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The Feasibility Study of a Solar Power Plant at Building B, Universitas Multimedia Nusantara

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Abstract

The use of environmentally friendly energy resources is becoming increasingly important in reducing the carbon footprint of buildings. One approach is to integrate solar power generation into the building's energy system. This research aims to reduce the carbon footprint by replacing conventional electricity sources with environmentally friendly renewable energy sources and integrating energy sources without disrupting the productivity of activities in Building B of Universitas Multimedia Nusantara (UMN). This study encompasses several key parameters, including the limited use of solar panels in Building B of UMN and simulations conducted using PVSyst software with shadow-free assumptions and solar panel orientation facing north. Additionally, the research considers the potential production of clean energy from available utilization areas, including the roof and fifth-floor balcony of Building B. This feasibility study also includes an analysis of electricity usage over three months, with electricity consumption sourced from PLN. The analysis results show that the use of solar panels can yield long-term economic benefits, with capital costs recoverable within 20 years. However, further review is needed regarding potential system losses, costs, and the addition of energy storage options. Cost calculations need to be adjusted to consider building owner profitability for more accurate results. This study only considers profits without accounting for repair and maintenance costs over the 20-year system operation period.

A. Introduction

Green Building is a concept that involves the design, construction, operation, and maintenance of buildings, considering factors such as the utilization of natural resources, indoor air quality, and the welfare of its inhabitants [1], [2], [3]. The application of Green Building concepts has long been discussed and implemented in several countries as a measure to mitigate global warming. In Indonesia, the implementation of environmentally friendly building concepts has only recently begun to gain traction. One of the benefits of implementing Green Building concepts is reducing carbon footprint [4], [5].

According to the U.S. Energy Information Administration (EIA), emissions from power plants vary according to fuel type/energy source and the type and efficiency of power plants [6]. The amount of carbon dioxide (CO_2) emitted per kWh over some time will vary depending on the electricity source flowing into the power grid during that time. Therefore, CO_2 emissions related to electricity and CO_2 emission factors will vary every hour, day, month, and year. The EIA publishes estimates of CO_2 emissions related to electricity generation on a monthly and annual basis.

The table provided displays information regarding the total annual net electricity generation and CO_2 emissions from utility-scale power plants, along with the CO_2 emission factor (measured in pounds of CO_2 per kilowatt-hour) for coal, natural gas, and petroleum, as well as the average across all energy sources. It should be noted that the actual CO_2 emissions per kWh from individual power plants may deviate significantly from the figures presented in Table 1 [6].

Table 1. The generation of electricity in the United States and the consequent emissions of CO_2 categorized by fuel type in the year 2022 [6]

	Electricity generation	**CO_2 emissions**		
	million kWh	**million metric tons**	**million short tons**	**pounds per kWh**
Coal	831,512	868	957	2.30
Natural gas	1,687,067	743	819	0.97
Petroleum	22,931	25	27	2.38
All energy sources	4,230,672	1,650	1,819	0.86

One way to reduce carbon footprint in buildings is by integrating solar power generation into the building's energy system [7], [8], [9]. In some buildings, solar panels are integrated into the building's structure, such as solar PV installed on the rooftop [10], [11]. Some buildings use solar PV as part of the building's design elements .

One of the buildings that implements Green Building concepts is the campus building of Universitas Multimedia Nusantara (UMN) [1]. UMN, located in Tangerang, Banten, has a unique characteristic. Buildings C and D of UMN are clad with an aluminum layer called a facade. The double facade layer in both buildings serves as protection against excessive solar radiation and is capable of reducing the building's temperature without the need for excessive active cooling mechanisms [12], [13].

However, in 2022, UMN has not yet integrated the use of PLTS as an additional step to significantly reduce carbon footprint. UMN has several open spaces that have the potential to be installed with solar PV modules.

This research aims to reduce carbon footprint by replacing electricity sources through the integration of conventional energy sources with environmentally friendly renewable energy sources. Additionally, this research aims to integrate energy sources without disrupting the productivity of activities in Building B of Universitas Multimedia Nusantara.

B. Research Method

The scope of this study encompasses several key parameters. Firstly, the utilization of solar panels is confined to Building B of UMN. Simulations are conducted utilizing the PVsyst software. PVsyst is specialized software utilized for conducting analytical assessments on clean energy ventures employing PV cells in specific locations. PVSyst concentrates on projects utilizing diverse PV cell systems. Additionally, PVSyst offers comprehensive analysis outcomes for PV system projects, encompassing system size, production data, and output evaluation [14]. The assumption is devoid of any shadow assumptions, and with solar panel orientation facing north. Furthermore, the simulations take into account the potential production of clean energy from the available utilization areas, which include both the rooftop and fifth-floor balcony areas of Building B. It's important to note that this study focuses solely on calculating the quantity of solar panels and inverters to be utilized.

In this feasibility study, the electricity usage is sourced from PLN (Perusahaan Listrik Negara), the national power company of Indonesia. The electricity consumption data for three months is analyzed, with a tariff/power type specified as B3. The energy consumption by Multimedia Nusantara University is shown in Table 2.

Table 2. The Consumption Electricity in IDR by UMN

Months	**KVARH**	**Bruto Price**
January 2022	333,540	361,290,422
February 2022	325,980	354,236,760
March 2022	388,680	422,846,827
Average	349,400	
A year	4,192,800	

Building B of Multimedia Nusantara University is described as having an elongated shape, with its shortest length facing east-west. This orientation allows sunlight to illuminate the rooftop and front balcony areas without being obstructed by neighboring buildings (such as buildings A, C, and D), making it conducive for solar panel placement. The study identifies two designated areas for solar panel utilization: the rooftop area (number 1 in Figure 1) and the fifth-floor balcony area (number 2 in Figure 1). While the fifth-floor balcony area experiences partial shading from the building structure, it remains suitable for solar panel installation. Utilization areas are precisely calculated using AutoCAD software, resulting in utilization area measurements for solar panels as described.

Figure 1. The utilization area for solar panels in Building B [15]

Utilization areas based on area calculations through AutoCAD software are as follows:

Utilization area 1: 1042.789 m^2 + 1251.156 m^2 = 2293.945 m^2
Utilization area for solar panels: 2293.945 m^2 / 2 = 1,146.972 = 1,146 m^2
Utilization area 2: 236.767 m^2
Utilization area for solar panels: 236.767 m^2 / 2 = 118.383 = 118 m^2

C. Result and Discussion

In this section, a simulation using PVsyst will be presented. The simulation involves irradiation conditions illuminating UMN. Solar irradiation data in the UMN environment is obtained from Meteornom8.1. The irradiation data refers to irradiation data over the past 5 years, with an average of 4.87 kWh/m^2/day and an average temperature of 26.6 degrees Celsius. Irradiation and temperature data influence the type and specifications of solar panels to be used in each utilization area.

The installation of solar panels using the fixed plane technique involves static placement of the panels without any movement capabilities. This technique offers advantages such as not requiring sensors, motorized mechanisms, and easy installation. Setting the panel inclination at 30 degrees facing north aims to ensure the panels receive full sunlight irradiation throughout the day, facilitating relatively easy maintenance.

The total maximum electricity production is influenced by both the total area of utilization and the selection of panels. Determining the area of utilization involves dividing the total area by two, considering the need for mobility for both installation and maintenance, as well as accommodating the panel system. The calculation of the utilization area is detailed in the visibility area section.

1. Simulation for Utilization Area 1

The maximum capacity for placing solar panels based on calculations is 1146m^2. In this simulation stage, Jinko Solar panels of type 400M-54HL4 with a production capacity of 400Wp are used. Based on the type and area, the total number of solar panel capacities is calculated to be 464 units arranged in 16 series and 29 parallels, with a system voltage of 370 Volts. Each panel is equipped with an optimizer to regulate and stabilize the DC electrical current voltage. Optimizers are used in a significant number of interconnected solar panel circuits, aiming to prevent production instability caused by factors such as partially shaded/dirty panels or resistances/heat generation due to unstable electrical currents, which may lead to fire hazards. The optimizer used is the Solar Edge model S440 Worldwide with a normal power of 440 W, installed on each module.

Inverter selection is based on the panel circuit voltage of 370 V. In this simulation, SolarEDGE inverters of type SE100K-Delta-Grid with a capacity of 57.7 kWac are used. The number of inverters used is determined by calculations and the panel circuit type, totaling 3 units with a maximum total power capacity of 173 kWac.

Figure 2 shows the percentage of losses occurring in a solar panel system based on irradiation conditions and the solar panel system (panels and inverters only). The diagram indicates an efficiency of only 20.5% of irradiation being converted into electrical energy, with the efficiency being attributed to the panels themselves.

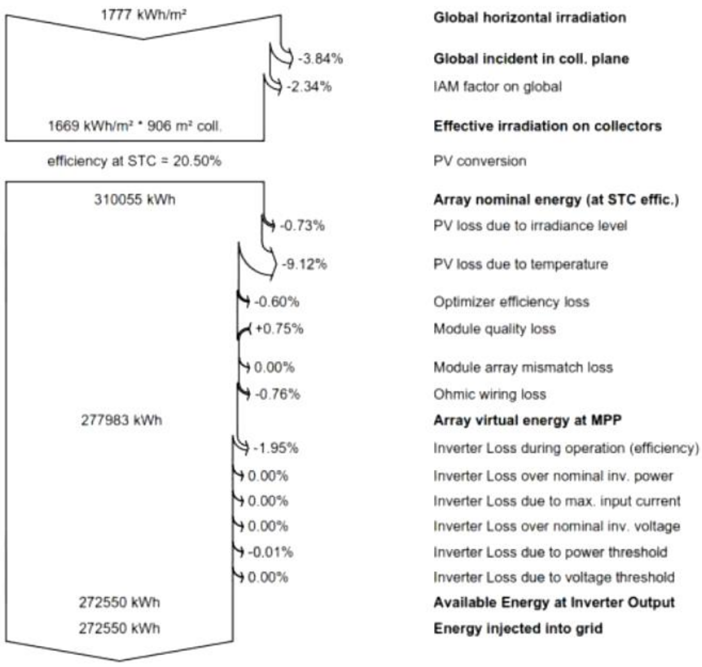

Figure 2. System Losses Diagram for Utilization Area 1

2. Simulation for Utilization Area 2

The maximum capacity for placing panels based on calculations is 118m^2. The simulation stage uses the same type of solar panels as the first simulation, Jinko Solar type 400M-54HL4 with a production capacity of 400Wp. Based on the type and area, the total number of solar panel capacities is calculated to be 36 units arranged entirely in series, resulting in an output voltage of 750V and a maximum production capacity of 13.14 kWp. Each panel is equipped with an optimizer to regulate and stabilize the DC electrical current voltage, using the Solar Edge model S440 Worldwide with a normal power of 440 W, installed on each module.

Inverter selection is based on the panel circuit voltage of 750V. In this simulation, SolarEDGE inverters of type SE12.5K-EU-APAC/AUS with a capacity of 12.5 kWac are used. The number of inverters used is determined by calculations and the panel circuit type, totaling 1 unit with a maximum total power capacity of 12.5 kWac.

Figure 3 shows the percentage of losses occurring in a solar panel system based on irradiation conditions and the solar panel system (panels and inverters only). The diagram indicates an efficiency of only 19.95% of irradiation being converted into electrical energy, with the efficiency being attributed to the panels themselves. The net energy production in utilization areas 1 and 2 only contributes 7% of the total electricity consumption in the UMN building area.

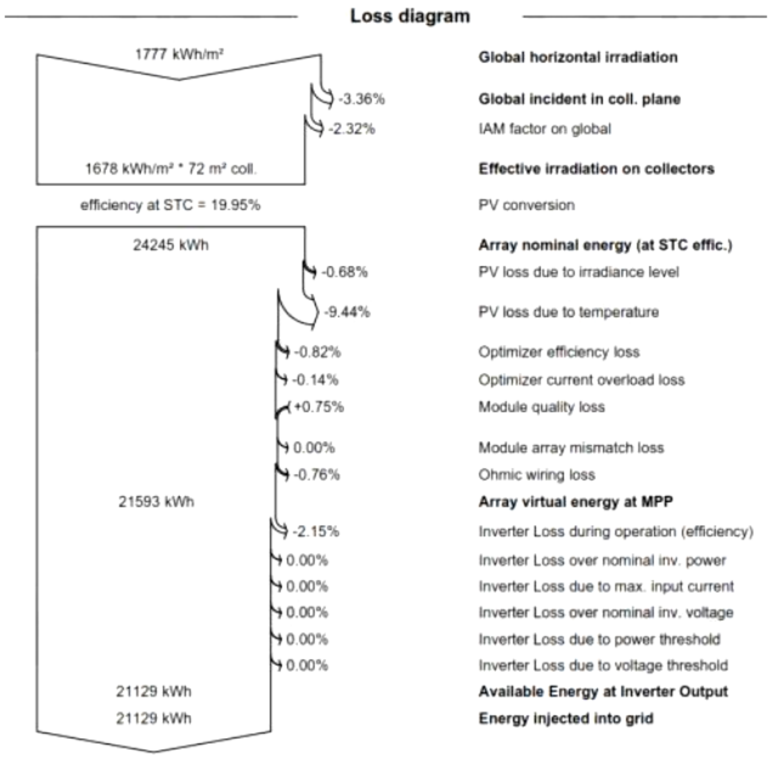

Figure 3. System Losses Diagram for Utilization Area 1

3. Cost Analysis (Economics)

The costs outlined are in accordance with the scope of the problem, which involves calculating the prices of solar panels and inverters. The assumption for the price of solar panel energy is Rp 1,035/kWh. The total for one year is = 293,679 kWh x Rp 1,035/kWh = Rp 303,957,765. The total investment (panels & inverters) for clean energy is Rp 1,252,096,790. An estimated additional assumption is Rp 800,000,000. The total assumption for total costs is 2,052,096,790. The system & solar panel lifespan is assumed to be 20 years. Rp

303,957,765 x 20 years = Rp 60,799,155,300. Profit: Rp 60,799,155,300 – Rp 2,052,096,790 = Rp 58,747,058,510.

D. Conclusion

The feasibility study for installing solar panels on Building B of UMN is designed with several assumptions. Firstly, the panels face north with a fixed plane orientation due to the east-west orientation of the sun, thus maximizing irradiation through the sun's direction, which changes every hour. The efficiency of solar panel reception is influenced by the brand, inverter, and quantity (in this study). From the total utilization area used as a solar panel area, it accommodates 7% of the total electricity needs of the entire Universitas Multimedia Nusantara.

A simple calculation of total financing is estimated at Rp 2.052 billion. The total production of solar panels for one year is 293,679 kWh, which when calculated through the LWP electricity tariff class B3 from PLN, amounts to Rp 303,957,765 per year. The lifespan of the solar panel system is assumed to be 20 years, and based on profit calculations, installing solar panels yields benefits, as the capital cost is recovered within 20 years.

The feasibility study for installation needs to be further reviewed, especially regarding the system (potential losses due to the system), costs, and the addition of energy storage options. Cost calculations need to consider the building owner's profit side to ensure more accurate and well-maintained calculations. The calculations in this study only consider profits, without calculating the repair and maintenance costs during the 20 years of system operation.

E. Acknowledgment

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F. References

[1] F. R. Saputri and V. Lee, "Web based Environment Monitoring System (Case Sudy: Laboratory of Universitas Multimedia Nusantara)," *G-Tech J. Teknol. Terap.*, vol. 7, no. 3, pp. 807–815, 2023.

[2] F. R. Saputri and B. Achmad, "Building Environment Monitoring System based on WiDo-Open Source IoT Node," *Proc. 3rd 2023 Int. Conf. Smart Cities, Autom. Intell. Comput. Syst. ICON-SONICS 2023*, no. December, pp. 85–90, 2023, doi: 10.1109/ICON-SONICS59898.2023.10434962.

[3] F. R. Saputri and S. F. Dhaneswari, "Sensor Design for Building Environment Monitoring System based on Blynk," *Ultim. Comput. J. Sist. Komput.*, vol. 14, no. 1, pp. 36–41, 2022, doi: 10.31937/sk.v14i1.2661.

[4] F. H. Ahram and S. A. S. Zakaria, "The contribution of green building in reducing the carbon footprint and attaining SDG 13," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1205, no. 1, 2023, doi: 10.1088/1755-1315/1205/1/012034.

[5] S. Baxi, "Green Building: An Innovative Approach to Reducing Carbon Footprint," Linkedin. Accessed: May 07, 2024. [Online]. Available: https://www.linkedin.com/pulse/green-building-innovative-approach-reducing-carbon-footprint-baxi

[6] U. S. E. I. Administration, "How much carbon dioxide is produced per kilowatthour of U.S. electricity generation?," eia.gov. Accessed: Apr. 22, 2024.

[Online]. Available: https://www.eia.gov/tools/faqs/faq.php?id=74&t=11
[7] I. Razzaq *et al.*, "Reduction in energy consumption and CO2 emissions by retrofitting an existing building to a net zero energy building for the implementation of SDGs 7 and 13," *Front. Environ. Sci.*, vol. 10, no. January, pp. 1–11, 2023, doi: 10.3389/fenvs.2022.1028793.
[8] S. A. Kalogirou, "Building integration of solar renewable energy systems towards zero or nearly zero energy buildings," *Int. J. Low-Carbon Technol.*, vol. 10, no. 4, pp. 379–385, 2015, doi: 10.1093/ijlct/ctt071.
[9] R. Liu, G. He, Y. Su, Y. Yang, and D. Ding, "Solar energy for low carbon buildings: choice of systems for minimal installation area, cost, and environmental impact," *City Built Environ.*, vol. 1, no. 1, pp. 1–21, 2023, doi: 10.1007/s44213-023-00019-8.
[10] S. C. M. Hui and S. C. Chan, "Integration of green roof and solar photovoltaic systems," *Jt. Symp. 2011 Integr. Build. Des. New Era Sustain.*, vol. 2011, no. November, pp. 1–12, 2011.
[11] H. Montagu-Pollock, J. O. Stoner, and R. Knijnenburg, "Rooftop solar," *Sci. Am.*, vol. 312, no. 3, p. 4, 2015.
[12] K. Pelletier, C. Wood, J. Calautit, and Y. Wu, "The viability of double-skin façade systems in the 21st century: A systematic review and meta-analysis of the nexus of factors affecting ventilation and thermal performance, and building integration," *Build. Environ.*, vol. 228, p. 109870, 2023, doi: https://doi.org/10.1016/j.buildenv.2022.109870.
[13] J. Maknun, T. Busono, and I. Hidayat, "Application of the Double Skin Facade Concept in an Effort To Increase the Thermal Comfort of Image Studio Room," *J. Archit. Res. Educ.*, vol. 2, no. 1, p. 90, 2020, doi: 10.17509/jare.v2i1.24128.
[14] F. R. Saputri, N. Pranata, and F. Dwiputra, "Analysis of Solar Power Plant Design Using RETScreen and PVSyst in Pekanbaru- Indonesia," in *2023 13th International Conference on Power, Energy and Electrical Engineering (CPEEE)*, 2023, pp. 496–500. doi: 10.1109/CPEEE56777.2023.10217460.
[15] Levina, "Discover Beautiful Views through UMN's Unique Campus Building Design," Universitas Multimedia Nusantara. Accessed: May 07, 2024. [Online]. Available: https://www.umn.ac.id/en/discover-beautiful-views-through-umns-unique-campus-building-design/