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Study on energy efficiency, carbon reduction and human comfort in Universitas Internasional Semen Indonesia

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Abstract. World energy consumption was used in several sectors. One of this was building sector that the electricity consumption, higher than other sectors. So as in Indonesia, electrical consumption in the building was higher than other sectors. Electricity consumption also becomes a huge contributor to greenhouse gasses especially carbon. Electricity consumption in Indonesia was getting higher because of human behavior and electrical tools, so it needed a management audit for controlling this problem. This research was studied energy efficiency and carbon reduction from the scenario in educational building which was Universitas Internasional Semen Indonesia building 1 in campus A. This research used energy audit method which decided by 4 main steps plus one, the audit identification process of temperature and lighting in the room, standard of energy used, energy efficiency scenarios and the calculation of carbon emission. The result showed that electricity consumption in UISI is 10.62 kWh/month which quite an energy efficient, while natural lighting (daylighting) and artificial lighting wasn't fulfilling Indonesian standard (SNI). Five energy efficiency recommendations were created to find the most energy-saving: energy efficient behavior, replenishment rubber on the door, the addition of window film, sleep mode on a computer and replace fluorescent lamps with lower wattage were saved 49% from total energy consumption. From the calculation, we get that by implementing five scenarios, it can reduce carbon emission about 11,037 tons CO_2 / year.

1. Introduction

Many cities in Indonesia are facing some environmental problems, including energy wastage and degradation of air quality. Exposure to air pollution is now an integral part of the life of cities around Indonesia. Worse air quality is especially true in some large cities in Indonesia, which generally do not have meters of air pollution control, so contamination is not detected.

Increases in emissions of greenhouse gases (GHGs) have caused fundamental changes in the ecosystem, with rising global average temperatures in the past few decades (Intergovernmental Panel on Climate Change) [1]. According to IPCC, human activities are considered the primary reason for increases in the concentration of GHGs since the middle of the twentieth century [1]. Carbon dioxide (CO_2) is the main component of GHGs and is generated primarily from burning fossil fuels for energy supply, industry usage, and transportation [1]. According to Indonesia's Energy Outlook, electricity usage in Indonesia is 13% of total energy consumption in 2014 [2]. Electricity demand in Indonesia rose by 6% yearly. Electricity usage is divided into several types of places, one of them is electricity consumption in educational buildings.

Many educational buildings continue to grow rapidly in Gresik, Indonesia. The highest level of education is the university which is also found in Gresik, one of them is Universitas Internasional Semen Indonesia (UISI). UISI has been established from 2013 to the present that already has some buildings as a place of learning. In every UISI building have the supporting equipment such as air conditioner (AC), projector, sound system, lighting, and many more. Each building is used to carry out lecture activities. Every student has access to use the facilities.

The number of UISI buildings continues to increase. In 2017, the number of UISI buildings increased from one to four buildings which used as a lecture room, a canteen building, and a mosque building. Based on research that has been done before, the use of building 1 electricity began to increase at 07.00 - 08.00 which at that time is the start time of lecturing activities and the employees have turned on electronic equipment supporting lecture activities such as lamps, air conditioners, projectors, and other supporting equipment. After that, energy consumption begins to stabilize at 09.00 - 18.00 WIB with power used about + 59,000 watts and then energy consumption will decrease at 18.00 - 20.00 due to the end of lecturing activity so that some electronic devices have been turned off [3].

Inefficiency electrical usage caused by internal factors, namely the use by human or from external that is less effective performance of electronic equipment that is currently being used. This causes negative impacts such as waste of electricity energy consumption which is directly proportional to the waste of costs. Besides, Inefficiency electrical usage can increase greenhouse gases especially carbon emissions. Because the use of electronic equipment with electrical power also plays a role in emitting greenhouse gases [4]. As a result, the excessive CO_2 could cause global warming that may disrupt the climate and also the lives of living beings.

CO_2 emission levels resulting from academic and non academic activities at UISI can be valuable information for all UISI academic community and citizens. Based on the source, emissions are divided into two, namely primary and secondary. Primary emission sources include burning fossil fuels transport and human respiration. While secondary sources of emissions include electricity usage and septic tank activities in UISI. After determining CO_2 emissions sources in UISI, the next step is to multiply by emission factor according to IPCC provisions in 2006 to obtain the value of existing CO_2 emissions in UISI [5]. Kennedy [6] on his article about Climate-change mitigation said that to reduce the emissions of greenhouse-gas in the short term, and catalyse longer-term cuts, a country must reduce the carbon intensity of electricity generation to below the universal target of 600 ton CO_{2e} GWH by 2020 [6]. However, the human comfort such as thermal and light are boundary to reduce electrical energy and carbon emission.

Furthermore, implementing energy efficient campus buildings has to be considered because this can partly contribute in addressing global warming. Moreover, universities are the places where young people come every year to study. They can learn about sustainable low carbon activities and designs, and also apply their knowledge after graduation [7].

The objective of this research is to find recommendation design with the highest energy efficient and the lowest carbon emission. The human comfort factor is considered in this study and use as boundary to reduce energy usage. This research using IPCC terms to counting the carbon emission.

2. Methods

This study aims to determine the energy consumption of the building International University Cement Indonesia (UISI) Campus A Building 1 and to be able to recommend the procedure of energy efficiency in building UISI so it can reduce the carbon emission.

The secondary data:

a. Data on electricity consumption of building 1 UISI.
b. Standard lighting data on the room (Lux).
c. Data calculation rate of heat transfer in each room.
d. Emission factor from electricity usage

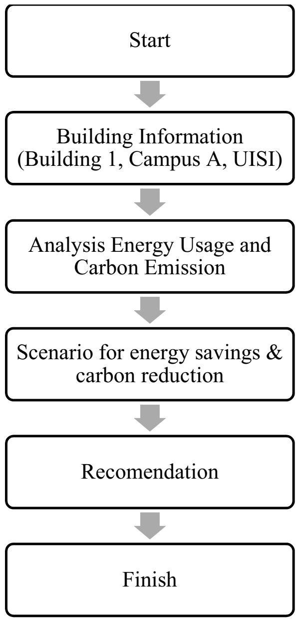

Figure 1. Research stage

The primary data collected as follow:

Table 1. The primary data.

Step	Data
Analysis of Electricity Energy Consumption and carbon emission	• Data of electricity consumption of building 1 for 1 year • Equipment type in every room • Electricity needs of each equipment in every building room 1 UISI • The use of electricity on every equipment in the room (actual) • 1 month electricity consumption of building (from the electricity meter)
Temperature and Exposure Audit Identification Process	• Calculate the lighting in each building room 1 UISI • Calculate the temperature in each building room 1 UISI • Calculation of COP
Baseline of Energy Usage in UISI	• Looking at actual electrical energy consumption data by EUI standards • View actual lighting data with SNI standard • View actual temperature data with human comfort standards
Scenario for energy savings	• Energy efficiency recommendation data collection

2.1. Energy audit

Energy Audit is a technique that is used to calculate the amount of energy consumption in buildings and identify ways to savings [8]. The method used in this study using observation and measurement methods where the data obtained from the primary data and secondary data. The results of measurements taken based on the consideration of the effectiveness and efficiency of the equipment can be seen in more detail in the next explanation. According to the detailed energy audit methodology, there is no time influence when conducting an audit but there is a required standard of data must be for one year before conducting an audit.

Energy audit calculations are divided into three stages. The first is the calculation of electrical energy consumption which will be compared with the Energy Use Intensity (EUI) standard. Then calculate the actual lighting in each room of building 1 UISI and the last is to calculate the actual temperature in each building room 1 UISI using Cooling Load Temperature Difference (CLTD) method. Equation for EUI is:

$$EUI\left(\frac{kWh}{m^2 year}\right) = \frac{Yearly\ Energy\ Use\ (kWh/year)}{area(m^2)} \quad (1)$$

The baseline for Energy Use Intensity [13] shows in Table 1.

Table 2. The baseline for energy use intensity.

Air Conditioning Building	
Baseline	kWh/m^2.year
Very efficient	< 8.5
Efficient	8.5 – 14
Quite Efficient	14 – 18.5
Inefficient	> 18.5

Cooling load (heat transfer rate) can be defined as the amount of heat that must be removed from the room to maintain the air condition of the room under certain conditions. The instantaneous heat transfer rate is not the same as the instantaneous heat load, due to the heat absorbed by the surface of the material surrounding the room (walls, floors, ceilings), and equipment in the room [9]. After a while, the material temperature is higher than room temperature.

There are several factors that are taken into account in determining the value of the heat transfer rate in an air-conditioner. Broadly speaking, the calculation of the rate of heat transfer is classified into two, namely the external load and the internal sacrifice. External load is the burden of incoming heat from outside the room into the room while the internal load is the heat load that comes from within the room itself. The external load consists of: transmission load through outer wall, roof and glass, solar radiation load through glass, infiltration load, ventilation load, while internal load consists of: partition load, lighting load, occupant load, equipment load.

The cooling load generated by the glass has two components:

$$Q_{conductive} = U * A * CLTD_{glass}$$
$$Q_{radiation} = A * SF * SHGC \quad (2)$$

Which:

$Q_{condustive}$, Q_{solar} : The rate of heat transfer caused by the glass (Watt)
U : Transition Coefficient from glass (W/m^2. K) → 1/Rt
A : Glass area (m^2)
CLTD : *Cooling Load Temperature Difference* (K)
SF : *Solar Factors* (W/m^2)
SHGC : *Solar Heat Gain Coefficient*

2.2. Carbon emission

EPA mentioned that the electricity sector involves the generation, transmission, and distribution of electricity. Carbon dioxide (CO_2) makes up the vast majority of greenhouse gas emissions from the sector, but smaller amounts of methane (CH_4) and nitrous oxide (N_2O) are also emitted. Electricity production generates the second largest share of greenhouse gas emissions.

Conservation of energy and hence reductions in emissions, requires the changes in energy consumption behavior and implementation of low-carbon economic development. This necessitates the optimization of energy consumption structure, improvement of endues energy efficiency and reduction of carbon emission intensity [10].

Basically a way to calculate greenhouse gas emissions using the following formula:

$$\text{GHG Emission} = \sum_i \boldsymbol{Ai\ x\ EFi} \qquad (3)$$

Ai is the consumption of the type or number of products. EFi is emission factor [11]. According to Pratiwi, ways to calculate CO2 emissions from electricity usage are as follows [12]:

$$Carbon\ Emission\ From\ Electricity\ Usage\ = P\ x\ EF \qquad (4)$$

Where, P is power consumption (kWh) and EF is the emission factor. The emission factor used here is 0.741 ton CO2/MWh [12].

3. Results and discussion

3.1. Electricity consumption

UISI's electric energy consumption from January 2016 to January 2017 is relatively stable. The decline in electricity consumption in July, August due to the month is the period of the semester holiday. After the semester breaks are September, October, and January the electricity consumption is relatively stable with a range of 25 - 30 kWh / m^2/month.

In this experiment, two units were focused to define the relationship between performance efficiency of power plant and inspection time, i.e. unit A and B. From the calculation results, the average value of EUI is 14.75 in the criteria is quite efficient.

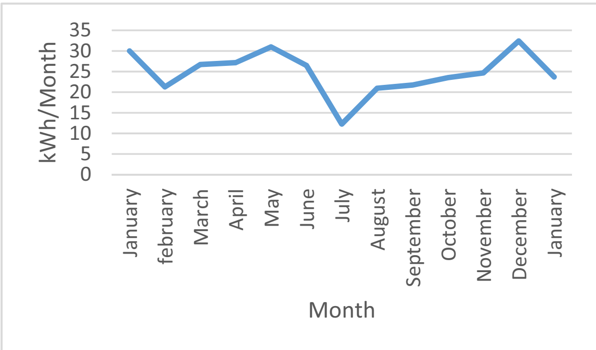

Figure 2. UISI’s electric energy consumption from January 2016 to January 2017

The results obtained from the analysis of electrical energy consumption based on equipment shows that the largest consumption of electrical energy is AC power consumption with percentage of 76%, then the second largest is the consumption of electronic equipment 17% and 7% consumption of lighting energy consumption.

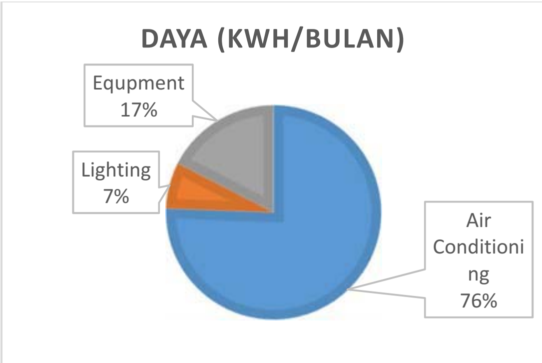

Figure 3. Electrical Energy Consumption Based On Equipment

3.2. Human Comfort

From the data obtained, it can be concluded that when the artificial data collection there is no room that is in accordance with the standard of SNI is 250 lux. The 250 lux standard is an artificial lighting standard based on room function. The room that has the largest lux is on the "PASIR BESI" room is 106.5. This can be caused by several factors, including because the lamp used is still using neon lights or the number of lights that are not in accordance with the purposes of lighting in the room.

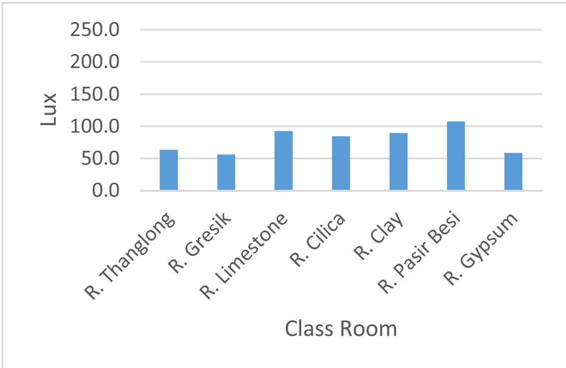

Figure 4. Artificial Lighting

Daylight measurement results show only 1 of 21 rooms that meet the standards, it is women's bathroom. This can be caused by the window glass in every room of the building 1 UISI wearing a film glass is quite dark and so the sun shine cannot get into the room freely and also because of the position of the building facing northwest so it does not get maximum sun exposure. Need to be informed also that the room in the building does not require sunlight either because it can increase the cooling load in the room or if only use the sunlight from the window then the light will not light the room evenly unless the room has a window on each side.

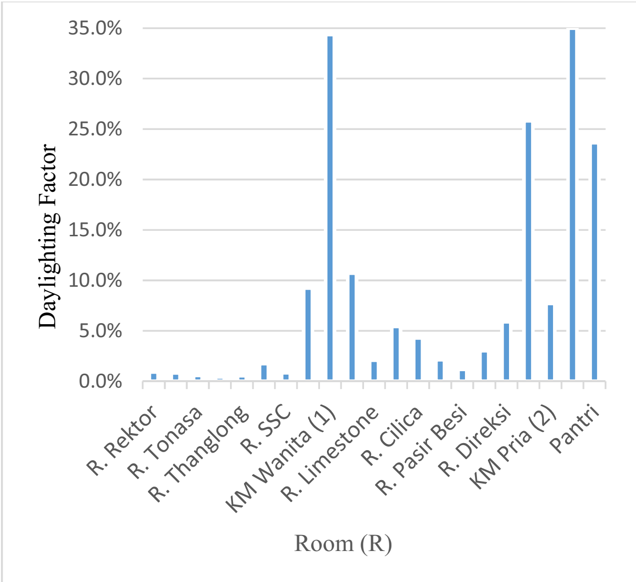

Figure 5. Daylighting

At this stage, a heat transfer rate calculation (Q Total) is calculated by summing up all predetermined heat transfer rates. The sum of the heat transfer rates in each section of the "PASIR BESI" will be compared with the rate of heat transfer of the iron room air conditioning chamber in order to know whether the value of AC heat transfer rate has satisfied the temperature requirement in the room or not. Likewise with another room will also be calculated value of heat transfer rate and compared with AC heat transfer rate.

The total value of heat transfer calculation shows that the value of the total heat transfer rate of "PASIR BESI" room is 4027.64 Watt with the largest heat transfer rate i.e. the heat transfer rate of the human factor.

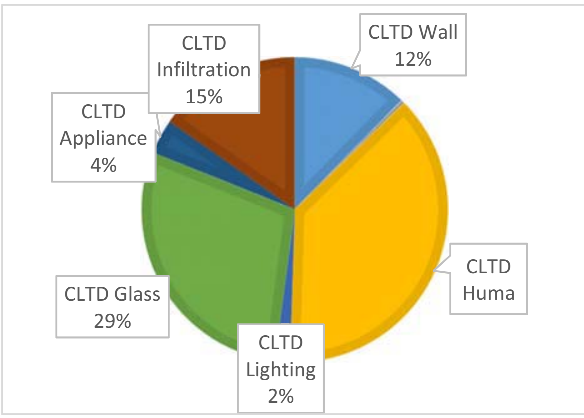

Figure 6. CLTD

3.3. Emission from Electricity Usage

Carbon emission from electricity usage is calculated using the terms of IPCC. Since it use the first TIER so the emission factor used is the default one.

$$\text{Carbon emission from electricity usage} = P \times EF \tag{5}$$

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Where, P is power consumption (*kWh*) and EF is the emission factor. The emission factor used here is 0.741 ton CO_2/MWh. From the calculation, we get that the higher the electrical consumption the higher emission.

Based on the calculation using the equation, then we get the trend in Figure 6. The emission value will increase along with the increase of electric energy consumption. The highest emission value occurred in December 2016 because the highest electric energy consumption is also happened in December.

Electricity is essential for buildings and all aspects of daily life. Including academic activity. But it has to be generated from a primary energy source, such as coal, natural gas, the sun, wind or water. The methods used to produce electricity also make it the main source of global CO_2 emissions. Fossil fuel power plants burn carbon fuels such coal, oil or gas to generate steam that drives large turbines that produce electricity. These plants can generate electricity reliably over long periods of time. However, by burning carbon fuels they produce large amounts of carbon dioxide, which has very high effect on our environment such as causes climate change.

Although carbon emissions from electrical energy are secondary sources, they still need special attention. There must still be an emission reduction effort from this source. Thus will improve the quality of our environment.

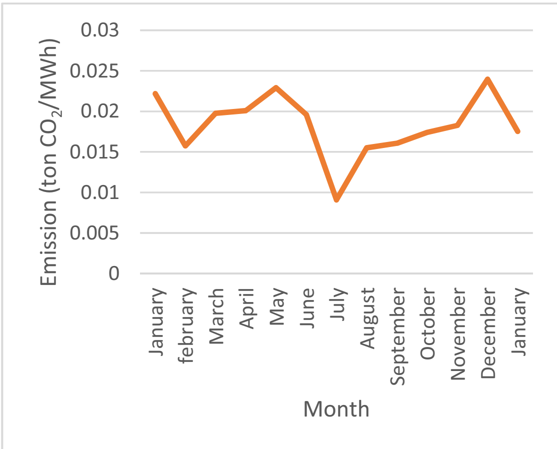

Figure 7. Carbon emission

3.4. Scenario for Energy Savings

These five scenario are the best saving scenario after the calculation.

Table 3. Saving Scenario

Scenario	Saving (Kwh/year)
Changing to energy efficient behavior	122,486.7
Minimize infiltration	19,952.5
Add glass film	6,439.08
Put computer in sleep mode	114.12
Change to LED lamp	153.6
Total	149,145.984

3.5. Calculation of Carbon Reduction

After the use of electric power is obtained, the amount of CO_2 emissions (EE) is calculated by multiplying the use of electricity by emission factor (EF), ie 0.741 tons CO_2 / MWh in accordance with the Letter of Ministry of Energy and Mineral Resources No. 1281/05 / 600.4 / 2012.

Table 4. Carbon Produced After Schenario

Scenario	Saving (Kwh/year)	Carbon produced (tons CO_2 / year)
Changing to energy efficient behaviour	122,486.7	9.064
Minimize infiltration	19,952.5	1.476
Add glass film	6,439.08	0.476
Put computer in sleep mode	114.12	0.008
Change to LED lamp	153.6	0.011
Total	149,145.984	11.037

These five scenario can reduce carbon emission up to 11.037 tons CO_2 / year.

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