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Rooftop PV Plant Development Planning at the Central Java Provincial DPRD Secretariat Office

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ABSTRACT

Central Java Province targets the achievement of the new and renewable energy (EBT) portion in the energy mix by 2030 at 22.55%. In order to achieve this target, the Central Java Provincial Government has consistently developed the use of EBT, one of which is through the construction of rooftop solar power plants (Rooftop PV Plant) in government buildings. In addition to requiring a fairly high initial investment cost, the construction of a Rooftop PV plant connected to the PT. PLN (Persero) requires a fairly complicated process, so proper planning must obtain optimal results. This paper will discuss an example of a Rooftop PV Plant development plan at the Secretariat Office of the Central Java Provincial DPRD, including the use of electrical energy prior to the installation of a Rooftop PV Plant; an analysis of the condition and availability of the location; the design and system of a Rooftop PV Plant; an estimate of the total potential energy that can generate; the investment costs of a Rooftop PV Plant; as well as evaluating the results of using Rooftop PV Plant. The electricity bill at the Central Java Provincial DPRD Secretariat Office prior to installing Rooftop PV Plant is Rp. 91.308.323,- per month. The recommended PV design, built on an area of 197 m2, is a rooftop on-grid PV Plant system with 6 PV arrays, each of which PV arrays are installed with as many as 20 solar modules arranged in series. The total number of solar modules installed is 120 solar modules with a total capacity equivalent to 30 kWp. Based on the simulation results using the PVSyst 6.4.3 software, the Rooftop PV Plant system can generate electrical energy of up to 43,420kWh per year or equivalent to 118.9kWh per day with a performance ratio of 79.4%. The potential for saving electricity costs from the simulation results can reach Rp. 4,034,441.- per month. The results of the evaluation of the utilization of the Rooftop PV Plant through the recording of the inverter monitoring system within 1 (one) year after installation shows the amount of electrical energy produced is 40,558 kWh, so that the manager of the Secretariat of the DPRD Central Java Province office can save a budget of Rp. 3,768,514.- per month from the use of the Rooftop PV Plant. This figure is not much different from the simulation results at planning. There is a difference in the cost savings of electricity payments at the Central Java Provincial DPRD Secretariat Office during 2020 of Rp. 4,493,300,- excluding savings due to the use of Rooftop PV Plant due to implementing the work from home (WFH) system during the COVID-19 pandemic, which resulted in a significant reduction in the use of electrical energy.

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1. INTRODUCTION

Central Java Provincial Government's target access portion of new and renewable energy (EBT) in the energy mix (energy mix) in 2030 amounted to 22.55% (Pemerintah Provinsi Jawa Tengah, 2018). In order to achieve these targets, the Central Java Provincial Government has consistently developed the use of EBT, one of which is through the construction of rooftop solar power plants (PV Plant) in Government buildings. Also, in line with the mandate of the Peraturan Presiden Nomor 22 Tahun 2017 tentang Rencana Umum Energi Nasional in the form of the obligation to utilize solar energy at least 30% of the total roof area of Government buildings (Pemerintah Republik Indonesia, 2017). The construction of the Rooftop PV Plant in Government buildings can also be a means of socializing the general public to use renewable energy in daily life. People must realize the importance of saving fossil fuels and turn to alternative renewable energy to conserve natural resources, one of which is solar energy (Amalia, 2019).

As a form of seriousness in increasing the utilization of the Rooftop PV Plant, Central Java Province is committed to being a pioneer solar province (Central Java Solar Province) in collaboration with the Institute of Essential Services Reform (IESR), Asosiasi Energi Surya Indonesia (AESI) and the Ministry of Energy and Mineral Resources (Tumiwa & Simanjuntak, 2020). According to the data released by the Ministry of Energy and Mineral Resources, with a total solar energy potential of 8,753 MW (Direktorat Jenderal EBTKE, 2020), Central Java Province has at least a technical potential PV Plant on the roof of government buildings of 2.4 MWp, which comes from the Central Java Provincial Government office building and the Mayor's Office in Central Java (Institute for Essential Services Reform, 2021).

According to Peraturan Menteri Energi dan Sumber Daya Mineral Nomor 49 Tahun 2018 tentang Penggunaan Sistem Pembangkit Listrik Tenaga Surya Atap oleh Konsumen PT. Perusahaan Listrik Negara (Persero), Rooftop PV Plant System generates electrical energy using photovoltaic modules installed and placed on the roof, wall, or other parts of a building and channelled through the consumer electrical connection system PT. PLN (Persero) (Pemerintah Republik Indonesia, 2018). In addition to requiring a relatively high initial investment cost (Diantari, Erlina, & Widyastuti, 2018), distribution to the network of PT. PLN (Persero) requires a fairly complex process, so proper planning must be done to obtain optimal and reliable results (Hani, Santoso, Subandi, & Arifin, 2020). One of the essential things in planning the Rooftop PV Plant is to estimate the sun's potential on the roof surface of the building to know the amount of energy produced (Redweik, Catita, & Brito, 2013).

This paper will discuss an example of planning the construction of a Rooftop PV Plant in a Government building, namely the Central Java Provincial DPRD Secretariat Office. This building, also known as Gedung Setwan Jateng, is one of the Government's assets which is the identity and symbol of the development of the people of Central Java. Through good planning, it is hoped that the construction of one of the pilot projects Rooftop PV Plant, in the Central Java Provincial Government building can be successful. Some of the things that will discuss in this paper are related to the use of electrical energy in the building prior to the installation of the Rooftop PV Plant, analysis of the condition and availability of the location, design, and system of the Rooftop PV Plant, estimation of the total potential energy that can generate, Rooftop PV Plant investment costs, and evaluation of the results of Rooftop PV Plant utilization at the Central Java Provincial DPRD Secretariat Office.

2. METHODS

2.1. Library Studies

This method is used to know in-depth about the object of study through observation and review of technical documents, records, reports, and other documented data. Secondary data used in this study include regulations and policies related to Rooftop PV Plant, contract documents for Rooftop PV Plant construction, final reports on the implementation of Rooftop PV Plant construction, basic electricity tariffs, and data obtained through literature and journals related to the utilization of Rooftop PV Plant.

2.2. Field Observation

This method is used to collect data and information in the field through direct observation and measurement. Measurement activities in the field include measuring light intensity, measuring area, recording coordinates, and recording the production of electrical energy generated through an inverter. The work tools needed in field observations are listed in Table 1.

Table 1. Work tools

Tool	Function	Capacity
Lux Meter	Measures light intensity	0 to 999 lux
Measuring Tape	Measures an area	0 to 999 meters
Handheld GPS	Pick up location coordination point	-
Camera	Documenting field conditions	wide-angle, autofocus

2.3. Data analysis

This paper, a computer simulation to determine the estimated total potential energy generated carried out using the PVSyst 6.4.3 software. PVSyst is a software package developed by Swiss physicist Andre Mermoud and electrical engineer Michel Villoz which is used for the complete learning, sizing, and data analysis of a solar cell or photovoltaic (PV) technology systems. This method analyzes the measurement data to calculate the PV plant's potential energy through computer-based simulations to assess the Rooftop PV Plant system (Tarigan, Djuwari, & Kartikasari, 2015). Computer simulations were carried out to find PV Plant components and installation (Kumar, Kumar, Rejoice, & Mathew, 2017). Meanwhile, using the Rooftop PV Plant was evaluated using Microsoft Excel software.

2.3.1. Calculation of the potential capacity of the solar module

To determine the number of solar modules that can be installed and the maximum potential capacity of the PV Plant generator in each rooftop area, it can be calculated using equations (1) and (2) below:

$$\text{N modules} = \frac{\text{p area}}{\text{p module}} \text{ x } \frac{\text{l area}}{\text{l module}} \quad (1)$$

Where:

N modules = Number of solar modules
p area = Length of available rooftop area
p module = Length of solar module
l area = Width of the available rooftop area
l module = Width of solar module

$$\text{Peak Power} = \text{N modules} \times \text{P max modules} \quad (2)$$

Where:

Peak Power = Max. power capacity of Rooftop PV Plant
N modules = Number of solar modules
P max module = Max. power of a solar module used

2.3.2. Calculation of generating capacity

To calculate the peak power of the installed Rooftop PV Plant by the design that has been made, equation (2) can be used so that the following results are obtained.

2.3.3. Calculation of estimated potential energy yield per day

The calculation of the potential energy yield per day was carried out using the following equation (3):

$$E = \text{Peak Power x Peak Sun Hour} \quad (3)$$

Where:

E = Potential energy yield per day
Peak Power = Maximum power capacity of Rooftop PV Plant
Peak Sun Hour = Average adequate solar irradiation time

3. RESULT AND DISCUSSION

3.1. Use of Electrical Energy in Buildings Before Installing Rooftop PV Plant

Based on the identification and data collection results of electricity bill payment PT. PLN (Persero) every month at the Central Java Provincial DPRD Secretariat Office building for the last 1 (one) year shows the amount of electrical energy used in the building before the Rooftop PV Plant installation is 1,021,480kWh with the bill to be paid is Rp. 1,095,699,874,- in 1 (one) year or equivalent to Rp. 91.308.323,- per month, as can be seen in Table 2.

Table 2. The use of electrical energy before installing the Rooftop PV Plant

No.	Code	Payment Date	Rate	Power (Va)	Usage (kWh)	Total Bill (Rp.)
1	201901	16 Jan 2019	P2	865000	80.130	86.042.245
2	201902	13 Feb 2019	P2	865000	79.390	84.892.529
3	201903	13 Mar 2019	P2	865000	68.860	73.669.852
4	201904	11 Apr 2019	P2	865000	77.280	82.417.015
5	201905	13 May 2019	P2	865000	72.500	77.486.701
6	201906	17 Jun 2019	P2	865000	76.900	82.655.244
7	201907	9 Jul 2019	P2	865000	70.540	76.052.147
8	201908	12 Aug 2019	P2	865000	86.990	92.961.255
9	201909	11 Sept 2019	P2	865000	103.120	111.341.172
10	201910	10 Oct 2019	P2	865000	104.880	112.361.414
11	201911	12 Nov 2019	P2	865000	104.910	112.288.910
12	201912	10 Dec 2019	P2	865000	95.980	103.531.390
		Total			1.021.480	1.095.699.874

3.2. Analysis of Conditions and Availability of Rooftop PV Plant Construction Sites

The Central Java Provincial DPRD Secretariat Office is located on Jl. Pahlawan No. 7, Mugassari Village, South Semarang District, Semarang City, Central Java Province, precisely located at coordinates 6.993296 South Latitude and 110.420595 East Longitude.

3.2.1. Available area measurement

The total roof area of the building is 1,600 m2, but not the entire roof area can be used because there is an elevator control building and other objects, namely the outdoor unit from the air conditioning machine. It is necessary to measure the area used to install a Rooftop PV Plant using shop drawings from buildings, satellite imaging, and direct measurements in the field.

The results of direct measurements in the field of potential solar power areas based on overlays from shop drawings of buildings and satellite imaging are presented in Table 3 below:

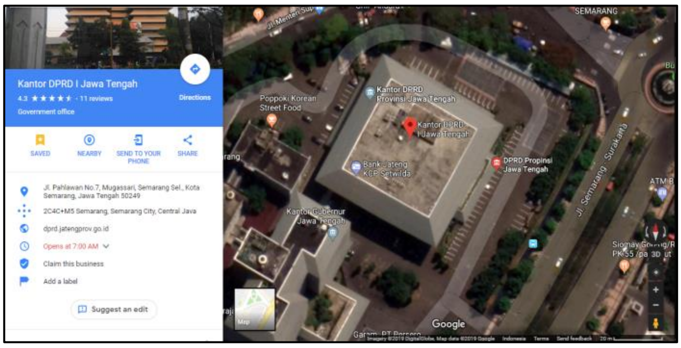


Figure 1. Location of the Central Java Provincial DPRD Secretariat Office based on Google Maps

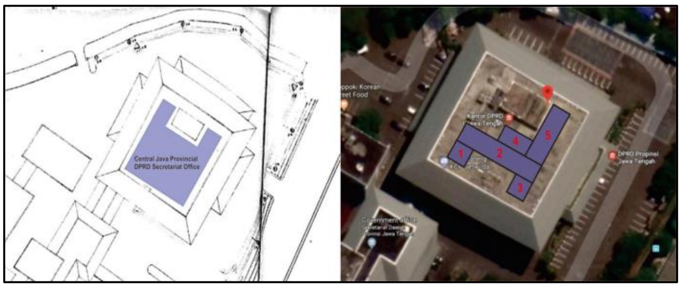


Figure 2. Solar potential area based on shop drawings and satellite imaging

Table 3. The results of the measurement of the rooftop area of the Central Java Provincial DPRD Secretariat Office

Zone	Length (m)	Width (m)	Area (m2)
1	9	9	81
2	32	6	192
3	9	9	81
4	12	6	72
5	15	9	135

Table 4. The results of the calculation of the maximum potential capacity of the solar module

No.	Length (m)	Width (m)	Area (m2)	Number of Modules (N)	Potential Peak Power (kWp)
1	9	9	81	49	12
2	32	6	192	116	29
3	9	9	81	49	12
4	12	6	72	44	11
5	15	9	135	82	20

*) Using 250Wp solar module size

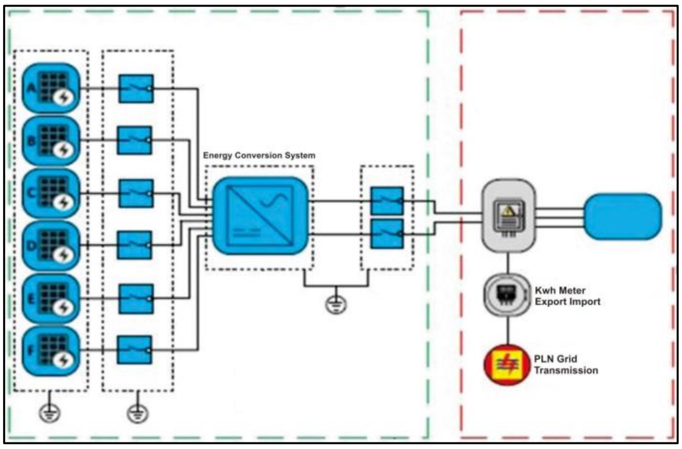


Figure 3. Rooftop PV Plant network topology on-grid system

3.2.2. Potential capacity of the solar module

Using the data on the length and width of each measured area, it is possible to determine the number of solar modules installed in the rooftop area. At this stage, the assumption is that each area will be covered entirely using a 250Wp solar module with dimensions of 1,650mm x 991mm (units and spare parts are often found in the market). To determine the number of solar modules that can be installed and the maximum potential capacity of PLTS generators in each rooftop area, it is calculated using equations (1) and (2) so that data on the number and maximum potential capacity of solar modules for each rooftop area is obtained as written in Table 4.

3.3. PV Plant Design and System

3.3.1. Rooftop PV Plant system topology

The topology of the Rooftop PV Plant system that is suitable for installation in the Central Java Provincial DPRD Secretariat Ofice is the topology of the Rooftop PV Plant grid-tie system or on-grid system, where the energy produced by solar modules is converted directly for consumption in the internal electricity network from the Office. If there is excess energy production, the rest will be sold to PT. PLN (Persero) through a bi-directional energy meter to reduce electricity bills (Rizkasari, Wilopo, & Ridwan, 2020). In simple terms, the topology of the Rooftop PV Plant system is as shown in Figure 3 below.

3.3.2. Determination of building block system

The type of solar module used as a design building block is 250Wp which is widely available. This can guarantee the availability of goods and after-sales services. The selected solar module is Conergy production type Conergy E 250P with 250Wp power in this simulation. In this plan, an inverter with grid-tie or on-grid capability used PT. PLN (Persero). This function aims to directly convert direct current (DC) energy from solar modules into alternating current (AC) energy which will then be used to operate the Central Java Provincial DPRD Secretariat Office. In this simulation, the inverter selected is Huawei Technologies' production type SUN2000-33k TL with a power of 30kWac. The inverter used has the term string-inverter, where the direct current input voltage (DC input voltage) has an extensive range with a maximum voltage of 1,000VDC. When designing a large generating capacity, solar modules can be connected in series (string). No current losses occur in the power transmission cable that connects the solar module with the string-inverter. The wiring configuration used is as many as 20 (twenty) solar modules arranged in series into a string to increase the voltage so that there is no current loss per string, as shown in Figure 4.

Furthermore, as many as 6 (six) strings of solar modules are arranged in parallel to increase the total current capacity, converted by the string-inverter into alternating current (AC) energy. With 20 (twenty) modules, the capacity per array is 5kWp. The layout of the solar modules per 5kWp array can be seen in Figures 5 and 6.

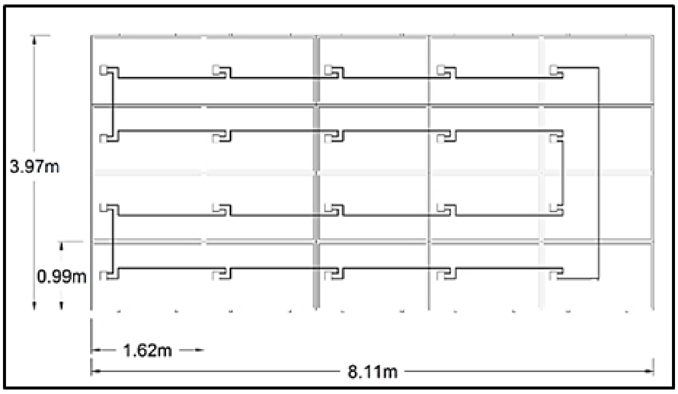


Figure 4. Solar module wiring diagram

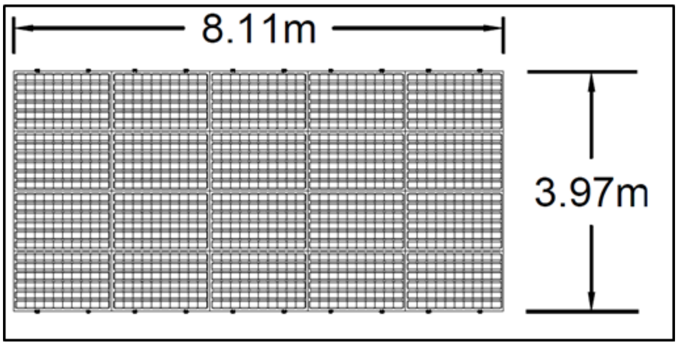


Figure 5. The layout of solar modules per 5kWp array array

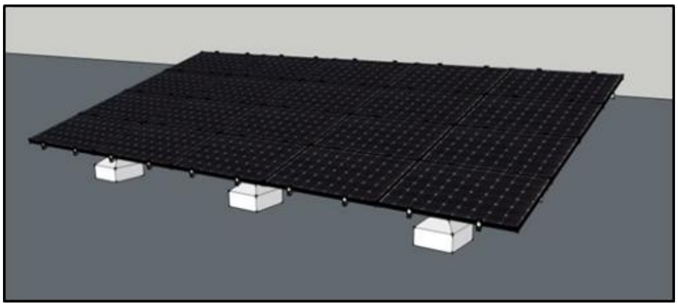


Figure 6. The 3D layout of solar modules per 5kWp array (angle/tilt 15o)

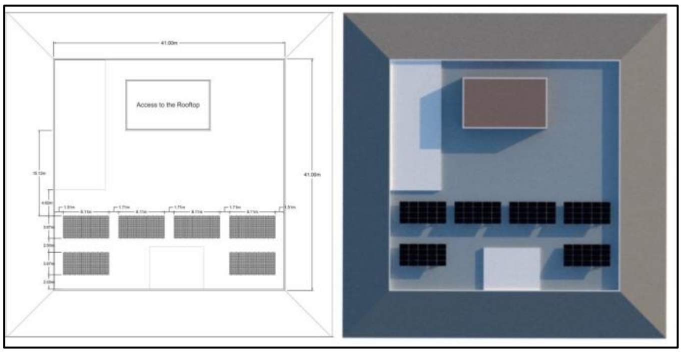


Figure 7. The layout of the placement of solar modules on the rooftop area of the building

3.3.3. Determination of the installation location of the solar module

In this plan, the area chosen for the placement of solar modules on the rooftop of the Central Java Provincial DPRD Secretariat Office took into account several factors, including:

1. The area is free from permanent shadings such as buildings and other buildings,
2. The area has the most optimal performance ratio compared to other prospective locations,
3. This area has the potential for additional solar module capacity in the future.
4. The area is adjacent to the location of the inverter system control room so that, technically, it does not cause losses in the wiring from the solar module array to the inverter.
5. This area can be used to install a Rooftop PV Plant and is visible from the outside of the building. It can also socialize the use of renewable energy, especially photovoltaic solar energy.

Based on the preceding, the most optimal areas for installing Rooftop PV Plants are areas 1, 2, and 3, 354 m2. They are symmetrical, are easy to maintain, and do not interfere with access routes in and out. Areas 4 and 5 can be used for other things, such as adding an outdoor air conditioning unit so that the design will focus on these three areas. The layout of the placement of solar modules in the rooftop area can be seen in Figure 7.

3.3.4. Generating capacity

Rooftop PV Plant design at the Central Java Provincial DPRD Secretariat Office in a predetermined area using 6 (six) PV arrays. Each PV array is installed with 20 (twenty) solar modules. The total number of solar modules installed is 120 (one hundred and twenty) solar modules with a 250Wp/solar module capacity. The calculation of the peak power of the Rooftop PV Plant generator installed following the design made using equation (2), and the peak power result is 30 kWp.

3.4. Estimated Potential Energy Yield Per Day

Based on the Rooftop PV Plant generation capacity obtained from the previous calculations, it is possible to calculate the energy potential generated every day. The calculation of the potential energy yield per day is carried out using equation (3) and using an estimate of the average adequate solar radiation time (peak sun hour) of 4 hours per day so that the potential for energy yields per day from Rooftop PV Plant at the Central Java Provincial DPRD Secretariat Office is 120kWh. The calculations above are estimates, wherein actual conditions, the energy yield per day may exceed or be less than the estimate. This is due to external factors such as weather, the condition of the PV Plant system (including solar module materials, inverter types, wiring installation materials, and circuits), and power consumption in the building. A computational simulation will use PVSyst 6.4.3 software for more detailed estimation results.

3.5. Shadow Analysis Simulation And Performance Ratio

The computational simulation using PVSyst 6.4.3 software includes a system loss diagram, energy yield, performance ratio, and shadow analysis. The performance ratio is obtained from the annual energy yield compared to the simulated generating capacity by considering the solar module's system losses, shading, location coordinates, direction, and slope. The simulation parameters used to adjust to the actual conditions in the rooftop area include:

1. The area to be installed solar modules,
2. The slope (tilt) of the solar module,
3. Orientation (azimuth) of the solar module,
4. The coordinates of the location are 6.993296 South Latitude and 110.420595 East Longitude,
5. The capacity of the solar module and inverter used,
6. The configuration of the solar module wiring was adjusted to the available area and the electrical parameters of the inverter.

All simulation parameter data entered into the PVSyst 6.4.3 software can be seen in Figure 8.

Shadow analysis simulation was carried out using the data mentioned above. The analysis results showed a shading factor with a value of 0 (zero), which means that there are no shadows from buildings around the installation location of the Rooftop PV Plant. This condition is beneficial because a good PV Plant placement must be free from permanent shadows (Mansur, 2019).

Based on the simulation results using PVSyst 6.4.3 software in Figure 11, the Rooftop PV Plant system at the Central Java Provincial DPRD Secretariat Office can produce electricity up to 43,420kWh per year, equivalent to 118.9kWh per day, with a performance ratio of 79.4%. Then the performance ratio is declared good because the results are included in the 70-90% value. Suppose adjusted to the Peraturan Menteri Energi dan Sumber Daya Mineral Nomor 28 Tahun 2016 tentang Tarif Tenaga Listrik yang Disediakan oleh PT. PLN (Persero), where for Government Offices and Public Street Lighting with a capacity above 200kVa, the basic electricity tariff per kWh is Rp. 1.115,- (Menteri Energi dan Sumber Daya Mineral, 2016), then the potential for large electricity cost savings felt by the manager of the Central Java Provincial DPRD Secretariat office in 1 (one) year can reach Rp. 48,413,300,- or equivalent to Rp. 4,034,441.- per month.

Grid-Connected System: Simulation parameters

Project :		**PLTS Rooftop Gedung DPRD I Jawa Tengah**		
Geographical Site		**Gedung DPRD I Jawa Tengah**	Country	**Indonesia**
Situation	Latitude	7.0°S	Longitude	110.4°E
Time defined as	Legal Time	Time zone UT+7	Altitude	50 m
	Albedo	0.20		
Meteo data:	**Gedung DPRD I Jawa Tengah**	Meteonorm 7.1 (2010-2014), Sat=100% - Synthetic		
Simulation variant :		**SUN2000 30kTL**		
	Simulation date	23/03/19 16h20		
Simulation parameters				
Collector Plane Orientation	Tilt	15°	Azimuth	-30°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	Linear shadings			
PV Array Characteristics				
PV module Si-poly	Model	**Conergy E 250P**		
Original PVsyst database	Manufacturer	Conergy		
Number of PV modules	In series	20 modules	In parallel	6 strings
Total number of PV modules	Nb. modules	120	Unit Nom. Power	250 Wp
Array global power	Nominal (STC)	**30.0 kWp**	At operating cond.	26.80 kWp (50°C)
Array operating characteristics (50°C)	U mpp	538 V	I mpp	50 A
Total area	Module area	**197 m²**	Cell area	175 m²
Inverter	Model	**SUN2000-33k TL**		
Original PVsyst database	Manufacturer	Huawei Technologies		
Characteristics	Operating Voltage	480-800 V	Unit Nom. Power	30.0 kWac
Inverter pack	Nb. of inverters	1 units	Total Power	30 kWac
PV Array loss factors				
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	180 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	1.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.05
User's needs :	Unlimited load (grid)			

Figure 8. Simulation parameter data using PVSyst 6.4.3. software

Status: Show existing table — Recompute

Plane orientation: Fixed Tilted Plane — Tilt = 15°, Azimut = -30°

Shading factor table (linear), for the beam component

Azimuth / Height	-180°	-160°	-140°	-120°	-100°	-80°	-60°	-40°	-20°	0°	20°	40°	60°	80°	100°	120°	140°	160°	180°
90°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30°	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.123	0.167	0.167	0.042
20°	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.181	0.736	0.524	0.333	0.042
10°	0.042	0.005	0.000	0.000	0.000	0.000	0.014	0.055	0.056	0.016	0.000	0.000	0.000	0.000	0.406	1.000	0.881	0.500	0.042
2°	1.000	0.010	0.000	0.013	0.049	0.218	0.529	0.501	0.494	0.536	0.239	0.056	0.000	0.000	0.632	1.000	1.000	1.000	1.000

Shading factor for diffuse: 0.015 and for albedo: 0.430

Figure 9. Shading factor at the installation location of the Rooftop PV Plant

3.6. Rooftop PV Plant Investment Cost

The initial investment costs for the Rooftop PV Plant at the DPRD Secretariat Office of Central Java Province include costs such as solar module costs, inverter system costs, installation and distribution system costs, integrated monitoring system costs, grounding and lightning rod costs, as well as operating-worthiness certificate fees (SLO).), training, and documentation. The total initial investment costs incurred for installing a Rooftop PV Plant with a total capacity of 30kWp is Rp. 903.342.000,-. This fee is the contract value for constructing a Rooftop PV Plant at the Central Java Provincial DPRD Secretariat Office.

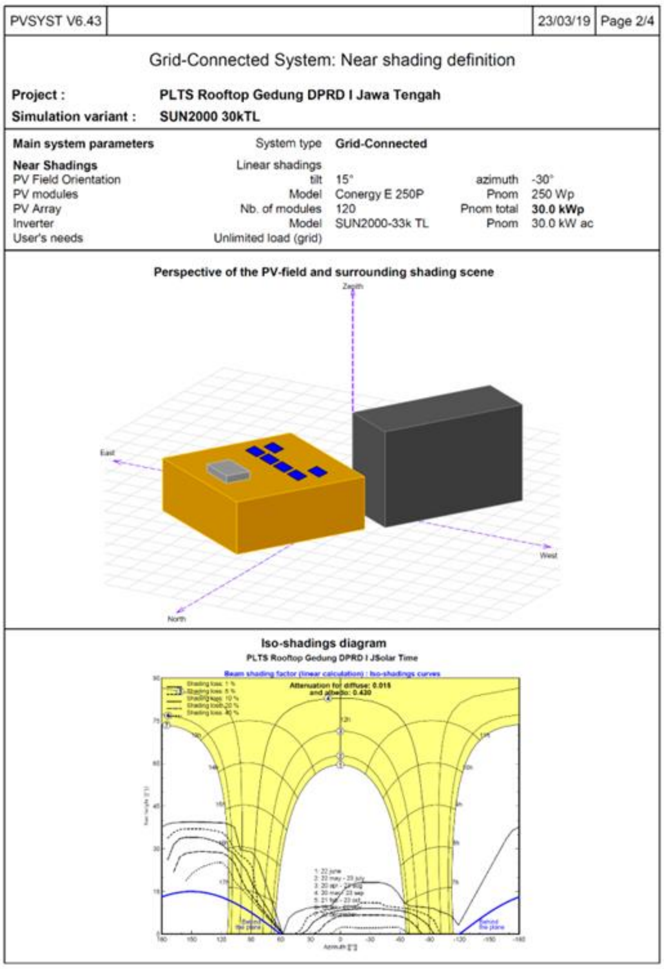
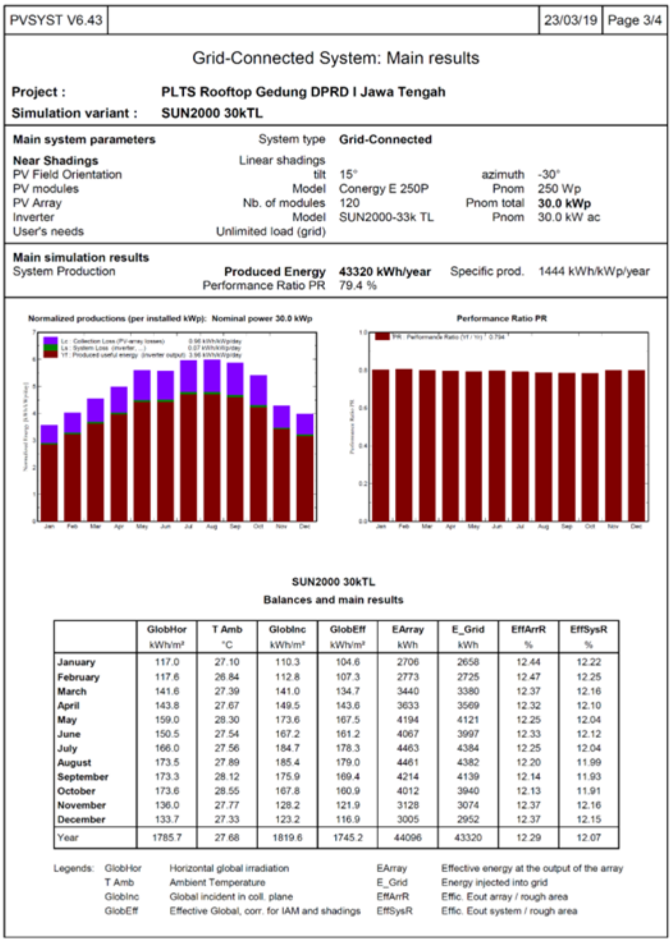


Figure 10. Shadow analysis simulation results using PVSyst 6.4.3. software

Table 5. Results of recording the production of electrical energy on the Rooftop PV Plant monitoring system

No.	Year	Month	Power Production (kWh)
1	2020	January	3,153
2	2020	February	2,999
3	2020	March	3,253
4	2020	April	3,311
5	2020	May	3,027
6	2020	June	3,188
7	2020	July	3,817
8	2020	August	4,113
9	2020	September	4,111
10	2020	October	3,544
11	2020	November	3,304
12	2020	December	2,739
	Total		40.558



	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	EffArrR %	EffSysR %
January	117.0	27.10	110.3	104.6	2706	2658	12.44	12.22
February	117.6	26.84	112.8	107.3	2773	2725	12.47	12.25
March	141.6	27.39	141.0	134.7	3440	3380	12.37	12.16
April	143.8	27.67	149.5	143.6	3633	3569	12.32	12.10
May	159.0	28.30	173.6	167.5	4194	4121	12.25	12.04
June	150.5	27.54	167.2	161.2	4067	3997	12.33	12.12
July	166.0	27.56	184.7	178.3	4463	4384	12.25	12.04
August	173.5	27.89	185.4	179.0	4461	4382	12.20	11.99
September	173.3	28.12	175.9	169.4	4214	4139	12.14	11.93
October	173.6	28.55	167.8	160.9	4012	3940	12.13	11.91
November	136.0	27.77	128.2	121.9	3128	3074	12.37	12.16
December	133.7	27.33	123.2	116.9	3005	2952	12.37	12.15
Year	1785.7	27.68	1819.6	1745.2	44096	43320	12.29	12.07

Legends: GlobHor Horizontal global irradiation; T Amb Ambient Temperature; GlobInc Global incident in coll. plane; GlobEff Effective Global, corr. for IAM and shadings; EArray Effective energy at the output of the array; E_Grid Energy injected into grid; EffArrR Effic. Eout array / rough area; EffSysR Effic. Eout system / rough area

Figure 11. Performance ratio simulation results using PVSyst 6.4.3. software

Figure 12. Results of recording the realization of the amount of power produced

Table 6. The use of electrical energy after the installation of the rooftop PV plant

No.	Code	Payment Date	Rate	Power (Va)	Usage (kWh)	Total Bill (Rp.)
1	202001	17 Jan 2020	P2	865000	88,020	94,494,209
2	202002	12 Feb 2020	P2	865000	82,434	88,057,873
3	202003	16 Mar 2020	P2	865000	76,506	82,193,286
4	202004	15 Apr 2020	P2	865000	81,450	87,129,814
5	202005	8 May 2020	P2	865000	77,450	82,914,189
6	202006	15 Jun 2020	P2	865000	64,930	69,568,164
7	202007	13 Jul 2020	P2	865000	88,020	93,779,521
8	202008	10 Aug 2020	P2	865000	71,180	76,678,793
9	202009	10 Sept 2020	P2	865000	77,010	82,836,505
10	202010	8 Oct 2020	P2	865000	86,490	92,448,544
11	202011	16 Nov 2020	P2	865000	67,690	72,722,114
12	202012	11 Dec 2020	P2	865000	68,838	73,735,107
		Total			930,018	996,558,119

3.7. Evaluation of the Results of Using Rooftop PV Plant

Evaluation of the results of the use of the Rooftop PV Plant carried out through identification and data collection of the realization of the amount of electrical energy produced by the Rooftop PV Plant in the Central Java Provincial DPRD Secretariat Office building through recording on the inverter monitoring system. The recordings carried out within 1 (one) year after installation show that the electrical energy produced is 40,558kWh. If calculated using the P2 tariff group (Government Offices and Public Street Lighting with a capacity above 200kVa), the basic electricity tariff per kWh is Rp. 1.115, -, then obtained a saving rate of Rp. 45.222.170,- or equivalent to Rp. 3,768,514.- per month. This figure is not much different from the simulation results using the PVSyst 6.4.3 software at planning. A detailed description of the amount of electrical energy produced by the Rooftop PV Plant in the Central Java Provincial DPRD Secretariat Office building, which is listed in the monthly data of the inverter monitoring system, can be seen in Table 5 and Figure 12.

Furthermore, the recording and calculation of data on payment of electricity bills of PT. PLN (Persero) every month at the Central Java Provincial DPRD Secretariat Office building within 1 (one) year after the Rooftop PV Plant installation and obtained an electrical energy usage figure of 930,018kWh with a bill to be paid in the amount of Rp. 996,558,119,- in 1 (one) year or equivalent to Rp. 83,046,509,- per month, as can be seen in Table 6.

Based on the data above, there is a difference between the average monthly bill before and after installing the Rooftop PV Plant of Rp. 8.261.814,-. If you look at the savings in electricity payment costs from recording electrical energy production on the Rooftop PV Plant inverter monitoring system, which is around Rp. 3,768,514.- per month, there is a difference in cost savings of Rp. 4,493,300,- in 2020. This was due to the influence of the COVID-19 pandemic, which resulted in changes to the employee work system by implementing work from home (WFH) alternately, resulting in a significant reduction in the use of electrical energy in the Secretariat Office of the Provincial DPRD Central Java.

4. CONCLUSION

The use of electrical energy in the Central Java Provincial DPRD Secretariat office building in the last 1 (one) year prior to installing the Rooftop PV Plant is 1,021,480kWh with a bill to be paid of Rp. 1,095,699,874,- or equivalent to Rp. 91.308.323,- per month.

The PV design recommended in 197 m2 is a Rooftop PV Plant system with 6 PV arrays in which 20 solar modules are installed in each PV array. The total number of solar modules installed is 120 solar modules with a capacity of 250Wp/solar module or a total capacity of 30kWp.

Based on the simulation results using the PVSyst 6.4.3 software, the Rooftop PV Plant system can generate electricity up to 43,420kWh per year or equivalent to 118.9kWh per day with a performance ratio of 79.4%. The potential for saving electricity costs from the simulation results can reach Rp. 48,413,300,- or equivalent to Rp. 4,034,441.- per month.

The results of the evaluation of the utilization of the Rooftop PV Plant through the recording of the inverter monitoring system within 1 (one) year after installation show the amount of electrical energy produced is 40,558 kWh, so that the manager of the Central Java Provincial DPRD Secretariat office can save a budget of Rp. 45.222.170,- or equivalent to Rp. 3,768,514.- per month from the use of the Rooftop PV Plant. This figure is not much different from the simulation results at planning.

Based on the realization of electricity bill payments within 1 (one) year after installing the Rooftop PV Plant, the electricity usage figure is 930,018kWh, with the bill to be paid Rp. 996,558,119,- or equivalent to Rp. 83,046,509,- per month. The difference between the average monthly bill before and after the Rooftop PV Plant installation is Rp. 8.261.814,-.There is a difference in the cost of electricity payments from saving the use of the Rooftop PV Plant with the realization of electricity payments during 2020 of Rp. 4,493,300, - due to the implementation of the work from home (WFH) system during the COVID-19 pandemic, which resulted in a significant reduction in the use of electrical energy at the Secretariat Office of the Central Java Provincial DPRD.

ACKNOWLEDGMENT

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