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# Energy Audit for Air Conditioning System of Office Building in Jakarta

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**ABSTRACT**

The need for electrical energy in the building is needed so that the supporting operational he need for electrical energy in the building is needed so that the supporting operational activities of the building can run normally. The need for electrical energy for the building must be maximized based on Energy Consumption Intensity (ECI). The most required electrical energy for supporting operational activities in the building is the air conditioning system. The need for electricity in the air conditioning system of the building requires the largest percentage of the energy requirement of the building. Hence, it requires special attention in terms of optimizing the use of electrical energy as well as the pattern of energy conservation for the increase of energy efficiency. In this research, the energy audit was performed for the central air conditioning system in an aging building located in the Slipi area in Jakarta. It was found that the Energy Consumption Intensity of the building is 19.11, which can be categorized as wasteful based on the current standard. The audit also shows that the Chiller no longer operated in the optimal condition with their COP ranged between 2.5 and 3.0. Similarly, the Air Handling Unit and the Chilled Water Pump also showed signs of degrading performance due to wear and tear. Therefore, the energy audit recommended the Chiller to be replaced with a newer model since it used the highest percentage of energy.

**Keywords**: Energy Audit, Energy Consumption, Chiller, Air Conditioning System

## 1 INTRODUCTION

The energy audit is an important tool in order to reduce the energy usage for office building, control its utility cost and minimize its carbon footprint. However, the application of energy reduction in the building should still provide enough cooling and ventilation to create comfortable environment for the building occupants [1]. The audit energy will provide the detailed analysis on which areas of the building consumed significant portion of the electrical energy, indicating where the highest energy savings can be potentially achieved.

In general, the majority of electrical energy consumption in the office building is by the heating, ventilating, and air conditioning system. In hot and humid countries, the HVAC system uses approximately 50%-70% of the total building energy consumption [2, 3], and up to 40% is consumed by air conditioning and chiller [4]. Due to its high energy usage and large potential for energy saving, the air conditioning system often becomes the main focus on energy audit. The energy audit of the air conditioning system reveals the level of energy usage for different areas of the office. The electrical energy saving can be achieved by simply reducing the energy usage in the areas where there is high energy loses [5, 6] or installing high efficiency air conditioners and chiller [7]. Other potential energy saving methods include changing the operating parameters of the chiller and the usage of variable pump in air conditioning system [8, 9]. Ultimately, the analysis of the audit energy of the air conditioning and chiller system results in maximizing the energy saving, reduce the building operating costs and minimize greenhouse gas emission.

The main purpose of this study is to conduct energy audit for the air conditioning and chiller system in the Wisma Slipi office building located in West Jakarta, Indonesia (106.796194 Longitude, -6.186694 Latitude). The energy audit was performed by both walk-through observation and field measurement audit with the focus on the Chiller, Air Handling Unit (AHU) and the Chilled Water Pump. In the analysis, the Chiller efficiency was calculated based on the COP (Coefficient Of Performance) obtained from the temperatures and pressures from the supply and return lines. On the other hand, the temperature difference in inlet and outlet was measured in order to quantify the efficiency level of the Air Handling Unit and the pump rotational speed was analyzed as the performance indicator for the Chilled Water Pump.

## 2 RESEARCH METHODOLOGY

### 2.1 Energy Audit Method

The energy audit procedure performed in this study was shown in Figure 1. The energy audit process involved three major steps. The first step involved the initial building survey, gathering primary data such as historical building energy usage and air conditioning data, and collecting secondary data (company profile, daily energy consumption, flow process, and equipment specification). Based on the energy consumption data from the previous year and information about the building, annual and monthly Energy Consumption Intensity (ECI) for the building can be calculated as follow:

$$ECI_{annual} = \text{Yearly Electricity Consumption} / \text{Building Area} \quad (1)$$

$$ECI_{monthly} = ECI_{annual} / 12 \quad (2)$$

If the ECI value is higher than 18.5, the building is categorized as wasteful in using electrical energy and recommended to implement an energy-saving strategy.

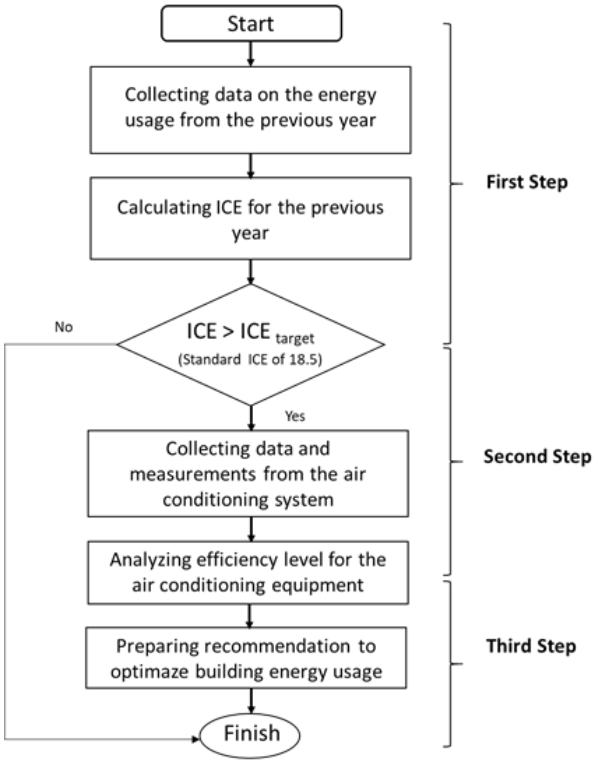


**Figure 1.** Energy Audit Method

After the preliminary audit is conducted, the second step was to conduct a detailed energy audit, particularly for the air conditioning system. Data collection and measurements were performed on the main components of the air conditioning system: Chiller, Air Handling Unit (AHU), and Chiller Water Pump. The Chiller efficiency, the temperature difference in inlet and outlet of the AHU, and the Chiller Water Pump were measured and calculated. Based on the assessment of their efficiency level, the potential energy savings option for the air conditioning system in the building can be formulated. The final step of the energy audit involved preparing and presenting the final report, which included recommending improvements that require relatively significant capital investments, such as replacing the equipment to reduce cooling energy usage in the building.

### 2.2 Data Collection for Air Conditioning System

In Wisma Slipi building, there are 2 Air Conditioning Zones: AS 4 zone and AS 7 zone. For the AS 4 zone, the building employed two Chiller units (AS 4A and AS 4B), three Chilled Water Pump units, and fifteen AHU units. Similarly, the second zone also utilized a similar configuration with two Chiller units (AS 7A and AS 7B), three Chilled Water Pump units, and fifteen AHU units. The Chiller is manufactured by York (model YCAH). During the energy audit, the following measurements for each Chiller were taken:

a. Water Discharge/Flow Water and Temperature

   Measurements of the water discharges and temperatures were carried out in the Inlet and Outlet Pipes (Supply and Return Lines in the Cooler section). The water discharge was measured with an ultrasonic flowmeter. The temperature measurements were conducted using thermocouples.

b. Refrigerant Pressure and Temperature

   Measurements of refrigerant pressure are done out in the suction and discharge sections of the compressor using pressure transducers. The refrigerant temperatures were measured in the metal outlet point and the compressor inlet using thermocouples.

For the Air Handling Unit (AHU), the measurements were conducted using thermocouples to obtain the AHU coil's inlet and outlet temperature values. The resulting temperature difference in the coil was then compared to the ideal temperature difference of 5°F for chilled-water cooling coil AHU based on the ASHRAE 90.1 standard. The pump motor rotation was measured using an infrared tachometer to quantify the performance of the Chilled Water Pump (CHWP). During the analysis, it is assumed that the pump efficiency is directly proportional to pump rotation, and hence, the higher the motor rotation, the higher the pump efficiency.

## 3 RESULTS AND DISCUSSION

### 3.1 Energy Consumption Calculation

Based on the initial survey, the electrical energy at Wisma Slipi was mainly used for lighting, elevator operations, computer, and air conditioning. The energy demand of the building, represented by Energy Consumption Intensity (ECI), can be determined from the historical data on building electricity consumption and total building area. The energy audit survey found that the total electricity consumption for Wisma Slipi in the previous year is 4,746,830 kWh, and the total area of the building is 20,700 m². Using equation (1) and (2), the annual and monthly ECI can be calculated as follow:

$ECI_{annual}$ = 4,746,830 kWh / 20,700 m² = 229.32

$ECI_{monthly}$ = 229.32 : 12 = 19.11

It can be seen that the value of the monthly ECI is 19.11 for the Wisma Slipi building. This value is above the standard ECI of 18.5. Based on the current government standard [10], the electricity consumption of Wisma Slipi can be classified as wasteful.

### 3.2 Chillers

Table 1 summarizes the pressure and temperature measurements in the suction and discharge pipes of the chillers. COP of each Chiller was then calculated based on the enthalpy obtained from the measured temperature and pressure. It can be observed that the range of the COP of the existing Air Cooled

York Chiller with reciprocating compressors in Wisma Slipi was between 2.5 and 3.3. For comparison, the new air-cooled Chiller with screw compressors can produce COP between 3.3 and 3.5. This finding indicated that some of the existing chillers no longer operated in optimal condition even though they are regularly maintained.

The decrease in the COP can be explained by the on-site inspection. During the field observation, it was found that the unit B chillers in both the AS 4 and AS 7 zone suffered a malfunction in one of their condensers. In order to operate optimally, each Chiller should be operated with both condensers running. Both chillers were kept running in since two chillers were needed in each zone to ensure comfortable indoor conditions for building occupants.

Table 1. Measurement Data and COP of Chillers

| **Zone** | **AS 4** | | **AS 4** | |
|---|---|---|---|---|
| **Unit** | A | | B | |
| **Compressor No.** | 1 | 2 | 1 (damage) | 2 |
| **$P_{suct}$ (kPa)** | 324,0 | 379,2 | - | 358.5 |
| **$P_{Disc}$ (kPa)** | 1965,0 | 1916,7 | - | 2033.9 |
| **$T_{suct}$ (°C)** | 19.0 | 18.0 | - | 19.0 |
| **$T_{Disc}$ (°C)** | 113.0 | 101.0 | - | 109.0 |
| **COP** | 3 | 3.3 | - | 2.9 |
| | | | | |
| **Zone** | **AS 7** | | **AS 7** | |
| **Unit** | A | | B | |
| **Compressor No.** | 1 | 2 | 1 (damage) | 2 |
| **$P_{suct}$ (kPa)** | 330.9 | 337.8 | - | 420.6 |
| **$P_{Disc}$ (kPa)** | 1999.5 | 1985.7 | - | 1792.6 |
| **$T_{suct}$ (°C)** | 20.0 | 20.0 | - | 20.0 |
| **$T_{Disc}$ (°C)** | 112.0 | 114.0 | - | 125.0 |
| **COP** | 3.1 | 2.8 | - | 2.5 |

In addition, the condenser in all chillers also displayed a sign of deterioration and the presence of rust due to exposure to outdoor weather. The build-up of rust affected the heat dissipation capabilities of the condenser since the heat could not be released entirely into the surrounding, which in turn increased the refrigerant pressure. This may result in the decrease of the Chiller's COP value, which caused an increase in the energy demand of the compressor.

Lastly, the current Chiller still uses refrigerant R22, which is banned in most countries because it depletes the ozone layer. Thus, the audit energy recommended the building management to replace the existing chillers with Air-Cooled Chillers equipped with Screw Compressors that have higher efficiency and uses environmentally friendly refrigerants R134a.

### 3.3 Air Handling Unit and Chiller Water Pump

The measurements of inlet and outlet temperatures of the heat exchanger coils were carried out to quantify the performance of existing Air Handling Units. The measurements were performed for all AHU units in each zone. The difference of temperature in the coil outlet and inlet was then calculated for each AHU unit. These temperature differences were compared to the ASHRAE standard in order to assess the AHU performance. Table 2 shows the average and standard error of the AHU coil temperature difference in zone AS 4 and AS 7.

**Table 2.** Average Temperature Difference of AHU

| | **AS 4** | **AS 7** |
|---|---|---|
| **ΔT** | **2.0 ± 0.01 °F** | **2,40 ± 0.13 °F** |

Comparing to the ideal temperature difference in the AHU coil of 10 ºF based on the ASHRAE standard, the measured temperature differences indicated that the AHU no longer operated under optimal conditions. The walk-through audit also noted that there is significant dust deposition on the surface of the AHU coils, which may contribute to the decrease in their performance. It was also recommended to routinely cleaning the surfaces of the coils.

A measurement audit was also performed on the Chilled Water Pump (CHWP). For each zone, there were three units of chiller pumps. The capacity of each pump is rated at around 15 kW. The actual motor rotation speed was measured to evaluate the performance of the pumps. The measurements of the pump motor rotation were done using a Tachometer. The results are summarized in Table 3.

**Table 3.** Chilled Water Pump Motor Rotation

| | **AS 4** | | | **AS 7** | | |
|---|---|---|---|---|---|---|
| | CHWP 1 | CHWP 2 | CHWP 3 | CHWP 1 | CHWP 2 | CHWP 3 |
| RPM | 1460 | 1462 | 1459 | 1460 | 1459 | 1463 |

The pumps produced lower rotation speeds compared to the factory standard of 1490 rpm. This indicates that the pump worked inefficiently and lead to the waste of electricity consumption. The pump also exhibited harsh sound, pointing to a lack of lubrication or wear of the bearings.

## 4 CONCLUSION

In this study, an energy audit of the air conditioning system in the Wisma Slipi office building was completed. The audit yielded the following outcomes:

1. The Index of Consumed Energy (ICE) for the Wisma Slipi building was 19,11, above the established standard of 18,5. This indicated that the building was categorized as inefficient in terms of energy consumption. Hence, it is necessary to introduce a strategy for maximizing building energy usage.
2. The Chiller, which is a critical component of the air conditioning system, needs to be revitalized. The measured Coefficient of Performance (COP) values of the existing chillers were lower than the expected value since all of them are older models with reciprocating compressors.
3. Both the Air Handling Unit (AHU) and Chilled Water Pump also exhibited performance degradation indicated by lower than expected temperature difference in AHU coils and loss in the pump rotational speed.

Based on the above findings, it was recommended to replace the chillers with the new Air-Cooled Chillers, which consumed significantly less electrical power. This will help reduce the cooling energy consumption in Wisma Slipi.

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