of light intensity on lamps is carried out under normal conditions during the day with a lux meter on a workbench[7]. The data of the measurement results are compared with the standard of SNI No. 6197 of 2020 concerning Energy Conservation in the Lighting System.

The value of light intensity (Lux) from the measurement results of each room will be categorized into 2 conditions, namely "Less" and "Exceed" which is adjusted to SNI Standard No. 6197 of 2020. Based on these standards, each room has a different standard of light intensity (Lux). Different according to the function of the room.

Table 2. Lighting level standards for office and educational institutions

Function Room	Minimum Lighting Level (Lux)
Reception Room	300
Director's Room	350
Workspace	350
Computer Room	150
Meeting Room	300
File Warehouse	150
Emergency Stair Room	100
Corridor	100
Toilet	200
Parking Space	100
Classroom	350
Library Reading Room	350
Laboratory	500
Teacher's Room	300
Sports Room	300
Auditorium	300
Languange Laboratory Room	300
Lobby	100
Ladder	100
Prayer Room	200

2.5. Database Design

Database design of energy audit data processing results using Microsoft Excel software. This concept is designed to make it easier for technicians/administrative staff at the Undip Jepara MSTP building to know and monitor data in the form of:

a. Value of Building Energy Consumption Intensity.
b. Significant Energy User Value.
c. Total Equipment, Total Power, Total Energy (kWh).
d. Comparison of Actual Light Intensity (Lux) Value and SNI Standard.
e. Comparison of the number of lamps installed and the calculation of the number of ideal lamps.
f. Savings Procedure.

The data that will be displayed in the database includes criteria per type of equipment, per room, per floor, and an overall summary in the Undip MSTP building. Meanwhile, the processing data will be grouped based on the equipment data sheet, ECI, SEU, LUX, kWh, and ESO. In the data processing, it is done using MS Excel formulas including SUM, *, /, COUNT, and IF. The following is a view of the audit database shown in the image below.

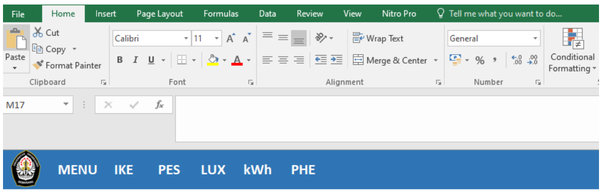

Figure 2. Audit Database Display

Figure 2 above is a view of the audit database on the user's main page. Users can choose various menus that are displayed to view the presentation of data that has been processed by the auditor. This final project focuses on discussing Significant Energy Users on SEU sheets and Energy Saving Opportunities on ESO sheets.

2.6. Procedure for Saving Energy Saving Opportunities

After designing the database and creating a savings table sheet. The calculation formulas for the ESO saving procedure are entered in the savings sheet. The formula used in the savings sheet is the basic formula for calculating SUM, *, /, and others. This savings sheet is divided into several categories as follows:

a. Lighting (Lamp) Savings
- Replacement of 24 Watt TL Neon lamps to 14 Watt LED TL lamps.
- Replacement of 20 Watt Spiral SL lamps to 12 Watt LED lamps.

b. Cooling (AC) Savings
- Setting the use of AC temperature.
- Reduction of AC operating hours.

c. PC Saving
- Replacement of old/conventional PC to All in one PC.
- Use sleep mode when the PC is left on/off hours.

3. Result and Analysis

3.1. Audit Database

The system used in the audit database in this final project based on Microsoft Excel software is the hyper link cells system from the main page. The hyper link cells feature on the main page will be connected with different displays including MENU, ECI, SEU, LUX, kWh, and ESO. The display used in this database is basically simple to make it easier for auditors and observers to understand the data presented and make it easier for auditors to process interactions between data and perform data calculations based on the data that has been collected. In the process, the system hyper link cells “MENU” is the main page of the database. Hyperlink cells “kWh” are the main part of the calculation of “SEU” and “ESO” cells that contain equipment data and energy consumption recap. This is intended when the interaction between data in the database starts from the "kWh" cells.

3.2. Electrical Account Data for the UNDIP Jepara MSTP Building

Based on electrical energy consumption data obtained from the SA-MWA of the Undip Household Section, the Undip Jepara MSTP building uses electrical energy sourced from PLN. Data on the electrical energy consumption of the Undip Jepara MSTP building from 2019 to 2021 can be seen in Table 3 below:

Table 3. Undip MSTP Building Electricity Account Data 2019-2021

No	Year	Total Energy (kWh)	Total Cost (Rp)
1	2019	362.277	531.560.037
2	2020	366.454	535.760.002
3	2021	373.100	539.018.150

Table 3 above displays data on the MSTP Building electricity bill from 2019 to 2021 which is divided into kWh and cost/kWh categories. From these data it can be seen that there is an increase in terms of kWh and annual costs. For more details, the following is a graphical representation of the total electricity cost and electricity consumption rates for 2019-2021 at the Undip Jepara MSTP building, shown in Figure 3 below.

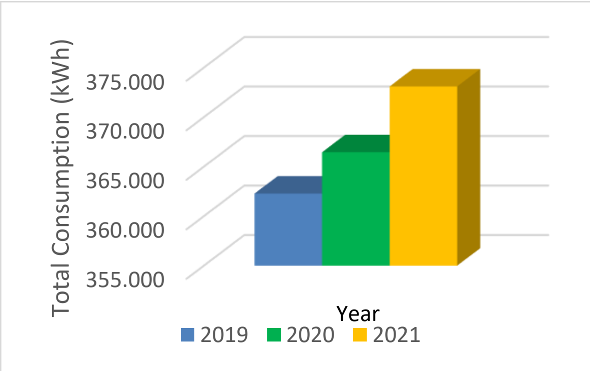

Figure 3. Graph of Total Electricity Consumption for 2019-2021

The picture above shows a graph of kWh consumption at the Undip Jepara MSTP Building. The energy consumption of kWh continues to increase every year and the highest energy consumption will be in 2021 at 373,100 kWh/year.

3.3. MSTP Building ECI Calculation and Analysis

Calculation of ECI in the MSTP Building serves to determine the use of electrical energy efficiency (kWh) to the area of the room per year. To know the calculation of ECI required data on electricity bills, total electricity consumption, and the total area of the room.

Table 4. MSTP Building's Annual ECI Value Calculation Results

Year	kWh	AC Room ECI ($kWh/m^2/year$)	Non-AC Room ECI ($kWh/m^2/year$)
2019	362.277	105,9	57,2
2020	366.454	106,7	58,0
2021	373.100	107,9	59,2

Based on the results of Table 4 above, it can be seen that the ECI value per year in the MSTP building continues to increase every year. The data from the annual ECI calculation in Table 4 can be converted into the monthly ECI value by dividing it by 12 so that it can be compared with the ECI from ESDM Regulation No. 13 of 2012 concerning ECI standards for air-conditioned and non-AC office buildings as shown in Table 1. The following is the conversion data:

Table 5. Monthly ECI Comparison Data for AC rooms

Year	Annual ECI ($kWh/m^2/year$)	Monthly ECI ($kWh/m^2/month$)	Description
2019	105,9	8,8	Efficient
2020	106,7	8,9	Efficient
2021	107,9	9,0	Efficient

Table 6. Monthly ECI Comparison Data for Non-AC rooms

Year	Annual ECI ($kWh/m^2/year$)	Monthly ECI ($kWh/m^2/month$)	Description
2019	57,2	4,8	Efficient
2020	58,0	4,8	Efficient
2021	59,2	4,9	Efficient

Tables 5 and 6 show the results of data processing on ECI values at the Undip MSTP Building for categories per year and per month in air-conditioned and non-AC rooms. From the results of the data processing, it can be seen an increase in the value of ECI in 2019-2021. Based on the results of data processing that has been carried out, it can be concluded that the MSTP Undip Jepara Building has an efficient ECI value criterion so that further savings can be made to increase the building criteria to become very efficient ECI criteria.

3.4. SEU Spread Calculation

A In calculating the SEU distribution, it is done by multiplying the power of the type of equipment by the number of installed equipment. The following is an example of the display of SEU calculation results in the MSTP Building using Ms. Excel shown in the image below.

Table 7. SEU Spread Calculation at MSTP Building

Nu	Equiptment	Total Equipment	Equipment Power (Watt)	Total Power (Watt)	Percentage (%)
		Lamp Equipment			
1	TL Neon	625	24	15000	24,4%
2	SL Spiral	52	20	1040	1,7%
3	LED 12	133	12	1596	2,6%
4	LED 8	180	8	1440	2,3%

		AC Equipment			
6	AC Split 1.5 PK	11	1054	11594	18,9%
7	AC Split 1 PK	14	744	10416	17,0%
8	AC 2 Split 1.5 PK	1	1720	1720	2,8%
9	AC 2 Split 1 PK	2	1380	2760	4,5%
		Electronic Equipment			
10	PC All in one	3	30	90	0,1%
11	PC Conventional	7	60	420	0,7%
12	Dispenser	1	85	85	0,1%
13	Refrigerator/freezer	4	152	744	1,2%
14	Printer/scanner	9	15	125	0,2%
15	Fan	13	110	1255	2,0%
16	Television	4	70	280	0,5%
17	Oven	1	750	750	1,2%
18	Laptops	4	30	120	0,2%
19	Photocopy machine	1	450	450	0,7%
20	CCTV	24	18	432	0,7%
21	Speaker	1	100	100	0,2%
22	Router	4	12	48	0,1%
23	Paper shredder	1	63	63	0,1%
		Laboratory Equipment			
24	Laboratory Equipment	20	10-1600	10866	18%
	Overall	**1115**	**5506**	**61394**	**100%**

Based on the distribution of SEU data above, then the data visualization is carried out with a pie chart. Pie chart was chosen because it has a chart display that makes it easy for users. The pie chart display is shown in the Figute 4 below.

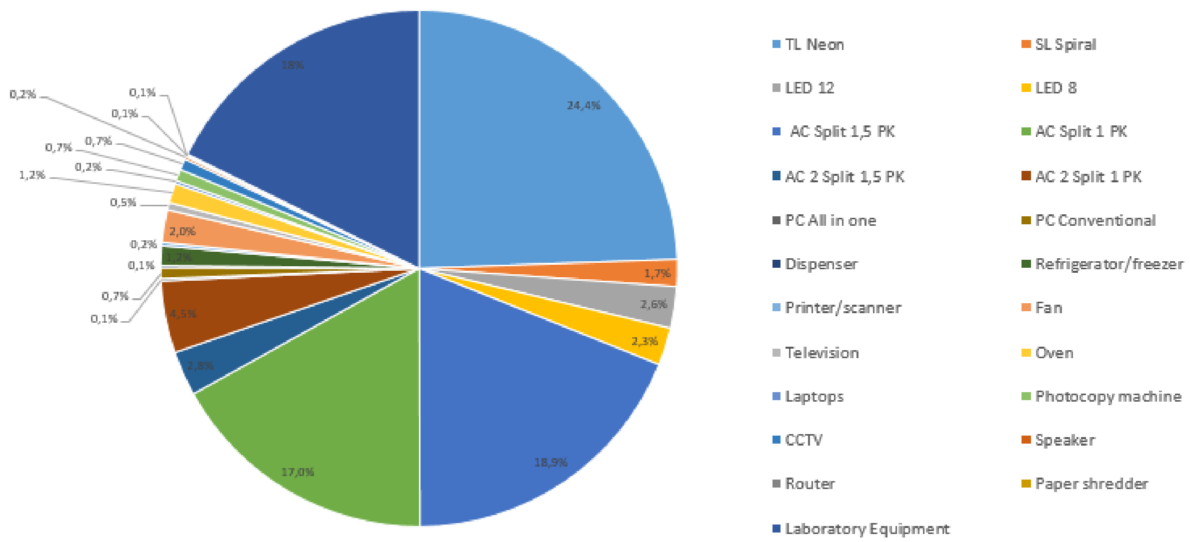

Figure 4. Pie Chart of SEU Distribution at MSTP Building

Based on the pie chart Figure 4, the largest SEU is in TL Neon lighting equipment with a percentage of 24.4%, followed by AC Split 1.5 PK, and AC 1 PK equipment with a percentage of 18.9%, and 17.0%. The equipment is included in the category of equipment with the largest energy consumption in Indonesian buildings with the cooling system in the first place and the lighting system in the second place [8]. Therefore, the next stage is mitigation by conducting a savings analysis.

3.5. Lighting Analysis

In the analysis of the lighting system in the Undip MSTP Building, a survey of light intensity measurements was carried out in the entire room from the 1st floor to the 3rd floor. The measurement of the lighting system was carried out with a lux meter measuring instrument with measurement conditions on a work table which was about 1.5 meters from the room light source. . Based on the survey results, the SEU of lights used in the building include the type of TL Neon 24 watts, Sl Spiral 20 watts, and LED 12 watts. Measurements were carried out in actual conditions when the room was used, namely at 08-16.00 WIB. The results of the measurement data that have been carried out are then presented in tabular form. The results of the survey are then compared based on standards that refer to SNI 6197 of 2020 concerning Energy Conservation in Lighting Systems. The following data on the measurement results with a lux meter and their comparisons are shown in the Table 8 below.

Table 8. Comparison Result of Lux Room 1st Floor in MSTP Building with SNI Standard

1st floor room name	Lux Measurement	SNI Lux Regulation	Description
Lobby	165	100	FULFILL
Administration room	322	300	FULFILL
Director's Room	353	350	FULFILL
Theater Room	351	300	FULFILL
Preparation Room	277	500	LESS THAN
Storage Space	155	150	FULFILL
Optical Room and Balance	320	300	FULFILL
Instrumentation Room	175	150	FULFILL
Instrumentation Sub Room I	196	150	FULFILL
Instrumentation Sub Room II	165	150	FULFILL
Genset Room	93	150	LESS THAN
Women's Toilet I	215	200	FULFILL
Men Toilet I	207	200	FULFILL
Diving Room	301	300	FULFILL
Wet Lab	104	300	LESS THAN
Tenant Production Room I	312	300	FULFILL
Tenant Production Room II	162	300	LESS THAN
Tenant Production Room III	176	300	LESS THAN
prayer room	216	200	FULFILL
Warehouse I	71	150	LESS THAN
Warehouse II	64	150	LESS THAN
Women's Toilet II	212	200	FULFILL
Male Toilet II	206	200	FULFILL
Corridor I	101	100	FULFILL
Corridor II	69	100	LESS THAN
1st to 2nd Floor Stairs	78	100	LESS THAN

Based on the Table 8 above, it can be seen that a number of rooms have met the recommended lighting intensity standards. But there are also other rooms that do not meet the recommended standards so that the recommended steps that can be taken to mitigate lighting system problems are to save energy consumption by doing the following [9]:

a. Utilize natural lighting during working hours as well as possible.
b. Turn off the electric light when it's really not in use.
c. Use the lights in the courtyard of the building when it is getting dark and immediately turn off when it is light again.
d. Perform routine maintenance and cleaning of lamps

3.6. Ideal Lamp Analysis

On buildings, the ideal use of the formula for calculating the number of lamps when implemented is as follows:

$$N = \frac{E \, . \, L \, . \, W}{\emptyset \, . \, LLF \, . \, Cu \, . \, n} \tag{1}$$

The calculation value of the ideal number of lamps above is assumed for = 2700 lumens and in office buildings using the standard E = 300lx[14]. The coefficient uses a value of 0.65 because the walls and ceilings of the building are bright and the light loss factor (LLF) uses a value of 0.8. Based on the results of the calculation of the number of lamps, it can be seen the number of ideal lighting needs for each room in the Undip Jepara MSTP Building when compared to the survey data and calculations. The results of the comparison table of the number of lamps are shown Table 9 below.

Table 9. Comparison of Calculation of the Ideal Number of Lights for MSTP Building

Floors	Room Name	Number of Lamps	Ideal Lamp Calculation Results	Description
3	Hall / Lobby	26	24	EXCEED
3	Transit Room I	9	14	LESS THAN
3	Transit Room II	5	10	LESS THAN
3	Hall	190	139	EXCEED
3	Warehouse I	8	6	EXCEED
3	Women's Toilet I	2	2	EXCEED
3	Male Toilet I	3	3	EXCEED
3	Hall Stairs	8	5	EXCEED
3	Lecture Room 301	20	28	LESS THAN
3	Lecture Room 302	13	23	LESS THAN
3	Lecture Room 303	32	23	EXCEED
3	Laboratory	6	23	LESS THAN
3	Warehouse II	8	3	EXCEED
3	Warehouse III	8	3	EXCEED
3	Women's Toilet II	2	3	LESS THAN
3	Men’s Toilet II	3	3	EXCEED
3	Hallway	5	34	LESS THAN

The Table 9 above is used as a sample calculation, for a detailed table of the results of the total space calculation is attached in the appendix. Based on the calculation table, in the MSTP Building there are 51 rooms that have an excess of the ideal number of lights and 23 rooms that are still less than the ideal number of lights. Mitigation steps that can be taken are by turning on half the lights when needed. In addition, reduction mitigation calculations are carried out to meet the amount of space that is still less than the ideal amount.

3.7. Summary of Energy Saving Opportunities
This section presents savings based on investment, kWh/year savings, Rp/kWh/year, percentage savings and payback period categories. The following is a summary of the MSTP Building savings summary in Table 10 below.

Table 10. Summary of Savings Opportunities

Saving type	Investation	Savings kWh/Year	Savings Rp/kWh		Energy Saving Percentage	Payback Period/year
NO COST/LOW COST						
AC temperature setting 20° to 24-27°	-	3,052	Rp	4,408,716	6%	-
Reduced AC operating hours by 1 hour	-	6,358	Rp	9,184,825	13%	-
Reduced AC operating hours by 2 hour	-	12,715	Rp	18,369,649	25%	-
MEDIUM COST						
TL Neon 24 > TL LED 14	Rp 28,125,000	12,000	Rp	17,336,400	42%	1,6
SL Spiral > LED	Rp 3,380,000	799	Rp	1,153,911	40%	2,9
Scenario of the ideal number of TL lamps	Rp 24,660,000	14,070	Rp	20,326,582	49%	1,2
Scenario of the ideal number of LED	Rp 13,195,000	3,118	Rp	4,504,690	40%	2,9
HIGH COST						
Conventional PC to PC All In One	Rp 16,100,000	403	Rp	582,503	57%	27,6
Overall	**Rp 85,460,000**	**52,514**	**Rp**	**75,867,276**		
Total No Cost/Low Cost		22,124	Rp	31,963,190		
Total Medium Cost		29,987	Rp	43,321,583		
Total High Cost		403	Rp	582,503		

Based on the summary Table 10 above, the total savings opportunity in the Jepara MSTP Building is 52,514/kWh/year or equivalent to Rp. 75,867,276. The following is a graphical representation of the total summary of savings at the Undip Jepara MSTP building, shown in Figure 5 below.

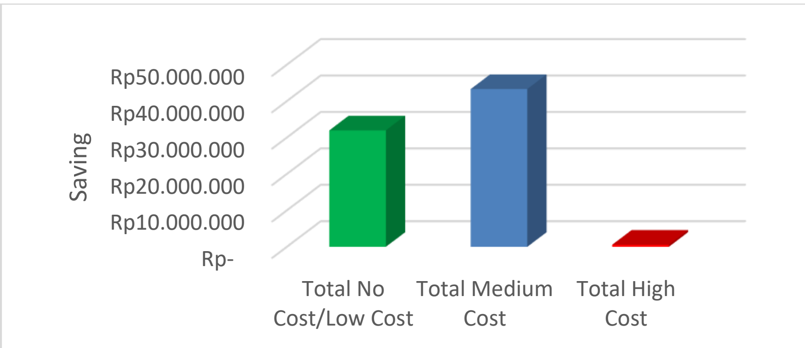

Figure 5. Summary graph of savings in MSTP Building

The summary of the savings opportunities shown in Figure 5 above has detailed recommendations for mitigation measures with the following categories[10]:

A. The No/Low Cost category has a saving opportunity of 22,124 kWh/year or equivalent to Rp. 31,963,190 with details of mitigation such as; setting the AC temperature from 20 degrees to 24 to 27 degrees with a savings opportunity of up to 6% and a reduction in air conditioning operating hours (1 to 2 hours reduction) with a savings opportunity of up to 13-25%.
B. The Medium Cost category has a saving opportunity of 29,987 kWh/year or equivalent to Rp. 43,321,583 with details of mitigation such as; replacement of TL Neon lighting equipment to TL LED with up to 42% savings opportunity, 1.6 years payback period and SL Spiral lighting equipment replacement to LED with up to 40% savings opportunity, 2.9 years payback period. Which lamp replacement is more profitable for the scenario of ideal lamp needs which results in a payback period of 1.2 and 2.9 years.
C. The High Cost category has a savings opportunity of 403 kWh/year or equivalent to Rp. 582,503 with details of mitigating the replacement of Conventional PCs to All-in-one PCs with savings opportunities of up to 57% and a payback period of 27.6 years.

4. Conclusion

The MSTP Undip Jepara building is included in the category of buildings with efficient energy consumption based on the standard of Ministerial Regulation No. 13 of 2012 with the ECI of air-conditioned and non air-conditioned buildings respectively in 2021 with a value of 9.0 kWh/m^2/month and 4.9 kWh/m^2/month.

Lux Analysis of the Undip Jepara MSTP Building, there are rooms that do not meet the Lux standard recommended by SNI 6197 so that mitigation steps are taken such as utilizing natural light, using lights when it is getting dark, and performing routine maintenance of lights.

Savings in the no/low cost category at the Undip Jepara MSTP Building resulted in savings of 22,124 kWh/year or equivalent to Rp. 31,963,190. The savings in the medium cost category at the Undip Jepara MSTP Building resulted in savings of 29,987 kWh/year or equivalent to Rp. 43,321,583. Savings in the high cost category at the MSTP Undip Jepara Building resulted in savings of 403 kWh/year or equivalent to Rp. 582,503/kWh.

Based on the overall savings, the highest savings were obtained in the medium cost category with savings of 29,987 kWh/year or equivalent to Rp. 43,321,583.

In terms of overall savings, for the no/low cost category, it is feasible to implement because it is in accordance with the regulation of the Minister of Energy and Mineral Resources No. 13 of 2012 concerning setting temperature settings and reducing air conditioning operating hours and no need for investment costs.

In medium cost, lamp replacement with ideal lamp needs is more feasible to implement than normal replacement because it is in accordance with standard SNI-03-6575-2001 and has a faster payback period value and greater savings.

Acknowledgment

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References

[1] S. Harsanto, *Statistik Listrik 2014-2019*. November. Jakarta, 2020.
[2] A. W. Biantoro, “Analisis Perbandingan Efisiensi Energi Pada Gedung P Kabupaten Tangerang Dan Gedung Tower Umb Jakarta,” *J. Tek. Mesin*, vol. 06. Juni, 164–173, 2017.
[3] Presiden RI, *Peraturan Presiden Republik Indonesia Nomor 22 Tahun 2017 Tentang Rencana Umum Energi Nasional*. 2017.
[4] Hudaya Wafid. 2019. Analisis Penggunaan Energi Listrik Kampus Undip Tembalang Dengan

Menggunakan Perancangan Perangkat Lunak Berbasis Web. Semarang: Departemen Teknik Elektro Universitas Diponegoro.
[5] Presiden RI, "Peraturan Pemerintah Republik Indonesia no 70/ 2009 Konservasi Energi," pp. 1–17, 2009.
[6] Menteri Energi dan Sumber Daya Mineral, *Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia No. 13 Tahun 2012 Tentang Penghematan Pemakaian Tenaga Listrik*. 2012.
[7] Badan Standardisasi Nasional, *SNI 6196 : 2011 Tentang Prosedur Audit Energi pada Bangunan Gedung*. 2011.
[8] Alajmi, Ali. "Energy audit of an educational building in a hot summer climate." *Energy and Buildings* 47 (2012): 122-130.
[9] Zanardo, R. Petri. "Energy audit model based on a performance evaluation system." *Energy* 154 (2018): 544-552
[10] Balai Besar Teknologi Konversi Energi, *Benchmarking Specific Energy Consumption Di Bangunan Komersial*. 2020.
[11] Balai Besar Teknologi Energi and Badan Pengkajian dan Penerapan Teknologi, *Prosedur Standar dan Teknik Audit Energi Di Industri*, no. 8. 2015.
[12] Presiden RI, *Undang Undang Republik Indonesia Nomor 30 Tahun 2007 Tentang Energi*. 2007.
[13] Menteri Energi dan Sumber Daya Mineral, *Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia No. 28 Tahun 2020 Tentang Tarif Tenaga Listrik Yang di sediakan PT PLN (PERSERO)*. 2020.
[14] C. Radityatama and J. Windarta, "Analisa Indeks Konsumsi Energi Dan Kualitas Daya Listrik Di Kampus Undip," vol. 10, no. 1, 2021.
[15] Pemerintah Provinsi DKI Jakarta, *Sistem Pencahayaan*, vol. 3, no. 38. 2012.
[16] Badan Standardisasi Nasional, *SNI 6197-2020 Konservasi Energi pada Sistem Pencahayaan*.
[17] Badan Standardisasi Nasional, *SNI 03-6575-2001 Tentang Tata Cara Perancangan Sistem Pencahayaan Buatan pada Bangunan Gedung*. 2001.
[18] R. Simatupang, M. Hafiz, and N. A. Sasongko, *Pedoman Teknis Audit Energi Dalam Implementasi Konservasi Energi Dan Pengurangan Emisi CO2 Di Sektor Industri (Fase 1)*, vol. 1. 2011.
[19] M. Nissanga, N. Rasanajan, N. Perera. "Energy audit: a case study." *2006 International Conference on Information and Automation*. IEEE, 2006.
[20] M. Krisna, "Analisis Pengguna Energi Signifikan Dan Program Konservasi Energi Pada Gedung Kampus Undip," 2021.
[21] Menteri Energi dan Sumber Daya Mineral, *Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia No. 13 Tahun 2012 Tentang Penghematan Pemakaian Tenaga Listrik*. 2012.
[22] M. Giatman, *Ekonomi Teknik*. 2006.
[23] Sugiyono, *Metode Penelitian Kuantitaif,Kualitatif dan R&D*, no. 465. 2013.
[24] Badan Standardisasi Nasional, *Sni 03-6196-2000 Prosedur Audit Energi pada Bagunan Gedung*. 2000
[25] P. H. T. Hutabarat and M. F. Zambak, "Penghematan Konsumsi Energy Melalui Analisa Ike Di Kampus II Efarina Pematangsiantar," *J. Electr. Syst. Control Eng.*, vol. 5, no. 1, 2021.
[26] Krarti, Moncef. *Energy audit of building systems: an engineering approach*. CRC press, 2020.
[27] Jadhav, Vivek. "Energy conservation through energy audit." *2017 International Conference on Trends in Electronics and Informatics (ICEI)*. IEEE, 2017.
[28] Fleiter, Tobias, Joachim Schleich, and Ployplearn Ravivanpong. "Adoption of energy-efficiency measures in SMEs—An empirical analysis based on energy audit data from Germany." *Energy Policy* 51 (2012): 863-875.
[29] Singh, Malkiat, G. Singh, H. Singh. "Energy audit: A case study to reduce lighting cost." *Asian*

Journal of Computer Science and Information Technology 2.5 (2012): 119-122.
[30] Khalid, M. Usman. "Energy conservation through lighting audit." *2012 IEEE International Conference on Power and Energy (PECon)*. IEEE, 2012.