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Research Paper

The Use of BIM Technology in Analyzing Building Energy and Economic Feasibility of Solar Panel

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Abstract

Buildings contribute more than 40% of world energy consumption, so it is feared that it will cause energy problems in the future, especially in the construction sector. One solution to reducing this problem is by analyzing energy use at the initial design stage and utilizing solar energy as one of the solar power plants (PLTS) in office buildings. To analyze the use of energy in buildings, Building Information Modeling (BIM) was used. The purpose of this research is to analyze the annual energy level of office buildings in Palembang using BIM software, namely Autodesk Revit. The number of solar panels as well as the amount of energy were also identified using web-based software (HelioScope) resulting the economic feasibility as indicated by the installation of solar panels as a component of PV mini-grid. The results showed that the use of BIM technology in analyzing building energy can provide a detailed description of the building model at the design stage. Revit analysis indicates that the building consumed electrical energy per year for about 3,647,713 kWh with a roof area of 1,657 m^2. In addition, based on the HelioScope analysis, the use of renewable energy from the installation of PLTS was 152,900 kWh/year. Meanwhile, for economic feasibility analysis, the installation of PLTS in office buildings can provide a positive Net Present Value (NPV), indicating a feasible project.

Keywords

Energy Analysis, Building Information Modeling (BIM), Solar Panels, Revit, Feasibility Analysis, Net Present Value (NPV)

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1. INTRODUCTION

Most of the existing energy needs are met by fossil fuel energy such as petroleum, coal, and natural gas. However, the available energy supply is decreasing (Ramadhan and Rangkuti, 2016). Globally, buildings contribute more than 40% of the energy in the world today (Adi, 2017). Climate Change (CC) is a change in climatic factors such as rainfall, temperature, humidity, sunlight, and wind speed over a long period of time, usually 30-50 years (Islam et al., 2020). With the rise of global issues, it is hoped that the concept of building design must be more concerned with aspects of natural balance so that the earth is maintained (Jamala, 2015). It turns out that one of the energy efficiency programs, namely converting fossil energy into electricity-based energy, can reduce energy consumption and the greenhouse effect in coal mining in Bukit Asam (Gusman et al., 2018). To maintain the balance of nature, renewable energy is needed as alternative energy. Of the many renewable energy sources such as biomass, geothermal energy, solar energy, water energy, wind energy, ocean energy, hydropower has not been widely used, energy use through solar cells is the most potential alternative to be applied in the region Indonesia (Widayana, 2012). Solar energy is one of the energies that is being actively developed. To obtain electrical energy from sunlight, a solar panel is needed. Solar panels are the main equipment for the solar power generation system which functions to convert sunlight energy directly into electrical energy (Fachri et al., 2015). In its installation, solar panels are installed in areas that can be directly exposed to sunlight. The roof of the building is a strategic location for installing solar panels because it is not obstructed by the ceiling and walls of the building (Ramadhan and Rangkuti, 2016). In this study, the South Sumatra Police Headquarters building was modeled using the Building Information Modeling application, namely Autodesk Revit. Building information modeling is a new breakthrough in the world of construction and infrastructure where all building information data is stored as one building model object that has been created. BIM can produce 3D image output, estimate building area, analysis, to building operation and maintenance needs (Azhar, 2011).

Utilization of the BIM Revit software makes it easy to identify the area to be installed with solar panels, as well as the amount of solar radiation (insulation cumulative) that can be received by the field to be installed on the panel. After the identification is carried out, the calculation of installation costs is planned with the reference to the 2020 RAB, the calculation of the power output generated for profit analysis and the length of ROI that can be achieved if the electricity is sold directly to PLN (State Electricity Company).

2. LITERATURE REVIEW

2.1 Building Information Modeling (BIM)

BIM is a model-based process consisting of several pieces of information to make it easier for architectural, construction and engineering professionals to be able to design, build, and operate buildings more efficiently (Deepa et al., 2019). With BIM, designers can create 3D models that include data related to the physical characteristics of the building so that they can provide a real-time picture to the building owner. In principle, BIM is not a single process that is used to only create 3D models with the help of computers, but the process of creating models and data simultaneously and collaborating between actors in the development process is an activity that cannot be separated (Indraprastha, 2018). Now BIM has various functions that allow collaboration between stakeholders such as construction industry, government and of course, software developers who have taken aim at the concept of "Building Information Modeling" (Pogorelskiy and Alava, 2018).

2.1.1 Autodesk Revit

Autodesk Revit is building information modeling software for architects, landscape architects, structural engineers, mechanical, electrical and plumbing (MEP) engineers, designers and contractors. Revit can analyze sunlight (Morales and Santiago, 2016).

2.1.2 Solar Power Plant (PLTS)

Based on solar radiation data collected from 18 locations in Indonesia, solar radiation in Indonesia can be classified as follows: for the western and eastern regions of Indonesia with the distribution of irradiation in the Western Region of Indonesia (KBI) around 4.5 kWh/m^2/day with a monthly variation of about 10%; and in Eastern Indonesia (KTI) about 5.1 kWh/m^2/day with a monthly variation of around 9%. Thus, the average solar radiation potential in Indonesia is around 4.8 kWh/m^2/day with a monthly variation of around 9%. The sun is the main energy source that radiates enormous energy to the earth's surface. In clear weather conditions, the earth's surface receives about 1,000 watts of solar energy per square meter (Widayana, 2012). To utilize solar energy, a solar power plant (PLTS) is needed. PLTS is a power generation system where solar energy is converted into electrical energy by utilizing photovoltaic technology (Ramadhan and Rangkuti, 2016). There are two ways of working with PLTS, namely PLTS Off-Grid and PLTS On-Grid.

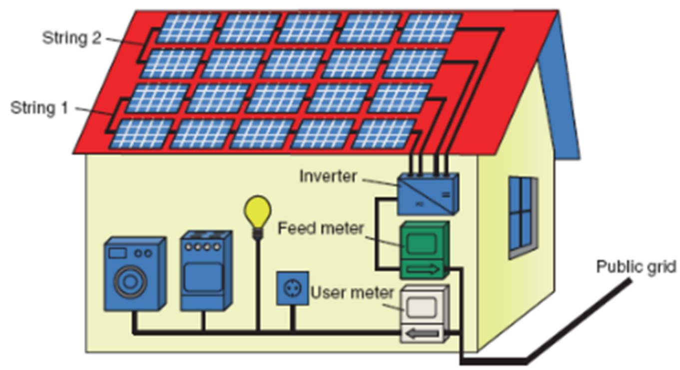

Figure 1. How the PLTS System Qorks in an on Grid House Building (Setiawan et al., 2018)

2.1.2.1 How the PLTS Off Grid Works

The way it works off the grid is a way of working that is not connected to the PLN network. This system is self-contained by relying on a battery that has stored energy from the solar panels.

2.1.2.2 How the PLTS On Grid Works

The way the on-grid PLTS generator works relies on sunlight to produce electrical energy and is connected to the electricity network (grid). How the Solar Power Generation system works by using Grid-Connected Photovoltaic solar cell panels for housing Photovoltaic solar cell modules convert solar energy into DC electricity. The resulting DC electric current will be flowed through an inverter (power regulator) which converts it into AC electricity, and will also automatically regulate the entire system. AC electricity will be distributed through an indoor distribution panel that will supply electricity as needed by electrical equipment. The amount and cost of electricity consumed at home will be measured by a WattHour Meters. Figure 1 shows the photovoltaic grid structure.

The advantages of an on-grid system among others; save on PLN electricity bills, can export and import electricity to PLN, fast BEP (break event point), low investment due to no battery, highly efficient solar module installation area, maintenance is very easy, suitable for home, industrial and commercial areas in urban areas/there is a PLN network. Lack of an on grid system is If the PLN is off then the electricity in the building will also be off

2.1.3 Main Component

The main components of PLTS Off-Grid are solar panels, solar/charger controllers, inverters, batteries, connecting panels.

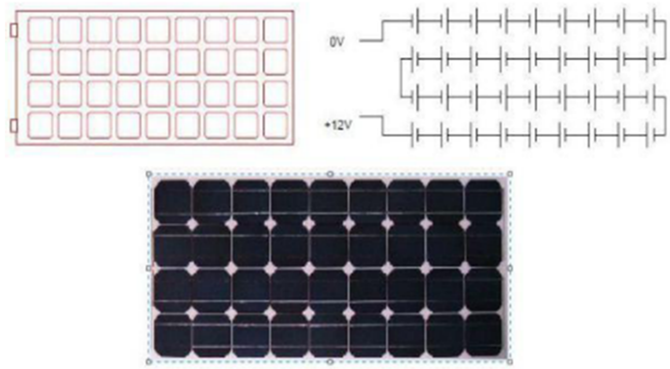

Figure 2. Solar Panel Modules that Have been Arranged (Setiawan et al., 2018)

2.1.4 Photovoltaic Module

Photovoltaic comes from the words photo meaning light and volt, a measurement of electricity. The main component of a photovoltaic solar system is a module which is an assembly unit of several photovoltaic solar cells. To manufacture photovoltaic modules, you can use crystal technology and thin film. Crystalline photovoltaic modules can be made with relatively simple technology, whereas to make photovoltaic cells high technology is required. A photovoltaic module is composed of several photovoltaic cells connected in series and parallel (Ramadhan and Rangkuti, 2016). Photovoltaic Cell/Solar Panel is the main tool that functions as a capture, converter, and producer of electrical energy. The size of this tool is only about 5 X 5 or 10 X 10 cm square but can change or generate power of 1-2 watts. This tool is assembled into several solar cell arrays-known as solar panels-according to the amount of power desired. This tool produces DC electrical energy.

In addition, several tools are needed to convert sunlight captured by solar panels into electrical energy including controllers, inverters, and kWh mater.

2.1.5 Controller

Serves to regulate the amount of voltage before it is divided into the load, and functions as a charger to charge the battery by utilizing excess energy from the PLTS.

2.1.6 Inverter

This tool serves to convert DC voltage into AC. This tool is very important because solar cells produce electrical energy in the form of DC.

2.1.7 kWh Meter

The tool used by the PLN to calculate the amount of consumer power consumption. This tool is very common in society. The main parts of a KWH meter are a voltage coil, a current coil, an aluminum plate, a fixed magnet whose job is to neutralize the aluminum plate from magnetic field induction and a mechanical gear that records the number of turns of the aluminum disc. This tool works using the magnetic field induction method where the magnetic field moves a dish made of aluminum. The rotation of the dish will move the counter digit as a display of the number of kWh. In the design of this PLTS, the kWh meter used is the export-import kWh meter.

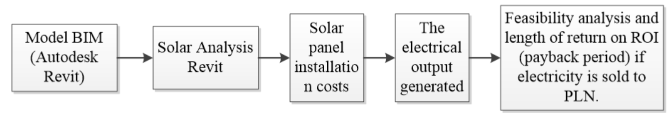

Figure 3. The Flow of the Solar Panel Analysis

3. METHODOLOGY

Research Methodology The design of this PLTS was carried out by following the steps as follows: Performs solar analysis on Revit. Revit makes it possible to calculate the incidence of solar radiation per building surface, articulate the potential for PV, and payback period; Calculation of the cost of installing solar panels on the roof of the South Sumatra Mapolda building; Calculate the power output (output) electricity generated from the installation of solar panels; Feasibility Analysis of Net Present Value; Analysis of the length of return on ROI (payback period) if electricity is sold to PLN; The sequence of research above can be illustrated in Figure 3 as follows.

3.1 Research Limitation

The research limitations are as follows: Autodesk Revit BIM application is used for 3-dimensional modeling, identifying the amount of annual electricity use and peak energy; For the installation of panels using references from the company Go Surya (PT. Permata Sinergi Madani) including the type of panels and inverters used and the unit price; Installation of solar panels only on the roof; The HelioScope application is used to identify the number of solar panels that can be installed as well as the amount of energy that can be generated from installing solar panels.

3.2 BIM Objects with Revit

The BIM model was created using the revit software, This study involved the original building, namely the South Sumatra provincial police office building in the city of Palembang. This building consists of seven floors with a system of reinforced concrete structures and light brick walls, the total area of this building is 14,304 m^2. See Figure 4 below.

3.3 Solar Panel

In the design of this study, a certified monocrystalline type solar panel was used. The solar panels used are TallMax type TSM-DE15M (II) solar panels with an output power of 390-415W. Below are the specifications of the solar panels (Setiawan et al., 2018).

Table 1. Solar Panel Specifications

Solar Cells	Monocrystalline
Cell Orientation	144 Cells (6 x 24)
Module Dimensions	2015 × 996 × 35 m
Weight	22.0 kg
Glass	3.2 mm, high transmission, AR coated heat strengthened glass
Encapsulant Material	EVA
Backsheet	White
Frame	35 mm anodized aluminium alloy
J-Box	IP 68 rated
Cables	Photovoltaic cable 4.0 mm^2, portrait: N 140 mm/P 285 mm, landscape: N 1,400 mm /P 1,400 mm
Connector	TS4

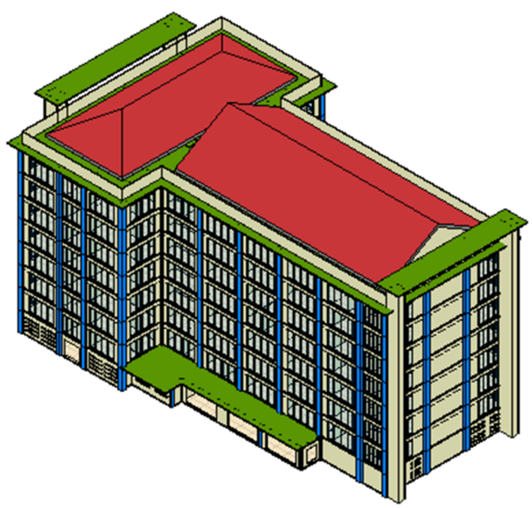

Figure 4. Revit BIM Model

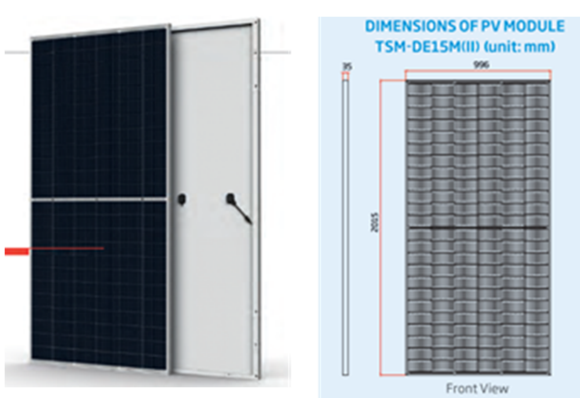

Figure 5. Monocrystalline Type Solar Panels

Figure 6. 600V Type Inverter

3.4 Inverter

In this design, inverters that are already on the market are used and have been certified to make it easier to select equipment. The inverter used is the inverter brand SOLIS with 600 volt power. Below are the specifications of the inverter.

4. RESULTS AND DISCUSSION

Retrieval of data using the building object of the South Sumatra Police Headquarters, the results and discussion are explained as follows:

4.1 BIM Analysis Using Revit

From the analysis of the BIM Model that has been made using Revit, it is known that the South Sumatra Regional Police Headquarters building has a total floor area of 14,179 m^2 (Figure 7). Then proceed with a web-based analysis of the Green Building Studio (GBS) to obtain the EUI value and the amount of peak electrical energy in the build-

Table 2. Inverter Specifications

Merk	SOLIS-125K-EHV-SG
INPUT DC	
Input Max. DC power	1500 V
Rated voltae	950 V
Start-up voltage	900 V
MPPT voltafe range	860 - 1450 V
Max input current	150 A
Max short circuit current	300 A
MPPT number/max. input strings number	Jan-20
OUTPUT AC	
Rated output power	125 kW
Max apparent output power	125 kVA
Max output power	125 kW
Rated grid voltage	3/PE, 600V
Rated grid frequency	50/60 Hz
Rated grid output current	120 A
Max output current	120 A
Power factor	>0.99 (0.8 leading - 0.8 lagging)
THDi	<3%
EFFICIENCY	
Max. Efficiency	99.10%
CEC efficiency	98.60%
GENERAL DATA	
Dimension (W*H*D)	1,178*713.5*315 mm
Weight	84 kg

ing, Figure 8 shows that the building has an EUI value of 962 MJ/m^2/year or equivalent to 267.24 kWh/m^2/year. The building's annual peak electrical energy requirement is 1,000.2 kW which is equal to 1,000,200 watts, so the apparent electric power is the amount of watts divided by 0.8, namely 1,250,250 VA or equivalent to 1,250.25 kVA for one year. If divided into 12 months, then per month obtained as much as 104.19 kVA. In accordance with the Regulation of the Minister of Energy and Mineral Resources No. 31 of 2014 and No. 9 of 2015 this building is included in the tariff group for low-voltage Medium Government offices, with a power of 6,600 VA-200 kVA (P-1)/TR) (PermenESDM, 2016). It is known that the electricity needs of buildings in one year are 3,647,713 kWh, while the cost of kWh is Rp 1,444.70/kWh.

After modeling and analyzing the building energy, the total area of the roof is 1,657 m^2. For the installation of solar panels of the type currently available on the market, it is not possible to install the entire roof area with a percentage of 100%, but there is an area that cannot be installed due to the bending/guttering of the roof itself and the type of panel that does not resemble roof coverings in general. To determine the number of panels installed, the research is continued using a web-based application, namely HelioScope, which will be explained in the next discussion.

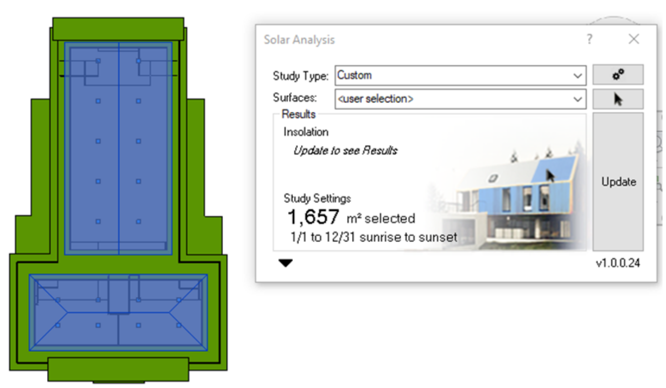

Figure 7. Overall Roof Area

Table 3. NPV

Year (n)	Discount Factor to 1/(1+r^n)	Present Value Net Cash Flow (PVNCF)	Comulative PVNCF
0			
1	0.9009	485,624,595	485,624,595
2	0.8116	437,499,635	923,124,229
3	0.7312	394,143,815	1,317,268,044
4	0.6587	355,084,518	1,672,352,563
5	0.5935	319,895,962	1,992,248,525
6	0.5346	288,194,561	2,280,443,085
7	0.4817	259,634,739	2,540,077,825
8	0.4339	233,905,171	2,773,982,995
9	0.3909	210,725,379	2,984,708,374
10	0.3522	189,842,684	3,174,551,058
11	0.3173	171,029,445	3,345,580,502
12	0.2858	154,080,581	3,499,661,083
13	0.2575	138,811,334	3,638,472,417
14	0.232	125,055,256	3,763,527,673
15	0.209	112,662,393	3,876,190,066
16	0.1883	101,497,651	3,977,687,717
17	0.1696	91,439,325	4,069,127,043
18	0.1528	82,377,771	4,151,504,813
19	0.1377	74,214,208	4,225,719,021
20	0.124	66,859,647	4,292,578,667
21	0.1117	60,233,916	4,352,812,583
22	0.1007	54,264,789	4,407,077,372
23	0.0907	48,887,197	4,455,964,570
24	0.0817	44,042,520	4,500,007,090
25	0.0736	39,677,946	4,539,685,036
	ΣPVNCF		4,539,685,036
	IA		1,521,920,000
	NPV = ΣPVNCF - IA		3,017,765,036

4.2 Solar Panel Identification

In making this design, it is done by designing the number of solar panels using the HelioScope application. HelioScope is a new program developed by Folsom Lab USA for the planning and evaluation of photovoltaic frameworks. HelioScope is a web-based tool. It uses weather files, shadow analysis, solar module physics, cable resistance, and other factors to perform the simulation. HelioScope uses the actual cable model and length based on the layout to calculate the cable resistance, and the amount of sunlight electricity production per hour (Tawsif Chowdhury, 2020). After analyzing the solar panels using HelioScope, a DC solar panel module with a total capacity of 131.2 kWp is obtained, an AC inverter with a capacity of 125.0 kW, and the annual production of solar panels is 152.9 MWh or 152,900 kWh/year. Figures 9 and 10. Shows the results of the HelioScope analysis.

4.3 Initial Investment Costs for Installing Solar Panels (IA)

From the analysis results obtained the required power of 131.2 kWP or equivalent to 131,200 WP. The cost of installing and procuring the inverter is used by the assumption of the company Go Surya (PT. Permata Sinergi Madani), which is $ 0.8 per WP. Rp 1,521,920,000.

4.4 Cash In Flow

Cash inflows are obtained from the purchase of electricity generated by solar power plants (PLTS). Based on the provisions of the Minister of Energy and Mineral Resources Regulation No. 17 of 2013 concerning the purchase of electricity by PLN from the Photovoltaic Solar Power Plant, which states that the purchase of electricity from PLTS will be set at a price of US$ 25 cents/kWh (twenty-five US cents per kilowatt hour). Assuming, 1 US$ = 14,500.00 IDR (Ramadhan and Rangkuti, 2016). So, 0.25 US$ = Rp 3,625 The total power generated per year is 152,900 kWh, so the

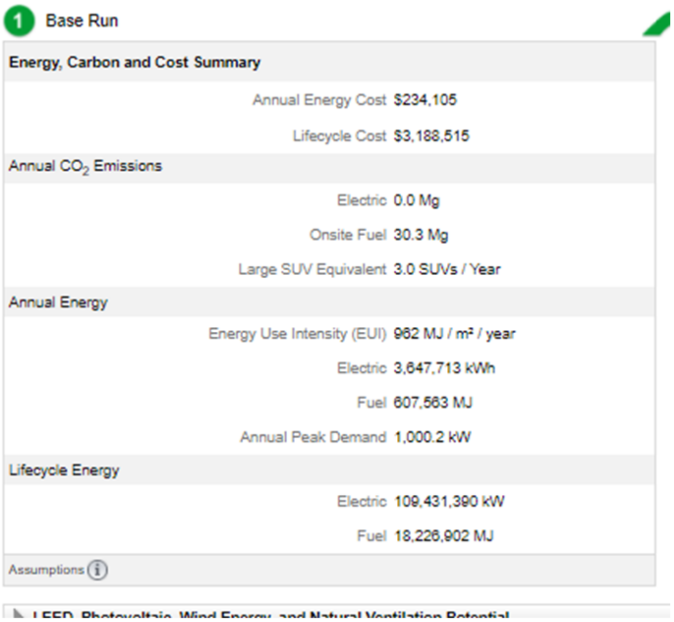

Figure 8. Results of the Analysis GBS

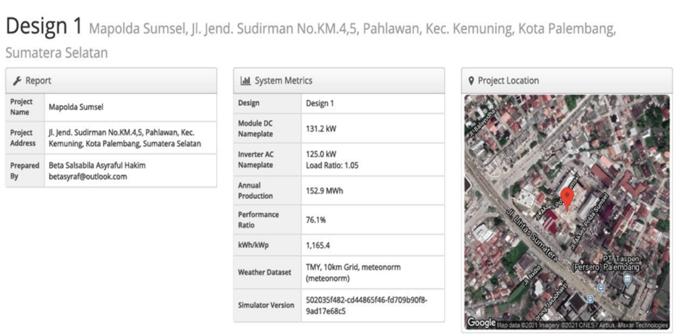

Figure 9. HelioScope Solar Panel Analysis

annual income generated from PLTS is Rp 3,625 x 152,900 kWh = Rp 554,262,500 - per year.

4.5 Maintenance and Operational Costs (M)

Maintenance and operational costs per year for PLTS are generally calculated as 1 - 2% of the total initial investment costs (Ramadhan and Rangkuti, 2016). Based on these references, in this study, the percentage for maintenance and operational costs per year of PLTS which includes costs for cleaning solar panels, maintenance and inspection costs for equipment and installations will be set at 1% of the total initial investment. The determination of the percentage of 1% is based on the fact that Indonesia only experiences two seasons, namely the rainy season and the dry season so that the costs for cleaning and maintaining solar panels are not as high as in a country that experiences four seasons in one year. In addition, this percentage determination is also based on the labor wage rate in Indonesia which is

Figure 10. Overall Roof Area

cheaper than the labor wage rate in developed countries. The maintenance and operational costs (M) per year for the PLTS to be developed are as follows:

M = 1% x Total Investment Costs
M = 1% x Rp 1,521,920,000
M = Rp 15,219,200 per year

If it is estimated that the age of the solar panels reaches 25 years, the total maintenance and operational costs for 25 years will be IDR 380,480,000

4.6 Total PLTS Investment

Total Investment for PLTS The total investment for PLTS is the total cost estimated for the PLTS, includes the total initial investment costs, and maintenance costs for 25 years.
Total investment = IDR 1,521,920,000 + IDR 380,480,000 -
Total investment = IDR 1,902,400,000

4.7 Feasibility Analysis

To identify whether the installation of solar panels has met the investment feasibility, it is necessary to conduct a feasibility analysis first. The feasibility analysis used is Net Present Value (NPV) and Payback Period (PP) (Hidayat et al., 2011).

4.8 Net Present Value (NPV)

Net Present Value or NPV is the difference between the present value of cash inflows and the present value of cash flows out of a certain period of time. An investment is at fair value if the NPV value is > 0. NPV calculations are made by projecting the calculation of income and expenses that occur over a period of 25 years (based on the use of an interest rate (interest) of 11% annually (Ramadhan and Rangkuti, 2016). NPV calculations can be calculated using

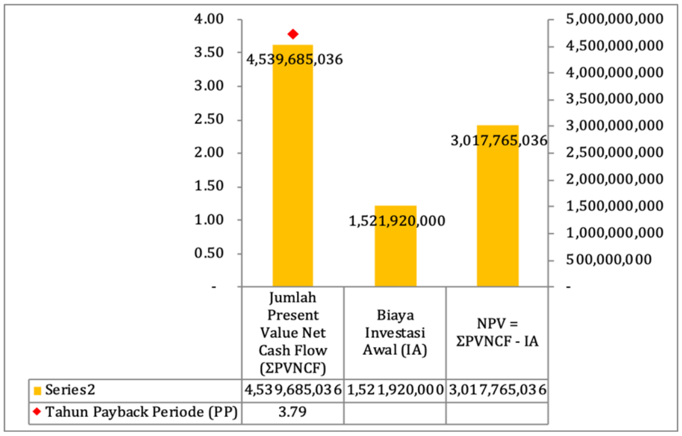

Figure 11. Graph of Payback Period (PP)

a formula 1:

$$NPV = \sum_{t=1}^{n} \frac{NCF_t}{(1+i)^t} - IA \quad (1)$$

IA = initial investment, NPV = net present value, I = interest rate per year, t = time of cash flow (years), NCF = net cash flow (inflows - outflows). It is known that the initial investment cost (IA) is IDR 1,521,920,000, cash flow in is IDR 554,262,500, cash outflow is IDR 15,219,200.

From Table 3 above, it can be seen that the NPV value is positive. So it can be concluded, the PLTS investment is acceptable. When compared with the age of the solar panels which is estimated to reach 25 years, from the results of the feasibility analysis obtained, the PLTS design will be very profitable.

4.9 Payback Period (PP)

The payback period (PP) is a period that shows how long the capital invested in the business can return. A business is considered feasible if the PP value is < the maximum PP value (Susilowati and Kurniati, 2018). PP calculations can be calculated using a formula 2:

$$PP = \frac{\text{Inventation value}}{\text{cash in net}} \text{x 1 year} \quad (2)$$

The total investment required for the manufacture of PLTS is IDR 2,869,777,544. So the length of ROI using the payback period method can be calculated using the formula below (Ramadhan and Rangkuti, 2016). Payback Period = (IDR 1,902,400,000/IDR 554,262,500) x 1 year. Payback Period = 3.79 years ≈ 3 years 9 months. Meaning shorter than the company's planned loan period, which is 10 years (Hidayat et al., 2011).

5. CONCLUSION

From the research results, the following conclusions were obtained: The area of the roof is obtained using the Autodesk Revit BIM application, which is 1,657 m^2. analysis of Green Building Studio or GBS where the annual electricity consumption is 3,647,713 kWh per year, the amount of building energy demand (annual peak demand) of 1,000.2 kW is equal to 1,000,200 watts, then the apparent electric power is the number of watts divided by 0.8, namely 1,250,250 VA or equivalent to 1,250.25 kVA for one year. if divided into 12 months, then per month is obtained as much as 104.19 kVA.

In planning the Solar Panel the use of an internet web-based application, namely HelioScope, from the HelioScope analysis obtained 320 units of solar panels with the monocrystalline type, the inverter used is the SOLIS brand inverter with 600 volt power. The solar panel components are designed to be placed on the roof with a slope of 10 degrees. Based on the number of solar panels installed, as many as 320 units with each solar panel power output of 410 watt/day are capable of producing electricity of 131,200 kWp and the power generated for 1 year is 152.9 MWh or 152,900 kWh/year.

From the data collection results, the initial investment cost for this PLTS is IDR 1,521,920,000 and the maintenance and operational costs are IDR 15,219,200. From the processing of the PLTS cash flow, it shows that with an estimated lifespan of the PLTS system for 25 years with an interest rate of 11%, a total cash flow of IDR 4,539,685,036. Economic analysis using the net present value (NPV) method is positive, where the difference between the net present value and the initial investment is IDR 3,017,765,036 so that the NPV analysis of this project is very feasible to be applied. With the data from the results of the calculation of the feasibility analysis, namely the payback period for 3 years and 9 months, compared to the estimated average usage life of solar panels which reaches 25 years, it can be concluded that making PLTS using this design will generate very good income and better for the future.

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