https://jurnaleeccis.ub.ac.id/
e-ISSN(Online): 2460-8122

Rooftop Solar Power Plant (PLTS) Design of Cita Buana School as a Nearly Zero Energy Building (nZEB) Development

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***Abstract*— The development of EBT in Indonesia is still far from the target of the National Energy Policy (KEN), the EBT mix of 23% in 2025 and 31% in 2050. One form of EBT development is utilizing solar energy in building technology that has high energy efficiency so that the number of electrical energy consumption is close to zero or called nearly Zero Energy Building (nZEB). Therefore, it is necessary to design the most optimal rooftop solar power plant (PLTS) so that it has good energy production and economic feasibility. To get a good energy production, simulation is carried out using HelioScope software by inputting data on the mechanical and electrical segments so that the amount of energy that can be produced by the rooftop solar power plant is obtained in detail. The results of the simulation of the rooftop solar power plant system that is installed on-grid in HelioScope are composed of 96 monocrystalline solar panels of Trina Solar TSM-DE20-605W (605W) and 3 3-phase inverters of Growatt MID 17KTL-X. The rooftop solar power plant produces an annual production of 84,08 MWh with a performance ratio of 82,1%. Thus, the average percentage of energy supply from rooftop solar power plants is 39,82% or can be said to be good in supplying the electrical energy needs of buildings so that the nZEB can be developed. From the simulation results, the economic feasibility is known, with the Break Even Point (BEP) reached in 12,4 years of the 25 years project period, and the Net Present Value (NPV) and Return on Investment (RoI) are positive, indicating that the rooftop solar power plant is profitable and feasible to develop.**

***Index Terms*— Rooftop Solar Power Plant, HelioScope, nearly Zero Energy Building, Feasibility Study**

I. Introduction

According to data on Indonesia's electricity consumption per capita reported by the Ministry of Energy and Mineral Resources (ESDM) of Indonesia, Indonesia consumed electricity of 1.123 kWh/capita in 2021, 1.173 kWh/capita in 2022, and 1.336 kWh/capita in 2023 which is still growing. The amount of electricity demand is mostly supplied from plants with fossil fuels, 42,38% coal, 31,4% oil, and 13,92% gas, then only 12,3% contribution from Renewable Energy (EBT) [1]. This minimal development of EBT in Indonesia is still far from the target of the National Energy Policy (KEN) set by the President in the form of PP No. 79 of 2014, namely the EBT mix of 23% in 2025 and 31% in 2050 [2]. The use of EBT to reduce dependence on fossil energy also has a promising impact on the environment, namely reducing greenhouse gas emissions due to hydrocarbon combustion as well as being an effort in realizing Indonesia's Net Zero Emission by 2060.

The growth of EBT that is being promoted in Indonesia must consider various elements, including the economy, potential, and capacity of the developed EBT itself [3]. One of the EBT that has advantages over other alternative energy is solar energy, a clean energy that is expected to reduce greenhouse action by 26% and has been regulated in the Master Plan for the Acceleration of Indonesian Economic Development (MP3EI) [4]. The development of solar energy to produce large amounts of electrical energy in a building requires integration with the central electricity grid (PLN). This has been regulated by the government through the Minister of Energy and Mineral Resources Regulation No. 49/2018 regarding the net metering incentive scheme [5]. The system applied in these conditions is an on-grid PLTS system that does not require expensive electricity storage batteries and requires additional maintenance.

This research focuses on the Special Education (SE) building or *Sekolah Luar Biasa (SLB)* in the Cita Buana School area. This SLB building is still 100% using electricity supplied by PLN, in other words still using non-renewable energy. The increasing demand for electricity due to the addition of electronic devices in the SLB building is one of the supporting factors for the need to develop buildings that can supply energy independently by utilizing the existing EBT. The shape of the building which has a flat roof is very suitable for developing solar power plants as an effort to optimize free space and the development of a nearly Zero Energy Building (nZEB).

II. Related Research

A. Solar Energy

The solar energy received by the Earth is only 69% of the total radiance or 3 × 1024 joules/year. The high potential of solar energy is because geographically Indonesia receives solar radiation for 6 to 8 hours per day [6]. Solar energy can be used directly or indirectly, examples of solar energy that can be used directly is water heaters with solar collectors and indirectly is electricity suppliers with photovoltaic [7].

Solar energy reaches Earth by being carried by electromagnetic waves that can be represented by photons with temperatures at the photosphere (the surface of the sun) reaching 6000 K. The source of energy from the sun itself is formed from nuclear reactions at the core of the sun which comes from the conversion of hydrogen to helium. The total solar radiation radiated at an average distance between the Earth and the sun in a plane perpendicular outside the Earth's atmosphere to the direction of incidence of solar rays is 1,361 W/m2. Solar radiation that radiates without modification in the atmosphere is called direct radiation, while radiation that spreads down the atmosphere and its energy is reflected to the surface of the environment is called diffuse radiation. The intensity of solar radiation that arrives at the Earth's surface per unit area and a certain time is known as solar insolation with units of kWh/m2 [8].

B. Rooftop Solar Power Plant (PLTS)

One form of utilization of solar energy in the form of light is by being used as a Solar Power Plant (PLTS). In principle, solar radiation will be converted into photons through solar cells (photovoltaic) and then converted into electrical energy in the form of direct current which can be converted into alternating current if needed [9]. The PLTS system requires an open space free of buildings, objects, or trees so that sunlight is not blocked and the energy absorbed by the panel can be maximized. This can be overcome by maximizing the placement of solar panels on the roof of the building.

The energy generation process that occurs in rooftop solar power plants can occur through connection with central electricity from PLN or in other words, electricity import- export with PLN. The government fully supports the development of rooftop PLTS in Minister of Energy and Mineral Resources Regulation No. 49/2018 on the use of rooftop PLTS systems by PLN consumers. This policy is a way to open PLN consumers from various sectors, ranging from the business sector, industry, government, and people who want to participate in contributing to efforts for energy security and independence, especially by utilizing solar energy [10].

The working principle of solar modules is to absorb sunlight-containing electromagnetic waves to produce kinetic energy and to release electrons into the conduction band so that an electric current arises. As the intensity of sunlight increases, the kinetic energy will also increase. In addition, the type of metal used also determines the performance of the solar module itself [11]. The electrical energy arising from this process is direct current (DC) electricity and then channeled to an inverter which functions to convert the DC voltage into an AC voltage which is later distributed to the load.

PLTS consists of 3 types of systems that are commonly used, off-grid PLTS systems use batteries to store their output power and are not connected to the PLN network. As for PLTS that is directly connected to the PLN network called the on-grid system, it is generally used for commercial-scale PLTS and the most suitable system for rooftop PLTS. Then, there are PLTS with hybrid systems and PLTS that use batteries but are also connected to the PLN network [12]. The majority of rooftop solar PV development uses an on-grid system that aims to reduce the use of PLN electricity to save on monthly bills and maintain the stability of its energy production [13]. The following is a diagram of an on-grid system rooftop solar power plant installation:

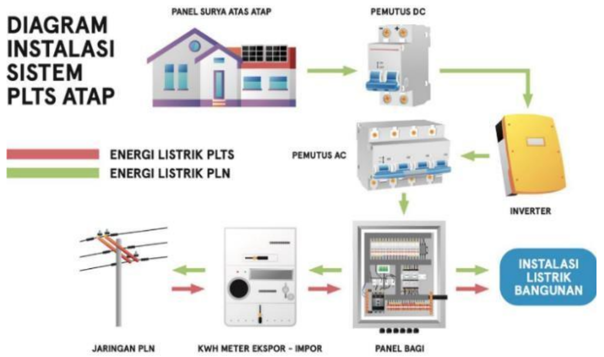


Fig. 1. Diagram of On-Grid Rooftop Solar System

The working principle of on-grid rooftop solar power plants starts with the operating solar power plant that will produce DC output current and then be connected to an inverter for conversion into AC current. When the power needs of consumers cannot be met by the electrical energy produced by the PLTS, electrical energy import occurs. Conversely, when the power produced by the PLTS exceeds the needs of the consumer load, the export of electrical energy occurs. The export-import activities of electrical energy will be automatically recorded on a special kWh meter commonly called kWh Exim [14].

C. Investment Feasibility of Rooftop Solar Power Plant

There are several things related to the economic aspects that need to be taken into account, among others:

1. Operation & Maintenance (O&M)

Operation & Maintenance (O&M) is the cost for maintenance, component inspection, and component cleaning paid by the PLTS owner with a value of 1% to 2% or can be set at 1.5% of the investment value [15]. The O&M value can be found by using the following equation:

$$O\&M = 1.5\% \times C \quad (1)$$

2. Life Cycle Cost (LCC)

Life Cycle Cost (LCC) is the cost of the sum of the initial planning costs and investment costs of the rooftop PLTS development, and O&M costs [15]. LCC costs can be found using the following equation:

$$LCC = C + MPW \quad (2)$$

3. Cost of Energy (COE)

Cost of Energy (CoE) is the cost required to produce energy per kWh [15]. The CoE value can be found using the following equation:

$$CoE = \frac{LCC \times CRF}{Econsumed} \quad (3)$$

4. Break Even Point (BEP)

Break Even Point (BEP) is a condition where the value of investment and income is at zero or when there is no profit or loss [16]. The BEP value can be found using the following equation:

$$BEP\ (Unit) = \frac{Fixed\ Cost}{COE - Variable\ Cost} \quad (4)$$

5. Net Present Value (NPV)

Net Present Value (NPV) is the difference between the investment value and the net cash value in a certain period [15]. The NPV value can be found using the following equation:

$$NPV = \sum_{t=1}^{n} \frac{Ct}{(1+i)^t} - Co \quad (5)$$

6. Return on Investment (RoI)

Return on Investment (RoI) is a ratio used to describe the profit or loss of an investment [17]. The RoI value can be found using the following equation:

$$RoI\ (\%) = \frac{Total\ Sales - Investment\ Cost}{Investment\ Cost} \times 100\% \quad (6)$$

D. Nearly Zero Energy Building (nZEB)

The Zero Energy Building concept is a building concept that meets its energy needs with renewable energy sources such as solar energy, water, wind, biogas, biomass, and others [18]. There are several inhibiting factors from the application of nZEB itself, such as the costs required in the development of nZEB are relatively expensive, the materials used are scarce and limited, nZEB lighting cannot be generalized in all regions in Indonesia, and several cases of indoor pollution that occur after applying the nZEB concept [19]. However, many studies emphasize that Building Integrated Photovoltaics (BIPV) or buildings connected to solar ower plants can be the main solution to generate clean electricity and reduce material and labor costs compared to the use of communal solar power plants [20]. The nZEB concept is determined by the building system, energy demand, energy generated, system losses, and energy exported. Thus, the relevance of using on-grid rooftop solar power systems that are directly connected to the PLN network in tropical climates such as Indonesia is very beneficial.

E. HelioScope

HelioScope is a web-based program used to perform simulations with a 3D view integrated with Google Earth. This 3D view on HelioScope helps users to know the potential for shadows or shading at the location planned to build a solar power plant [21].

III. METHODS

A. Research Flowchart

The flow used to achieve the objectives of this research was carried out in the following steps:

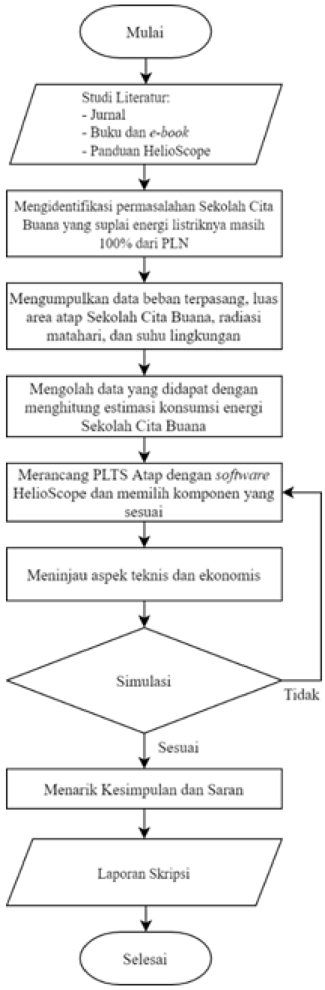


Fig. 2. Research Flowchart

B. Data Collection

The data needed to complete this research are primary and secondary data. Primary data is data taken by the author directly from the object of research using observation or interview methods in the form of installed load data and building roof area data. Secondary data is data taken by the author from previous research, guidebooks, handbooks, or others to be used as a reference and support the content of the research.

C. Design and Simulation

The design of the rooftop PLTS system begins after all the data needed by the author is fulfilled. Starting from setting the area that will be used to design the rooftop PLTS so that the PLTS capacity can be known. Next, the mechanical segment in HelioScope is set, namely the selection of the type of solar panel, its placement, the distance between the rows of panels, the distance between panels, the distance between panel frames, and the boundary between the panel and the end of the building. Then, settings are made in the electrical segment of HelioScope, namely the selection of inverters according to the needs of rooftop solar power plants. After all the settings are adjusted, then the simulation is carried out.

IV. Results and Discussions

A. Building Electrical Energy Consumption Data

The SLB Cita Buana School building has four floors which are still connected to the PLN 100% electricity network. The SLB Cita Buana School building is connected to PLN 380V/3 phase AC. The estimated electricity needs of SLB Cita Buana School are shown in Figure 3 below:

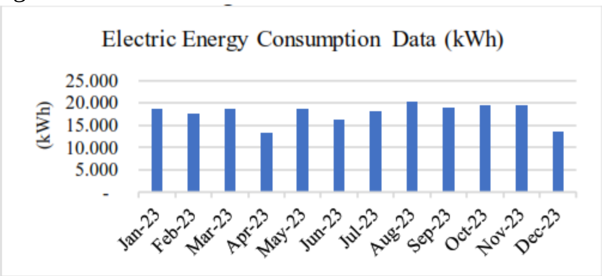


Fig. 3. Electric Energy Consumption Data

Based on Figure 3, the peak of electrical energy consumption at SLB Sekolah Cita Buana is in August, which is 20.234 kWh and the lowest electrical energy consumption is in April, which is 13.383 kWh. Thus, the total energy consumption of SLB Sekolah Cita Buana in one year is 213.606 kWh and the average energy consumption per month is 17.800 kWh.

B. Solar Radiation Intensity and Temperature Data

The location of the Cita Buana School SLB has coordinates -6,3158 latitude and 106,8146 longitude. The following is data on the intensity of solar radiation and air temperature of SLB Sekolah Cita Buana in 2022 taken from NASA's Power Data Access Viewer:

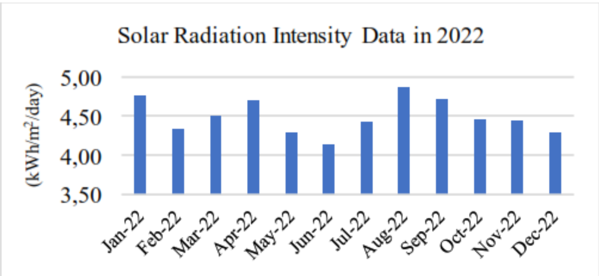


Fig. 4. Solar Radiation Intensity Data in 2022

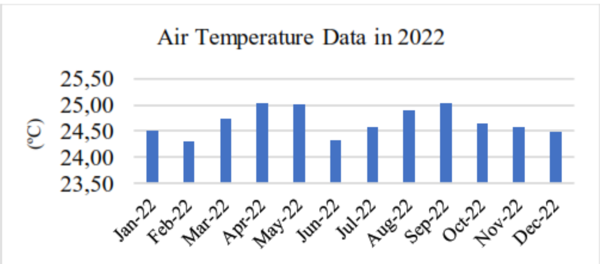


Fig. 5. Air Temperature Data in 2022

Based on Figure 4, all-sky shortwave downward irradiance data in 2022 at SLB Sekolah Cita Buana shows the highest radiation intensity value in August 2022 of 4.87 kWh/m2 /day and the lowest radiation intensity value in June 2022 of 4.14 kWh/m2 /day. Then Figure 5, the temperature at 2 meters data shows the highest air temperature value is in September 2022, which is 25.04ºC and the lowest air temperature is in February 2022, which is 24.02 ºC.

C. Technical Analysis of Rooftop Solar Design

1. Solar Panel

The design of a rooftop solar power plant at SLB Sekolah Cita Buana uses an on-grid system using monocrystalline solar panels. The SLB Sekolah Cita Buana building has a flat roof with a length and width of 38.7 m and 12.27 m, respectively. So the value of the area for solar panels is 474.8 m2. Based on the area obtained, a solar panel with a power capacity of 605Wp produced by Trina Solar type TSM-DE20-605W (605W) is used. The following is the TSM-DE20-605W (605W) specification data:

TABLE I
TSM-DE20-605W (605W)

Electrical Data (STC)	
Power Tolerance	0 ~ +5
Maximum Power Voltage (Vmax)	34,6 V
Maximum Power Current (Imax)	17,49 A
Open Circuit Voltage (Voc)	41,7 V
Short Circuit Current (Isc)	18,57 A
Module Efficiency (%)	21,4%
Mechanical Data	
Number of Cells	120 Sel
Module Dimensions	2172 x 1303 x 34 mm
Weight	30,9 kg
Temperature Ratings	
NOCT (Nominal Operating Cell Temperature)	43ºC(±2ºC)
Temperature Coefficient of Pmax	-0,34%/ºC
Operational Temperature	-40 ~ +85ºC
Warranty	
Power Warranty	25 tahun
Product Workmanship Warranty	12 tahun

The type of solar panel is the input data to the mechanical segment needed to perform simulations using HelioScope software. The following is the input data for the mechanical segment in HelioScope:

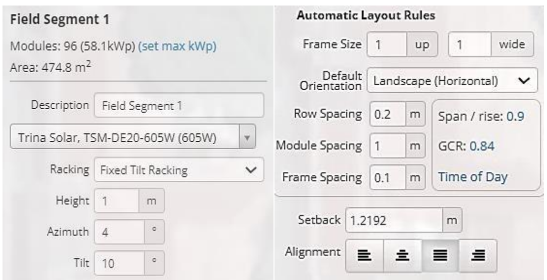


Fig. 6. HelioScope Mechanical Segment

The amount of power production and the number of modules automatically follow the input settings in Figure 6. The input settings produce 58.1 kWp of power from 96 solar modules on a roof area of 474.8 m2 .

2. Inverter

PLTS on the roof of SLB Cita Buana School uses a three-phase inverter type connected to the central network (PLN). The selection of the inverter to be used is based on the performance of the component in terms of its efficiency. The greater the efficiency value of the inverter, the better its performance. The relationship between the amount of solar panel output DC power connected to the inverter AC power is called the DC/AC ratio. One factor that affects the DC/AC ratio of the inverter is the type of components chosen. In this SLB Cita Buana School rooftop solar power system using an inverter Growatt MID 17KTL-X with the following specifications:

TABLE II
SPECIFICATIONS OF GROWATT MID 17KTL-X

Input Data (DC)	
Maximum DC Voltage	1100 V
Start Voltage	250 V
Maximum Input Current per MPPT Tracker	25 A
Maximum Short Circuit Current	32 A
MPPT Voltage Range	160V-1000V
Output Data (AC)	
Rated AC Output Power	17000 W
Nominal AC Voltage (range)	220V/380V, 230V/400V(340-440V)
Maximum Output Current	27,4 A
Total Harmonic Distortion	<3%
Efficiency	
Maximum Efficiency	98,75%

The known inverter type becomes the input to be simulated using HelioScope software. The following is the input data on the electrical segment in HelioScope:

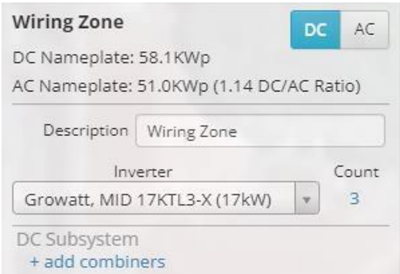


Fig. 7. HelioScope Electrical Segment

From the input of Figure 7, it is known that the system DC/AC ratio is 1.14 from the optimal DC/AC ratio of 1.25. The number of inverters used is set to the default of 3 inverters with a capacity of 17kW each.

The system configuration obtained from the calculation of the series-parallel relationship of solar panels and system simulation on HelioScope resulted in 6 strings of solar panels with each string consisting of 16 solar modules.

3. HelioScope Simulated Energy Production

The PLTS system is placed on the roof of SLB Sekolah Cita Buana under a measured area of 474.8 m2 . Solar panels are arranged horizontally as many as 96 pieces with a laying description as follows:

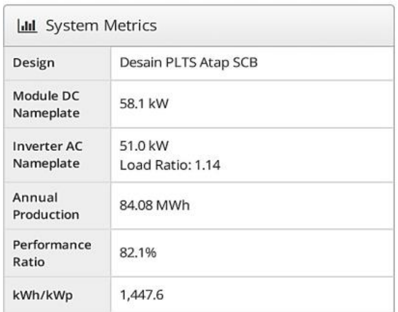
Fig. 8. Solar Panel Placement

The distance at which the solar panels are placed is one of the factors in the amount of power produced by the solar panels. After all the data is inputted on the mechanical segment (Figure 6) and electrical segment (Figure 7), a simulation is performed on HelioScope and produces monthly energy production data, PLTS system performance, and power losses that are known to the percentage of the source. The following is the energy production data obtained:

TABLE III
ROOFTOP SOLAR ENERGY PRODUCTION

Month	GHI (kWh/m^2)	POA (kWh/m^2)	Energy Production (kWh)
January	131,7	125,9	6.004,40
February	121,2	117,7	5.636,80
March	146,4	146,8	7.004,40
April	142,9	148,3	7.081,20
May	146,7	156,8	7.441,80
June	136,7	148,1	7.036,00
July	151,0	162,9	7.739,90
August	162,2	170,4	8.136,20
September	163,7	166,6	7.960,50
October	158,4	155,9	7.439,10
November	142,6	137,6	6.583,80
December	132,6	125,8	6.013,50

Based on Table 3, the highest energy production was in August, which amounted to 8,136.20 kWh. This is by the peak of the dry season in Indonesia from August to the end of September. In contrast, the lowest energy production was in February, which amounted to 5,636.80 kWh. In addition to simulation result data in the form of GHI, POA, and monthly energy production, annual energy production data, performance ratio, and specific yield are also obtained. The following is a system metrics report of the simulation results:



System Metrics

Design	Desain PLTS Atap SCB
Module DC Nameplate	58.1 kW
Inverter AC Nameplate	51.0 kW Load Ratio: 1.14
Annual Production	84.08 MWh
Performance Ratio	82.1%
kWh/kWp	1,447.6

Fig. 9. Rooftop Solar System Metrics Report

From Figure 9, the annual production or annual energy production of the system reaches 84.08 MWh with a high-performance ratio and specific yield of 82.1% and 1,447.6 kWh/kWp, respectively. As for the power loss data on the PLTS system obtained from the simulation, the following is the percentage of power loss in the PLTS system:

TABLE IV
POWER LOSS OF ROOFTOP SOLAR SYSTEM

Module Power (Wp)	**605 Wp**	
Source of Losses	**Losses Percentage (%)**	**Power (Wp)**
Soiling	1,1	6,6
Irradiance	0,6	3,6
Wiring	0,4	2,4
Temperature	6,8	41,1
Shading	1,1	6,6
Reflection	3,2	19,2
AC System	0,5	3,0
Inverter	1,8	10,8
Total Power Losses	**93,3 Wp**	

Based on Table 4, shows that the largest percentage of losses or power losses is generated from temperature, which is 6.6% of the installed module power. To overcome these power losses it is necessary to carry out appropriate monitoring, maintenance, and repair so that the PLTS system can work optimally.

The analysis of nZEB development in the SLB Cita Buana School building was carried out by calculating the percentage of energy supply from rooftop solar power plants with the total electrical energy needs in each month of the year. The following is the percentage of energy supply from PLTS every month of SLB Cita Buana School:

TABLE V
ENERGY SUPPLY PERCENTAGE OF ROOFTOP SOLAR POWER PLANT

Month	**Energy Supply Percentage**
January	31,97%
February	32,08%
March	37,29%
April	52,91%
May	39,62%
June	43,20%
July	42,32%
August	40,21%
September	42,05%
October	38,13%
November	33,90%
December	44,11%
Average	**39,82%**

Based on Table 5, the rooftop PLTS of SLB Cita Buana School has an average energy supply value of 39.82%. This percentage can be said to be high for rooftop PLTS in meeting the electrical energy needs of school buildings. The largest supply of electrical energy is in June, which is 52.91%, which can meet half of the school's electricity needs. The lowest energy supply was in January, which amounted to 31.97%.

D. Economic Feasibility of Rooftoop Solar Power Plant Design

1. Cost Budget Plan

The design of the SLB Cita Buana School roof solar power plant requires a fairly large calculation of the Budget Plan (RAB). The following is the RAB of the rooftop solar power plant design:

TABLE VI
COST BUDGET PLAN (RAB) FOR ROOFTOP SOLAR POWER PLANT

Component	**Amount**	**Unit Price**	**Total Price**
Solar Panel (Trina Solar, TSM-DE20-605 (605W))	96	Rp 3.137.930	Rp 301.241.280
Inverter (Growatt, MID 17KTL3-X)	3	Rp 17.101.707	Rp 51.305.121
kWh Meter Exim (DDS238-2 WiFi)	1	Rp 1.163.000	Rp 1.163.000
Roof Mounting System (Empery Solar, EPR-BM02)	58	Rp 78.448	Rp 4.549.984
PV Combainer Box	1	Rp 1.510.000	Rp 1.510.000
Installation Accessories	1	Rp 12.000.000	Rp 12.000.000
Services	*Crew*	Rp 35.500.000	Rp 35.500.000
TAX 10%			Rp 40.726.939
TOTAL			**Rp 447.996.324**

The prices of the components in Table 6 are volatile, affecting the size of the investment. In addition, the prices of these components are affected by the global economy and unstable market conditions.

2. Operation & Maintenance (O&M)

In the design of the SLB rooftop PLTS system, Cita Buana School takes into account O&M costs of 1.5% of the initial investment costs that will be incurred every year. The following is the calculation of O&M costs based on equation (1):

$$O\&A = 1{,}5\% \times Investment\ Cost$$
$$= 1{,}5\% \times Rp.447.996.324$$
$$= Rp.6.719.945$$

Based on the above calculations, the O&M cost of the PLTS system on the roof of the SLB Cita Buana School is Rp 6.719.945 in one year.

3. Life Cycle Cost (LCC)

The calculation of the LCC value uses the P-A relationship with a project duration of 25 years and the Bank Indonesia interest rate as of October 2023 of 6%. The following is the LCC calculation based on equation (2):

$$LCC = C + MPW$$
$$= C + O\&M\left[\frac{(1+i)^n - 1}{i1+i)^n}\right]$$
$$= Rp.447.996.324 + Rp.6.719.945\left[\frac{(1+0{,}06)^{25} - 1}{0{,}06(1+0{,}06)^{25}}\right]$$
$$= Rp.447.996.324 + Rp.85.903.449$$
$$= Rp.533.899.773$$

Based on the calculations, LCC value of the rooftop solar power plant in SLB Cita Buana School for 25 years is Rp 533.899.773.

4. Cost of Energy (CoE)

The CoE calculation based on equation (3) with a project duration of 25 years and a Bank Indonesia interest rate of 6% as of October 2023 can be expressed as follows:

$$CoE = \frac{LCC \times CRF}{A\ kWh}$$

$$= \frac{LCC \times \left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]}{(P_{module} \times Number\ of\ Modules \times PSH) \times 365\ days}$$

$$= \frac{Rp.533.899.773 \times \left[\frac{0{,}06(1+0{,}06)^{25}}{(1+0{,}06)^{25} - 1}\right]}{\left((605Wp - 93{,}34Wp) \times 96 \times 4{,}4975\right) \times 365days}$$

$$= \frac{Rp.533.899.773 \times 0{,}078}{80.633{,}61kWh/year}$$

$$= Rp.516{,}46/kWh$$

Based on the above calculations, it can be seen that the price of energy obtained from the PLTS on-grid system at SLB Sekolah Cita Buana is Rp 516,46/kWh and it can be concluded that /kWh of energy generated from the rooftop solar power plant system is profitable.

5. Break Event Point (BEP)

The Break Even Point (BEP) calculation is projected to be the target of a project in producing energy so that the PLTS project can break even. The shorter the break-even point can be reached, the stronger the reason to proceed with the project. The following is the calculation of BEP based on equation (4):

$$BEP = \frac{Fixed\ Cost}{COE - Variable\ Cost}$$

$$= \frac{Rp.447.996.324 + Rp.6.719.945}{Rp.516{,}46/kWh - \left(\frac{Rp.6.719.945}{84.077{,}6kWh}\right)}$$

$$= \frac{Rp.454.716.269}{Rp.Rp.\frac{516{,}46}{kWh} - Rp.79{,}92/kWh}$$

$$= 1.041.637{,}12\ kWh$$

$$BEP\ Revenue = 1.041.637{,}12\ kWh - Rp.516{,}46$$
$$= Rp.537.963.908$$

Based on the above calculations, the SLB Sekolah Cita Buana rooftop solar power plant must produce 1.041.637,12 kWh of energy to break even. Then, the revenue from energy sales that need to be received in order to break even is Rp 537.963.908. It is known that the PLTS annual energy production is 84,077.6 kWh so the energy savings that occur are Rp 43.422.717 per year and the BEP value is reached in 12.4 years from the assumed 25 years project period.

6. Net Present Value (NPV)

The Net Present Value (NPV) calculation is used to evaluate the economic viability of a project by calculating the present value of a project's expected cash flow over the life of the project. NPV can project the economic feasibility of the calculation. The following is the NPV calculation using Microsoft Excel based on equation (5):

TABLE VII
NET PRESENT VALUE (NPV)

Year	Investment	*Benefit*	O&M	*Net Cash Flow* (*Benefit* - O&M)	DF (6%)	*PV Net Cash Flow*
0	Rp447.996.323,50					
1		Rp41.644.182,29	Rp6.719.944,85	Rp34.924.237,44	0,943	Rp32.947.393,81
2		Rp57.661.175,48	Rp6.820.744,03	Rp50.840.431,46	0,890	Rp45.247.803,01
3		Rp73.678.168,67	Rp6.921.543,20	Rp66.756.625,48	0,840	Rp56.050.150,02
4		Rp89.695.161,86	Rp7.022.342,37	Rp82.672.819,49	0,792	Rp65.484.616,44
5		Rp105.712.155,05	Rp7.123.141,54	Rp98.589.013,51	0,747	Rp73.671.446,10
6		Rp121.729.148,24	Rp7.223.940,72	Rp114.505.207,53	0,705	Rp80.721.652,98
7		Rp137.746.141,43	Rp7.324.739,89	Rp130.421.401,54	0,665	Rp86.737.680,87
8		Rp153.763.134,62	Rp7.425.539,06	Rp146.337.595,56	0,627	Rp91.814.017,85
9		Rp169.780.127,81	Rp7.526.338,23	Rp162.253.789,58	0,592	Rp96.037.768,75
10		Rp185.797.121,00	Rp7.627.137,41	Rp178.169.983,60	0,558	Rp99.489.188,24
11		Rp201.814.114,19	Rp7.727.936,58	Rp194.086.177,61	0,527	Rp102.242.177,22
12		Rp217.831.107,38	Rp7.828.735,75	Rp210.002.371,63	0,497	Rp104.364.744,98
13		Rp233.848.100,57	Rp7.929.534,93	Rp225.918.565,65	0,469	Rp105.919.439,42
14		Rp249.865.093,76	Rp8.030.334,10	Rp241.834.759,67	0,442	Rp106.963.747,42
15		Rp265.882.086,95	Rp8.131.133,27	Rp257.750.953,68	0,417	Rp107.550.467,34
16		Rp281.899.080,14	Rp8.231.932,44	Rp273.667.147,70	0,394	Rp107.728.055,67
17		Rp297.916.073,33	Rp8.332.731,62	Rp289.583.341,72	0,371	Rp107.540.949,33
18		Rp313.933.066,52	Rp8.433.530,79	Rp305.499.535,73	0,350	Rp107.029.865,54
19		Rp329.950.059,71	Rp8.534.329,96	Rp321.415.729,75	0,331	Rp106.232.080,46
20		Rp345.967.052,90	Rp8.635.129,14	Rp337.331.923,77	0,312	Rp105.181.688,36
21		Rp361.984.046,09	Rp8.735.928,31	Rp353.248.117,79	0,294	Rp103.909.842,35
22		Rp378.001.039,28	Rp8.836.727,48	Rp369.164.311,80	0,278	Rp102.444.978,12
23		Rp394.018.032,47	Rp8.937.526,65	Rp385.080.505,82	0,262	Rp100.813.021,78
24		Rp410.035.025,66	Rp9.038.325,83	Rp400.996.699,84	0,247	Rp99.037.582,81
25		Rp426.052.018,85	Rp9.139.125,00	Rp416.912.893,85	0,233	Rp97.140.133,31
Total	**Rp447.996.323,50**	**Rp5.846.202.514,35**		**Rp5.647.964.141,20**		Rp2.292.300.492,19

Based on Table 7, the NPV value is obtained by reducing the PV Net Cash Flow by the initial investment cost so that the NPV value of Rp 1.844.304.168,69 is obtained, which indicates that the SLB Sekolah Cita Buana rooftop solar power plant project is profitable because the NPV value> 0.

7. Returnn on Investment (RoI)

The calculation of Return on Investment (RoI) is carried out to find out whether the investment costs that have been incurred get adequate profits or not. The following is the RoI calculation based on equation (6):

$$RoI = \frac{Total\ Sales - Investment\ Cost}{Investment\ Cost} \times 100\%$$

$$= \frac{(Rp. 516{,}46 \times 84.077{,}6kWh \times 25tahun) - Rp. 447.996.324}{Rp. 447.996.324} \times 100\%$$

$$= 142\%$$

Based on the above calculations, a RoI value of 142% is obtained, which shows that the SLB Sekolah Cita Buana rooftop solar power plant project allows it to make a profit exceeding the initial investment cost. The high positive RoI value is very promising for building rooftop solar power plants as a profitable long-term investment.

V. Conclusion and Suggestions

A. Conclusion

The design of PLTS on the roof of SLB Cita Buana School which has been technically simulated using HelioScope software and taking into account economic feasibility, can be concluded as follows.

The rooftop solar power plant of SLB Sekolah Cita Buana uses an on-grid system with a composition of 96 solar panels and 3 inverters in an area of 474.8m2. The solar panels used are monocrystalline type branded Trina Solar TSM-DE20-605W (605W) and the inverter used is branded Growatt MID 17KTL-X. The solar panel configuration consists of 6 strings with each string consisting of 16 solar modules.

The rooftop PLTS of SLB Cita Buana School is said to be feasible to be realized based on a review of the technical aspects with energy production in one year reaching 84,077.6 kWh and a performance ratio of 82.1%. This rooftop PLTS is able to supply electrical energy with an average energy supply of 39.82% which is economically beneficial so that it can reduce the building's electricity bill every month. Thus, the nZEB concept can also be developed.

The calculation of the economic feasibility of PLTS on the roof of SLB Cita Buana School with an initial investment cost of Rp447,996,324 in a project period of 25 years can be declared feasible to be realized based on the calculation of BEP, NPV, and RoI.

B. Suggestion

This research maximizes the roof area for the installation of solar power plants because the available area is limited but the power demand is high. Therefore, it is still possible to consider the types of panels and inverters that can supply more electrical energy so that the percentage of energy supply can be increased again. Then, if this rooftop solar project is realized, it is expected to carry out maintenance by the provisions so that the performance of the system does not decrease and can even increase.

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