Opsi
Vol. 17, No. 1, June 2024
p-ISSN 1693-2102
e-ISSN 2686-2352

Investment analysis of solar power plant installation on the roof of the central business district office building with the best investment value

Raden Muhammad Nalindra Poerbaningrat [1], Irwan Soejanto [1*], Trismi Ristyowati [1], Puryani [1]
[1]Faculty of Industrial Engineering, Department of Industrial Engineering, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Yogyakarta, Indonesia

*__Corresponding Author__: irwansoejanto@upnyk.ac.id

Article history:
Received: 18 November 2023
Revised: 27 April 2024
Accepted: 03 June 2024
Published: 30 June 2024

Keywords:
Investment Analysis
Solar Power Plant Installation
Verein Deutsche Inginieuer 2222
Benefit-Cost Ratio
Cost of Energy

ABSTRACT

The Central Business District (CBD) office building is making efforts to reduce building electricity costs, and one alternative is solar power plant installation. PT. Rancang Prima Sejahtera, engaged in the solar energy industry, conducts consulting services with Central Business District office buildings, so PT. Rancang Prima Sejahtera made an indicative proposal with several solar power plant installation scenarios to be installed on the roof of the Central Business District office building. Four scenarios are created from the combination of 2 PV modules and two inverters. Each scenario created will be assessed for the level of opt, and the investment value will be calculated. In combining components using the principles of the Verein Deutsche Inginieuer (VDI) 2222 method and assessed each scenario using six aspects of assessment.
Meanwhile, the investment analysis assessment uses the parameters of Cost of Energy (CoE), Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (B-CR), and discounted payback period. The results of the analysis conducted found that the third scenario was the best scenario with a percentage of the design value of 82.5%, CoE value of Rp398.31/kWh, NPV value of Rp2,451,719,005, IRR percentage of 23.75%, B-CR value of 7.8, and DPP value for 6.8 years with a project life of 30 years. The findings of the investment research indicate that the implementation of solar power plant installations in office buildings located in Central Business Districts yields long-term cost reductions in electricity expenses over a 30-year period, as opposed to relying solely on the services provided by the State Electricity Enterprise.

DOI:
https://doi.org/10.31315/opsi.v17i1.11233

1. INTRODUCTION

Solar power plant installation, also known as solar panels, is a device that converts sunlight energy into electrical energy through the photovoltaic effect, therefore also called photovoltaic cells [1-3]. This technology is included in the category of new renewable energy because its use is considered environmentally friendly and has minimal pollution. Compared to other renewable energy sources like wind and geothermal, photovoltaic (SPV) technology is now much more affordable when compared to fossil fuel sources [4-6]. Solar energy has the greatest rate of growth among all renewable energy sources, which means it has the potential to significantly lessen reliance on fossil fuels and cut CO2 emissions worldwide [7-8]. The inverter in Solar power plant installation converts the direct current generated by solar panels into alternating electric current [9]. Large-scale solar power plant utilization was formerly restricted to regions known as the "Sunbelt" that have abundant sun radiation [10]. It is possible to distribute the production of solar power, usually in smaller plants with or without basic optical complexity (i.e., concentration) [7].

As stated in the Minister of Energy and Mineral Resources Regulation No. 26/2021, the government has supported solar power plant installation in Indonesia for its use. Although the amount of solar energy is abundant in tropical climates, Solar power plant installation technology in Indonesia is classified as still having a fairly high price for now [11]. This is because most of the components needed are still imported from abroad, thus affecting the Domestic Component Level. Supporting components have benefits to improve the performance of the main component and as an added value obtained by customers from the product in terms of services, warranty, and installation [12].

PT. Rancang Prima Sejahtera is an Engineering, Procurement, and Construction (EPC) company engaged in the solar panel industry and owns the Solar Panel House brand. PT. Rancang Prima Sejahtera serves the Solar power plant installation with On-Grid, Off-Grid, and Hybrid systems. PT. Rancang Prima Sejahtera is quite experienced in the Solar power plant installation field. It is proven that PT. Rancang Prima Sejahtera already has many clients who have consulted about the installation of Solar power plant installations and clients who have Solar power plant installations—one of the clients of PT. Rancang Prima Sejahtera is consulting the installation of a Solar power plant, an office building in Central Jakarta. In Indonesia, solar power plants get important attention [13]

Office building Central Business District is a building used as a property office with 13 floors of Basement Parking up to the rooftop top. It is used for daily business activities, so it requires a Supply large enough, about 100,000 VA. The management wants to make efforts to save electricity costs that are quite large, one of which is installing solar rooftops. Based on the efforts of the Building, PT. Rancang Prima Sejahtera offers consulting services and the procurement and installation of solar rooftops in Central Business District office buildings. The offer uses a solar system On-Grid, and optimal solar scenario options will be installed in Central Business District office buildings from financial and technical aspects. This system does not have a battery, but it has the advantage of exporting excess energy to the State Electricity Enterprise [14]. Due to the Domestic Component Level problem, which is still quite high, the cost will be compared if using Solar power plant installation and State Electricity Enterprise, which the Building currently uses. The scenario options are created using a Verein Deutsche Inginieuer (VDI) 2222 design method, combining 2 PV modules and two different inverters. Once designed, the investment analysis will be calculated from each alternative scenario using CoE, NPV, IRR, B-CR, and DPP parameters. The Verein Deutsche Inginieuer (VDI) 2222 method and investment analysis are tools used in research to measure the most optimal scenarios from a technical and economic perspective. So, it will provide the results of which option is the most optimal. The decision-making stages include defining the problem, analyzing the problem, developing an alternate solution, deciding upon the best solution, and converting the decision into effective action [15].

2. MATERIALS AND METHODS

This research uses several methods with the following flow.

2.1. Verein Deutsche Inginieuer (VDI) 2222

The Verein Deutsche Inginieuer (VDI) 2222 employs a systematic methodology for developing product designs, which enables the incorporation of diverse designs that emerge from performed research [16]. German engineers frequently employ the VDI technique to articulate concepts for resolving problems, facilitating the development of problem-solving designs [17]. The VDI 2222, as described by Ridwan [18], is an organization that addresses challenges and enhances the efficiency of raw materials and industrial processes. This study examines the utilization of Verein Deutsche Inginieuer (VDI) 2222 as a framework for designing solar power plant installation scenarios. The design process is divided into two distinct stages: planning and conceptualization.

a. Planning

The planning process involves the calculation of projected savings and productivity gains resulting from installing a solar power plant at the Central Business District office building, assuming optimal functioning without any hindrances. The calculations encompass the Capacity Charge (CC) establishes the minimum cost customers must pay to the State Electricity Enterprise. The formula employed in this context is:

$$CC = IC\ x\ 5\ hour\ x\ BET \quad (1)$$

where:
CC = Capacity Charge
IC = Inverter Capacity
BET = Basic Electricity Tariff

The obtained CC value will be utilized to compute the expenses that the implementation of Solar power plant installation technology can offset. The formula employed in this context is:

$$CB = BME - CC \quad (2)$$

where:
CB = Costs Borne by Solar power plant installation
BME = Bill Monthly Electricity

Finally, it will calculate the customer's estimated average daily electricity usage. The formula used is:

$$DA = \frac{CB}{30\ days}\ x\ \frac{1}{TDL} \quad (3)$$

where:
DA = Daily Average
The data used for this calculation can be seen in Table 1.

Table 1. Electrical data of CBD office buildings

Parameters	Value	Unit
Power Connected	100,000	Volt Ampere (VA)
Basic Electricity Tariff	1,444.7	rupiah/kWh
Monthly Billing	9,500,000	Rupiah
Location coordinates	-6.1845566197301105, 106.83561106067621	-

b. Conceptualizing

The initial phase involves conceptualizing the performance of a Solar power plant installation by utilizing a Data Flow Diagram (DFD), assessment of component compatibility, and simulation using helioscope software. The consideration of cable cross-sectional area is also necessary as it directly impacts the voltage drop, which can increase with longer cable lengths and potentially lead to fire hazards [14]. The computation for component fit is determined by utilizing the following formula.

$$Voc, \max = Voc + (T\ coef\ Voc\ x\ Voc\ x\ (T\ PV \min - 25°C)) \quad (4)$$

where:
Voc, max = Open circuit maximum voltage (Volt)
Voc = Open circuit voltage (Volt)
T coef Voc = Voc temperature coefficient (OC)
T PVmin = Minimum temperature PV module (OC)

$$T\ module \max = T \max ambient + (\frac{NMOT - 20°C}{80}\ x\ 100) \quad (5)$$

where:
T Module Max = Maximum temperature PV module (OC)
T Max Ambient = Maximum temperature in the environment PV module (OC)

NMOT = Nominal Module Operating Temperature (OC)

$$Isc, \max = Isc + (T\ coef\ Isc\ x\ Isc\ x\ (T\ PV\ \max - 25°C)) \tag{6}$$

where:

Isc, max = Short circuit current maximum (Amperes)
Isc = Short circuit current (Amperes)
T coef Isc = Temperature coefficient Isc (OC)
T PV max = Maximum temperature PV module (OC)

$$Max\ Voltage\ PV = NOP\ x\ Voc \tag{7}$$

where:

Max Voltage PV= Maximum voltage of PV module (Volt)
NOP = Number of panels per string (units)

$$Max\ current\ PV = total\ string\ per\ MPPT\ x\ Isc\ max \tag{8}$$

where:

Max current PV = Maximum current of PV module (Volt)

The data used for this calculation is a specification of the components used, which can be seen in Table 2 to Table 5.

Table 2. BSM700PMB6-70SDC Specifications

Parameters	**Value**	**Unit**
Capacity	700	Peak wattage (Wp)
Voc *module*	47.7	Volt (V)
T *coefficient* Voc	-0.26%	per degree centigrade (/(°C))
NMOT	43	degree Celsius (°C)
Isc *module*	18.8	Ampere (A)
T *coefficient* Isc	0.048%	per degree centigrade (/(°C))
Long	238.4	centimeter (cm)
Wide	130.3	centimeter (cm)

Source: Datasheet PV module BSM700PMB6-70SDC

Table 3. RCM-700-8BHM Specifications

Parameters	**Value**	**Unit**
Capacity	700	Peak wattage (Wp)
Voc *module*	50	Volt (V)
T *coefficient* Voc	-0.22%	per degree centigrade (/(°C))
NMOT	42	degree Celsius (°C)
Isc *module*	17.26	Ampere (A)
T *coefficient* Isc	0.047%	per degree centigrade (/(°C))
Long	238.4	centimeter (cm)
Wide	130.3	centimeter (cm)

Source: Datasheet PV module RCM-700-8BHM

Once the various stages of the Verein Deutsche Inginieuer (VDI) 2222 process have been executed, it is necessary to compute the Bill of Quantity (BoQ) for each scenario to ascertain the monetary worth of the initial investment. The Bill of Quantity (BoQ) calculation encompasses the expenses associated with the necessary components, services costs, profit margins, and applicable taxes. After acquiring information regarding each scenario's initial investment, a comprehensive evaluation is conducted to determine the scenario's technical and financial optimization.

2.2. Assessment Aspects

Aspect evaluation is a method employed to evaluate an object by considering multiple aspects or criteria, as possible options exist [15-16]. The assessment component evaluates the location's viability, production scale, technology selection, and design layout [17-18]. Following the research conducted by Adhiharto [17], the assessment aspect can be computed utilizing the subsequent formula.

$$\text{Total Value} = \text{Value AOF x} \left(\frac{\text{Wight}}{100}\right) \quad (9)$$

where:
AOF = Alternative Overall Function

$$\text{Percentage} = \frac{(\text{Total value AOF x } 100\%)}{\text{Ideal total value}} \quad (10)$$

Table 4. Trinergy Plus-60kW Specifications

Parameters	Value	Unit
Type	*On-Grid*	-
Capacity	60,000	Watt (W)
Feed in Phase	3	-
Number of MPPT	1	-
Number of strings per MPPT	14	-
Max Isc per MPPT	96	Ampere (A)
Minimum MPPT Voltage Range	570	Volt (V)
Maximum MPPT Voltage Range	950	Volt (V)

Source: Trinergy Plus-60kW inverter datasheet

Table 5. 5G-Mega-60kW Specifications

Parameters	Value	Unit
Type	*On-Grid*	-
Capacity	60,000	Watt (W)
Feed in Phase	3	-
Number of MPPT	4	-
Number of strings per MPPT	3	-
Max Isc per MPPT	86.7	Ampere (A)
Minimum MPPT Voltage Range	250	Volt (V)
Maximum MPPT Voltage Range	1,000	Volt (V)

Source: Datasheet inverter 5G-Mega-60kW

2.3. Investment Analysis

Technical economics is a scholarly field that examines factors that impact the economic aspects of an investment or technical undertaking [18-20]. Investment analysis is a practical application of engineering economics wherein investments are evaluated and assessed [20-21]. Individuals can assign a certain worth to their assets to generate future earnings [21-22]. Investment analysis is employed to ascertain the potential investment value derived from various scenarios and evaluate the degree of investment required for installing a Solar power plant compared to the State Electricity Enterprise. Investment analysis typically consists of two main components: static investment analysis and dynamic investment analysis [22]. This study employs five investment analysis parameters to assess the viability of installing a solar power plant from multiple perspectives. The authors Simanjuntak [23] discuss calculating the cost of energy (CoE) in their study. CoE is determined by dividing the whole yearly cost of the plant (Rp/year) by the total annual energy available for the load (kWh). The formula employed in this context is:

$$EYn = (EYn - 1) - (AD\ x\ (EYn - 1)) \quad (11)$$

where:
EYn = *Energy Yield* Nth period
AD = *Annual Degradation*

$$EOM = (1\% \, x \, CAPEX) \, x \, (1 + i)^n \quad (12)$$

where:
CAPEX = *Capital Expenditure*
EOM = *Expenditure operation &; maintenance*
i = *Interest rate*

$$ER = ER_{n=0} \, x \, (1 - APR)^n \quad (13)$$

where:
ER = *Expenditure Replacement*
APR = *Annual Price Reduction*

$$PVE = \frac{EOMn}{(1+i)^n} + ERn \quad (14)$$

where:
PVE = *Present Value Expenditure*

$$LCC = initial \; investment + \sum PVE \quad (15)$$

where:
LCC = *Life Cycle Cost*

$$COE = \frac{LCC}{\sum EY} \quad (16)$$

where:
COE = *Cost of Energy*

The second parameter is the net present value (NPV) utilized to evaluate cash flow investments. The utilization of Net Present Value (NPV) is predicated on the assumption of the rate of return for cash inflows invested within a specific time frame [24]. The net present value (NPV) benefits from incorporating temporal considerations, hence rendering the computation more accurate in reflecting price fluctuations and determining the presence of residual investment value [25]. The formula employed in this context is:

$$R = (EY \, x \, TDL) \, x \, (1 + i)^n \quad (17)$$

where:
TDL = Basic Electricity Tariff
R = *Revenue*

$$PV \; NCF = \frac{R}{(1+i)^n} - \frac{EOMn}{(1+i)^n} - ERn \quad (18)$$

where:
PV NCF = *Present Value Cash Flow*

$$NPV = \sum PV \; NCF - initial \; investment \quad (19)$$

where:
NPV = *Net Present Value*

The third parameter pertains to the internal rate of return (IRR), a metric utilized to assess the rate or percentage of return on investment [26]. The concept of investment capital is commonly expressed as a percentage (%) over a specific period [27]. According to Giatman [28], an investment plan can be considered viable or advantageous if the internal rate of return (IRR) exceeds the minimum acceptable rate of return (MARR). The formula employed in this context is:

$$ACFn = \frac{\sum R - \sum EOM - \sum ER}{30} \quad (20)$$

where:
ACFn = *Annual cash flow* Nth year

$$NPV = ACF\left(\frac{P}{A}, i\%, n\right) - \ initial\ investment \tag{21}$$

$$NIRR = i^1 + \{\frac{NPV^1}{NPV^1 - NPV^2}\ (i^1 - i^2)\} \tag{22}$$

where:
IRR = *Internal rate of return*

As described by Hidayat [29], the B-CR parameter represents the outcome of evaluating the benefits gained against the costs incurred. According to Wardana [30], investment proposals may be acceptable if the Benefit-Cost Ratio (BCR) exceeds 1. The BCR formula employed in the study conducted by Siregar [31] is as follows:

$$BCR = \frac{B}{C} \tag{23}$$

where:
B = *Benefits*
C = *Cost*

The fifth parameter pertains to DPP analysis, a method employed to determine the time required for an investment to generate returns equivalent to the initial capital invested in the project [32]. The formula employed in this context is:

$$DPP = \frac{initial\ investment}{\sum PV\ NCF}\ x\ lifetime\ Solar\ power\ plant\ installation \tag{24}$$

where:
DPP = *Discounted Payback Period*

After determining each criterion's investment value, a subsequent evaluation will be conducted to ascertain the most lucrative investment situation.

3. RESULTS

This study aims to evaluate the installation scenarios of a solar power plant on the rooftop of a Central Business District (CBD) office building. The proposed approach combines two photovoltaic (PV) modules and two inverters. The objective is to estimate the best performance of each scenario and determine the most lucrative investment option.

3.1. Using the Verein Deutsche Inginieuer (VDI) 2222 method, the stage of "planning" by calculating the potential of the solar power plant if it is fully operational

During the initial phase of the project, the calculation of the potential of a Solar power plant installation will be conducted using an inverter with a total power capacity of 60 kW. The objective of this potential estimate is to assess the efficiency of a Solar power plant installation in the absence of any hindrances.

Assuming optimal functionality, the solar power plant installation necessitates utilizing an inverter with a capacity of 60 kilowatts (kW). In this scenario, it is approximated that customers must pay a minimum cost of Rp 433,410 to the State Electricity Enterprise. This payment generates an average daily energy production of 209.19 kWh/day. The installation of a Solar power plant, with associated costs amounting to Rp 9,066,590, can sufficiently cover these expenses.

3.2. Using the Verein Deutsche Inginieuer (VDI) 2222 Method, the "Drafting" Stage by Creating DFDs, Calculating Component Compatibility, Performing Software Simulations, and Technical &; Financial Optimization Assessments

A Data Flow Diagram (DFD) is used to deliver and explain how the Solar power plant installation system works. Next, we will calculate the compatibility of the PV module and inverter using Equation 4 to Equation 8. The match calculation results can be seen in Table 6.

Based on the match results, each scenario has a result that satisfies one or both conditions (+-/++) and none of the scenarios in which both conditions are not met (--). Then, it can be continued to be simulated and calculated BoQ with the results seen in Table 7.

Table 6. PV module and inverter matching results

Name	Component (*PV module-inverter*)	Parameters	Result (*PV module*)	Limiter (Inverter)	*Match*
Scenario 1	BlueSun-ARMSolar	*Voc, max* (V)	48.09	-	++
		T module max (°C)	63.75	-	
		Isc, max (A)	19.15	-	
		Voltage (V)	865.62	570-950	
		Current (A)	95.75	96	
Scenario 2	BlueSun-KSolare	*Voc, max* (V)	49.09	-	+-
		T module max (°C)	63.75	-	
		Isc, max (A)	19.15	-	
		Voltage (V)	865.62	250-1000	
		Current (A)	95.75	86.7	
Scenario 3	RECOM-ARMSolar	*Voc, max* (V)	50.41	-	++
		T module max (°C)	62.5	-	
		Isc, max (A)	17.58	-	
		Voltage (V)	907.38	570-950	
		Current (A)	87.9	96	
Scenario 4	RECOM-KSolare	*Voc, max* (V)	50.41	-	+-
		T module max (°C)	62.5	-	
		Isc, max (A)	17.58	-	
		Voltage (V)	907.38	250-1000	
		Current (A)	87.9	86.7	

3.3. Calculating Investment Analysis Using 5 Parameters and Investment Excellence Assessment

Investment analysis using five parameters to assess investment can be seen from various sides. It is expected that the use of 5 investment analysis parameters can produce accurate investment values. Investment appraisals can be seen in Table 8.

The optimal deployment of solar power plants is assessed by considering factors such as technology, cost, and investment value. The assessment is employed as a criterion for choosing the optimal solar power plant installation possibilities. The aggregation and selection of prior calculations are necessary, employing Equations 9 and 10 as indicated in Table 9 and Table 10, respectively. Table 9 incorporates six assessment criteria previously employed in calculations: installation costs, performance ratio, energy per year, component compatibility, minimum loss, and maintenance and handling.

The evaluation presented in Table 9 serves as the primary factor to be considered when choosing scenarios for installing solar power plants. The second consideration is based on Equation 9 and Equation 10, as presented in Table 10. Table 10 incorporates five investment analysis characteristics duly considered in every given scenario.

Table 7. Simulation results & BoQ

Name	*Energy Production/year* (kWh)	*Performance Ratio* (%)	*Loss* (%)	*Initial investment* (Rp)
Scenario 1	80,400	79	23.4	713,799,471
Scenario 2	79,380	78	24.7	721,320,258
Scenario 3	81,960	80.5	21.6	722,457,025
Scenario 4	80,710	79.3	23.1	729,977,441

Table 8. Investment calculation results

Name	CoE (Rp/kWh)	NPV (IDR)	IRR (%)	B-CR	DPP (year)
Scenario 1	404,627	2,371,733,499	24.43	7.65	6.9
Scenario 2	398,141	2,350,108,607	15.02	7.5	7
Scenario 3	398,307	2,451,719,005	23.75	7.83	6.8
Scenario 4	392,061	2,428,737,808	24.35	7.68	6.9

Table 9. Assessment of technical and financial aspects

Excellent	Good	Enough	Less
4	3	2	1

No.	**Assessment Aspect**	**Weight (%)**	**Scenario Options**				**Ideal Value**
			Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	
1.	Installation cost	30	4	3	2	1	4
2.	*Performance Ratio*	25	2	1	4	3	4
3.	*Energy/year*	25	2	1	4	3	4
4.	*Components Matching*	10	4	3	4	3	4
5.	*Minimum Loss*	5	2	1	4	3	4
6.	*Maintenance & Handling*	5	4	3	2	1	4
	Total Value		**2.9**	**1.9**	**3.3**	**2.3**	4
	Optimal Percentage		**72.5%**	**47.5%**	**82.5%**	**57.5%**	100%

This study aims to evaluate the technical optimization and investment benefits associated with scenarios generated through the utilization of Helioscope software. To evaluate the precision of the evaluation conducted, it is important to use on-site measures to actively monitor the data produced by the Solar power plant installation project. The determination of assessment usage is contingent upon the specific conditions and aims of the study subject.

4. DISCUSSION

Based on Table 6, for scenario 1 a voltage match of 865.62 V is obtained, and the allowable voltage limit is in the range of 570V-950V. So voltage in scenario 1 is suitable. While the current match result is 95.75 A, and the maximum allowed current limit is 96 A. So that the current in scenario 1 is suitable. Conclusion Scenario 1 has a match on both parameters so that for scenario 1 Solar power plant installation can operate optimally.

In scenario 2, a voltage match of 865.62 V is obtained, and the allowable voltage limit is in the range of 250V-1000V. So for voltage in scenario 2 is suitable. While the current match result is 95.75 A, and the maximum allowed current limit is 86.7 A. So the current in scenario 2 is not suitable. Conclusion Scenario 2 only has one match of two parameters so for scenario 2 Solar power plant installation is less able to operate optimally. In scenario 3, a voltage match of 907.38 V is obtained, and the allowable voltage limit is in the range of 570V-950V. So for voltage in scenario 3 is suitable. While the current match result is 87.9 A, and the maximum allowable current limit is 96 A. So the current in scenario 3 is suitable. Conclusion Scenario 3 has a match in both parameters so that for scenario 3 Solar power plant installation can operate optimally.

Table 10. Investment appraisal

Excellent	Good	Enough	Less
4	3	2	1

No.	Parameters	Weight (%)	Scenario Options				Ideal Value
			Seknario 1	**Seknario 2**	**Scenario 3**	**Scenario 4**	
1.	*Cost of Energy*	20	1	3	2	4	4
2.	*Net Present Value*	20	2	1	4	3	4
3.	*Internal Rate of Return*	20	4	1	2	3	4
4.	*Benefit-Cost Ratio*	20	2	1	4	3	4
5.	*Discounted Payback Period*	20	3	1	4	2	4
Total Value			**2.4**	**1.4**	**3.2**	**3**	4
Superior Percentage			**60%**	**35%**	**80%**	**75%**	100%

In scenario 4, a voltage match of 907.38 V is obtained, and the allowable voltage limit is in the range of 250V-1000V. So for voltage in scenario 4 is suitable. While the current match result is 87.9 A, and the maximum allowed current limit is 86.7 A. So the current in scenario 4 is not suitable. Conclusion Scenario 4 only has one match of two parameters so that for scenario 4 Solar power plant installation is less able to operate optimally.

Simulation analysis and BoQ can be seen in Table 7. Making simulation designs using helioscope software determines the field segment on the roof of the CBD office building. There are 3 field segments with different heights. Field segment 1 has a height of 44 m, field segment 2 has a height of 48 m, and field segment 3 has 52 m. BoQ calculations are needed to prepare the initial investment budget. The components used in each scenario are almost all the same, but for PV modules and inverters used are different, so the initial investment in each scenario can be different.

The most optimal design is scenario 3 which has a design optimization percentage of 82.5%. This is because based on the six parameters used. Scenario 3 gets an ideal score, which is 4, in Table 9 as many as 4 aspects of the assessment. The ideal value is given to scenario 3 because, for these aspects, scenario 3 has advantages over other scenarios. However, there are two aspects of assessment in scenario 3 that do not get ideal values, namely in the aspect of installation costs and maintenance & handling parameters. Scenario 3 has more expensive installation and maintenance costs than other scenarios. So the installation cost parameters and maintenance & handling parameters in scenario 3 are given a value of 2.

The parameters used in the calculation of investment analysis of each scenario are the cost of energy, net present value, internal rate of return, benefit-cost ratio, and discounted payback period. The use of 5 parameters is intended so that investment calculations can be more valid because there are 5 points of view of investment appraisal. The values of the five parameters in each of these scenarios can be seen in Table 8.

The best investment ranking is obtained by scenario 3. The determination of this ranking can be seen from the calculation of assessments that use 5 parameters as aspects of assessment. In scenario 3 we get the ideal value, which is 4, for three parameters. The three parameters are NPV, B-CR, and DPP. This is because scenario 3 has an advantage in the value of investment in these parameters compared to other scenarios. However, in scenario 3 two parameters do not get ideal values, namely the CoE and IRR parameters. This parameter gets a value that is less favorable than other scenarios. The percentage of investment advantage that scenario 3 has is 80%. So when viewed from the CoE parameter in scenario 3, Rp 398.31/kWh is obtained, while if you use Electricity State Enterprise the basic electricity tariff set for CBD office buildings is Rp 1,444.7/kWh. In the NPV parameter in scenario 3, Rp 2,451,719,005 is obtained and if divided into 360 months (30 years of Solar power plant installation life), the monthly electricity cost is Rp6,810,331, while if using Electricity State Enterprise, the monthly electricity cost is Rp 9,500,000. Based on these calculations, it can be concluded that the cost of electricity using rooftop Solar Power Plant Installation for CBD office buildings is cheaper than the cost of electricity using Electricity State Enterprise.

5. CONCLUSION

Based on the findings and further deliberations, the study reveals that scenario 3 emerges as the most financially viable option for installing a solar power plant on the rooftop of the office building in the Central Business District. Scenario three's technical and economic worth may be observed, as evidenced by its score of 3.3 out of 4 and a design optimization percentage of 82.5%. In the context of investment calculation, the Cost of Equity (CoE) parameter was determined to be Rp 398,307/kWh. The Net Present Value (NPV) was calculated to be Rp 2,451,719,005, while the Internal Rate of Return (IRR) stood at 23.75%. Additionally, the Benefit-Cost Ratio (B-CR) was 7.8, and the Payback Period (DPP) was estimated to be 6.8 years. The findings of this study demonstrate that using rooftop solar systems in office buildings located in Central Business Districts can yield significant cost reductions in electricity expenses over the 30-year lifespan of the solar power plant installation. In scenario 3, the investment value is determined to be 3.2 on a scale of 4, indicating a significant investment advantage of 80%. The findings of investment estimates involving the building of solar power plants have demonstrated cost-effectiveness compared to the State Electricity Enterprise over a 30-year timeframe. The utilization of solar power plant installations demonstrates a notable reduction in electricity expenses, amounting to Rp 6,810,331, in contrast to the utilization of State Electricity Enterprise, which incurs expenditures of Rp 9,500,000.

The present study uses the Helioscope software for computations and scenario analysis without actual implementation in real-world settings. Installing a solar power plant enables more precise calculations to be conducted, enhancing the accuracy of assessing technical and financial issues. Additionally, the estimation of investment required for installing a solar power plant can be more precise. The results of this study encourage further research on new renewable energy, especially in the solar power sector that uses solar panel technology. Providing solutions for the application of green energy and contributing to the field of electricity.

REFERENCES

[1] B. K. Vyas, A. Adhwaryu, and K. Bhaskar, “Planning and developing large solar power plants: A case study of 750 MW Rewa Solar Park in India,” Clean. Eng. Technol., vol. 6, p. 100396, 2022, doi: 10.1016/j.clet.2022.100396.

[2] A. Pawlak-Jakubowska, “Retractable roof module with photovoltaic panel as small solar power plant,” Energy Build., vol. 288, p. 112994, 2023, doi: 10.1016/j.enbuild.2023.112994.

[3] I. F. Purwoto, B. H., Jatmiko, J., Fadilah, M. A., & Huda, “Efisiensi Penggunaan Panel Surya sebagai Sumber Energi Alternatif.,” Emit. J. Tek. Elektro, vol. 18, no. 1, pp. 10–14, 2018.

[4] S. Basu, T. Ogawa, H. Okumura, and K. N. Ishihara, “Assessing the geospatial nature of location-dependent costs in installation of solar photovoltaic plants,” Energy Reports, vol. 7, no. 2021, pp. 4882–4894, 2021, doi: 10.1016/j.egyr.2021.07.068.

[5] K. A. Kavadias, P. Alexopoulos, and G. Charis, “Techno-economic evaluation of geothermal-solar power plant in Nisyros island in Greece,” Energy Procedia, vol. 159, pp. 136–141, 2019, doi: 10.1016/j.egypro.2018.12.031.

[6] H. Sumayli et al., “Integrated CSP-PV hybrid solar power plant for two cities in Saudi Arabia,” Case

Stud. Therm. Eng., vol. 44, no. February, p. 102835, 2023, doi: 10.1016/j.csite.2023.102835.

[7] A. A. Al Kindi, P. Sapin, A. M. Pantaleo, K. Wang, and C. N. Markides, "Thermo-economic analysis of steam accumulation and solid thermal energy storage in direct steam generation concentrated solar power plants," Energy Convers. Manag., vol. 274, no. September, p. 116222, 2022, doi: 10.1016/j.enconman.2022.116222.

[8] D. K. Dhaked, S. Dadhich, and D. Birla, "Power output forecasting of solar photovoltaic plant using LSTM," Green Energy Intell. Transp., vol. 2, no. 5, p. 100113, 2023, doi: 10.1016/j.geits.2023.100113.

[9] R. P. Nugraha, A. T., & Eviningsih, Konsep Dasar Elektronika Daya. Deepublish, 2022.

[10] I. Frimannslund, T. Thiis, A. D. Ferreira, and B. Thorud, "Impact of solar power plant design parameters on snowdrift accumulation and energy yield," Cold Reg. Sci. Technol., vol. 201, no. June, 2022, doi: 10.1016/j.coldregions.2022.103613.

[11] A. Saleh, A. S., & Bahariawan, Buku Ajar Energi dan Elektrifikasi Pertanian. Deepublish, 2018.

[12] T. F. Musfar, "Manajemen Produk dan Merek," Media Sains Indonesia, 2021.

[13] H. T. Paradongan et al., "Techno-economic feasibility study of solar photovoltaic power plant using RETScreen to achieve Indonesia energy transition," Heliyon, vol. 10, no. 7, p. e27680, 2024, doi: 10.1016/j.heliyon.2024.e27680.

[14] B. Kencana, "Panduan Studi Kelayakan Pembangkit Listrik Tenaga Sutya (PLTS) Terpusat," Tetra Tech ES, Inc. 2018.

[15] B. Yulianti, "Pemilihan Desain Jaringan Akses Menggunakan Teori," J. Mitra Manaj., pp. 107–112, 2020.

[16] F. Rahmadani, D. A., Nuryani, N. I., Krida, G. M., & Yuamita, "Perancangan Produk Meja Pencelupan Batik dengan Metode Verein Deutsche Inginieuer (VDI) 2222.," J. Ris. Tek. Ind., pp. 1–8, 2023, [Online]. Available: https://doi.org/10.29313/jrti.v3i1.1727

[17] & R. Yuliar, M. B., Prassetiyo, H., "Usulan Rancangan Handtruck Menggunakan Metode Verein Deutsche Inginieuer 2222 (Studi Kasus di Pasar Induk Caringin Bandung)," J. Online Inst. Tekologi Nas., vol. 1, no. 2, pp. 74–84, 2013.

[18] & H. V. Dermawan, R., "Pengembangan Mesin Pengupas Kulit Kopi Menggunakan Metode VDI 2221," Presisi, vol. 24, no. 2, pp. 55–63, 2022, [Online]. Available: https://ejournal.istn.ac.id/index.php/presisi/article/view/1323

[19] R. Arindya, "Pembangkit Listrik Tenaga Surya (PLTS)," Mitra Cendekia Media, 2022.

[20] Z. T. Kosztyán, T. Csizmadia, Z. Kovács, and I. Mihálcz, Total risk evaluation framework, vol. 37, no. 4. 2020. doi: 10.1108/IJQRM-05-2019-0167.

[21] A. Arcasi, A. W. Mauro, G. Napoli, F. Tariello, and G. P. Vanoli, "Energy and cost analysis for a crop production in a vertical farm," Appl. Therm. Eng., vol. 239, no. December 2023, p. 122129, 2024, doi: 10.1016/j.applthermaleng.2023.122129.

[22] S. M. Praveena, A. Z. Aris, and V. Singh, "Quality assessment for methodological aspects of microplastics analysis in soil," Trends in Environmental Analytical Chemistry, vol. 34. 2022. doi: 10.1016/j.teac.2022.e00159.

[23] S. M. Praveena and S. Laohaprapanon, "Quality assessment for methodological aspects of microplastics analysis in bottled water – A critical review," Food Control, vol. 130, 2021, doi: 10.1016/j.foodcont.2021.108285.

[24] E. Adhiharto, R., Fauzan, M. I., & Patriatna, "Studi Perancangan Mesin Press Hidrolik 50 ton dengan Metode VDI 2222," in Seminar Nasional Teknologi Dan Rekayasa (SENTRA) 2018, 2019, pp. 1–12.

[25] K. V. Smith, E. J. Elton, and M. J. Gruber, "Modern Portfolio Theory and Investment Analysis.," J. Finance, vol. 37, no. 5, 1982, doi: 10.2307/2327857.

[26] B. A. Wallingford and F. K. Reilly, "Investment Analysis and Portfolio Management.," J. Finance, vol. 34, no. 5, 1979, doi: 10.2307/2327255.

[27] I. Kuswandi, Ekonomi Teknik. Media Nusa Creative Publishing, 2021.

[28] L. Corvo, L. Pastore, M. Mastrodascio, and D. Cepiku, "The social return on investment model: a systematic literature review," Meditari Account. Res., vol. 30, no. 7, pp. 49–86, 2022, doi: 10.1108/MEDAR-05-2021-1307.

[29] M. Sciarelli, S. Cosimato, G. Landi, and F. Iandolo, "Socially responsible investment strategies for the transition towards sustainable development: the importance of integrating and communicating ESG,"

TQM J., vol. 33, no. 7, pp. 39–56, 2021, doi: 10.1108/TQM-08-2020-0180.

[30] V. N. Salin, O. Y. Sitnikova , O. G. Tret'yakova , and E. P. Shpakovskaya , "Investment Analysis and Management," Manag. Sci., vol. 13, no. 2, 2023, doi: 10.26794/2304-022x-2023-13-2-109-120.

[31] L. D. Mahmudah, F. N., & Prasojo, "Keefektifan Human Capital Investment Pendidikan Tenaga Kependidikan si Universitas Negeri Yogyakarta," J. Akuntabilitas Manaj. Pendidik., vol. 4, no. 1, pp. 77–86, 2016.

[32] G. Simanjuntak, J. C. H., & Alvianingsih, "Analisis Tekno-Ekonomi Hibrid Sistem PLTD PLTS Di Pulau Gersik, Belitung Menggunakan Perangkat Lunak Homer," Sutet, vol. 11, no. 1, pp. 1–12, 2021, [Online]. Available: https://doi.org/10.33322/sutet.v11i1.1372

[33] & S. W. M. Hiswandi, M. F., Iswahyudi, F., "Analisis Kelayakan Investasi Pembangkit Listrik Tenaga Surya Atap Dengan Sistem on-Grid Di Pabrik Minuman Siap Saji," Sebatik, vol. 27, no. 1, pp. 22–29, 2023, doi: https://doi.org/10.46984/sebatik.v27i1.2246.

[34] & S. W. M. Ridwan, A. F., Romli, Z., "Analisa Kelayakan Investasi Proyek Penggantian Secondary Crusher Pada Pt Berau Coal Site Binungan," Sebatik, vol. 26, no. 1, pp. 1–8, 2022, doi: https://doi.org/10.46984/sebatik.v26i1.1832.

[35] & N. F. Nuzula, N. F., Dasar-Dasar Manajemen Investasi. Universitas Brawijaya Press, 2020.

[36] Y. Abuk, G. M., & Rumbino, "Analisis Kelayakan Ekonomi Menggunakan Metode Net Present Value (NPV), Metode Internal Rate of Return (IRR) Payback Period (PBP) pada Unit Stone Crusher di CV. X Kab. Kupang Prov. NTTNo Title," J. Ilm. Teknol. FST Undana, vol. 14, no. 2, pp. 68–75, 2020.

[37] M. Giatman, Ekonomi Teknik. Rajawali Pers, 2017.

[38] A. Hidayat, F., Winardi, B., & Nugroho, "Analisis Ekonomi Perencanaan Pembangkit Listrik Tenaga Surya (Plts) Di Departemen Teknik Elektro Universitas Diponegoro," Transient, vol. 7, no. 4, pp. 875–882, 2019, [Online]. Available: https://doi.org/10.14710/transient.7.4.875-882

[39] W. Wardana, F. K., Qomaruddin, M., & Mas Soeroto, "Analisis Kelayakan Investasi Dengan Pendekatan Aspek Financial Dan Strategi Pemasaran Pada Program Ayam Petelur Di Bum Desa Bumi Makmur," Sebatik, vol. 25, no. 2, pp. 318–325, 2021.

[40] G. Siregar, "Analisis Kelayakan dan Strategi Pengembangan Usaha Ternak Sapi Potong," AGRIUM J. Ilmu Pertan., vol. 17, p. 3, 2012.

[41] & L. R. D. Andawayanti, U., Rekayasa Ekonomi untuk Pengembangan Sumber Daya Air. Universitas Brawijaya Press, 2021.