Techno – Economic Analysis of Rooftop Solar Panel Uprating on Commercial Building (Casestudy on Karawang Branch Office of XYZ Company)

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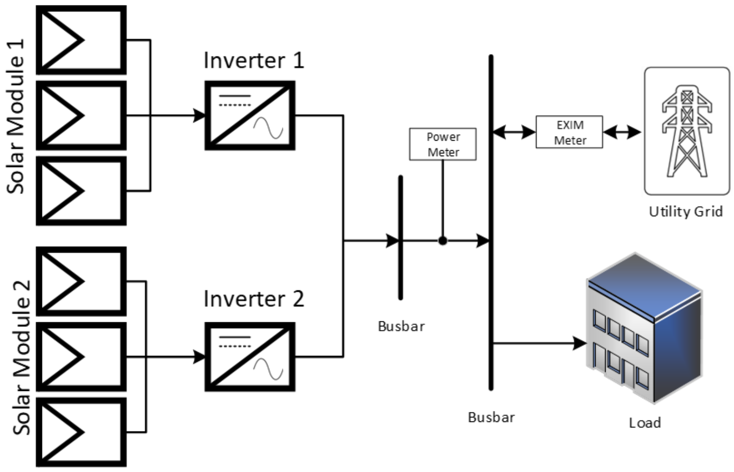
ABSTRACT



On April 22nd, 2016, Indonesia signed the Paris Agreement, which goal is that the world will enter the net-zero emission phase in 2060. To support that, it is better to increase the solar rooftop capacity have been installed. In this study, there are some variations, such as the capacity of solar rooftops based on load profile and installed power (75%, 90%, and 100%), variation of solar module placement, and variation of solar module types. The result shows that to fulfill the load needs, it will need 40 kW of inverter capacity and 49.5 kWp of PV capacity with a total module of 113 pcs. Based on the solar module type simulations result, the 440 Wp B – brand has the highest performance result among the others. Uprating solar rooftop capacity will cost around Rp.1,138,529,870 for the investment, and the payback period is around 18 years. This study finds that uprating the capacity of rooftop solar panel can reduce electricity tariffs and increase energy production. Moreover, the results of the economic analysis revealed that the initial cost, interest rate, and electricity price will play crucial roles in determining whether to launch a project or not.

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1. INTRODUCTION

According to reports, global energy consumption grew by almost 40% between 2000 and 2019. Global energy consumption decreased by 4.5% in 2020 due to the global pandemic but increased by 5% in 2021 [1]. Over 80% of the world's energy needs are met by fossil fuels, including coal, oil, and gas [2]. Numerous obstacles, including the depletion of fossil fuel reserves, fluctuating energy costs, risks to the supply's security, and environmental emissions, face the global energy landscape [3]. Due to causes including infrastructure development, modernization, urbanization, and a growing population, developing countries are primarily responsible for the rise in demand. One of the major issues confronting humanity now is global warming, which is closely related to how we utilize energy.

Countries worldwide are putting an ever-greater focus on the sustainable use of energy and natural resources because of the energy and environmental difficulties they face. In order to combat climate change, the Paris Agreement committed 196 nations to a legally binding agreement that would restrict the increase in global atmospheric temperature to less than 2 C. The Indonesian government is committed to preserving the earth by signing the Paris Agreement on April 22nd, 2016 (Earth Day), at the UN headquarters in New York, United States of America [4]. The goal of the Paris agreement is for the world will enter the net-zero emission phase. Indonesia has set the target to enter the net-zero emissions phase by 2060, which means that Indonesia must immediately reduce the number of carbon emissions produced [5]. The objectives of the Paris agreement are in line with the SDG targets or Sustainable Development Goals, which are in accordance with point number 7th that is affordable and clean energy, and point number 13th, which emphasizes climate action, that is to hold the increase of the earth's temperature below 2° Celsius and protect the earth from the greenhouse effect [6].

Indonesia has a lot of renewable energy potentials, such as ocean current energy (17.90 GW), geothermal energy (23.90 GW), bioenergy (32.60 GW), wind energy (60 GW), (60 GW), water energy (75 GW) and solar energy (207.80 GW) [7]. It can conclude that the enormous potential for new and renewable energy is solar energy. This potential is also supported by Indonesia's geographical location, which only has two seasons and a longer solar radiation time. However, the utilization of solar energy is still far from the total energy potential, where the utilization rate of solar energy is only around 150 MW or about 0.08% out of the total 207.80 GW of solar energy available [8]-[10].

A third of global greenhouse gas (GHG) emissions and over forty percent of total energy consumption are attributed to the building and construction sector [11]. Buildings are undergoing a significant shift in terms of increasing their energy and environmental efficiency all over the world, but notably in developed nations. An essential component of these efforts has been the use of renewable energy. One of the most widely employed renewable energy sources in the building industry worldwide is solar photovoltaic (PV) [12].

Nowadays, solar panel technology is more advanced, and many choices of types of solar panels are offered with different types [13]. Therefore, the stakeholder must increase solar energy usage to maximize the potential and achieve the goal of net zero emissions to support the transition of fossil fuel energy into clean energy. The use of solar photovoltaics (PV) in building construction has seen tremendous success worldwide, making it a popular subject for researchers to study and investigate. The active research and development in PV technology have given a new dimension to the field of renewable energy [14][15]. Previous studies suggest that further research on implementing, perfecting, and assessing solar photovoltaic systems in specific locations in Indonesia would be intriguing [16][17]. Additional research has also highlighted that exploring the cost optimization of solar PV systems for structures other than homes with varying characteristics would be a worthwhile topic to investigate [18][19]. Prior research on the technical and economic analysis of solar rooftop PV systems has been conducted on industrial, commercial, and public buildings [20]-[23]. This study contributed on techno–economic analysis related to increasing the power capacity of the solar rooftop, which has been installed at the XYZ company, Karawang branch office.

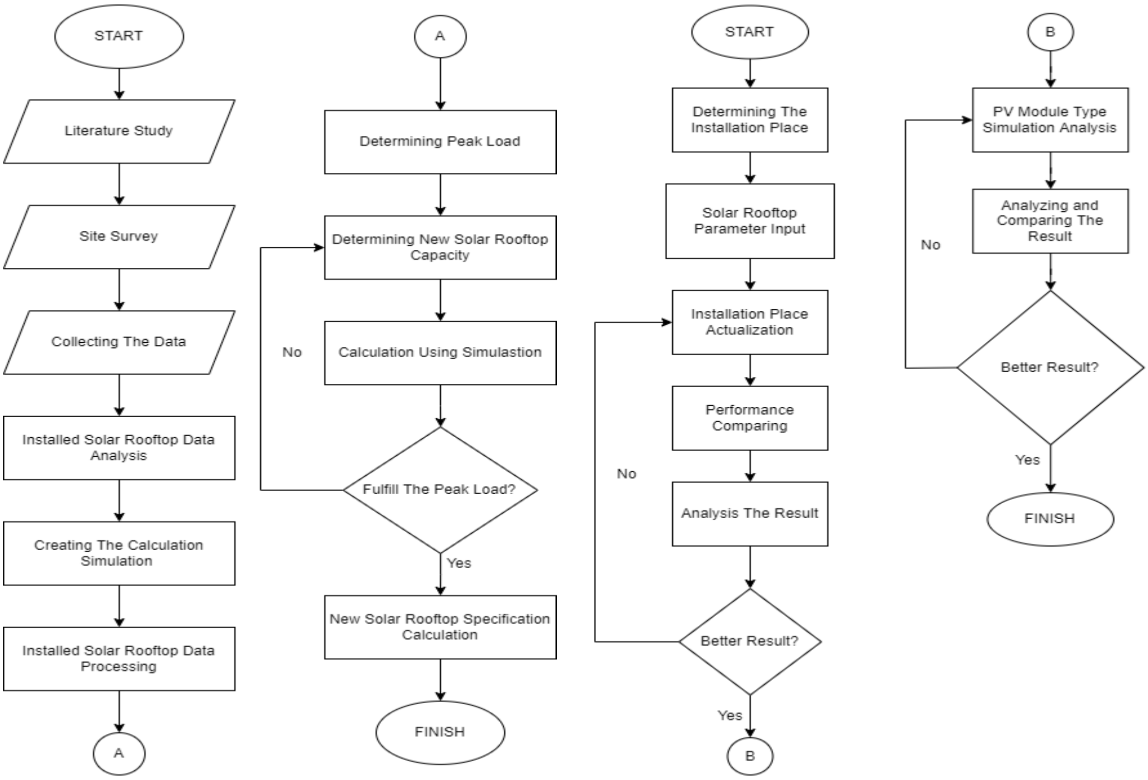
2. METHODS

Solar rooftop power plant utilizes solar energy to generate electricity, where the electrical power generated by this power plant is DC electricity. Solar power plants are basically power supplies (devices that provide power). They can be designed to supply small to large electricity needs, either independently (stand-alone) or in combination with other energy sources such as generators, wind energy, and hydrogen, commonly known as a Hybrid solar power plant. There are two primary solar rooftop components: the solar panel and the inverter.

The solar panel is a component to convert the energy emitted from the sun into radiation, which can be converted into electrical energy that we can use for our daily needs. Solar panels use the photovoltaic effect in the energy conversion process. The photovoltaic effect works by utilizing solar energy, which consists of tiny particles called photons, which will then be received by the solar panel, where the energy conversion process will occur. The inverter is a component that converts direct voltage (DC) into alternating (AC). The solar rooftop regulation that is currently used in Indonesia is The Ministry of Energy and Mineral Resources Regulation No. 26 of 2021 about the solar rooftop power plant [24].

2.1. Research and Simulation Schematic

Research conducted on increasing solar energy at the XYZ Company Karawang branch office was carried out using several stages as described in Figure 1(a).



(a) (b)

Figure 1. (a) Research flowchart and (b) simulation flowchart

The calculation was done by using the calculation simulation. The simulation flowchart shows in Figure 1(b). The data was taken from Isolarcloud, representing the actual condition of the installed solar rooftop at the Karawang branch office. The obtained data will later be classified per day and month. The calculation will be divided into two sections: the calculation of the average and the maximum of the data. This data was used as the reference in analyzing and determining the power output capacity of the new solar rooftop power plant, which will be installed at the Karawang branch office.

2.2. The Schematic Diagram of The On-Grid Rooftop Solar System

An on-grid solar rooftop system is connected to the national electricity distribution network (PLN). This setup eliminates the need for batteries as any excess energy generated by the solar rooftop can be supplied by the PLN network. This configuration is advantageous because it reduces electricity costs by allowing the existing load to rely partially on the PLN network. This type of rooftop PV system also features a kWh Export-Import (kWh-EXIM) system, which can measure and send surplus electrical power to the PLN network. The existing schematic diagram of the on-grid rooftop solar power plant at the Karawang branch office is illustrated in Figure 2.

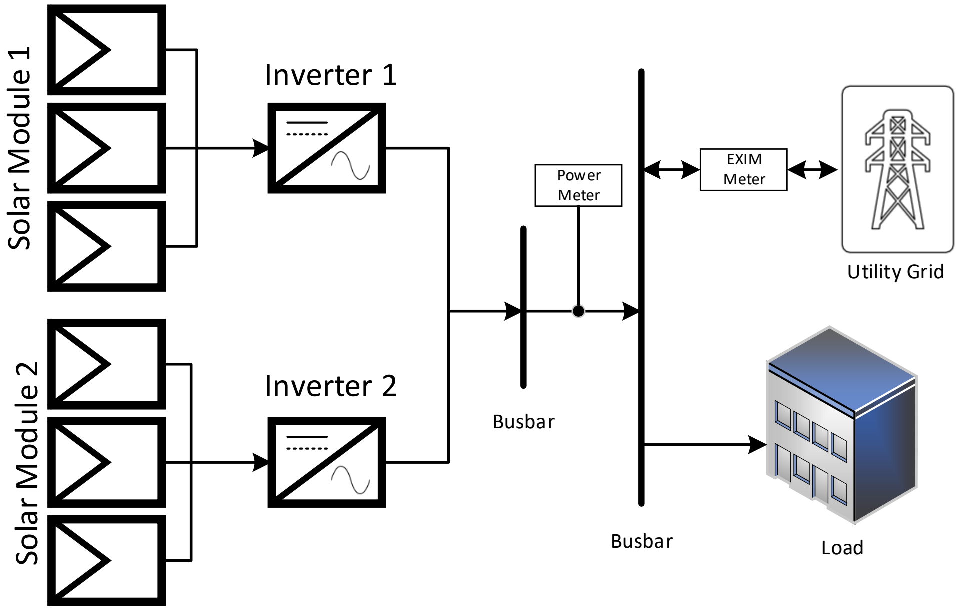


Figure 2. The existing schematic diagram of the on-grid rooftop solar

2.3. Equations of Technical Specifications

In order to build a solar rooftop power plant, some steps must be taken. There are:

1. Analysis of Parameter and Conditions

Before installing a solar rooftop power plant, some conditions and parameters need to be calculated and considered: Azimuth degree, tilt angle degree, roof size, solar irradiation, installed power capacity, load profile, temperature, wind speed, regulations, and solar rooftop system type.

2. Calculation of Technical Specification

Specification of the solar power plant needs to be calculated using the equation of each specification. There are:

- Difference factor (k)

  The difference factor is a factor that represents the power difference between the inverter and PV. In Indonesia, the difference factor is between 1.1 to 1.4. In this research, the difference factor used is 1.2375, as shown in Equation (1). This value is based on where this research takes place, in XYZ Company Karawang branch office.

$$k = 1.2375 \approx 1.24 \tag{1}$$

- PV Power (PPV)

  The calculation of PV power depends on the value of inverter power and the difference factor is calculated using the formula in Equation (2).

$$P_{PV} = P_{INV} \times k \tag{2}$$

- PV Module Quantity (Σ_{Modul})

  The total PV modules is proportional to the PV power needs. Where the total PV modules are formulated by the Equation (3).

$$\Sigma_{Modul} = \frac{P_{PV}}{STC\ Rating} \tag{3}$$

  STC rating is the output power of the module.

- Total Energy (E)

  The total energy is a value showing the amount of electrical energy PV can produce under maximum and optimal lighting conditions. The unit used to represent the amount of electrical energy produced by PV is the Watt-hour, commonly abbreviated as Wh. To calculate the total electrical energy produced by PV, we need several values, including the inverter power, the irradiation time, and the efficiency of the PV (assumed 75% or 0.75), with these parameters calculations can be carried out using Equation (4).

$$E = P_{INV} \times t \times 0.75 \quad (4)$$

- Total Investment Cost

  The calculation of investment costs consists of several components, including PV investment costs, inverter investment costs and installation costs consisting of DC and AC cable investment costs, walkway investment costs, cable tray investment costs, inverter room investment costs, construction costs, water costs pipe and several other investment costs, where for the calculation of the total investment cost consists of several values, namely the total cost of components, total costs of support and installation and total operational costs.
- Cost Saving Per Month

  Cost savings is a value that shows the amount of cost savings generated by PV per month, where this value is a factor in reducing electricity costs each month. The calculation of saving costs is influenced by the amount of electric power and the price of electric power set by PLN using the calculation formula with Equation (5).

$$Cost\ saving_{\ Month} = E_{Month} \times Rp. 1{,}035.78 \quad (5)$$

- Cost Saving Per Year

  This research analyzed six months of data from an installed solar rooftop power plant. The cost saving for one year can be calculated by adding a factor representing the cost saving per month of energy production. Based on irradiation data from Global Solar Atlas, the factor of one-year energy production is 1.3. Thus, the calculation for cost savings will be like Equation (6).

$$Cost\ Saving_{\ Year} = E_{Month} \times Rp. 1{,}035.78 \times 1.3 \quad (6)$$

- Payback Period (PP)

  The total investment spent in the construction of the solar rooftop must be calculated on how long the investment will meet the turnover, where cash flow calculations are carried out for 20 years to calculate the payback period value.

3. Analysis of The Calculation Result

After calculating the technical specifications of the solar rooftop power plant, an analysis is needed to analyze the results of these calculations. The calculation results will be compared with the parameters that influence the Solar Rooftop and see whether the results meet the parameter criteria needed in constructing Rooftop PV or not. For the specifications of the installed solar rooftop can be seen in Table 1.

Table 1. Installed solar rooftop specifications

No.	Components	Specifications
1	Inverter Power	160 kW
2	PV Power	198 kWp
3	PV Modules	450 Pcs
4	STC *Rating*	440 Wp
5	Installed Power	240 kVA

The solar rooftop power plant installed at the XYZ Company Karawang branch office uses an inverter from SG – brand with two different types of output power. Those are SG – brand with an output power of 110 kW and SG – brand with an output power of 50 kW, with a total output power of all inverters of 160 kW. The type of PV module used comes from the SP – brand with an output power rating of 440 Wp.

3. RESULT AND DISCUSSION

This research analyzed the data from 6 months of operations of the solar rooftop system, from October 2021 until March 2022. The result shows that the capacity of the installed solar rooftop system, with an inverter output power of 160 kW, cannot supply enough electrical power to cover the peak load, either the highest peak load or the average load each day. Based on processed data, it is known that the peak load for six months (October 2021 to March 2022) is on October 26th at 11:00 WIB, where the peak load reaches 190.47 kW. Because of that, the installed solar rooftop needs to increase its power capacity to supply enough power. The uprating of PV includes all the calculations and parameters shown in section III.

3.1. Rooftop Specifications

In the rooftop specifications, there are several parameters that are used as a reference, which are shown in Table 2.

Table 2. Roof specifications

No.	Parameters	Specifications
1	Roof Area	8,280 m^2
2	Solar Radiation Intensity	1163.60 kWh/m^2
3	Solar Power Plants System Types	On-grid
4	Installed Power	240 kVA
5	Load Profile	190.47 kW
6	Tilt Degree	5°

Based on the roof profile, the other parameters should be calculated as follows:

1. Azimuth Degree

Azimuth represents the direction of where the solar module is facing. The azimuth value for each area is different and depends on the location of the equator corresponding to the area. Based on the simulation, the best azimuth degree for the XYZ Company Branch office is 3°.

2. Tilt Angle

The size of the roof slope is one of the parameters that need to be considered in designing a solar rooftop, where the degree of roof slope will affect the slope of the solar modules. Based on the recommendations [25][26], the best tilt angle is 10°, which will be used in this research, as shown in Table 3.

Table 3. Tilt degree

Components	Tilt Angle (°)
Rooftop	5
Solar Module	5
Total	10

3.2. Analysis of Technical Specification Calculations

The formula to calculate solar rooftop specifications is shown in section III. Based on the calculations, the specifications needed to cover the peak load require the appropriate parameters as shown in Table 4 and Table 5.

Table 4. New solar rooftop specifications

No.	Parameters	Specifications
1	Inverter Power	40 kW
2	PV Power	49.5 kWp
3	PV Modules	113 Pcs
4	Energy Production per day	330,000 Wh
5	Cost Saving per Month	Rp. 7,095,618
6	Cost Saving per Year	Rp. 85,147,416

Table 5. Specifications of total capacity of solar rooftop (installed + new)

Parameters	Specifications
Inverter Power	200,000 W
PV Power	247,500 Wp
PV Modules	563 Pcs
STC Rating	440 Wp

The analysis of the PV module type includes three brands of solar modules, which are A - Brand, B - Brand and C - Brand, with two variations of the output power of the solar module, those are 440 Wp and 540 Wp. Simulations were carried out at the module installation site with variation 1 (on the right bottom side of the roof). Then, an analysis of the performance generated for each solar module brand with two output power variations was carried out. The following is a simulation result using the Helioscope software.

Based on the simulation results shown in Table 6, it can be seen that solar modules with the B - brand have the highest values among the others for the performance ratio and annual production parameters. Table 7 shows that solar modules with the A & B - brands have the same weight per module for 440 Wp. Based on the specifications and performance data produced, it can be concluded that the best option for solar modules is the B - brand, with an STC Rating of 440 Wp.

Table 6. Analysis of module type

Output Power (Wp)	Brand	Performance rate (%)	Total Energy Per Year (MWh)	Total Module (Pcs)	Total Area (m^2)
	A	82.2	69.4	112	247.52
440	B	82.4	69.54	112	248.64
	C	82.1	69.29	112	240.8
	A	82.4	69.34	91	233.87
540	B	82.4	69.38	91	232.96
	C	82.2	69.19	91	231.14

Table 7. Weight analysis

Output Power (Wp)	Brand	Total Module (Pcs)	Weight Per Module (kg)	Total Weight (kg)	Area Per Module (m^2)	Total Area (m^2)
	A	112	25	2800	2.21	247.52
440	B	112	25	2800	2.22	248.64
	C	112	27.5	2080	2.15	240.8
	A	91	27	2457	2.57	233.87
540	B	91	28.6	2602.6	2.56	232.96
	C	91	32.3	2939.3	2.54	231.14

3.3. Analysis of PV Module Placement Variations

Installation of PV modules for a solar rooftop with the new capacity will be carried out on the warehouse's roof. The PV module installation site was actualized at the XYZ Company Karawang branch office using the Helioscope simulation software. This simulation can simulate the solar module installation site according to the circumstances. There are four variations of module placement in the warehouse's roof. The first variation is on the right bottom side of the roof, and the second is on the right top side. The third variation is on the left top side of the roof, and the fourth is on the left bottom side.

Table 8 shows simulation results related to PV module placement. It can be seen from the Table 8 that the first variation produces the best performance, that is, on the bottom right side of the warehouse roof, where variation 1 gets the highest performance ratio and annual production values compared to other variations. Thus, the first variation is the best place to place the solar modules.

Table 8. Simulation result of PV module placement

Variations	Performance Rate (%)	Shadowing Rate (%)	Total Energy Per year (MWh)
1	82.2	0.7	69.4
2	81.9	0.7	69.12
3	81.7	0.7	68.97
4	82	0.7	69.23

3.4. Analysis of the Economic Aspects

1. Payback Period

Based on the results of the technical specifications, several components are needed to build the 40kW solar rooftop power plant. Each of these costs will be included in the total investment cost. The detail of the components shows in the Table 9.

Table 9. Total investment of 40 kW solar rooftop

Components	Type	Unit	Cost per Unit (Rupiah)	Total Cost (Rupiah)
PV Panel	B - Brand	113	3,685,000	416,405,000
Inverter	Same as Exixting	1	44,750,000	44,750,000
Cable	AWG 10	1,795	7,560	13,570,000
Total Cost of Main Components				474,725,000
Maintenance Cost				220,360,620
Operasional Cost				89,500,000
Supporting Component & Installation Cost				353,944,250
Total Investment Cost				1,138,529,870

The Table 9 shows the details of the component costs and the total initial investment cost of a solar rooftop power plant with a power capacity of 40 kW. The operational cost is replacing the inverter, where the lifetime of the inverter is ten years. So, during the 20-year lifetime of the PV module, there will be two times of inverter changes which will then be included in operating costs. The cost of supporting components and installation services is calculated from 85% of the total cost of solar modules. That cost includes walkway costs, cable tray costs, space for inverter placement costs, construction costs, and water pipe costs. Then there are also maintenance costs assumed from 1% of total investment per year from the initial investment cost.

From the total investment data that has been calculated, the payback period can be calculated using the cash flow calculation. The results of the calculations can be seen in Table 10.

Table 10. Payback period calculations

Year	Investment (Rupiah)	Cost (Rupiah)	Remaining Investment (Rupiah)
0	1,138,529,870	-	1,138,529,870
1	-	82,268,037	1,056,261,833
2	-	79,486,026	976,775,806
3	-	76,798,093	899,977,713
4	-	74,201,056	825,776,657
5	-	71,691,842	754,084,815
6	-	69,267,480	684,817,335
7	-	66,925,101	617,892,233
8	-	64,661,934	553,230,300
9	-	62,475,298	490,755,001
10	-	60,362,607	430,392,394
11	-	61,237,427	369,154,967
12	-	59,166,597	309,988,370
13	-	57,165,794	252,822,576
14	-	55,232,651	197,589,925
15	-	53,364,880	144,225,045
16	-	51,560,271	92,664,774
17	-	49,816,687	42,848,088
18	-	48,132,064	5,283,977
19	-	46,504,410	51,788,387
20	-	44,931,797	96,720,184

It can be seen from Table 10 that the payback period occurred in the 18th year of operations. There was a return on investment, where the remaining investment becomes positive so that in the 20-year lifetime of the solar panel (PV lifetime), the investment will return the capital in the 18th year. In calculating the NPV, the discounted rate or interest rate value is needed, where this interest rate will affect the NPV value in the future in a calculation of investment in cash flow. The interest rate used in this cash flow calculation is 3.5% in accordance with Bank Indonesia regulations on October 19th, 2021.

Based on the results of cash flow calculations, the total initial investment capital for installing a 40-kW solar rooftop power plant is Rp. 1,138529,870. The total saving cost of electricity bills generated from solar rooftop energy is Rp. 1,745,522,084, with the total Net Present Value (NPV) of net cash, Rp.1,235,250,054.

2. Levelized Cost of Energy (LCOE)

The LCOE is used to determine the net present value of the average energy cost of electricity generation over the power plant's lifetime. LCOE is used to make investment plans and compare the power plant's costs with other power plants. The LCOE value refers to the electricity tariff of PLN, where the XYZ Company Karawang branch office subscribes to an electric power capacity of 240 kVA and is included in group B-3 with an electric power tariff of Rp. 1,035.78 per kWh. The following Table 11 shows the calculation of the LCOE of installed solar rooftop and Table 12 shows the calculation of the LCOE of installed solar rooftop + additions of 40 kW. And the calculation of the total for each solar rooftop installation is shown in Table 13.

Table 11. Total investment of 160 kW solar rooftop

Components	Type	Unit	Cost per Unit (Rupiah)	Total Cost (Rupiah)
PV Panel	Same As Exixting	450	3,200,000	1,440,000,000
Inverter	Same As Exixting 1	1	85,850,000	85,850,000
	Same As Exixting 2	1	48,480,000	48,480,000
Cable	AWG 10	7179.2	7,560	54,274,752
Total Cost of Main Components				1,628,604,752
Maintenance Cost				16,286,048
Operational Cost				268,660,000
Supporting Components and Installation Cost				1,224,000,000

Table 12. Total investment of 200 kW solar rooftop (160 kW + 40 kW)

Components	Type	Unit	Cost per Unit (Rupiah)	Total Cost (Rupiah)
PV Panel	Same As Exixting	450	3,200,000	1,440,000,000
	B - Brand	113	3,685,000	416,405,000
Inverter	Same As Exixting 1	1	85,850,000	85,850,000
	Same As Exixting 2	1	48,480,000	48,480,000
	Same As Exixsting 3	1	44,750,000	44,750,000
Cable	AWG 10	8974	7,560	67,843,440
Total Cost of Main Components				2,103,328,440
Maintenance Cost				21,033,284
Operasional Cost				358,160,000
Supporting Component & Installation Cost				1,577,944,250
Total Investment Cost				4,060,465,974

Table 13. LCOE calculations

Factor	Solar Rooftop (160 kW)	Solar Rooftop (200 kW)
Energy Production Per Year (kWh)	252,942	316,177
Degradation Value (%)	0.55	0.55
Initial Investment (Rp)	3,137,550,800	4,060,465,974
Total Energi of 20 Years (kWh)	4,804,388.082	6,005,485.10
LCOE (Rp)	653.06	676.13

It can be seen from Table 13 that there is a difference in LCOE around Rp. 23.07 / kWh. The LCOE value for a solar Rooftop with a capacity of 200 kW is Rp. 676.13 /kWh, where the LCOE value is smaller than the tariff value set by PLN for group B-3 of Rp 1035.78. So, from the LCOE aspect, this project is feasible.

3. Energy and Cost Savings

The aspect of electricity and PV energy saving is one of the essential parameters that must be considered in building a solar rooftop. The Table 14 shows the energy savings from the solar rooftop before and after the addition of electrical power capacity conditions.

Table 15 shows the increasing electricity cost saving after increasing PV capacity. From the Table 14 and Table 15, it can be seen that after adding the 40 kW of solar rooftop capacity, there was an increment in PV energy production and monthly electricity cost savings of around 20%.

Table 14. Comparison of PV power saving

Month	Total PV Power Saving (kWh)		Saving Rate
	Solar Rooftop (160 kW)	Soalr Rooftop (200 kW)	
2021 -10	25,267	31,583	20%
2021-11	19,888	24,860	
2021-12	19,640	24,550	
2022-01	21,077	26,346	
2022-02	17,268	21,585	
2022-03	23,332	29,165	

Table 15. Comparison of cost saving

Month	Total Cost Saving		Saving Rate
	Solar Rooftop (160 kW)	Soalr Rooftop (200 kW)	
2021 -10	Rp. 26,170,639	Rp. 32,713,299	20%
2021-11	Rp. 20,599,593	Rp. 25,749,491	
2021-12	Rp. 20,342,616	Rp. 25,428,270	
2022-01	Rp. 21,830,721	Rp. 27,288,401	
2022-02	Rp. 17,886,056	Rp. 22,357,570	
2022-03	Rp. 24,166,405	Rp. 30,208,006	

4. Technical and Economics Feasibility Analysis

Based on the technical aspect, after the addition of 40 kW solar rooftop, the highest peak load from the XYZ Company Karawang branch office has been fulfilled. The average daily load can be met when the sun is in peak hours condition (from 10.00 Am to 2.00 Pm). Thus, it can be concluded that the additional 40 kW solar rooftop capacity is feasible.

Meanwhile, from the economic side, several parameters must be analyzed, including payback period analysis, LCOE analysis, and analysis of electricity and PV energy costs. In terms of the payback period, the year obtained is 18 years, which is still below the 20 years lifetime of PV. In terms of LCOE, the value is Rp.

676.13, which is still below the value of the PLN electricity tariff of Rp.1,035.78, so it still meets the requirements in terms of the LCOE value.

The last analysis is from the savings in electricity and PV energy costs. After increasing the capacity of the solar rooftop by 40 kW, the savings in electricity and PV energy costs increased by 20% from the previous capacity for each month. This parameter is the deduction rate of the electricity cost bill every month. The results obtained in this study is in accordance with other studies [27][29].

In addition to these three factors, the increasing capacity of the solar rooftop is also one of the steps taken by XYZ Company to support one of Indonesia's goals to reduce the level of carbon emissions produced and will enter the net zero emission phase in 2060. Based on technical, economic, and environmental aspects, it can be said that this project is feasible.

4. CONCLUSIONS

Technical and economic analysis related to the uprating solar rooftop at the Karawang branch office of XYZ company has been made. Based on technical analysis, an additional inverter output power of 40 kW and a PV power of 49.5 kWp is required to cover the increasing load requirements of the XYZ Company Karawang branch office. The best PV module placement is variation 1, on the lower right side of the warehouse roof, with 440 Wp B – Brand. The payback period obtained is 18 years, where these values are still below the lifetime PV of 20 years. Based on the LCOE value of Rp. 676.13, the LCOE value is still below the value of the PLN electricity tariff for class B-3 in 2022 which is Rp. 1,035.78. Then in terms of cost and PV energy savings, there is a reduction in electricity costs and an increase in PV energy by 20% from solar rooftop installed for each month. In addition to these three factors, increasing the capacity of solar rooftop is also one of the steps taken by XYZ Company to support one of Indonesia's goals to reduce the level of carbon emissions produced and will enter the net zero emission phase in 2060. For further study, techno-economic analysis can be conducted for repowering the solar rooftop. Repowering means replacing the old module with newly manufactured system, and more efficient. It is intended to improve the power output and/or efficiency and the area use efficiency.

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