Retrofit Plans on Building Envelopes as Energy Efficiency Efforts: A Green Building Concept

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Abstract. Buildings with all their activities use considerable energy in the urban environment. Environmentally friendly buildings concept becomes essential with energy conservation. The application of this concept to existing buildings can be made through retrofit, by carrying out a series of improvements or changes to facilities and elements, to reduce energy consumption. This research was conducted to investigate how much energy savings will be generated through the simulation of several retrofit plans on the building envelope. The model in this study is the public office building, Jakarta Provincial Government's office. The projects are carried out by simulating the reduction of Window Wall Ratio, the addition of shading, and the replacement of glass material. The analytical method used is energy simulation with sensitivity analysis using the Autocad Greenbuilding Studio application. From the simulation, the results showed that retrofit plans proved to be able to save energy use in the building by 18 - 22%. This simulation also affects the savings in operational costs.

1. Introduction

Energy conservation and natural resources have become a global issue as a result of the mismatch between the availability of natural resources and energy due to the depletion of resources [1]. The building uses 30–40% of all primary energy [2]. Various researches and efforts have been made to overcome this, focusing on the concept of maintaining energy, renewable resources, leading to a sustainable green concept of the built environment or green building.

According to Greendepot [3], the idea consists of three supporting factors, including energy efficiency (both in terms of the selection of materials and the use of actual energy); healthy life, including air quality; and careful management of energy sources. The Green Building Council Indonesia states it is efficiency in land use, energy, water, and materials, both in terms of quantity and type of environmentally friendly materials [4]. Transformation into the concept in existing buildings is done through a process of retrofitting or customization, by carrying out a series of improvements or changes to facilities and elements.

Research related to retrofit can be categorized into two types, the study of indoor components and building envelope systems [5]. Compared to indoor parts, Kang and Liu [6] proposed a multi-objective optimization model on a HEN (Heat Exchanger Network) retrofit with a heat pump, it minimizing the total annual cost for the retrofit and maximizing the overall CO₂ yearly emission reduction.
In building envelope systems, Asadi et al. [7] propose a multi-purpose optimization method to help decision-makers in determining intervention measures aimed at cost-effectively minimizing energy consumption. Edeisy and Cecere [5] evaluate envelope retrofit as a tool to decrease reliance on air conditioning units in hot arid climates, and retrofit through glazing improvement is evaluated with cooling load and carbon emissions. Güçyeter and Günaydın [8] simulating retrofit strategies through calibrated base-case model, and results are assessed according to changes in indoor environmental parameters and annual energy consumption. Fan et al. [9] propose reducing the complexity of systematic optimization models using notch test data considering energy performance certificate compliance. In agreement with Güçyeter and Günaydın [8], this present study focuses on simulating a retrofit design plan on the building envelope.

Heating Ventilating and Air Conditioning (HVAC), consumes a large proportion of the total energy consumption. The embodied energy of HVAC 22.8% was consumed by the conditioning system, and 17.6% by heating system consume [10]. Therefore, reducing energy consumption for HVAC and artificial lighting through passive and active design will significantly reduce overall building [11]. Building envelopes can have an enormous impact on total energy consumption for HVAC, because they can dramatically affect cooling loads, mainly because of controlling the acquisition of heat radiation through windows, and the use of natural lighting [8]. Combined passive design strategies have the potential for energy savings of around 31% in office buildings [8]. This can be achieved through the envelope designs that include shading, Window to Wall Ratio (WWR), glass selection with a low shading coefficient, and the use of natural light for indoor lighting [12].

This study aims to analyze retrofit efforts that can be achieved through changes to the sheathing or building appearance. From this retrofitting, the benefit-cost generated from energy efficiency can be observed and analyzed. The building that becomes the object of research is the public office building in West Jakarta. This building was picked because it has a shape and size that is typical of buildings owned by other DKI Jakarta Regional Governments. From the retrofit, it also can be seen how much the benefit-cost resulted from the efficiency energy carried out.

2. Materials and method
This research was conducted with energy simulation using sensitivity analysis through analytical methods. Sensitivity analysis is a study to show variations in output based on several input parameters. These parameters include the shape of the building mass, geographical location and climate data, number and area of the floor, fill material properties, and fill the characteristics of space, percentage of artificial ventilation, Window to Wall Ratio, type of roof, type of window glass, and kind of wall. Sensitivity analysis of energy simulation is done by changing parameters to measure its performance in this case in terms of energy savings. Create a 3d model or baseline model (Fig 1). The next step is to evaluate energy use by reconstructing the conceptual mass, then making changes or adding facade elements so that they can be analyzed for energy use. All this simulation and evaluation use the Autocad Green Building Studio application.
The building consists of 4 floors with a total area of 2,468 m². The ignition system uses mechanical ventilation in the form of Split AC on the 1st to 4th floor. It has a sheath of brick-window construction walls and curtain walls on several parts of the 1st and 2nd floors. Only in some rooms such as stairs and toilets that use natural ventilation. Parameter data can be seen in table 1.

Table 1. Existing building data

|                  |               |
|------------------|---------------|
| Floors           | 4             |
| % Artificial Ventilation Area | 60%          |
| Window to Wall Ratio | 0.95         |
| Glass Type       | Single Pane Clear - No Coating |
| SHGC             | 0.81          |
| U value          | 6.18          |
| Wall Type        | Lightweight Construction - Low insulation |
| U-Value Wall     | 1.38          |
| Roof Type        | Typical Insulation - Cool Roof  |
| Roof U-Value     | 21.99         |

The first retrofit plan was carried out by making changes to the setting opening ratio of the Window to Wall Ratio (WWR). Reducing the window area is one solution that is effective enough to reduce the cooling load and overall energy consumption. The reduction is made in spaces that do not require many windows functionally. The reduction can be made until WWR reaches 0.65. The second retrofit plan uses shade elements. The type of shade element used is a generic external type of vertical fin. This addition is applied to the walls of the West-Northwest direction.

The third retrofit plan is to make changes to the type of glass material. The existing glazing construction, Single Pane Clear - No Coating, was changed to Double Pane Clear - High Performance, LowE, High Tvis, Low SHGC. It is applied to all glass material. The three alternative retrofit plans are carried out with the consideration that there is no need to make significant changes to the shape and design of the building, and it only requires minimal costs.
3. Result and Discussion

![Figure 2. Site plan of an office building: a public office building](image)

When the initial calculation simulation using Autodesk Green Building Studio, the simulation results show that the EUI value is 170.4 kWh / m² / year. The diagram in figure 3 shows the use of electrical energy used as lighting and artificial airing and other mechanical equipment. The building has a large amount of electrical energy use in the form of artificial HVAC, which is 48% of the total consumption of electricity.

![Figure 3. Use of electrical energy](image)

After the initial calculation, then the simulation according to the retrofit plan. The first plan is reducing the building’s WWR from 95% to 60%. The second plan, use shading elements in some parts of the building, especially parts facing West – North West, the third plan replacing the glass material. A comparison of building energy from the three proposed alternatives can be seen in table 2.
Based on the simulation, the proposed alternative has been proven to reduce energy use in the building. In table 2 and figure 4 above, it can be seen that with the right design changes, energy use
can be reduced. The smallest EUI value is 132.9 kWh / m² / year obtained by the second alternative. In the first alternative, reducing the WWR of buildings from 95% to 60% can affect energy performance for the better, which can reduce the EUI by 30.6 kWh / m² / year or can make savings of 18%.

![Figure 5](image-url)

**Figure 5.** Diagram of energy use intensity comparison

Without making changes to the WWR, energy reduction was also able to be fulfilled by the addition of shading in the western - northwest area of the building. The addition of shading can reduce EUI by 37.5 kWh / m² / year or can make savings of 22%. Replacement of glass material types as in the third alternative using the Double Pane Clear glass type - High-Performance LowE, high Tvis, low SHGC, able to reduce Energy Use Intensity by 34 kWh / m² / year or can make savings of 20%. The addition of shading has the highest savings, 22% (figure 6).

![Figure 6](image-url)

**Figure 6.** Diagram of EUI savings comparison

Based on the simulations carried out, alternatives to the proposed retrofit plan, energy use can be reduced. In addition to having an impact on efforts to reduce energy use, this retrofit effort also affects the decline in building operating costs in the aspect of electricity cost. From energy savings carried out according to alternative retrofit efforts, a percentage of operational cost savings can be calculated.

4. Conclusion

Retrofit efforts on existing buildings in the form of WWR value reduction, the addition of shading, and replacement of glass materials with energy-saving glass proved to be able to save energy use in the building by 18-22%. Savings with a value above 20% can be achieved with two alternatives, namely
by adding shading or by replacing glass material that has a small U Value. Agreed with [12], although differences in the amount of efficiency the study results show that simple retrofit strategies such as solar shading, window glazing, water tightness can reduce energy consumption. Furthermore, it is necessary to examine the most effective shading design that can be applied to this building envelope. It can mitigate solar insolation, thereby offering reductions in heating/cooling loads, and improve the distribution of daylight [13].

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