An application of solar panel for energy efficiency at vertical building in Lebak Bulus Jakarta

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Abstract. This article contains a research on position and placement of solar panels to reduce electrical energy consumption of an office building with analysis on sunlight of the site, which located in Lebak Bulus, Kawasan Koridor, Jalan TB Simatupang, South Jakarta. The method of the research is as follows: (1) Analyze the site location, (2) Analyze the climate in the site location, (3) Analyze the solar panels placement based on the result of analysis of sunlight, (4) Analysis of Electricity Supply Demand Calculation in Buildings, and (5) Calculate the efficiency based on the amount comparison of electricity needs of the air conditioner and the energy produced by solar panels. The result shows that solar panels will work optimally if placed on the upper side, the northeast side and the northwest side of the building. The amount of solar panel needed are as many as 4,398 pieces, based on comparisons between energy consumption and building area. So, it can be concluded that the use of solar panels on the top side, and 2 other sides namely east and west can produce electricity use efficiency of 53.08%

1. Introduction

The office can be interpreted as a part of the organization which is the center for administrative and data or information processing activities [1]. In line with the increasing business activities of the community, many offices are built in urban areas. They are built, not only horizontally, but vertically. However, the presence of office buildings also comes with negative impacts. In terms of energy consumption, office buildings are notorious for being quite wasteful [1]. The data by Kompas.com (www.properti.kompas.com accessed on February 2020) which is titled “Sektor Gedung Habiskan 40% Energi Global” (Buildings Takes 40% of Global Energy Consumption), they reported that globally, buildings consume 40% of world’s energy and resources. It makes buildings, particularly offices, as one of the world’s biggest energy users. Therefore, it is appropriate for energy savings to start from the building complex.
This also happens in Indonesia where the use of electricity in its buildings is one of the contributors to energy waste. Green Building Council shows that energy consumption of office buildings in Indonesia are twice as much if compared to similar buildings in Malaysia and Singapore [2]. This kind of energy use is required by these buildings, especially electricity for air conditioning. Moreover, in a tropical climate [3], it is needed more than anywhere else. This is confirmed by Taylor's statement in his book, The Handbook of Energy Efficiency and Renewable Energy (2007). He also states that 50-80% of energy use from large buildings is mainly influenced by the heat conduction from direct sunlight through the building's surface. As the use of electrical energy for air conditioner is increasing due to the hot climate, a solution is needed so that sunlight can be utilized for energy efficiency [4].

As any other problems, there are solutions for it. In this case, the use of alternative energy with natural resources can be one of them. There is a technology that is perfect for this situation, which can convert sunlight into electricity. Instead of having a negative impact on the building, sunlight can be utilized to provide extra energy for it. The technology is called photovoltaic cells or also known as solar panels. Scientist has developed solar panels to convert light into electricity based on the law of conservation of energy. To address the definition, solar panel is a device that consists of solar cells, which can be used to convert light to electricity. Solar panels, unlike fossil fuels, do not produce any greenhouse emissions which can have severe effect on our environment in the long run. With solar panels, we can obtain much cleaner and sustainable energy [5]. However, there are some considerations in the application of solar panels on office buildings. According to the Director of Industrial, Manufacturing, Telematics, and Electronics Research of Agency for the Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi or BPPT), Andhika Prastawa, via an article by Tempo.com, accessed in February 2020, titled “Begini Cara Pasang Panel Listrik Tenaga Surya yang Benar” (How to Properly Install Solar Panels), solar panels have to be installed in an open area not under any shade of buildings or other objects. They also require spaces for air circulation [6]. If possible, they have to orientate towards the equator. For example, on Java island, they have to face north. Moreover, there is a need for easy access to the panels for routine maintenance in order to keep them working optimally [7].

This article is a research on how to effectively install solar panels on buildings that applied in office building. The placement of the panels is expected to provide optimal energy gain for the building. The placement also took the consideration of location characteristics, which determine their position relating to solar orbit, intensity and also maintenance of the panels themselves [7].

2. Methodology
There are 3 mains analysis in this study, first is site and climate analysis, and second is solar panels placement analysis and application of solar panel analysis. The result of this study is the ideal placement of solar panels and the estimation of energy efficiency gained by using solar panels [7].

3. Results
3.1 The Location of Building
For the case study, we choose a site in southern part of Jakarta, at Kebayoran Lama area 6°17'14.1"S 106°46'43.6"E (Figures 1-2). The site is surrounded by some buildings such as hotels, hospitals, MRT station, Transjakarta bus stops and residential area. Refer to the city spatial plan, this site is plan as commercial and office area. It is very likely that other office buildings will be developed around the area in the next 5-10 years [8].

Regarding to this location, an overview of the aspects of temperature and rain is important. According to one of the solar panel distributor websites in Indonesia, mentarisolarled.com, so that solar panels can work optimally, Environmental estrangement means that the position of the solar cell installation site must be rich in sunlight. Environmental estrangement could be around the solar panels that will be installed surrounded by trees or tall buildings, so that sunlight can work optimally. This must be anticipated by placing solar panels higher than environmental disturbances.
According to en.climate-data.org, the minimum temperature of South Jakarta is 21.8 °C and the maximum is 33.2 °C. Since the ideal standard operational temperature for solar panels is 25°C [9], Jakarta as a tropical city is considered a perfect area for solar panels. According to Bmkg.go.id, which is an official institution in Indonesia (Badan Meteorologi, Klimatologi, dan Geofisika) precipitation can be divided into 3 categories, which is low (0 - 100 mm), moderate (100 - 300 mm) and high (300 – 500 mm). South Jakarta only have high precipitation for 3 months in 1 year, the rest are moderate to high. It is due to the geographical location of Indonesia which belongs to tropical climate zone [10]. Consequently, the Polycrystalline type of solar panel can be ideal for this situation due to its capability of performing even without direct sunlight [11]. This type of solar panel can optimally function as long as there are bright indirect sunlight. Based on climatology data, Indonesia receive an average of 1460 KWh of solar radiation, which is considered decent for photovoltaic cell system application [12].

3.2 Climate Analysis
The climate analysis (Table 1) is carried out in accordance with the climatic conditions at the site, Kebayoran Lama, South Jakarta, and based on the proper use of solar panels.

| Jakarta Climatic Conditions | Standard Use of Solar Panels | Result |
|-----------------------------|-----------------------------|--------|
| South Jakarta Temperature is 21.8 °C - 33.2 °C | Solar panels work at standard temperatures 25°C | Indonesia is a suitable area to use solar panels |
| Moderate Rainfall (100–300 mm) to High Rainfall (300–500 mm) | Monocrystalline (high efficiency), Polycrystalline (low efficiency) | Use Monocrystalline which is more optimal in tropis climate |
Selection of the most suitable type of solar panel is the type of Monocrystalline. The efficiency of the Monocrystalline type is 15% higher but it has the disadvantage that it will not function properly in low sunlight (shade). According to Bambang Hari Purwoto in a journal entitled Efficient Use of Solar Panels as an Alternative Energy Source. This type of solar panel is based on its efficiency of 100Wp and does not require a larger space than Polycrystalline to produce the same energy.

3.3 Solar Panel Placement Analysis
The analysis of sunlight is accomplished based on the site location using FormIt app. By measuring the annual average of solar radiation, the hottest side of the building and the ideal spot for to place the solar panels can be determined (Table 2). The building analysis is based on building mass construction with main road facing southeast.

| Area                  | Sunlight analysis using FormIt | Annual average radiation yield |
|-----------------------|--------------------------------|-------------------------------|
| Southeast             | ![Southeast Sunlight Analysis](image) | 665.1 kWh/m²                  |
| Southwest             | ![Southwest Sunlight Analysis](image) | 722.4 kWh/m²                  |
| Northwest             | ![Northwest Sunlight Analysis](image) | 824 kWh/m²                    |
| Northeast             | ![Northeast Sunlight Analysis](image) | 854.8 kWh/m²                  |
| Top of the building   | ![Top of Building Sunlight Analysis](image) | 1,853 kWh/m²                  |

The upper side, the northeast and northwest side are the top 3 side that receive the most solar radiation. And the results of this study will be connected with the next analysis, placement based on analysis of sunlight.

3.4 Analysis of Solar Panels Placement Based on Various Factors
- Placement Based on Analysis of Sunlight
  Solar panels can work optimally in areas exposed to sunlight or large amount of solar radiation. According to the analysis of sunlight, the greatest amount of solar radiation is on the upper, northeastern and northwestern sides. Therefore, the ideal side to lay the solar panels are the upper side, northeastern side and northwestern side.
• Solar Panel Placement Based on Equator Line
  Jakarta is located in the south side of equator line. From this analysis, it can be determined that the side exposed to the most and the longest sunlight is northeast and northwest. This supports the analysis where northwestern and northeastern are the sides which receive the most sunlight.

• Solar Panel Placement Based on Other Factors
  When laying solar panels, there are other supporting factors other than sunlight that we need to consider, which are:
  1. Solar panel requires an open space not under a shade of other objects either small or big.
  2. Make sure the solar panels are laid in a place that is easy to access for cleaning and maintenance purposes.

Based on the actual site location, there is a building on the northeast side of the site location, the BCA Bank building, which could potentially casts shadows that would fall on the northeastern side of the design building. Therefore, an analysis is needed whether or not the BCA Bank building blocks the sunlight on the planned building, as shown in Figures 3-4.

![Figure 3. Analysis of Shadow at 10:00 AM](image)

![Figure 4. Analysis of Shadow at 12:00 noon](image)

As we can see in the analysis shown in Figures 3-4, at 10:00 AM the sun is on the east side and the BCA building casts shadows that falls to the northeastern side of planned building. However, the shadow of does not cover the surface of planned building. Therefore, the northeast side of the planned building is available to use. The other side of the planned building is also viable because there is no other building and the area is very much lower than the planned building.

3.5 Solar Panel Slant Analysis
The analysis is carried out using the FormIt application to determine the most effective degree of tilt of the solar panel. The step is analyzing one by one the degree of slope from 0-30 degrees with a multiple of 10, namely 0, 10, 20, and 30 degrees (Table 3).

| Degree of Tilt | Radiation (Lowest-Highest) |
|----------------|-----------------------------|
| 0 degree       | Roof = 1853, Façade = 845.3 - 1839 |
| 10 degree      | Roof = 1753 – 1879, Façade = 980.2 - 1879 |
| 20 degree      | Roof = 1535 – 1858, Façade = 1075 - 1858 |
| 30 degree      | Roof = 1782 – 1792, Façade = 1145 – 1792 |

From the analysis using the FormIt application, the results are as shown in the table above. And the result:
1. The solar panel on the roof will have a slope of 10 degrees, because it has the greatest radiation, which is 1879 kWh.
2. The solar panel on the façade will have a slope of 10 degrees, because it has the greatest radiation, which is 1879 kWh.

3.6 Analysis of Electricity Supply Demand Calculation in Buildings
This analysis is carried out to determine the energy ratio percentage electricity generated by solar panels to the needs of air conditioning. Where in the background of this research it is written that Taylor in his book, Handbook of Energy Efficiency and Renewable Energy (2007) states that energy use from large buildings is dominated by climatic influences because the heat obtained from direct conduction from sunlight through the building surface reaches 50-80 % of energy consumed. HVAC contributes around 47% to 65% of the total energy consumption of buildings. Therefore, reducing energy use for HVAC is very influential and very much needed.

3.7 Analysis of Electricity Needs for Air Conditioning (AC)
The first step that must be taken in calculating this percentage is to calculate the AC requirement (BTU) in the design building. The length and width of the room are united in the floor area of the 1.2 and typical floor podium. Therefore, the total AC power consumption per year is 1,061,130,163.43 W/year.

3.8 Analyzing Solar Panel Energy Reduction
The design of the Solar Power Plant (PLTS) supplies 100% of the total electrical energy needed. Determined by Bien, Kasim, & Wibowo, 2008: 41 in his book Mark Hankins, 1991: 68, losses are set at 15%. Based on this stipulation, the load energy that the PLTS can supply is equal to:

\[
EB = EP - \text{loss system} = EP - (15\% \times EP) = 500 \text{ W/h} - (15\% \times 500 \text{ W/h}) = 425 \text{ W/h}
\]

3.9 Analysis of Total Energy Generated by All Solar Panels in Buildings
This analysis is done by calculating the number of solar panels obtained multiplied by the power of the solar panels produced (which has been reduced by system losses), so that the W/hour power is obtained (Table 4).

| Total solar panel | Solar panel capacity (300 Wp) | Solar panel power reduction | Power generated (W/h) | Sun effectiveness (hour/day) | Total power earned per day |
|-------------------|------------------------------|-----------------------------|-----------------------|-----------------------------|---------------------------|
| 323               | 500                          | 425                         | 137,275               | 5                           | 686,375                   |
| 576               | 350                          | 297.5                       | 171,360               | 5                           | 856,800                   |
| **Total of power (W) gained per day** | **1,543,175** |
| **Total of power (W) gained per year (365 days)** | **563,258,875** |

In the table above, the total power per year obtained by solar panels that has been applied to buildings is 563,258,875 W/year. And then the results of this total power can be used as a percentage comparison to the needs of air conditioning (AC).

4. Discussions
4.1 Solar Panels Placement
Based on the result of the analysis, solar panels will perform optimally if they are placed on the upper, northeastern, and northwestern sides. From the analysis on the previous chapter we can concur that the
upper side of the building receive the most solar radiation of 1,853 kWh/m². Therefore, solar panels are very effective if placed on the rooftop of buildings (Figure 5).

![Figure 5. The placement of solar panel on building roof](image)

Solar panels are very commonly placed on the upper side of the buildings or the rooftop. Just as the analysis suggest, the large amount of solar radiation are in the top side of the building. Because it is high in elevation, therefore the sun will not be blocked by other objects around the building. As a result, the solar panels are more safely and optimally placed on the rooftop.

On the analysis of northeastern and northwestern side of solar radiation, we can concur that both of these sides also receive quite large amount of radiation. Commonly, solar panels are placed on the roof or the upper side of the building. However, based on the analysis, the solar panels can also be placed in the building facades. In this case, due to large amount of radiation received in the building facades, the solar panels can be effectively placed on the northeastern and northwestern sides of the building. The installation of solar panels on building facades can also be a significant innovation due to the infrequent manner of its application, especially in Indonesia. So, it can be concluded that the optimal use of solar panels in the planned building is on the upper, northeastern and northwestern sides based on solar radiation analysis, equator lines, and other factors.

4.2 The Application of Solar Panel

Based on the calculation of the AC requirement (BTU) of the design building in Table 3, the total AC power consumption per year is 1,061,130,163.43 W/year. Meanwhile, based on the calculation of the energy produced by solar panels applied to the design building in section Table 4, the total power is 557,829,500 W/year. The result:

\[
\frac{563,258,875}{1,061,130,163.43} \times 100 = 53.08\%
\]

Conclusion

In conclusion, it is obtained a percentage of 53.08% of electrical energy which can cover the needs of air conditioning (AC) electricity as an effort to efficiency electrical energy on the use of air conditioning. The use of solar panels in office building will efficiently reduce the building dependance on fossil-based energy by using alternative natural resources which are available in abundance in Indonesia.

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