Harvesting Energy Saving Through Energy Audit : A Case Study of Local Government Building in Jakarta

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ABSTRACT

Electrical energy is a very important requirement to support regional government office activities. Excessive energy use can certainly cause energy waste, so to prevent excessive energy use it is necessary to take energy efficiency measurement. Energy Audit is the one method to measure how efficient the energy usage. Based on SNI ISO 50002 : 2018 regarding energy audit guidance, We conduct the energy audit at the one of local government building in Jakarta City. In doing so, the scope and objective of this energy audit project are to review and evaluate the energy consumption 3 years ago particular for electric, cooling and lighting system saving opportunities. The result from this project are the Enpi's value are 184 kWh/m2 per year. it can be indicated that the building inefficient in energy usage. The Power Quality Analyzer showing inefficient from electrical system because the cosh phi value is 0,75 and automatically get the penalty from PLN. The lighting system still in non LED technology. The Cooling system need improvement to make the energy consumption more efficient. There is a Solar pV rooftop potential installation that could give the contribution in energy saving around 134.963 kWh/Year. All of summary and recommendation that can be proposed in energy saving potential is 244.169 kWh/Year or 53% cost energy saving from existing cost energy consumption.

Keywords*: Energy Saving, Energy Audit, Energy Performance Indicators, Energy Conservation Opportunities*

ABSTRAK

Energi listrik merupakan kebutuhan yang sangat penting untuk mendukung aktivitas kantor pemerintahan daerah. Pemakaian energi yang berlebihan tentunya dapat menimbulkan pemborosan energi, sehingga untuk mencegah pemakaian energi yang berlebihan maka perlu dilakukan pengukuran efisiensi energi. Audit Energi merupakan salah satu metode untuk mengukur seberapa efisien pemakaian energi. Berdasarkan SNI ISO 50002 : 2018 tentang pedoman audit energi, Kami melaksanakan audit energi pada salah satu gedung pemerintahan daerah di Kota Jakarta. Dalam pelaksanaannya, ruang lingkup dan tujuan dari proyek audit energi ini adalah untuk meninjau dan mengevaluasi konsumsi energi 3 tahun yang lalu khususnya untuk peluang penghematan sistem listrik, pendingin dan penerangan. Hasil dari proyek ini adalah nilai Enpi sebesar 184 kWh/m2 per tahun. Hal ini dapat diindikasikan bahwa gedung tersebut tidak efisien dalam penggunaan energi. Power Quality Analyzer menunjukkan ketidakefisienan dari sistem kelistrikan karena nilai cosh phi sebesar 0,75 dan secara otomatis mendapatkan penalti dari PLN. Sistem penerangan masih dalam teknologi non LED. Sistem pendingin perlu ditingkatkan agar konsumsi energi lebih efisien. Terdapat potensi pemasangan panel surya atap yang dapat memberikan kontribusi penghematan energi sebesar 134.963 kWh/Tahun. Seluruh ringkasan dan rekomendasi yang dapat diajukan dalam potensi penghematan energi adalah sebesar 244.169 kWh/Tahun atau penghematan biaya energi sebesar 53% dari biaya konsumsi energi eksisting.

Kata kunci: Penghematan Energi, Audit Energi, Indikator Kinerja Energi, Peluang Konservasi Energi

INTRODUCTION

To Strenghtening to energy conservation program in Indonesia, The Indonesia Government already issued the Government Regulation No. 33 Year 2023 about Energy Conservation. In term of therminology, energy conservation is a systematic, planned, and integrated effort to preserve domestic energy resources and enhance their utilization eficiency. One of the clausul statement is the goverment building has to implement the energy management by energy audit conducted periodically (Gov. Regulation 33,2023). Electricity is the largest source of energy consumed by buildings, and it will continue to increase every year. Building sector represented 23% of final energy consumption in Indonesia in 2021 (IEA,2022). Efficient use of energy is also one of the main challenges considering from Indonesia Goverment. The way to achive of energy saving potential from building sector are energy audit implementation, the application of minimum energy performance at appliances and online energy consumption reporting (Ministry of Energy and Mineral Resources,2020). High-rise office buildings can have energy consumption of 40–50% for their heating, ventilation, and air conditioning systems (Perez-Lombard et al., 2008).

Jakarta currently holds the highest energy consumption per capita (3.330 kWh/capita), and the level of electrification ratio reached 100% in 2013 (HEESI,2020). The building energy consumption is getting higher because a lot of high rise building that consume a lot of energy especially for cooling system. As the key of energy consumption appliance, air conditioning is one of the growing sources of electricity in high rise buidling with tropical climates. The primary energy from HVAC consume up to 151 kWh/m2 per year (Jinkyun Cho,2018).

To determine the current energy usage status in buildings and how efficient their energy efficiency levels is by measuring the intensity of energy consumption or energy performance indicators (Enpi's). That represented by kWh/m2/year. An office building in South Jakarta can consume energy up 250 kWh/m2/year (Amalia et al., 2022). Another study for energy optimization by considering the technology of double skin facade of museum building, the orientation of buidling, decision building shape and mechanical cooling system has significantly impact for dominating

building energy use (Paramita et al, 2019). Indoor air quality (IAQ), energy consumption, thermal comfort, and stratification are all significantly impacted by a VAV terminal unit's minimum air flow (Su-Hyun Kang,2013).

The goal of an energy audit is to find operational issues, enhance occupant comfort, and maximize the energy consumption of existing facilities (Sterling,1994). The person who in charge in this activity called as energy auditor. In doing so, Indonesia has regulation to condut the energy audit based on SNI ISO 50002:2014 and certification body to issued and conducting the energy audit based on Indonesian National Work Competency Standards (SKKNI) Energy Auditor No. 53 Year 2018. A list of energy conservation opportunities (ECOs) that were categorized as requiring no or low investment, moderate investment, or high investment was generated by the building's energy audit. In a hot summer climate, there are 52% overall savings for an educational building (Alajmi,2011). An investigation conducted in climate comparable to that of the current study examined different strategies aimed at conservation energy in offcie buildings located in hot and humid environment. Although some measures were hypotetical, a saving of 36% of annual energy consumption was expected (Iqbal,Al Homoud et al.,2007). Using the Rooftop solar photovoltaics in buidling can be saving energy up 18% (worlaka,2022). The energy audit consist of several types or levels. Type 1 is walkthrough audit, type 2 is preleminary audit and type 3 is detailed Audit (Thumann,2008). By doing the energy audit, the Co2 emission were also decreased through the energy conservation activity based on energy audit recomendations (Momani et all,2023).

The objective of this study is thus to analysis the profile of energy consumption for exisiting local goverment building in jakarta and produceds the energy conservation opportunitys. We conduct the energy audit procedure as a tools to investigate the energy consumption profile, measuring the appliances to get the primary data and interviewing the building manager to get the secondary data. Then we also conduct the simple techno economy analysis to make the recomendations is feasible to be implement. It can also provide the baseline energy that can be used for standard minimum of energy usage.

METHOD

Figure 1 presents the metodology of this research. The study is based on Indonesian National Standards International Standards Organization (SNI ISO 50002 : 2014) regarding Energy Audit – Requirement With Guidances for use. For this study, we use type 2 to conduct the energy audit. Doing so, this study use the SNI 6196-2011 regarding energy audit procedure in building. Table 1 presents comparation between type 1, 2 and 3 of energy audit.

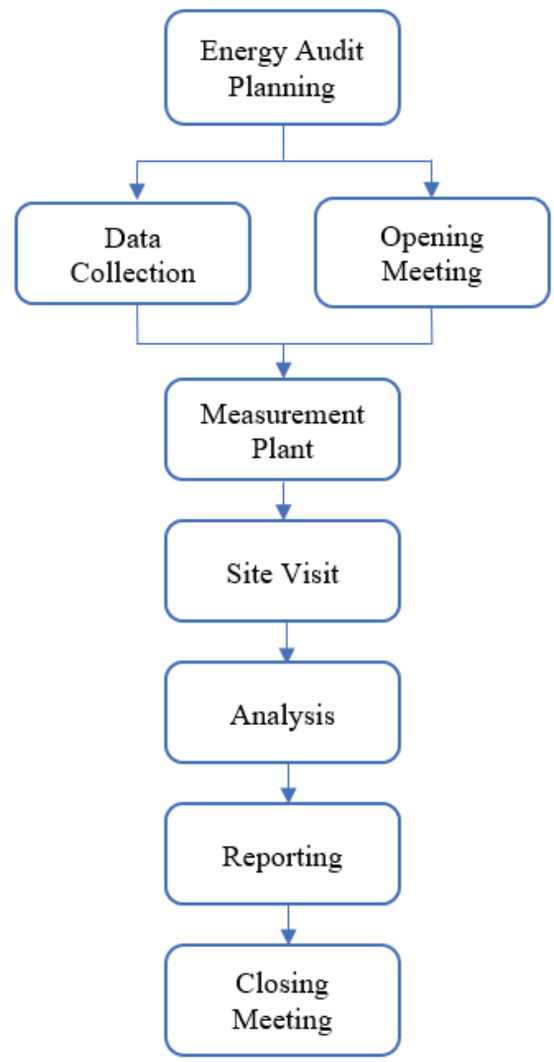


Figure 1. Energy audit methodology based on SNI ISO 50002 : 2014

Starting with the energy audit planning, this step is very important to decide the scope of work and objective of the energy audit. After that, we do the opening meeting with stakeholder or building manager to deliver the objective, boundaries and energy audit methode or type. This activity paralell with data collection. The energy auditor should ensure the avaibility of secondary data. If the data unavailable, they need to do the maesurement activity in the field. For site visit, conduct the data logger installment at the certain utilities. After the measurement activity is complete, then the energy auditor will do the analysis. The results from energy audit is deliver the ECO's and make the agrrement with stakeholder in order to implement the ECO's then conduct the closing meeting.

In this study, The first step was to define the energy audit's scope, which included the areas to be inspected. We decide to conduct the type 2 of energy audit or preliminary audit. The areas to be audited is electrical system, cooling system, lighting system and energy managemet system. In the beginning, preparation is being made by coordinating with building manager. After that, a field survey is conducted. The particullar step is necessary to compare the exisiting condition with the standard to obtain the ECO's recomendations.

Table 1. Comparation Between Type 1,2 and 3 of Energy Audit Procedure (Adopted by SNI 6196:2011)

Items	Type 1 (Walk-Through)	Type 2 (Preliminary)	Type 3 (Detailed)
Data Collections	• The History Energy Consumption • Installed Capacity • Production Capacity • Visual observation • Interview	Type 1 + Electrical Bill	Type 2 + Profile of all utilities
Measurement	No Need	Sampling and Temporary Measurement	Complete measurement of all utilities
Analysis	• Enpi's • ECO's	• Enpi's • ECO's • Simple CBA	Type 2 + Techno Economics, energy balance and utilities detailed performance.

In addition to determine the ECO's, this energy audit activity needed to collect information about the secondary data such as size of the building that air conditioning exposured (m2), electricity bills in 3 years ago, information about significant energy uses / SEU's (Type of AC, Amount of AC, lamp technology and Amount of lamp), the information regarding how to implement the energy management system, conduct site survey and measurements plans, and analyze the data to complete the energy audit process.

The boundary of this study is we are not calculate the Overall Thermal Transfer Value's (OTTV) building. We assume the building wall construction has the insulation material.

2.1 Energy Performance Indicators (Enpi's)

Office buildings are one of the objects that high energy consume in building sector. Based on specific energy consumption survey, energy consumption in office building rank third after shopping centres and hotels (MEMR-UNDP-

BPPT, 2020). Most of energy sources used come from electrical energy supply. To determine the building energy consumption level, we use energy performance indicator (Enpi's). Enpi's is defined as the amount of energy (spesifically electricity) per unit area of the building served by energy.

$$Enpi's = \frac{\text{(Σ energy consumption (kWh))}}{\text{(Σ conditioning of Building Area (m}^2\text{))}} \text{ per Year} \quad (1)$$

For the office building, the Enpi's benchmarking value is 180,95 kWh/m2/year (MEMR-UNDP-BPPT,2020).

2.2. Building description and Significant Energy Uses (SEU's) Profile.

The local government building have 8 floors with a total floor area of 8,000 square meters, but the area that cool conditioned is 6,800 m2. The buildings is oriented toward the south direction with one main entrance. On average, 250 employes use the building with regular occupancy from 8 am to 4 pm and 5 days per week for office working day. Regarding the main power system, electricity is mainly supplied 100% by PLN, a public utility company in Indonesia with trafo installed capacity is 1.110 kVa and has 1 generator-set with capacity is 350 kVa for back up power system. The energy cost from this local goverment building average IDR 250.000.000 per month with basic electric tarif IDR 1.600 per kilo watt hour (kWh).

Related with significant energy uses (SEU's), this local government building consist of Mechanical Air Conditioner, Lighting System, Lift System and Water Pump transfer System and others utilities. The SeU can be assumed by mechanical air conditioner.

2.3 SEU's Measurement Points

In this study, the energy audit planned to conduct a thoroughly level 2 audit (Preliminary assessment). The energy audit measurement activity started with electrical system. We use Power Quality Analyzer (PQA) to recording the electrical profile and detect the anomali of electrical system each energy utilities. Lighting system will be measured by lux meter to measure the light intensity. For mechanical air conditioner system, we need to check the indoor temperature setting and humidity value. All of the information gathered is coming from the primary and secondary data as well.

(a)

(b)

(c)

Figure 2. Power Quality Analyzer (a), Lux Meter (b) Temperature & Humidity Meter (c).

Because of its preliminary audit, we do the sampling measurement at the SEU's. The data logger will working in one week. After doing the measurement, all the recorded data were analyzed in section results and recomendation to identify the ECO's. The energy auditors should have the tools necessary to measure critical factors including temperature, illumination lux level, and running current in order to acquire correct operating conditions and the performance of the systems and equipment. The temperature, relative humidity, and light intensity datasets for most of the office building zones were collected in one

week. The findings will be discussed in section data collection.

2.4 Data Collection and Finding

The energy audit was conducted on June, 2023. At this point in the audit, the energy audit activiy has gathered a lot of data about the buildings funcionally, electrical system operations, mechanical air conditioner, lighting and plug in device usage. The data can be show as follows :

1. The electric energy consumption of building was obtained from utility ;
2. The utility / system profile obtained from utility measurement ;
3. The utility / system was operated based on design or standard operating procedures.

Firstly, the energy consumption gathered from year 2020 until 2022.

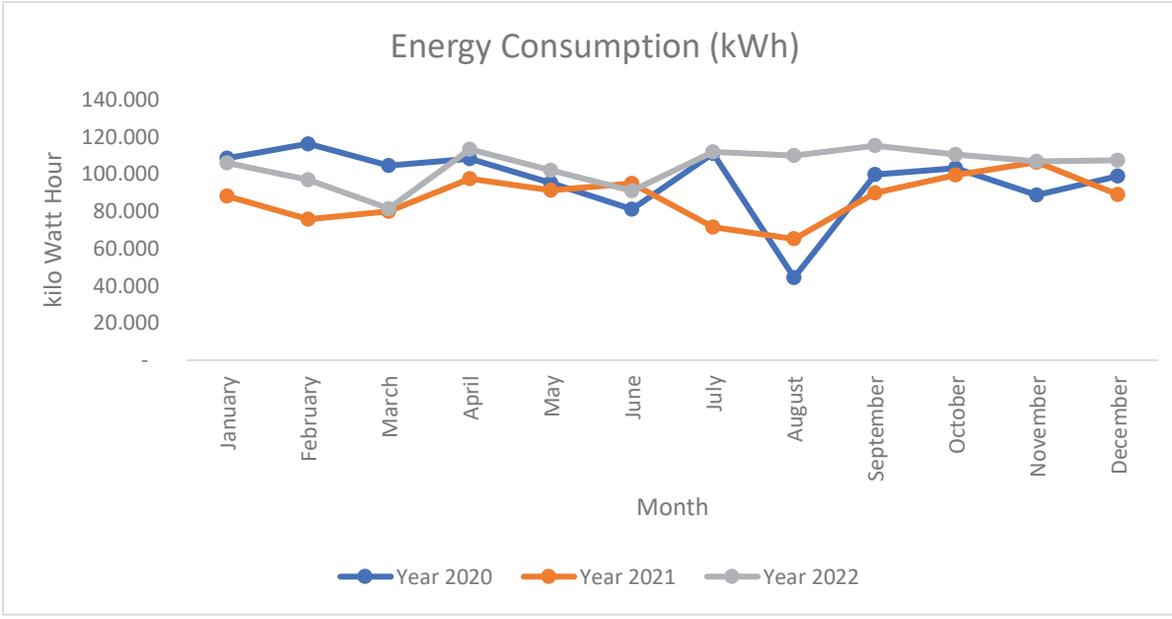


Figure 3. Electric Energy Consumption Cummulative (kWh)

From the trend of electrical energy consumption in Figure 3, electrical energy consumption in year 2022 will increase compared to year 2021. From the trendline equation obtained, it shows that the gradient of the equation is positive and indicated an increasing trend in kWh usage. The electrical energy consumption increase. After that, we determine the energy performance indicators of the office building that represent in fig.4.

Air Conditioning Area	6.800	m2	
Total of Energy Consumtion			
Year	2021	2022	2023
Energy Consumptions	1.159.552	1.049.136	1.253.264
Enpi's (kWh/ m2/Year)	171	154	184

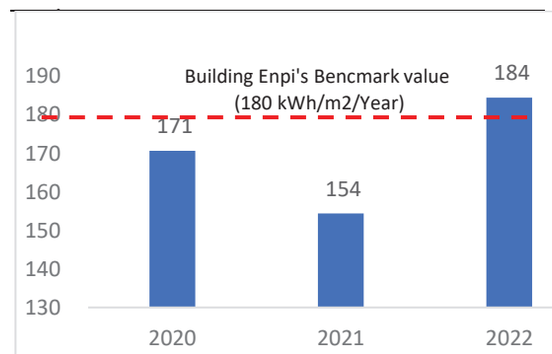
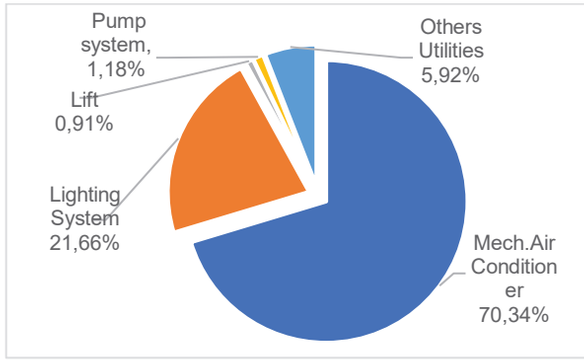


Figure 4. The Energy Performace Indicators (Enpi's)

Based on report from MEMR-UNDP-BPPT 2020, the standard benchmarking of Enpi's for office building is 180,95 kWh/m2/year. This office building show that in year 2022 is above Enpi's benchmarking value. It will indicates that the building energy consumption is ineficienct. From

the electrical system, we devided the profile of energy distribution in each equipments that use the electric power using power quality analyzer tool.



Energy Appliance	kWh/year
Mech.Air Conditioner	881.526
Lighting System	271.404
Lift	11.368
Pump system	14.751
Others Utilities	74.214
Energy Consumption Based on measurement approach in 2023	**1.253.264**

Figure 5. The Profile of Energy Consumption Distribution Based On Equipment Measurement

The Anomali condition was found in cosh phi system. The value is under the 0,85. The consequnces from that is the office building get the penalty cost from PLN that can be seen in Fig 6.

Figure 6. Cosh Phi value Based on PQA Measurement

On the other side, we also measure the daily energy consumption in one week from the office building. From Fig.7 the daily energy consumption profile show that there is a differentiation between weekend and weekday energy consumption.

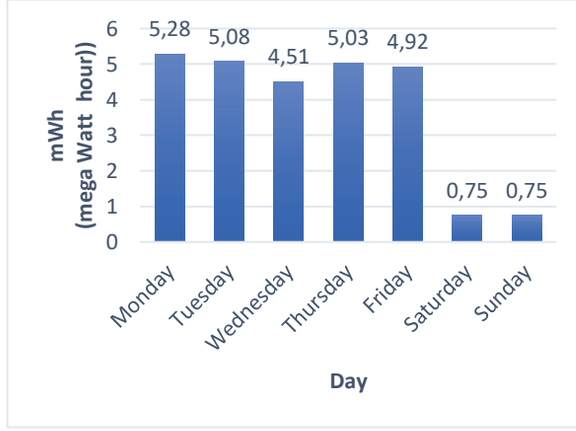


Figure 7. Energy Daily Consumption

For Lighting system, the building almost use the CFL lamp tehcnology. There are 1,000 lamps that still use non LED bulb. Then we do the measurement and compare to the Indonesian National Standard (SNI) number 6197 Year 2020 about energy conservation in lighting system as represented in table 2.

Table 2. Lux intensity value based on measurement

No	Room Name	Lux Measurement	Standard (SNI 6197 : 2020)	Remarks
Floor 1				
1	Loby	70	300	Out Standard
2	Guest Waiting Room	194	250	Out Standard
Floor 2				
3	Aula	67	300	Out Standard
4	Office Room	86	250	Out Standard
Floor 3				
5	Office Room	172	250	Out Standard
6	Meeting Room	197	300	Out Standard
Floor 4				
7	Office Room	90	250	Out Standard
8	Meeting Room	270	300	Out Standard
Floor 5				
9	Office Room	141	250	Out Standard
10	Meeting Room	210	300	Out Standard
Floor 6				
11	Office Room	261	250	Out Standard
12	Meeting Room	261	300	Out Standard
Floor 7				
13	Office Room	92	250	Out Standard
14	Meeting Room	282	300	Out Standard
Floor 8				
15	Office Room	77	250	Out Standard
16	Meeting Room	61	300	Out Standard

From the measurement results shows that the lamp intensity is out of standard. It will be effect to the level of working convenience of employee. In HVAC system especially in mechanical air conditioner, this building still use the central conventional of mech air conditioner type. To make sure the thermal confort, we do the measurement and compare to the Indonesian National Standard (SNI) number 6390 Year 2020 about energy conservation in cooling system that show the thermal comfort range for human is 25±1°C and 50±10% of humidity. The finding from Cooling system is, this office building set up the thermostat temperture in 19-20°C. We can said that, a lot of energy consumption that will usage from cooling system. There's no major issue in lift, pump and plug in device system. the quality of unbalance and harmonics still in good performance. The cosh phi still being the minor issues becuase the value is under 0,85.

Another things that could be consider regarding energy saving potential is energy management system from office building. From interview to the energy manager building, they still not applied the energy management system. There's no energy policy and awarness from management level to make the energy usage is more efficient.

There's a energy saving potential come from rooftop of office building. The solar photovoltaic is potential to be installed and give the energy contribution in the grid system.

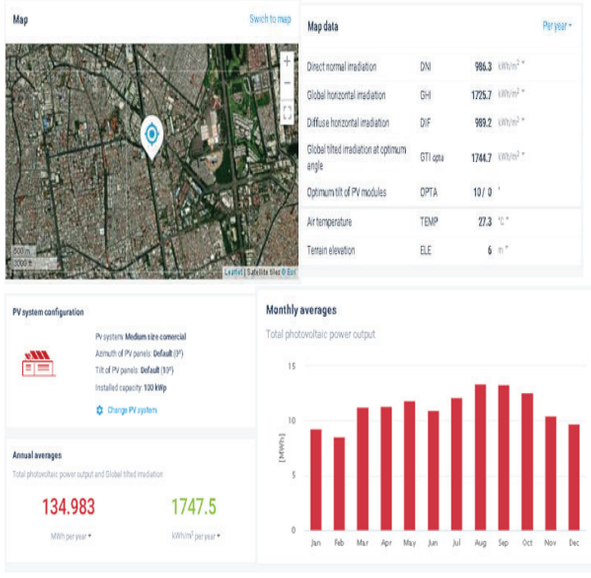


Figure 8. Simulation of sun irrandiance for Solar PV rooftop

Especially for cooling system, these building use mechanical air conditioner with central type and has Air Handling Unit / AHU for each floor. The control system is centrallised in AHU room. The room didnt has occupation also cooled by mech. AC unit. The impact from centrallized cooling is inefficiency of energy. There are hall room that has less occupation, but always cooled by mech. AC because the type of air flow is constant air volume / CAV. There is energy efficienct technology equipment that will be able to minimize air volume from centrallized AC using VRF technology. Part-load energy peformance can be managed by Variable refrigerant flow systems, has the advantage of flexibility on control system and also it has quite easy to install and to maintain (Zhang et al., 2019). The other solution is install the open / close damper inside the ducting or the common name is variable air volume. The volume of air passing through a Variable Air Volume (VAV) box determines the indoor air quality, thermal comfort, and energy efficiency of a system, hence it is an essential part (Y-H.Cho,2009). Install VAV also saving the energy up to 12,6% (UNIDO,2017). The others finding from cooling system is re set up of temperature setting from AHU. Fig.9 show The lowest value 16°C of temperature always conducted to meet thermal comfort. It can be the potential of energy saving if the temperature value were able to increase.

Figure 9. Cooling room activity in 2nd floor but there's no occupation and Temperature from AHU on every floor

RESULTS AND RECOMMENDATIONS

From the results of the energy audit activity especially on the electrical system, cooling system and lighting system, several potential energy saving potentials were obtained that could be carried out to obtain more efficinet energy use, these potentials as as follow :

Electrical system at this building office can be improved by installation of capacitor bank. The results of measurements carried out at at the Main Distribution Panel using PQA HIOKI 3100 and that can be seen in Figure.6 show that cos phi is smaller than 0.85. For the record, the ideal cos phi value is (0.9~1). The cos phi magnitude is in the range (0,74 – 0,76) with an apparent power (Q) of 360 – 375 kVar at peak/maximum load. Steps to improve the Cos Phi amount are carried out by installing a minimum capacitor bank device at a Cos Phi value of 0.85. However, to get a better cos phi value (0.95 ~ 1) and consider future building loads, the proposed bank capacitor size is in accordance with the measured KVAR size due to the energy audit (360 – 380) kVar. The proposed capacity is 400 kVar. The main potential savings are savings in kVarh fine costs of IDR 75.000.000/ month. The potential for saving electrical energy is around (0,5 – 1) % of current energy use. There is solar photovoltaic potential installation at the rooftop of the building with area is 574,51 m2. Based on figure 9, the potential power capacity from solar pV that can be installed in the rooftop is 100 kWp. The potential electrical energy produced during a year according to the installed power capacity of Solar pV can be reached 134.983 kWh or similar with cost energy saving for one year is IDR 205.563.000. For the cooling system also has energy saving potential with using variable air volume / VaV and increase the room temperature value. The energy saving potential can be reached is 79.290 kWh/year or IDR 112.195.911. For the lighting system also has the energy saving potential. With the replacement activity from CFL to LED can be reach the energy saving is 24.332 kWh/year or IDR 34.429.582.

The total energy saving recomendations that can be implemented will show in table.3

Table 3. The summary of energy saving potential

No.	Energy Conservation Activity	Energy Saving (kWh/ year)	Cost Energy Saving (IDR/ Year)	Investment Cost (IDR)	Simple Pay Back Period (year)
1	Installation of Bank Capasitor 400 kvar/3P/400 Volt	5.564	908.469.157	200.000.000	0,22
2	Installation of VaV in Ducting line and optimalization of several room with partition	70.696	100.035.039	120.000.000	2,51
3	Decreasing of temperature setting from 16°C to 22°C.	8.594	12.160.872	0	0
4	Replacing lighting system with LED 1000 lamps	20.812	29.448.414	90.000.000	5,80
5	Management operation in lighting operating procedure and occupation motion sensors	3.520	4.981.168	4.000.000	0,8
6	Solar pV rooftop installation	134.983	205.562.911,04	2.000.000.000	9,73
	Total	244.169	1.260.657.561	2.112.000.000	
	Energy consumption average based on PLN bill in 2021-2022 (kWh/ Year)	1.184.400			
	Cost Energy Consumption average (IDR/Year)	2.352.000.000			
	Total of Energy Saving Percentage	20,62 %			
	Total of Cost Energy Saving Percentage	53,6 %			

As indicatated of the environmental aspect of energy management, we also calculated the emissions factor. Based on the aims of ISO 50001:2018 regarding Energy Management Systems with a systematic approach to enhance an organization's continuous improvement of energy management. One of the activity is help to reduce the emission reduction of CO_2. The energy management activity in this office buiding can reduce CO2 emissions 195.534 KgCo2 with the emission factor is 0,83.

Lastly, the energy management system from this office building was not implemented. From interview activity to the building manager, this building doesn't has the energy manager, energy policy and energy conservation program. To support an energy management system's, a supportive system is needed. An energy policy outlining the general policies that have been established by the company is necessary in order to implement an energy management system.

CONCLUSIONS

The objective of the research are to describe the energy saving potential that can feasible to be achived. By doing the energy audit, consumption profile and opportunity improvement can be profilled. This activity also necessary for measuring the energy performance indicators. There is an energy conservation acitivity that can be implemented in order to reduce the energy consumption. Cooling system as the significant energy use can give energy saving potential is 7 % or 79.290 kWh/year. For lighting system also give the contribution arround 2% or 24.332 kWh/year and solar pV roof top installation also give the contribution arround 11% or 134.983 kWh/year. Ultimately, 20,62% of the total energy consumption can be saved if all the recommendations are implemented. Regarding the CO_2 emission reduction, the recommendations of energy audit from the building's electricity use will be reduced by 195 tons a year. Energy management is mandatory to implemented. The energy audit recommendations help the office building to increase the energy saving related with energy management. For the future study, the measurment and verification of energy audit is needed to measure and verify energy saving and for determining how succesfull a project has been. The study also possible to implement the other energy measures such as thermal insulation or OTTV.

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