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Energy Audit Role in Building Planning

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Abstract. An energy audit is one way to overcome the excessive use of energy in buildings. The increasing growth of population, economy, and industry will have an impact on energy demand and the formation of greenhouse gas emissions. Indonesian National Standard (SNI) concerning the building has not been implemented optimally due to the socialization process by a government not yet been conducted. An energy audit of buildings has been carried out at offices and public services. Most electrical energy in buildings used for air refresher equipment or air conditioning. Calculation of OTTV has demonstrated the importance of performing since the beginning of the planning of a building to get energy-efficient buildings.

INTRODUCTION

The increasing number of buildings associated with the growth and economic development in the city of Palembang resulted in increased energy demand. The current national energy is limited because the main sources of fossil fuel energy such as oil, gas, and coal are increasingly used. On the other hand, the greenhouse gas emissions are increasing, resulting in increased global warming and climate change impacts [1].

Green building is a predicate given to a building that is energy efficient and meets several other criteria. The concept of green building can be applied to new buildings or old buildings (already standing). The building to be built must follow certain criteria to get the green building certificate, while the old building, must be able to make efficiency in the use of energy and to increase the other parameters to get the green building certificate [2].

One of the most effective efforts to overcome the limited supply of energy and greenhouse gases is to create a national energy policy on energy conservation. Energy conservation measures include, among others, through energy audits and the implementation of the results. Energy conservation opportunities in Indonesia are enormous. From the distribution of energy use in a building can be seen that the biggest energy consumption component is the air system. The goal of energy saving in buildings is aimed at the optimization of the air system and the lighting system. The efficiency of the air system can be done by minimizing the cooling load as well as the proper system selection and control of the air system.

The cooling load of a conditioned building consists of internal and external loads. The inner load is the cooling load generated by lamps, occupants and other equipment that generate heat, while the external load is the heat that enters the building due to solar radiation and conduction through the building envelope. The building envelope and roof planes are important building elements to be taken into account in energy use. To limit external loads, the Indonesian National Standardization Agency determines the criteria for the design of building envelopes expressed in the Overall Thermal Transfer Value (OTTV).

Apart from the use of opaque walls and fenestration, areas covered by plants can be utilized for saving cooling loads within a building [3]. Some researchers [4] have been researching Phase Change Materials or PCM for floor, roof and building walls. The results show that energy savings when using the program especially for moderate temperatures outside the building. Other researchers [5] have investigated generalized expressions for surface-averaged forced CHTC at building facades and roofs. These expressions are derived from CFD simulations of wind

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flow and forced convective heat transfer for 81 different isolated buildings. Furthermore, some researchers [6] have studied the comparison of the performance of conventional buildings and buildings with lightweight structures. It has been investigated the orientation and location of buildings without using PCM. The results obtained are that the greatest cooling energy savings are achieved when PCM is arranged on the ceiling and not on the external or internal wall.

Other researchers [7] have studied a relationship to predict values of Overall Thermal Transfer Value (OTTV) of the building at the different time in one day.

LITERATURE REVIEW

Definition and Purpose of Green Building

Green building is a way to reduce the adverse impact of excessive energy use for human health and the environment, through the determination of the location, design, construction, maintenance, operation, complete with the life cycle of the building. This concept is expanded with due regard to aspects of economy, utility, endurance, and comfort.

Generally, the percentage of energy use in the housing sector consists of 46% room warmers and 9% cooling. While in commercial buildings consisting of heating and cooling respectively reached 32% and 16%. For that, it has developed various technologies to complement and support the concept of green buildings. The role of various sciences is needed in the planning of buildings, not only from the point of view of architecture and the building alone but also related to the mechanical and electrical equipment used in a building.

Green Building Rating System

Green Building Rating System is a system to build a building as "Green Building" which further aims to get the certification of the building. The certifying parties in the world include:

- Building and Construction Authority (BCA) which is a green building association based in Singapore. The assessment points are in the BCA Green Mark For Non-Residual Building which consists of 5 main components: energy efficiency, water efficiency, environmental protection, indoor environmental, and other green features.
- BREEAM (Building Research Establishment Environmental Assessment Method), BREEAM comes from the UK and consists of 9 categories, those are management, energy use, health and welfare, pollution, transportation, land use, ecology, materials, and water.
- LEED (Leadership in Energy and Environmental Design). The LEED program of the United States Green Building Council is a rating system for buildings that assesses energy and environmental performance. LEED consists of six categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation in design.
- Star is a voluntary environmental rating system for buildings in Australia that is divided into nine categories: management, indoor environmental quality, energy, transportation, water, materials, land use and ecology, emissions, and innovation.
- GREENSHIP rotating system is an Indonesian rating tool used in the building industry by employers, engineers, and other stakeholders to implement best practices and achieve measurable standards that can be understood by the general public, especially tenants and building users. GREENSHIP review standards cover areas of planning, construction, operations, and daily maintenance.

According to [8], the building assessment criteria are grouped as follows:

- Appropriate Site Development (ASD).
- Energy Efficiency and Conservation (EEC).
- Water Conservotion (WAC).
- Materials Resources and Cycling (MRC).
- Indoor air Health and Comfort (IHC).
- Building and Environment Management (BEM).

Energy Audit

The use of energy audits in the process of evaluating energy utilization and identifying energy saving opportunities as well as recommendations on improving efficiency in users of energy sources and energy users in the context of energy conservation. The purpose of this energy audit is to examine how energy use is taking place at a facility and look for other alternatives to reduce energy use costs and can then be used to submit to certification programs such as green building certification or the like.

Energy Conservation

Energy conservation is an effort to efficiently use energy for a need for the waste of energy to be avoided. Conservation of energy here means preserving/saving the use of electrical energy derived from non-renewable energy sources, such as fossil energy (petroleum, coal and natural gas). Conservation of energy is one step that can be done to save the use of fossil resources are depleted increasingly.

Energy Conservation

OTTV is a value designated as a design criterion for the outer walls and glass of a conditioned building. OTTV for each outer wall area oriented to East, West, North, and South is calculated based on SNI 03-6389-2000, that is:

$$OTTV = \alpha[(Uw \times (1\text{-}WWR)] \times TDEk + (SC \times WWR \times SF) + (U_f \times WWR \times \Delta T) \quad (1)$$

Where:
OTTV = overall thermal transfer value on the outer wall having a certain orientation (W/m^2)
α = absorbance of solar radiation.
Uw = not translucent wall thermal transmittance (W/m^2.K)
WWR = the ratio of the window area to the overall area of the outer wall in a particular orientation
TDEk = the equivalent temperature difference (K)
SF = solar factor (W/m^2)
SC = shading coefficient
Ur = thermal transmittance of phenestration (W/m^2.K)
ΔT = designed temperature difference between outside and inside building (taken 5 K)

The total OTTV from the outer wall is the overall calculation of OTTV oriented to West, East, North, and South using the following equation:

$$OTTV_{total} = \frac{(A_{01}xOTTV_1)+(A_{02}xOTTV_2)+\cdots+(A_{0i}xOTTV_i)}{A_{01}+A_{02}+A_{0i}} \quad (2)$$

Where:
$OTTV_{total}$ = the overall calculation of OTTV oriented to West, East, North and South
A_{oi} = the area of the outer wall including all the surface of the wall and the surface area of the window that is located on the wall (m^2)
A_{01} = the area of the outer wall-1 including all the surface of the wall and the surface area of the window that is located on the wall-1 (m^2)
A_{02} = the area of the outer wall-2 including all the surface of the wall and the surface area of the window that is located on the wall-2 (m^2)

Cooling Load Calculation

The cooling load is the amount of heat energy that would need to be removed from a space (cooling) to maintain the temperature in an acceptable range. The heating and cooling loads, or "thermal loads", take into account the dwelling's construction and insulation, including floors, walls, ceilings, and roofs.

The cooling load is the total amount of heat energy that must be eliminated in units of time from the desired space. Cooling loads are calculated using the ASHRAE Fundamentals Handbook standard [9].

Cooling loads are divided into external and internal loads. Main external loads include cooling loads through walls, glass windows, roof, ceiling and floor and solar radiation cooling loads through the glass. While the inner cooling load consists of cooling loads of electrical devices, lamps, occupants, ventilation, and infiltration.

The cooling load through the wall can be determined by the following equation:

$$Q_{wall} = U_w x A_w x CLTD_{wall} \tag{3}$$

Where:

Q_{wall} = cooling load through the wall (W)
U_w = not translucent wall thermal transmittance (W/m^2.K)
A_w = total wall area (m^2)
$CLTD_{wall}$ = cooling load temperature difference (K)
= CLTD + (298.5 - t_r) + (t_m – 302.4)
t_r = room temperature (K)
t_m = T_{max}- (daily range)/2

The cooling load through the glass window can be determined by the following equation:

$$Q_{glass} = U_g \text{ x } A_g \text{ x } CLTD_{glass} \tag{4}$$

Where:

Q_{glass} = thecooling load through the glass window (W)
U_g = thermal transmittance of glass window (W/m^2.K)
A_g = total glass window area (m^2)
$CLTD_{glass}$ = the cooling load temperature difference of glass window (K)

The cooling load through the roof can be determined by the following equation:

$$Q_{roof} = U_r \text{ x } A_r \text{ x } CLTD_{roof} \tag{5}$$

Where:

Q_{roof} = the cooling load through the roof (W)
U_r = thermal transmittance of roof (W/m^2.K)
A_r = total roof area (m^2)
$CLTD_{roof}$ = the cooling load temperature difference of roof (K)

The cooling load through the ceiling and floor can be determined by the following equation:

$$Q_{CF} = U_{CF} \text{ x } A_{CF} \text{ x } CLTD_{CF} \tag{6}$$

Where:

Q_{CF} = cooling load through the ceiling and floor (W)
U_{CF} = thermal transmittance of ceiling and floor (W/m^2.K)
A_{CF} = total ceiling and floor area (m^2).
$CLTD_{CF}$ = cooling load temperature difference of ceilings and floors (K).

The solar radiation cooling load through glass can be determined by the following equation:

$$Q_{SR} = A \text{ x } SC \text{ x } SF \tag{7}$$

Where:

Q_{SR} = solar radiation cooling load through glass (W)
A = glass surface area (m^2)
SC = shading coefficient of glass

SF = solar factor (W/m^2)

The electrical device cooling load of inner load can be determined as follows:

$$Q_{ED} = Input \times CLF_{ED} \tag{8}$$

Where:
Q_{ED} = the electrical device cooling load (W)
Input = the power of electrical device (W)
CLF_{ED} = the electrical device cooling load factor

The lamp cooling load can be determined as follows:

$$Q_{Lamp} = 3.412 \times Input \times F_u \times F_{sa} \times CLF_{Lamp} \tag{9}$$

Where:
Q_{Lamp} = the lamp cooling load (W)
Input = the power of lamp (W)
F_u = on/off ratio
F_{sa} = 1.2
CLF_{Lamp} = lamp cooling load factor

The occupant cooling load can be determined as follows:

$$Q_o = (n \times Q_s \times CLF_O) + (n \times Q_l) \tag{10}$$

Where:
Q_o = the occupant cooling load (W)
n = the number of occupants
Q_s = the sensible heat (W)
CLF_O = the occupant cooling load factor
Q_l = the latent heat (W)

The ventilation and infiltration cooling load can be determined as follows:

$$Q_{v\&i} = (1.23 \times V_f (t_o - t_i)) + (3010 \times V_f (W_o - W_i)) \tag{11}$$

Where:
$Q_{v\&i}$ = ventilation and infiltration cooling load (W)
V_f = ACH x V_{room} x (1000/3600) (l/s)
ACH = 0.48 (for summer area)
V_{room} = room volume (m^3)
t_o = dry bulb temperature (°C)
t_i = wet bulb temperature (°C)
w_o = moisture content kg/kg dry air at t_i and t_o
w_i = moisture content at t_i and relative humidity of 46%.

RESULTS AND DISCUSSIONS

Field Survey Results

The following data from the survey results of Faculty of Engineering Building Sriwijaya University in Palembang:

TABLE 1. Values of OTTV buildings at Engineering Faculty of Sriwijaya University Palembang

Name of Building	OTTV (W/m^2) $OTTV_{wall}$ N	S	W	E	OTTV (Building)
A	20.72	27.24	44.89	44.17	39.81
B	23.16	22.14	47.63	38.40	38.39
C	21.75	22.78	34.28	33.38	25.64
D	35.20	37.57	19.99	21.96	32.88
E	23.56	23.77	30.64	24.43	25.31
F	31.34	26.79	19.38	17.84	26.96
G	19.30	19.30	34.63	23.29	27.43
GBA	31.74	28.94	59.83	32.14	35.46
Mosque	23.60	23.60	23.60	25.43	23.97
I	28.36	33.43	35.29	22.97	27.33

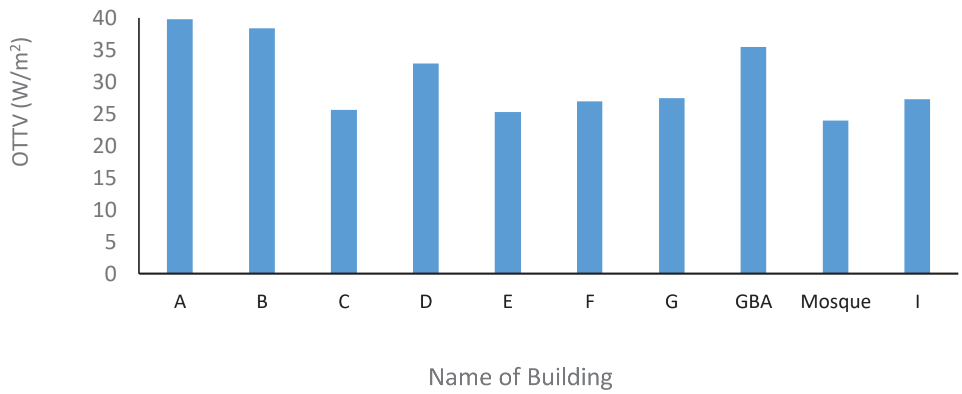

FIGURE 1. OTTV for each building

It appears that OTTV for each building is still below the recommended value of SNI03-6389-2000, which is 45 W/m^2. The smallest value of OTTV is found in Mushola buildings because the orientation of North, South and West Mosque buildings does not have glass but uses iron wire. The largest OTTV total value is in building A because in that building there is a large glass and wall area ratio on the West and East side of the building. The large ratio of glass and wall will affect the indoor thermal conditions because of the influence of sunlight that directly penetrates the translucent glass wall. In Building-I which is the object of this study, the values of OTTV total and RTTV obtained are still below the Indonesian standard [10] those are 27.33 W/m^2 and 8 W/m^2, respectively.

Building Cooling Load

The cooling load is the total amount of heat energy that must be eliminated in units of time from the desired space. The following is the calculation of the cooling load of a building I (chosen the largest area and activity).

TABLE 2. Values of cooling load

Cooling Load	Value (Watt)
Total external load	70002
Wall	18002
Glass window	1071
Solar radiation	12411
Ceiling	16095
Floor	22593
Total internal load	24464
Electrical devices	6000
Lamp	2274
Occupants	5500
Ventilation and infiltration	8851

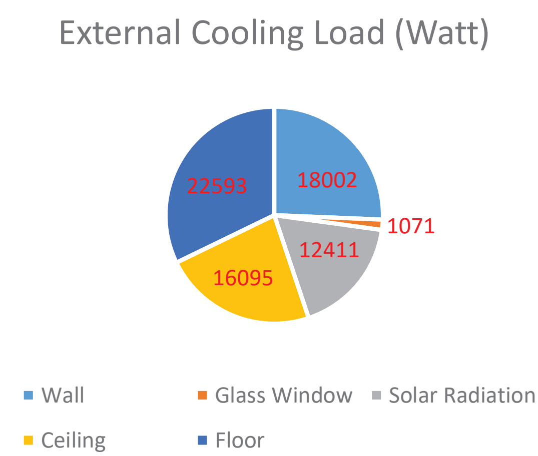

FIGURE 2. Distribution of external cooling loads

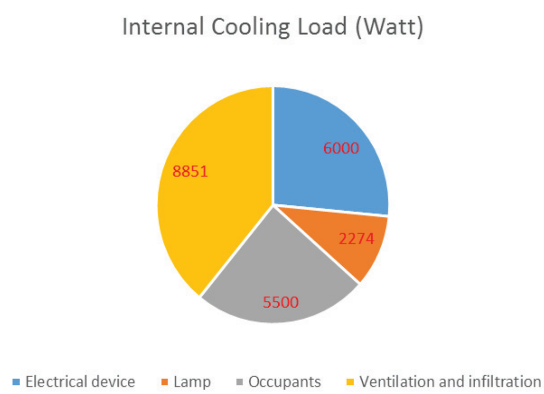

FIGURE 3. Distribution of internal cooling loads

CONCLUSIONS

The heating load in a room varies with time. The current cooling load increase is influenced by the previous cooling load. The main factors affecting the cooling load are solar radiation received and human activity as well as electrical equipment.

From the calculation results show that the value of OTTV total is for all buildings in the Faculty of Engineering, Sriwijaya University, Palembang does not exceed the recommended OTTV standard in Indonesia that is <45 W/m^2. In this study, building-I has an OTTV value of 27.33 W/m^2 while the RTTV value is 8 W/m^2, both of which meet the recommended standard.

The OTTV value is greater than the RTTV value. The cause is the area of the building envelope (880 m^2) larger than the roof area (684 m^2). Because the larger the building envelope the greater the value of heat transfer from the outer wall into the room consequently the resulting OTTV value will be greater.

The cooling loads calculated from heat recovery due to internal heat load (lamp, human, electrical appliances, ventilation, and infiltration) are 24,464.1Watt and external heat load (wall, glass, roof, sky).

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