Energy efficiency evaluation of hospital building office

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Abstract. One of the strategy employed in building design is reducing energy consumption while maintaining the best comfort zone in building indoor climate. The first step to improve office buildings energy performance by evaluating its existing energy usage using energy consumption intensity (Intensitas Konsumsi Energi, IKE) index. Energy evaluation of office building for hospital dr. Sayidiman at Kabupaten Magetan has been carried out in the initial investigation. The office building is operated with active cooling (air conditioning, AC) and use limited daylighting which consumes 14.61 kWh/m²/month. This IKE value is attributed into a slightly inefficient category. Further investigation was carried out by modeling and simulating thermal energy load and room lighting in every building zone using of Ecotect from Autodesk. Three scenarios of building energy and lighting retrofit have been performed simulating representing energy efficiency using cross ventilation, room openings, and passive cooling. The results of the numerical simulation indicate that the third scenario by employing additional windows, reflector media and skylight exhibit the best result and in accordance with SNI 03-6575-2001 lighting standard. Total thermal load of the existing building which includes fabric gains, indirect solar gains, direct solar gains, ventilation fans, internal gains, inter-zonal gains and cooling load were 162,145.40 kWh. Based on the three scenarios, the thermal load value (kWh) obtained was lowest achieved scenario 2 with the thermal value of 117,539.08 kWh. The final results are interpreted from the total energy emissions evaluated using the Ecotect software, the heating and cooling demand value and specific design of the windows are important factors to determine the energy efficiency of the buildings.

1. Introduction

The global contribution from buildings towards energy consumption, both residential and commercial, has steadily increased, reaching figures of 20% to 40% in developed countries [1,2]. Office buildings are types of commercial buildings with large amounts of energy consumption. Energy saving has always been one of the ultimate objectives for efficient building design is that be able in sustainable development. One of the strategies employed in building design, reducing energy consumption while maintaining the best comfort zone in building indoor climate. In tropical countries such as Indonesia, the major energy consumption in buildings is for air-conditioning and lighting which should be properly managed to avoid high cost. Lighting consumption depends on the purpose of the building, the use of daylight, illumination levels for certain areas and the hours of usage. A well-designed lighting system in buildings would not only significantly reduce long-term energy utilization, but it would also reduce long terms cost.

The study of lighting performance in the building tends to concentrate on aspects relating to energy consumption and involves building design including that of fenestrations and lighting level, whether daylighting and artificial lighting [3].
In this study, the object of research is a hospital building office at Kabupaten Magetan it is required that 30% of working floor area has natural light with 300 lux [8]. Based on preliminary observations, the existing of natural conditions in the space of building visible dark in the north and west sides of the building, but in the south side its visible over bright. This research is intended to develop an accurate computer model of office buildings in dr. Sayidiman Hospital at Kabupaten Magetan about daylight and thermal (a) to ensure that the model is accessible and adaptable for future users, (b) to investigate the lighting and thermal performance within the office model using simulation models, (c) to concentrate on the energy saving through daylighting and thermal control.

2. Methodology

The study of daylighting and thermal performance of buildings can be achieved by experimental measurements and computer modeling. As the experimental measurements are costly and time-consuming, computer modeling has recently attracted great attention for their simplicity and reliability. Computational simulation is the best method for this study because it can predict the lighting and thermal performance in a building. Computer-based building energy simulations have proven a useful tool in analyzing lighting and thermal schemes.[4,5].

Magetan city is located in East Java, Indonesia. It is located at 7°38'30” north latitude and 111°25'45” – 111°20'30” east longitude. Typical year weather data of Surabaya city where located in East Java is adopted, which is very close to Magetan. Then relevant data is put into weather tool of Ecotect which could automatically output the analysis results of Magetan climate.

2.1. Energy Consumption Intensity

The energy consumption intensity (Intensitas Konsumsi Energy, IKE) is a term to determine amount of energy use in buildings and has been applied in various countries (ASEAN, APEC), expressed in units of kWh/m²/month [6]. Table 1 presents the standard IKE buildings in Indonesia [7].

| IKE (kWh/m²/month) | Category     |
|--------------------|--------------|
| 4,17 - 7.92        | Extremely efficient |
| 7.92 - 12.08       | Efficient    |
| 12.08 - 14.58      | Slightly efficient |
| 14.58 - 19.17      | Slightly inefficient |
| 19.17 - 23.73      | Inefficient  |
| 23.75 - 37.75      | Extremely inefficient |

The energy consumption intensity in each room can be calculated using the following equation:

\[
IKE = \frac{P_K}{A} \quad (1)
\]

where IKE = energy consumption intensity (kWh/m²/month), \( P_K \) = total electricity consumption (kWh), \( A \) = area (m²). It should be emphasized that as-built drawing in each room of the building should complete. Criteria such as the air-conditioned room or not air-conditioned room and spacious rooms should be evident and accurate. The data type of equipment, the amount of equipment, the power supply of any type of electrical appliances as well as the area for each room also needs to be included in the report energy consumption.

2.2. Lighting

Natural light sources can be categorized into direct (in the form of direct light or diffuse light from the sky) or indirect (reflection light or natural light that has been modified from its main source) [8]. SNI (Indonesian national standard) does not take into account solar intensity, therefore lighting level data were taken as a uniform, which is 10,000 lux. Table 2 shows that standard illumination index to
achieve visual comfort for the occupant in the building. The standard is based on the function and effectiveness of the lighting space [9].

Table 2. Standard illumination (Indonesian national standard, SNI) index

| Type of Building | Rooms          | The recommended illumination values (Lux) |
|------------------|----------------|-------------------------------------------|
| Office           | President room | 350                                       |
|                  | Workspace room | 350                                       |
|                  | Meeting room   | 300                                       |
|                  | Computer room  | 350                                       |
|                  | Active archive | 300                                       |
|                  | Archive room   | 150                                       |

2.3. Thermal

The physical aspects of thermal comfort depends on six main factors which serve as an interrelated system is influenced by psychological factors; (1) ambient air temperature, (2) mean radiant temperature, (3) relative humidity (4) air movement, (5) clothing insulation, (6) metabolic heat rate [10]. The method of cooling load temperature difference is needed to cope with the external heat load caused by the heat entering through conduction (walls, ceilings, glass, partitions, floors), radiation (glass), and convection (ventilation and infiltration). Internal heat load caused by the heat arising persons/occupants, lights and equipment/machinery [11].

To determine the internal heat gains due to electrical appliances within the building, a stastic model based on the load profile or the power density of electrical appliances has been applied in most of building energy simulation tools. These gains are usually used to calculate the heating and cooling energy demand of a building and to design an adequate HVAC system for building.

3. Results and Discussion

3.1. Intensity of Energy Consumption

To calculate the IKE air conditioning in a room, the necessary data collection on the type of air-conditioning installed in the room below its installed power capacity (Watt). Observation and data collection on the building of the electrical appliances shown in Table 3.

Table 3. Type of equipment and power capacity (Watt) on the office building

| Type of Load | Electrical Equipment | Capacity (Watt) | Quantity (Unit) | Total   | Sub Total |
|--------------|----------------------|-----------------|-----------------|---------|-----------|
| 1 Light      | DL PL-C Lamp         | 18              | 53              | 954     | 1,918     |
|              | RM 2xTL5 Lamp        | 28              | 33              | 924     |           |
|              | Baret TL Lamp        | 20              | 2               | 40      |           |
| 2 HVAC       | AC 2,5 PK            | 1,865           | 15              | 27,975  | 47,371    |
|              | AC 2 PK              | 1,492           | 10              | 14,920  |           |
|              | AC 1,5 PK            | 1,119           | 4               | 4,476   |           |
| 3 Others     | Exhaust fan          | 50              | 2               | 100     | 7,685     |
|              | Computer             | 125             | 16              | 2,000   |           |
|              | Laptop               | 20              | 10              | 200     |           |
|              | Printer 1            | 40              | 4               | 160     |           |
|              | Printer 2            | 20              | 9               | 180     |           |
|              | LED TV 32"           | 100             | 2               | 200     |           |
|              | LED TV 29"           | 70              | 8               | 560     |           |
|              | Foto Copy            | 175             | 2               | 350     |           |
|              | Refrigerator         | 200             | 1               | 200     |           |
|              | Telephone            | 20              | 11              | 220     |           |
|              | Finger print         | 10              | 1               | 10      |           |
| Type of Load     | Electrical Equipment | Capacity (Watt) | Quantity (Unit) | Total (Watt) | Sub Total |
|------------------|----------------------|-----------------|-----------------|--------------|-----------|
| Dispenser        | 100                  | 2               | 200             |              |           |
| Water heater     | 300                  | 2               | 600             |              |           |
| Wifi server      | 150                  | 1               | 150             |              |           |
| Camera CCTV      | 120                  | 6               | 720             |              |           |
| Integrated sound | 835                  | 1               | 835             |              |           |
| Water pump       | 1000                 | 1               | 1,000           |              |           |
| **Total**        |                      |                 | **56,974**      |              |           |

It is assumed that the number of hours worked (operational activities) in one day for eight hours, starting from 07.30 am to 15:30 pm and factor load requirements for six working days which is 24 days in a month. The consumption of electric energy per month is 10.939 kWh/day. The total areas of the selected offices were 748.85 m². Thus IKE air-conditioned 14.61 kWh/m²/month. This value when associated with the IKE standards for the air-conditioned room for an office building is included in a slightly inefficient category.

3.2. Energy Simulation

3.2.1. Lighting.

This research was carried out during a sunny day on July 9th, 2016 at 12.00 pm using lux-meter placed 75 cm above the floor at several points assuming the average height of working table when people were sitting in the room. The values obtained were used as the benchmark. In figure 1 shows the location point in the building, respectively.

![Figure 1. Location points](image)

The average of illuminance level is about under 350 lux. Stated that an office should have a design of 350 lux for illuminance level illustrated in Table 4. So, the interior illuminance level in office areas is less than the recommended value, based on the SNI.

a. Lighting Analysis

The results of the simulation using Ecotect programming of natural lighting in the northern and eastern side of the building is the color of blue and purple means look less good lighting quality while on the south side have the quality of lighting the excess is marked in yellow. From the measurement results obtained that natural and artificial lighting in a space not meet its standard of 350 lux for the boardroom, a work room and a computer room, 300 lux to 100 lux and a meeting room for the
corridor. Simulation with Ecotect of the existing condition of the building, given three experiments conducted, the experiment can be seen as in Figure 4.

**Figure 4.** (a) Scenario 1 (b) Scenario 2 (c) Scenario 3

In the first scenario of the existing building is added with the opening of the window on the north side, the blue color is an added window. Scenario 2 Each window openings both existing as well as additional on the north, south, and west in the given additional media self-light reflector is placed at a position above the human eye. In addition to the south side added shading to reduce incoming sunlight, so not too much glare and heat in the room. While in scenario 3 Any opening additional windows either existing or in the north, south, and west, which has been given additional self-light and shading, then added with a skylight in the roof of the building.

b. Simulation Analysis

There are three results of the following simulation have analyzed by Ecotect simulation, Consist of scenario 1, scenario 2, and scenario 3.

**Figure 5.** The results of natural lighting daylight analysis from computation (a) scenario 1 (b) scenario 2 (c) scenario 3

Daylight analysis results as seen in Figure 5 consist of first scenario (a) with the addition of light windows of the north side of the lux level is increasing although not up to the middle of the room, while the south side is still too strong. Second scenario (b) visible in the middle of the room lux level
is increasing because it is assisted by a self-light from windows north and south sides, while on the south side looks lux levels declining as by shading of windows on the south side. The third scenario (c) with an additional four roof sky the center of the room appear brighter than the other scenarios. The comparison data between existing lux levels and three scenario are summarized in Table 4.

Table 4. Lux value of the comparison rooms each scenario without artificial light

| No | Rooms                        | Points | Lux Existing | Lux Sim. 1 | Lux Sim. 2 | Lux Sim. 3 |
|----|------------------------------|--------|--------------|------------|------------|------------|
| 1  | Big meeting room 1           | 1      | 83           | 148        | 195        | 305        |
| 2  | Big meeting room 1           | 2      | 139          | 250        | 275        | 350        |
| 3  | Free Function                | 3      | 174          | 250        | 280        | 300        |
| 4  | General affair room          | 4      | 47           | 255        | 275        | 265        |
| 5  | Officialdom room             | 5      | 53           | 260        | 280        | 265        |
| 6  | Program & planning room      | 6      | 27           | 245        | 265        | 265        |
| 7  | Small meeting room           | 7      | 42           | 250        | 280        | 345        |
| 8  | President room               | 8      | 37           | 245        | 275        | 300        |
| 9  | Corridor 1                   | 9      | 47           | 97         | 250        | 280        |
| 10 | Corridor 2                   | 10     | 91           | 125        | 265        | 275        |
| 11 | Head of administration room  | 11     | 187          | 187        | 257        | 300        |
| 12 | Service room                 | 12     | 243          | 243        | 275        | 310        |
| 13 | Support room                 | 13     | 583          | 583        | 350        | 350        |
| 14 | Finance room                 | 14     | 500          | 500        | 350        | 350        |
| 15 | Head of finance room         | 15     | 600          | 600        | 350        | 350        |

Shown in Table 5 comparison lux levels at any points of space, and the scenario three which has a lux level approaching 03-6575-2001 and SNI standard 6197: 2011. Graph of simulation results also be displayed in Figure 6.

3.2.2. Thermal Simulation

The average annual of thermal reveal that the hottest day is on November 2nd where it reached 37.4°C and the coldest day is on August 3rd where it down to 18.6°C.

Table 5. Comparison result of thermal load and cooling load each scenario
| No | Type of Load       | Scenario 1 (kWh) | Scenario 2 (kWh) | Scenario 3 (kWh) |
|----|-------------------|------------------|------------------|------------------|
| 1  | Fabric gains      | 2,873.77         | 2,773.77         | 2,465.07         | 2,463.81         |
| 2  | Indirect Solar Gains | 638.64           | 600.64           | 538.24           | 537.67           |
| 3  | Direct Solar Gains | 1,026.61         | 1,026.61         | 646.06           | 646.06           |
| 4  | Ventilation Gains | 1,243.29         | 1,243.29         | 1,242.01         | 1,242.01         |
| 5  | Internal Gains    | 1,331.36         | 1,331.36         | 1,332.02         | 1,332.02         |
| 6  | Inter-zonal Gains | 130.73           | 130.73           | 125.27           | 88.38            |
| 7  | Cooling Load      | 154,901.00       | 153,901.00       | 111,190.42       | 112,148.51       |
|    | Total             | 162,145.40       | 161,007.40       | 117,539.08       | 118,458.45       |

Illustrated in Table 5 kWh comparison to the existing level of the building and each scenario, and which has the lowest load total is in scenario two, as expressed in Figure 7 is a graph of each scenario.

![Figure 7](image-url)

**Figure 7.** (a) heating load (b) cooling load

By the meteorological analysis of Ecotect, the design strategies are achieved. Through the simulation analysis and comparison of building natural ventilation. So what have been done is that ecological energy-saving planning will save a lot of time and energy and can create much more pleasant and comfortable space.

4. Conclusion

For the data analysis, dr. Sayidiman Hospital the value of IKE air-conditioned space is at 14.61 kWh/m²/month. This energy consumption intensity (intensitas konsumsi energi, IKE) index value is attributed into a slightly inefficient.

Three scenarios of building energy and lighting retrofit have been performed simulating representing energy efficiency using cross ventilation, room openings, and passive cooling. The results of the numerical simulation indicate that the third scenario by employing additional windows, reflector media, and skylight exhibit the best result and in accordance with SNI 03-6575-2001 lighting standard.

Total thermal load of the existing building which includes fabric gains, indirect solar gains, direct solar gains, ventilation fans, internal gains, inter-zonal gains and cooling load reached 162,145.40
kWh. Based on the three scenarios, the thermal load value (kWh) obtained was lowest achieved scenario 2 with the thermal value of 117,539.08 kWh. The final results are interpreted from the total energy emissions evaluated using the Ecotect software, the heating and cooling demand value and specific design of the windows which are some of the important factors to determine the energy efficiency of the buildings. However, as more accurate results and the shorter time step of simulations are required, the gains have to be modeled in more detail.

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