COST SAVING ON ELECTRICITY CONSUMPTION BASED ON BUILDING POSITION

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Abstract

Position of a building has a significant impact on energy consumption. Proper orientation in respect to how light will come in through the building needs to be considered in order to reduce energy consumption. The objective of this paper is to find out costs saving achieved by considering the position of a building. It is achieved by conducting an analysis on the energy (electricity) consumption costs on one of Bung Hatta University's Building in Padang, Indonesia. The building was modelled in two conditions, one is by using the existing layout and second is by turning the orientation of existing layout into the position with lowest energy consumption resulted from software simulation. Costs for electricity consumption was calculated for each model and then compared. In addition, sensitivity analysis was also conducted by varying the interest rate and the price per kilowatt hour. The finding illustrates that, by considering building position, a building can be 'greener' and leads to a sustainable building.

Keywords: *energy consumption, sustainable building, building layout*

1.0 INTRODUCTION

The issue of energy efficient buildings becomes widely recognized as people become aware of diminishing world energy resources and global warming. It is known that nearly 40% of the total energy consumption was represented by residential and commercial buildings (Illeperuma, 2014). In order to reduce the energy consumption of the building, the building construction which is considering sustainable green building design approach is needed. The green building is defined by (Khosta and Sigh, 2014) as an outcome of a design philosophy which focuses on increasing the efficiency of resource use, such as energy, water, and materials while reducing the impact on human health and environment during the building's lifecycle, through better design, construction, operation, maintenance and removal.

There are various ways on how to reduce energy consumption. For energy consumption on a building, it can be achieved such as by selecting the site of the building, building materials especially the roof and walls materials, energy efficient appliances, and building orientation. The benefit of this is not only cost saving but it can also reduce pollution and increase the comfortableness of the building's user.

Recently, there are numerous studies of building energy efficiency. However, only limited research has been discussed on this issue, particularly in the context of an orientation of the building. The optimization of orientation building is one of energy saving concepts which allows the building to avoid overheating caused by daylighting (Khosta and Sigh, 2014). The aim of this paper is to find out costs saving achieved by considering the orientation of a building. In this context, an analysis on the energy (electricity) consumption costs on one of Bung Hatta University's Building in Padang, Indonesia, is selected as a case study.

2.0 LITERATURE REVIEW – ENERGY EFFICIENCY

Buildings are major consumers of energy and in the European Community, around 40% of final energy consumption is in the building sector (EU directing on the energy performance of buildings, UK: Department for Environment, Food & Rural Affairs, 2008). Moreover, academic study found that the energy consumption of public building is about 10 times higher than residential buildings (Ministry of Construction in China, 2005). Jafary et al., (2016) investigated the interaction of people, buildings and technology on energy consumption and explored how to reduce the energy use in order to decrease costs in a campus.

2.1 Building energy efficiency in tropical region climates

Tropical countries have rapid growth in population and economy activities. This situation may lead to an increase in energy consumption in this area. Therefore, the construction of a green building is highly needed. Some characteristics of a green building are it has a high environmental rating, sustainable development, and improved comfortableness for users. The objective of building energy efficiency is to construct a comfortable building, with the use of little energy and produce little pollution. In order to achieve this objective, the efficient cooperation between the professional (architects, engineering, and university researcher) is needed (Garde-Bentaled *et al*., 2002).

For tropical countries' climate, thermal comfort is an important aspect in achieving the objective of building energy efficiency. Thermal comfort is defined as "that condition of mind, which expresses satisfaction with the thermal environment" (ISO Standard 7730 in 1994). Thermal comfort is affected by heat, convection heat, radiation and absorption of heat loss (evaporative heat loss) and retained the heat produced by the human metabolism can be removed (Puteh *et al*., 2012). There are several studies that have been conducted to discuss the issue of thermal comfort in green building contexts such as Nematchoua *et al.* (2014) which measured wind speed, air temperature, and relative humidity and CO2 levels in 28 building school. This study found that more than 40% occupants are out of comfort range.

Furthermore, Puteh *et al*. (2012) conducted a survey to investigate the students' perception towards classroom thermal comfort. As thermal comfort being an important aspect, the use of air-conditioning units have become the main barrier to achieving the objective of green building in such area. Kwong *et al*. (2014) conducted a comprehensive review of the energy efficiency improvement potentials in air-conditioned tropical buildings by considering the thermal comfort of occupants. Moreover, Bastide *et al*. (2006) deals with the optimization of building energy efficiency in tropical climates by reducing the period of air-conditioning thanks to natural ventilation and a better bioclimatic design.

2.2 Energy Saving Concept

There are several ways to construct building energy efficiency. Khosta and Sigh (2014) explains that the leadership in energy and environmental design (LEED-INDIA) Green Building, one of a nationally and internationally accepted benchmarks for the design, construction and operation of high performance green buildings, proposes five key areas for sustainable building approach, these are sustainable site development, water savings, energy efficiency, material selection and indoor environment quality. This paper also argues that there are various energy saving concepts such as site selection, orientation, walls and roof of a building, and appliances used in the buildings.

In the context of building's orientation, Abanda and Byers (2016) conducted an investigation on the impact of building orientation on energy consumption in a domestic building using Building Information Modelling. Material selection and determination of the optimum thickness of the material, particularly for external walls and roof of the building, are two of the solution`s in energy efficiency building (Moghimi *at al*., 2013). This study investigates the energy performance of the building by finding the optimum thickness of material and find out if mineral wool has better performance than other material with the optimum over 5, 10, and 20 life times are 4 cm, 8 cm, and 10 cm, respectively. In terms of energy efficient appliances, Mizobuchi and Takeuchi (2016) argues that energy-efficient air-conditioners used by households have a better performance in term of energy-savings compared to non-energy-efficient air-conditioners. Moreover, this study states that government's policies on electricity saving have significant impact in energy-saving campaign.

2.3 Economic Analysis

Energy efficiency (FE) investments provide financial rewards and environmental benefits. However, energy managers identify budget constraints as one of the main obstacles in improving the energy efficiency of buildings (Illeperuma, 2014).

Present Worth or Net Present Value (NPV) is one of the common tools in economic analysis. In NPV, all cash flows which will be occurred in the future are converted into its present value. When future amount F is given in (n) period in the future at interest i, then its present value P can be calculated as:

$$P = F\left(\frac{1}{(1+i)^n}\right)$$

Economic analysis requires an estimation of certain parameters, such as initial costs, interest rate, or maintenance costs. This estimates may have uncertainties and contain errors, and can affect a decision. The effect of variation in the estimates may be determined by deploying sensitivity analysis. It determines how a measure of worth, such as Present Worth or Net Present Value (NPV), is altered when one or more parameters vary over a selected range of values (Blank and Tarquin, 2013).

3.0 RESEARCH METHODOLOGY

This research used a building of Bung Hatta University in Padang, Indonesia (Building A3) as a case study. The azimuth of this building is 145^o and the total area of the building is 2,429 m^2. The building is used for lecture theatres, meeting rooms, and lecturer's working spaces on the first floor; general office on the 2^{nd} floor; and lecture theatres on the 3^{rd} floor. The building is only accessible during weekdays from 7 am to 6 pm. To obtain the optimal building orientation, Autodesk Revit software is used. Seventeen different orientation are simulated (preliminary research by (Mulyani and Kholidasari, 2016)

In order to calculate the cost saving of an electricity, some assumptions have to be made. The existing electricity cost for Building A3 is Rp. 44.712.509 per year, which is based on the sum of electricity monthly cost. The increase of electricity cost per kWH per year varies, depending on such as government policy on cutting the subsidy and the oil prices or coal prices. However, according to ESDM (2016) the average is around 15% per year. The interest rate is assumed to be 10% annually.

NPV is deployed to conduct the economics analysis. The NPV for costs saving per year is established by calculating the electricity costs for 30 years, with an increase of 15% per year. It is then converted into its net present value with an interest rate of 10% and sum up. The cost saving is achieved by multiplying it with 2% saving gathered from turning building orientation 202,5 degrees South-South-West SSW (Mulyani and Kholidasari, 2016). In addition to NPV analysis, the sensitivity analysis is also conducted in order to find out its sensitivity on the increase of interest rate and the increase of costs per kWh, two sensitivity analysis are conducted. First is by varying the interest rate from 7.5% to 25% with an interval of 2.5%. Second is by varying the increase of electricity cost also at the same interval.

4.0 ANALYSIS AND DISCUSSION

4.1 Cost saving

As discussed in previous sub section, by turning the orientation of the Building A3 202.5 degree, it can lower electricity consumption by 2%. Table 1 shows the amount of electricity costs per year and its NPV on 10% interest rate. It can be seen that the total electricity cost is Rp 19.4 billion while its NPV is nearly Rp 2.5 billion. The total saving of electricity costs for 30 years generated by building orientation is nearly Rp 50 million. It means that if building orientation was considered in design or just before the staking out of Building A3, Bung Hatta University can save some budget and contributed to sustainability development.

Table 1: The costs of electricity consumption for 30 years

Year	Electricity Costs (Rp)	NPV of electricity cost (Rp)
1	44,712,509	40,647,735
2	51,419,385	42,495,360
3	59,132,293	44,426,967
4	68,002,137	46,446,374
5	78,202,457	48,557,573
6	89,932,826	50,764,736
7	103,422,750	53,072,224
8	118,936,162	55,484,598
9	136,776,587	58,006,625
10	157,293,075	60,643,289
11	180,887,036	63,399,803
12	208,020,091	66,281,612
13	239,223,105	69,294,412
14	275,106,571	72,444,158
15	316,372,557	75,737,075
16	363,828,440	79,179,669
17	418,402,706	82,778,745
18	481,163,112	86,541,415
19	553,337,579	90,475,116
20	636,338,215	94,587,621
21	731,788,948	98,887,058
22	841,557,290	103,381,925
23	967,790,883	108,081,103
24	1,112,959,516	112,993,880
25	1,279,903,443	118,129,966
26	1,471,888,960	123,499,510
27	1,692,672,304	129,113,124
28	1,946,573,149	134,981,902
29	2,238,559,122	141,117,443
30	2,574,342,990	147,531,872
Total electricity costs for 30 years (Rp)		19,438,546,199
NPV of total electricity costs for 30 years (Rp)		2,498,982,890
Total saving of NPV electricity costs for 30 years (Rp)		49,979,658

The finding is in line with Zalejska-Jonsson *et al.* (2012) and Illeperuma (2014) which find that low energy building gives more benefit in term of cost and profit compared to conventional building.

4.2 Sensitity Analysis

Figure 1 shows the sensitivity of electricity cost saving due the variation of interest rate. It can be seen that, the lower the interest rate the higher the cost saving gained. At 7% interest rate, NPV of cost saving is Rp 78.25 million while at 25% the cost saving is only Rp 8.2 million.

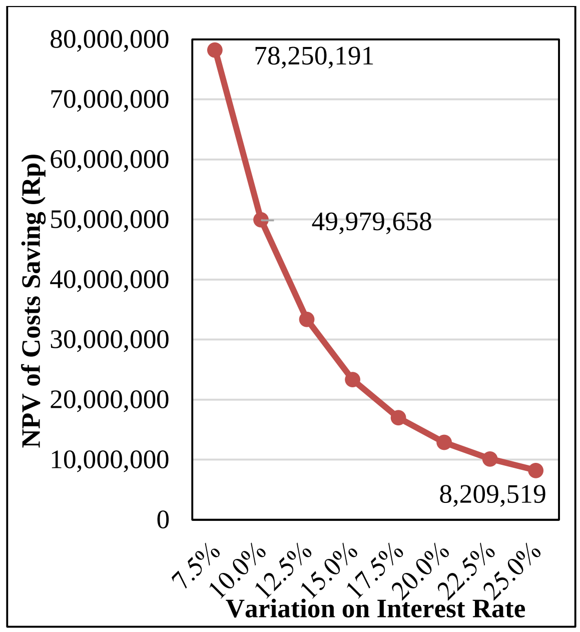

Figure 1: NPV of electricity cost saving according to interest rate

On Figure 2, the analysis is conducted by varying the increase in the percentage of electricity costs. It can be seen that at an increase of 25% of kWH, the cost saving is Rp 270 million.

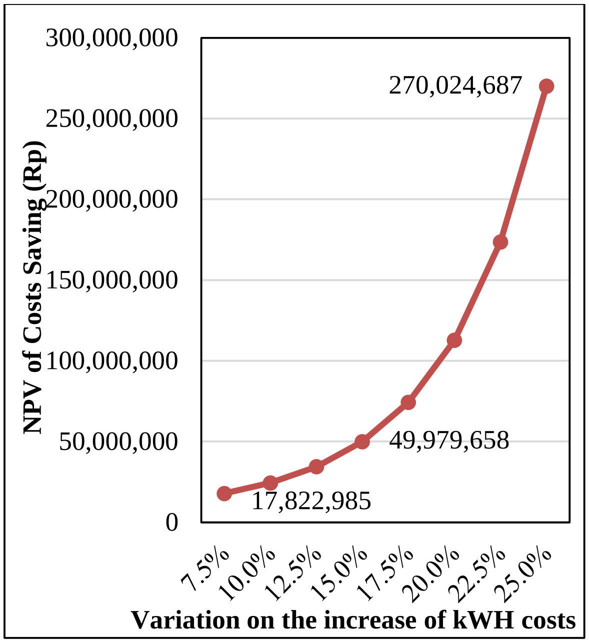

Figure 2: NPV of electricity cost saving according to the increase of KWH rate

5.0 CONCLUSION

Optimization of building orientation is one way to achieve energy efficiency building. This paper discusses the cost saving on energy consumption based on building position. Using A3 building in Bung Hatta University, Padang, Indonesia, as case study building, a comparison between electricity cost of existing layout of building and the optimal orientation of building layout is conducted. The analysis of the optimization of building orientation is a preliminary study conducted by Mulyani and Kholidasari (2016). By deploying NPV method it is found that the total saving of electricity costs for 30 years generated by building orientation is nearly Rp 50 million.. Sensitivity analysis was also conducted by varying the interest rate and the price per kilowatt hour. The finding illustrates that, by considering building position, a building can be 'greener' and leads to a sustainable building.

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