Building energy efficiency and conservation on air conditioning loads (Case study: residential and building development information center in Makassar)

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Abstract. Environmental problems are a concern of the world today, considering the exploitation of energy sources from natural resources such as coal and oil causing damage to the environment, humans and ecosystems. Sustainable development programs are strategies to meet current human needs without reducing future needs. Reducing energy consumption is one that can be done in various ways to meet sustainable development programs. 50% of energy consumption is dominated by the building sector, while 50% of building energy consumption is charged by air conditioning. Conservation and energy efficiency of the building load is carried out to achieve the target of potential energy savings of 10-30%. This study aims to analyze the air conditioning loads and conservation and efficiency strategies in the building of Information and Settlement Information Center in Makassar with a target of 10-30% energy savings. This method uses thermal balance analysis by calculating heat energy from external, internal and human heat that will be charged by AC (Air Conditioner). The Conservation Strategy by planning microclimate control with vegetation and the use of materials in building envelopes that can reduce heat and efficiency strategies on thermal comfort by raising the maximum temperature from the comfort standard can save energy from 17-19% energy. the burden on the building sector to reduce the total overall energy consumption of 8-9%.

Keywords: Air Conditioning Loads, Building, Conservation, Efficiency, Energy

1. Introduction
Environmental damage caused by human behaviour exploiting its natural resources to improve their economy and welfare. Humans are related by their environment and it produces natural resources, environmental services. Disasters, poverty, diseases caused by environmental degradation. Sustainable Development [1], as a form of human awareness towards the environment by carrying out development to meet current human needs without reducing the needs of future generations. several world conferences on environmental issues [2,3,4,5], were conducted to create a program of environmental stewardship that resulted in 17 (seventeen) Sustainable Development Goals originating from the Paris Summit 2015 including energy efficiency and conservation.

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Energy sources from natural resources by fossil fuels such as oil and coal. Energy consumption has increased from 383 Billion GJ in 1990 to 812 Billion GJ in 2035 [6]. In Indonesia, energy consumption increased to 1.23 billion BOE (Barrels of Oil Equivalent), which increased 9% from the previous year. Indonesia Government targets to reduce 23% energy consumption by 2025 and reach 31% by 2050 [7]. Energy consumption is 50% responsible for the building sector [8,9], and 50% of energy consumption in the building sector is by the air conditioning loads, while Indonesia's potential can be 10-30% to reduce energy consumption in the building sector.

There are many buildings considering by visual and aesthetic aspect instead of efficiency energy and conservation [10]. Building energy efficiency and conservation can be developed by some strategies including planning on building material and environmentally friendly by human behaviour. This research evaluates the amount of energy consumption on Residential and Building Development Information Center (PIP2B Building). The planned building on the report of CV. Karya Prima Consultant (2010), is not considered by the environmental aspect which is the highest amount of energy loads [11]. Energy efficiency and conservation strategies can be used to reach target 10-30% on building loads and decrease environmental impact by energy sources from natural resources.

1.1. Energy Efficiency and Conservation
Environmental issues are based on Ecological and multidisciplinary analysis including economic, geographic, environmental and social [13]. Current environmental degradation is caused by the industrial revolution which increased energy consumption from natural resources [14]. Energy consumption in Indonesia is the highest in the ASEAN countries [15], while more than 50% of energy consumption is consumed by the building sector [16], air conditioning and lighting are the highest energy consumption in the building sector [17,18]. Indonesia's National Master Plan for Energy Conservation plan to save 10-30% of energy consumption by 2025 [6].

1.2. Case Study
Residential and Building Development Information Center (PIP2B) is located on Jl. Batara Bima KM 16 Makassar (figure 1). CV Karya Prima report that the building plan is not considered by energy efficiency and conservation [10]. Many buildings only consider by visual aspect instead of the function of the building. Built the Building was not planned as well as caused high energy consumption [6] and could increase operational cost and exploitation of energy consumption from natural resources which caused environmental degradation.

Figure 1. The Site Plan of the building is located on open area space with rarely surrounding buildings.

The Building Location is in business and industrial area with 1,185.74 m² total area and floor area 727.17 m². the building envelopes is used red brick plaster with shiny white paint, the roof is used zinc with a red wavy pattern, and the clear glass at the windows (figure 2 and table 1).
Figure 2. The building is designed to deal with hot weather and rain that is suitable for Indonesia's tropical climate.

Table 1. The Existing values of absorption and transmittance through the building materials.

| No | Type of Materials                        | Wall Absorption (αw) | Paint Absorption (αw) | Total Absorption (α) | Transmittance (U) |
|----|----------------------------------------|----------------------|-----------------------|----------------------|-------------------|
| 1  | Red Bricks with slightly shiny white paint | 0.89                 | 0.3                   | 0.59                 | 3.24              |
| 2  | Clear Glass, zinc with gypsum           | -                    | -                     | -                    | 4.48              |
| 3  | Zinc roof with a red wavy pattern      | 0.26                 | 0.52                  | 0.39                 | 3.18              |

2. Methods
This method uses thermal balance analysis by calculating the type of air conditioning load, which resulted by solar radiation, material conduction, heat from electronic devices, air changes load in every hour, and human heat loads. Energy efficiency and conservation strategies are used to reduce air conditioning loads. The thermal balances method produces the value of energy consumption that will be matched by air conditioning standard of Ministry of Energy and Mineral Resources (no more than 19.17 kWh/m²/month). The conservation strategy uses some materials for building envelopes (roofs, walls and glass) efficiency strategies considered by human behaviour to save energy consumption according to thermal comfort standards (24-27 °C). Ecotect Software is used to measure the solar radiation axes through buildings, the intensity of radiation, temperature around the building, and the conduction value on the building envelopes (roof, wall, and glass) and these values used as part of the thermal balance method [19,20].

\[ Q = Q_p + Q_d + Q_s + Q_c + Q_v \]  
(1)

\[ Q_p = \sum p.C_p \]  
(2)

\[ Q_d = \sum d.C_d \]  
(3)

\[ Q_p = \text{People heat gain, kW} \]

\[ Q_d = \text{Device heat gain, kW} \]

\[ Q_s = \text{Radiation heat, kW} \]

\[ Q_c = \text{Conduction heat, kW} \]

\[ Q_v = \text{Convection heat, kW} \]

\[ Q = \text{Air Conditioning Loads, kW} \]

\[ Cp = \text{Value of human heat, kW/m}^3 \]

\[ Cd = \text{Value of Heat Electronic Device, kW/m}^3 \]
\[ Q_v = 1300V\Delta T \] (4)

\[ Q_v = \text{convection loads, kW} \quad V = \text{ventilation change, m}^3/\text{s} \]
\[ 1300 = \text{heat of air, J/m}^3\text{˚C} \quad \Delta T = \text{Distinction of temperature, degC} \]

\[ Q_s = AgI\Theta \] (5)

\[ Q_s = \text{Radiation heat loads, kW} \quad I = \text{Intensity of radiation, W/m}^2 \]
\[ Ag = \text{area of windows and ventilation, m}^2 \quad \Theta = \text{Solar gain factor of glass} \]

\[ Q_c = (AwUw\Delta Tw) + (AgUg\Delta Tg) + (ArUr\Delta Tr) \] (6)

\[ Q_c = \text{Conduction Loads, kW} \quad Uw = \text{Transmittan wall value, kW/m}^2 \]
\[ Aw = \text{Area of Wall, m}^2 \quad Ug = \text{Transmittan glass value, kW/m}^2 \]
\[ Ag = \text{Area of windows and ventilation, m}^2 \quad Ur = \text{transmittan roof value, kW/m}^2 \]
\[ Ar = \text{Area of Roff, m}^2 \quad \Delta T = \text{distinction of temperature, degC} \]

\[ Ts = To + (I\cos\beta\alpha/fo) \] (7)

\[ Ts = \text{Temperature on building surface, degC} \quad \alpha = \text{absorption of material} \]
\[ To = \text{Temperature on around building, degC} \quad \beta = \text{angle of radiation} \]
\[ I = \text{Intensity of radiation, W/m}^2 \quad fo = \text{Conduction of building surface W/m}^2\text{degC} \]

\[ \alpha = (\alpha w + \alpha p)/2 \] (8)

\[ \alpha = \text{Value absorption of building material} \quad \alpha p = \text{Value absorption of paint} \]
\[ \alpha w = \text{Value absorption of walls} \]

\[ \Delta Tw = Ts - Ti \] (9)

\[ \Delta Tw = \text{Distinction, of inside and outside temperature, degC} \]
\[ Ts = \text{Temperature on building surface, degC} \]
\[ Ti = \text{Temperature desire (standart appropriated 24-27˚C).} \]

3. Result and discussion

3.1. Calculation of Air Conditioning Loads Values

Building air conditioning load values measure each kind of building air conditioning loads, the standard of building energy consumption, cost of air conditioning loads and thermal comfort.

3.1.1. Environmental Analysis around the Building. Ecotect simulations shows the value of the incoming angle of solar radiation towards the building (Cos \( \beta \)) which is 0° at 12.00 noon and will increase 5° ± every hour, the value of the intensity of solar radiation around the building is 480-700 W/m², the value of the temperature around the building is 24-35 °C, and the surface value of the conduction building is 10-30 W/m².

Analysis values show there is a relation between the intensity of solar radiation, temperature around building and conduction building surfaces (table 2) the values of solar radiation. Every 1 °C of temperature value, it would be increased 20 W/m² intensity of solar radiation and also 1.81 W/m² of conduction on building surfaces.
Table 2. The relation between the values of intensity of solar radiation, temperature around the building and conduction on the building surface.

| No | Solar Radiation Intensity W/m² | The temperature around Building °C | Conduction on Building Surfaces W/m² |
|----|-------------------------------|-----------------------------------|----------------------------------|
| 1. | 480                           | 24                                | 10                               |
| 2. | 500                           | 25                                | 11.81                            |
| 3. | 520                           | 26                                | 13.62                            |
| 4. | 540                           | 27                                | 15.43                            |
| 5. | 560                           | 28                                | 17.24                            |
| 6. | 580                           | 29                                | 19.05                            |
| 7. | 600                           | 30                                | 20.86                            |
| 8. | 620                           | 31                                | 22.67                            |
| 9. | 640                           | 32                                | 24.48                            |
| 10. | 660                          | 33                                | 26.29                            |
| 11. | 680                         | 34                                | 28.2                             |
| 12. | 700                         | 35                                | 30                               |

Analysis results show the lowest-highest conditions around the building on December 18, 2018, at 08.00 am and September 11 at 12.00 noon with the value of the solar radiation angle (Cos 60°-Cos 0°), the intensity of solar radiation was 480-700 W/m², the temperature around the building value is 24-35 °C, and the conduction value at the building surface value is 10-30 W/m².

3.1.2. The values Air Conditioning Loads. Air conditioning loads values at lowest-highest condition resulted in 126.07 – 234.79 kW, which is Each kind of air conditioning from radiation (Qs) is 58.16 – 84.82 kW, conduction (Qc) is 40.58 – 83.63 kW, electronic devices (Qd) is 22.84 kW (permanently assumption), convection (Qv) is 0 – 34.6 kW and human heat (Qp) is 4.48 – 8.89 kW (figure 3).

![Figure 3](image-url) Each kind of air conditioning loads at lowest (left); Each kind of air conditioning loads the highest condition (right).

3.1.3. Energy Consumption Intensity Standard. The standard value of energy consumption for AC loads for the office category is not more than 19.17 kWh/m²/month. The lowest - the highest air conditioning values (Q) is 126.07 - 234.79 kW with assuming each day's work (8:00 a.m. - 5:00 p.m.) in a month (22 days) divides the total floor area of the building (A) 727.17 m² (table 3).
Table 3. Values air conditioning load with the standard of energy consumption by the Ministry of Energy and Mineral Resources [12]

| Lowest-highest air conditioning values (kW) | Air conditioning values in a month (kWh/m²/month) | Total building floor area (m²) | Standard values of Energy consumption on air conditioning loads (no more than 19.17 kWh/m²/month) |
|---------------------------------------------|-----------------------------------------------|-------------------------------|--------------------------------------------------|
| 126.07                                      | 34.32                                         | 727.72                        | High                                             |
| 234.79                                      | 63.93                                         | 727.72                        | Very High                                        |

3.1.4. Building Air Conditioning Cost. The cost of building an AC can be found with the amount of AC (ΣAC) which is the lowest AC load of 126.07 - 234.79 kW divided by the capacity of AC (P) in units of horsepower (HP) is 3.75 kW (equivalent to 1 HP) (table 4).

Table 4. The values of building air conditioning cost

| Lowest-highest air conditioning values (kW) | Air Conditioner for 5 HP (kW) | Number of AC Capacity each kind of HP (ΣAC) | Cost/ kWh (IDR) | Building air conditioning cost (IDR/hour) |
|---------------------------------------------|--------------------------------|---------------------------------------------|-----------------|------------------------------------------|
| 126.07                                      | 3.75                           | 33 (5 HP) and 1 (3 HP)                      | 1,467.00        | 184,841.00                               |
| 234.79                                      | 3.75                           | 62 (5 HP) and 1 (3 HP)                      | 1,467.00        | 344,378.00                               |

3.1.5. Social Factor of Thermal Comfort. Thermal comfort is a standard of human comfort temperatures. In Indonesia, the thermal comfort standard is 24-27°C [21]. Lowest-Highest values of air conditioning load are resulted by 24-35°C. Reduction of energy consumption on air conditioning loads can be done with decrease thermal comfort which is an increased value of temperature degree (figure 4).

Figure 4. The Lowest-Highest values of Energy Consumption on Thermal Comfort of Temperature Degree.

Air conditioning loads from heat radiation of the sun is the highest load at lowest-highest conditions of 46-36%, the results are different from [22] which states "conduction factor is the highest type of air conditioning load which is 50 - 80%. Building AC costs are IDR184,841.00 - 344,378.00 per hour. and reducing the standard of thermal comfort can decrease 3-7% of the air load in every 1°C compared to Karyono, stating that "the reduction in air conditioning load can reduce the air load by 10% by increasing 1°C [23].
3.2. Building Energy Efficiency and Conservation Strategies on air conditioning loads

There are various ways and programs to save energy including Energy Efficiency and Conservation in Building Air Conditioning loads. Using several materials in the building envelope (Roof, Wall and Glass) and also human behaviour greatly influences and can reduce energy consumption by lowering the value of thermal comfort standards.

3.2.1. Conservation Strategies of Material on Building Envelopes. Material strategies are used for reduction radiation and conduction heat with absorption, transmittance, and solar-gain. Changing and adding of building envelopes material (roof, Wall, and Glass) is more effective to decrease building air conditioning loads (table 5).

Table 5. The Lowest-Highest values of Solar Radiation through the glass material

| Window-wall Area (m²) | The intensity of Solar Radiation (W/m²) | Solar-Gain Factor of Glass | Air Conditioning Loads from solar radiation (kW) |
|-----------------------|----------------------------------------|---------------------------|-----------------------------------------------|
| 144.26                | 480                                    | 0.30                      | 20.77                                         |
| 144.26                | 700                                    | 0.30                      | 30.29                                         |

Changing the regular glass material with a solar gain factor value (θ) of 0.84 to a glass Stopray of 0.30 can reduce 65% of the building load from solar radiation.

Adding and changing of building envelopes (roof, glass, and Wall) material with lowest absorption and transmittance values can be reduced by 75% and 65% air conditioning from conduction at the lowest and highest condition (table 6).

The material conservation strategy in the building envelope aims to reduce the value of the building load in the lowest-highest conditions resulting in 58.51 - 128.96 kW. Each type of carrying load is: radiation (Qs) is 20.77 - 30.29 kW, conduction (Qc) is 10.42 – 32.33 kW, electronic devices (Qd) are 22.84 (permanent assumption), convection (Qv) is 0 - 34.6 kW and human heat (Qp) are 4.48 - 8.89 kW.

Table 6. The Lowest-Highest values of Solar Radiation through the glass material

| No. | Type of Materials | Wall Absorption (aw) | Paint Absorption (aw) | Total Absorption (α) | Transmittance (U) |
|-----|-------------------|----------------------|-----------------------|----------------------|-------------------|
| 1.  | Red Bricks with Cork Isolator and white varnish          | 0.89                 | 0.21                  | 0.55                 | 0.85              |
| 2.  | Stopray Glass                                            | -                    | -                     | -                    | 1.3               |
| 3.  | Shiny aluminium sheet zinc with gypsum ceiling.          | 0.12                 | 0.25                  | 0.185                | 1.88              |

3.2.2 Efficiency Strategies on Social Factor Thermal Comfort. The efficiency strategy is to reduce the temperature. The calculation of the air conditioning load is set to 24 °C, according to the standard thermal comfort is 24-27 °C. the results show (figure 5) that each 1 °C temperature rise can reduce energy consumption by 4-10% and can save 8% of the cost of the air conditioner.
4. Conclusion
Environmental around building analysis shows that the relation temperature, the intensity of solar radiation and conduction of building surfaces which affected increased energy consumption on air conditioning load, and solar radiation is the highest kind of air conditioning load. Every increase temperature value can be reduced 3-7% energy consumption energy efficiency and conservation strategies with using right material on building envelopes (roof, wall, and glass) can increase temperature values from 24 °C to 27 °C can be reduce 66% and 52% at lowest-highest condition which mean it contributes to save 17-24% energy consumption on building sector.

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