SAINSTECH NUSANTARA

Jurnal Sainstech Nusantara
https://nusantarajournal.id/sainstech
Vol.1 No.3 (2024) 13-27
ISSN: 3063-0657

Feasibility Analysis of Roof PLTS Development For Electricity Fulfillment at Station

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Article Info

Article history:

Received 06 March, 2024
Revised 07 April, 2024
Accepted 10 August, 2024

Abstract

Lemah Abang Station is a station located in Cikarang, this station is used for Cikarang-Cikampek, Cikarang-Purwakarta trips and KRL trips. To support the general national energy plan (RUEN) through Presidential Regulation No.79 of 2014, the Government of Indonesia has set a policy of increasing the share of renewable energy in the national energy mix to 23% by 2025. To support this effort, PLN's electrical power is converted to solar panels. This can be seen from the abundant solar energy potential in Cikarang, namely 5,040 Kwh/m2/day with a total duration of 2-9 hours of solar radiation per day. The solar panels that will be made have a capacity of 20 kWp using 48 units of 450Wp solar panels. Other components needed are a 20 kW inverter, 8 12V 200Ah batteries, kWh Exim, Solar Charger. Based on the economic analysis, the cheapest energy cost is 1762/kWh. In addition, the investment analysis for the construction of solar panels with the NPV, IRR, PI, and DPP methods is declared feasible to be carried out.

Keyword: Lemah Abang Station, Solar panels, Investment

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1. Introduction

Indonesia is currently still dependent on the use of fossil fuels and Indonesia itself is included as a country with an increase consumption energy per year reaching 6.04% during the period 2017-2050 According to the PLN Statistics report, throughout 2021 PLN's power plants use 3.09 million kiloliters (kl) of fuel oil (BBM). This figure increased by 15.76% from 2020 which was only 2.67 million kl. The use of coal for power plant fuel also increased by 2.69% to 68.47 million tons in 2021, compared to the previous year which amounted to 66.68 million tons[1]. This is discussed in the General National Energy Plan (RUEN), through Presidential Regulation No. 79 of 2014, Solutions from the Indonesian

DOI: https://doi.org/10.71225/jstn.v1i3.69

government set a policy of increasing the share of renewable energy in the national energy mix to 23% by 2025 [2]

One way to reduce the impact global greenhouse at the weak brother station by changing the use of PLN to solar panels. Lemah Abang Station is a station with the use of PLN electricity that is integrated with residents, this results in use of generators and causes a greenhouse effect, therefore an innovation to reduce the greenhouse effect is to make solar panels, this is by looking at the potential of sunlight In Cikarang , which reaches 5040 kWh/m^2/day, it is also to save on electricity bills, and to prevent a prolonged power outage when the weak brother station can continue to operate.

To build a solar power plant, further research is needed both regarding what aspects are needed in order to find out whether the manufacture of solar panels is feasible or not to be built at the weak brother station so the author takes the title "FEASIBILITY ANALYSIS OF DEVELOPMENT OF PLTS ROOF FOR ELECTRICITY FULFILLMENT AT LEMAH ABANG STATION"

2. Research Method

2.1 Flowchart

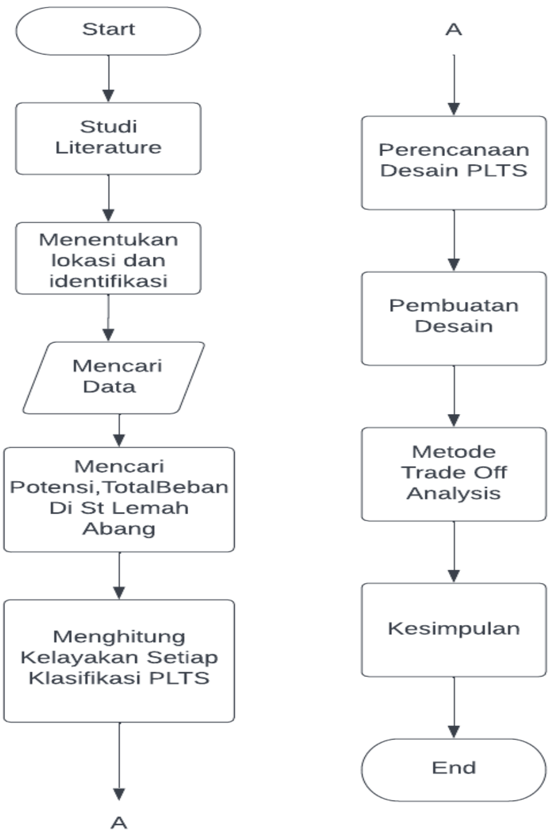

Figure 1. Flowchart

The initial stage of this research is a literature researcher reads PM 50 of 2018 regarding electrical installations as a research basis, then the researcher makes observations at the research site in St Lemah Abang, then looks for data to conduct research and be analyzed, the last to provide conclusions and suggestions.

DOI: https://doi.org/10.71225/jstn.v1i3.69

2.2 Data Collection

Methods Data collection methods by using sources from the internet and data from several years or months before and used to determine the next steps for making PLTS

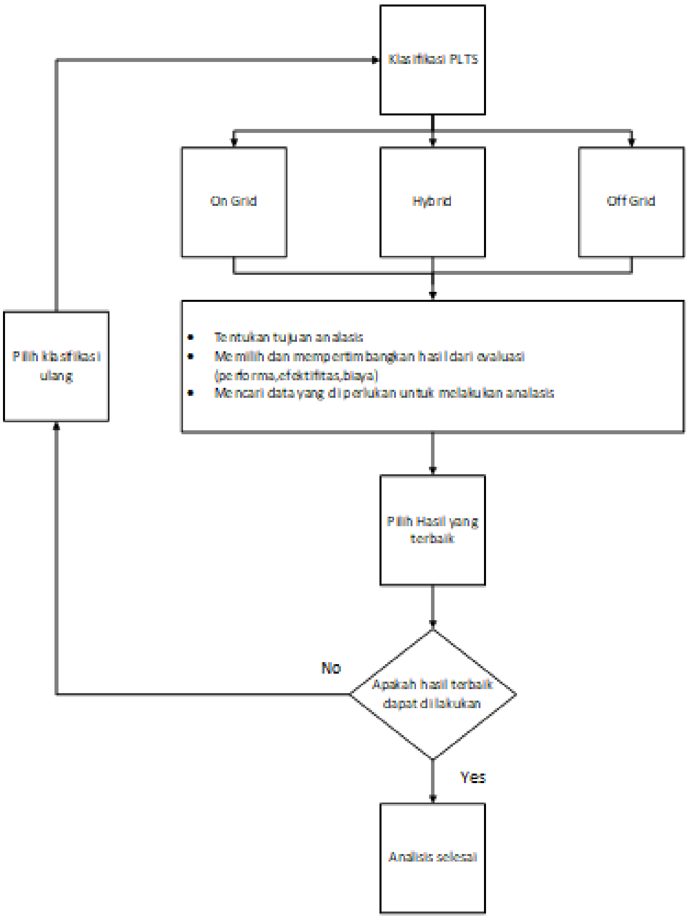

Figure 2. Method of collecting data

3. Results And Discussion

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [2, 5]. The discussion can be made in several sub-chapters.

3.1. Solar Panel Requirements Design

In designing the PV mini-grid system at Lemah Abang Station, calculations were carried out to find out how many requirements were needed. The requirements needed are to calculate the number of PV and the number of inverters adjusted to the capacity of the solar cells. In this study used , solar panels with using a Monocrystalline type a power of 450 Wp and a 20,000 Watt inverter [8]

- capacity of required 21 kWp
- Solar Panel Module: Maximum power: 450 Wp
- Voltage: 36V
- Inverter: Power capacity: 20 kWp
- Input voltage : 600V
- Battery : Voltage : 12 V Ah : 200 Ah

DOI: https://doi.org/10.71225/jstn.v1i3.69

3.1.1 Total Watt Peak Requirement (WP)

To determine the amount of watt peak needed in this study using the formula.
Total kWh = Total Wp x duration of sunshine x 365
Total Wp = 21,026/(5 x 365)
Total Wp = 11,521

3.1.2 Total PV Requirement

Based on the above calculation, it is found that the required Wp is 11,521 then we can calculate the amount of PV needed to meet the power requirement.
Total PV = (Total Wp)/(Wp Solar panels) (4. SEQ formula2 * ARABIC 2)
Total PV = (11.521 Wp)/(450 Wp)
Total PV = 25.6 ≈ 26 panels

3.1.3 Inverter Needs

To calculate how much inverter power is needed at the weak brother station using the formula
Total Inverter Power = (Total Wp)/(Efficiency Inverter)
Total Inverter Power = 11.521/0.98
Total Inverter Power = 11.756

3.1.4 Kwh/day Requirement

Then we will calculate how many batteries are needed with the formula.
kWh/day = Total Wp x duration of sunshine (4. SEQ formula2 * ARABIC 3)
kWh/day = 11,521 x 5
kWh/day = 57.605 kWh

3.1.5 Ah Needs

After looking for kWh/day then we must know how much Ah is needed to determine the number of batteries to be used
Ah = kWh/Volts
Ah = 57,605/12
Ah = 4800 Ah

3.1.6 Number of Batteries

Once the Ah of the battery is known we can calculate the number of batteries

$$\text{Number of Batteries} = \frac{Ah}{Batteries\ Ah} \quad (4. SEQ\ formula2 \backslash *\ ARABIC\ 5)$$

$$\text{Number of Batteries} = \frac{4800}{200}$$

Number of Batteries = 24 batteries

Table 1 System specifications PLTS

General Information	
Location	of Lemah Abang Station
Life Cycle	20 years

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Maximum ambient temperature	35of
Minimum ambient temperature	System$design$
data	Number$modules$
solar	panel 25 $Azimuth\ angle$ 18
48	
units	@ 450Wp
Total power capacity	21 kWp
Number of inverters	1 unit @ 20kW
Estimated energy per day	5040 kWh/m^2/day

3.2. Estimated Energy Per Year

The estimated amount of energy produced by the PLTS that is built can be known by considering radiation in the Cikarang area. Calculation of the daily amount of energy produced is calculated using the following formula.

Energy Estimation =(Maximum Total)/Radiation x Irradiation

Energy Estimation=20,000Wp/(1000 w/m^2) x 5040 kWh/m^2 x365 days

Estimated Energy= 36,792 kWh/year

3.3. Goods Price

3.3.1 Solar Panel

Panel used in this study is the Longi brand using the Monocrystalline with power 450 Wp. The price of this solar canadian solar panel is Rp. 2,600,000.00 in this study the need for 48 solar panels.

3.3.2 Inverter

Inverter is an electronic component that supports PV panels to convert direct current (direct current, DC) into alternating current (AC) which electrical equipment generally needs. The selection of the right inverter for a particular application depends on load requirements. In this study, the required load is 17 kW, therefore the Goodwe is able to withstand and issue a load of 20 kW at a price of Rp. 16,374,500.00. [7] The source of this price is obtained from Tokopedia as a reference for the price of goods [9]

3.3.3 Battery

Battery serves to store electrical energy generated from the absorption of sunlight by solar panels keep. The electrical energy stored in the battery can be used toprovides electrical energy when sunlight is not radiated optimally such as when the sky is cloudy or rainy and at night. The battery used Voz type with a specification of 12 V 200Ah needs batteryThe price per 1 battery is Rp. 2,850.000,00 [7] This price was obtained from Tokopedia. As a reference for the price of goods

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3.3.4 Cable

Cables are used as a medium to conduct electricity from the solar panel to the inverter and then to the PLN meter box. The determination of the cross-sectional area of the selected cable refers to the B1 installation method because the cable will be inserted into the conduit to make it more protected. Based on (General Electrical Installation Requirements 2011, 2011) The cable needed is a cable with a minimum cross-sectional area of 1.5 mm2, so a slocable brand PV1-F 12 AWG cable with a cross-sectional area of 4mm2 will be used at a price of IDR 3,587,000 [5] with long 250 m

3.3.5 kWh Meter

Net Metering or EXIM meter is a service mechanism, where the electricity generated by the rooftop solar panel system can be exported to the PLN distribution network, and can be reused for household consumption.The kWh meter used in this study is EM519033-04 at a price of Rp. 450.378. This price is obtained from alibaba as a reference price [10]

3.4. Goods Price

A Formula Efficiency $= pxl$

$P = Vmp \ x \ Imp$

$\eta \frac{P}{A} \ x \ 100\%$

Information :

η = *efficiency Solar panel*

Vmp = *Open circuit voltage (V)*

Imp = *Short circuit current (A)*

P = *The highest power of the solar panel*

p = $Length \ (m)$

l = $width \ (m)$

A = *Solar cross-sectional area* (m^2)

3.5. Goods Price

3.5.1 Solar cell design

Figure 3. On Grid

3.5.2 Total cost of solar needs

Table 2 Details of the Cost of Making On Grid Solar Panels

DOI: https://doi.org/10.71225/jstn.v1i3.69

No.	Name of Material	Qty	Unit Unit	Price (Rp)	Total Price (Rp)
1	Solar Panel	26	Pcs	2,600,000	67,600,000
2	Inverters	1	Pcs	16,374,500	16,374 .500
3	Cable $4mm^2$	250	meters	3,587,000	3,000,000
4	kWh Meters	1	Pcs	450,378	450,378
5	Installation Services	1	Package	4,000,000	20,000,000
6	Mild steel	1	package	587,000	587,000
			Total		108,011,878

3.5. Cost operational and repair

Table 3 Costs O&M On grid

Component	Number	of Units	Reference	Fee Monthly	Cost Annual Cost	Escalation 20 years
			Fix Cost			
Technical Employee	1	Person /Month	UMR	Rp 4,000,000	Rp 48,000,000	Rp 960,000,000
Office Operations		Per month		Rp 1,000,000	Rp 12,000,000	Rp 240,000,000
		Total Cost				Rp 1,200,000,000
			Variable Cost			
Inverter (per 15 years)						Rp 18,093,792
		Total Variable Cost				Rp 18,093,792
		Total O&M Cost				Rp 1,218,093,792
		O&M/Year				Rp 60,904,690

This PLTS is planned to work for 20 years based on the assumption of a lifetime of panels and other equipment that supports the PV mini-grid system. The interest rate used to determine the present value is 10.95% (Government Bank in 2022)

MPW(10.95 20) = O&M x ((1+i)^N-1)/ 〚i(1+i)〛 ^N (4. SEQ formula2 * ARABIC 6)

= 60,904,690 x 6.9/(0.87)

= 60,904,690 x 7.9

= Rp 481.147,051

After knowing the investment costs and operational and repair costs, you can find out the LCC value with the formula

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LCC=II+MPW

LCC=59,173.378+ 481.147.051

LCC=540,320,429

3.5.4 Calculation of Energy Costs

Calculation of energy costs (cost of energy) of a PLTS is determined by the cost of Life Cycle Cost (LCC), capital recovery factor (CRF), and the amount of energy produced in one year [11]. The cost of energy for PV mini-grid is calculated by the following formula :

$$COE = \frac{LCC\ x\ CRF}{A\ kWh}$$

Capital recovery factor to convert cash flow Life Cycle Cost into a series of annual costs, calculated by the following formula:

$$\text{CRF} = \frac{i(1+i)^N}{(1+i)^N - 1}$$

$$\text{CRF} = \frac{0.87}{6.9}$$

$$\text{CRF} = 0.12$$

Based on the calculation results of LCC, CRF, and energy estimates in one year, the cost of energy for PV mini-grid which will be developed at Lemah Abang Station for On Grid type solar panels as follows.

$$COE = \frac{LCC\ x\ CRF}{A\ kWh}$$

$$COE = \frac{540{,}320{,}429\ x\ 0.12}{36{,}792}$$

$$COE = 1{,}762/\text{kWh}$$

3.6. Off Grid

3.6.1 Solar cell design

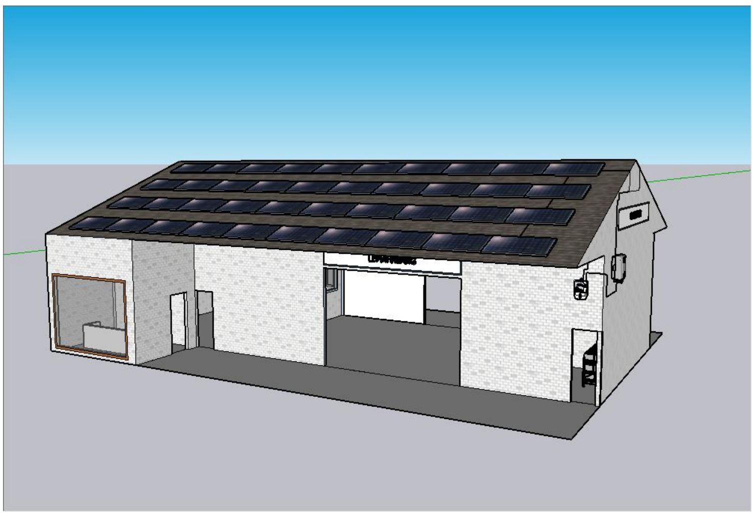

Figure 4. OffGrid

DOI: https://doi.org/10.71225/jstn.v1i3.69

3.6.2 Total Cost of Solar Cell Requirements

Table 4 Details of Cost of Making Off Grid Solar Panels

No	Name of Material	Qty	Unit Unit	Price (Rp)	Total Price (Rp)
1	Solar Panel	26	Pcs	2,600,000	67,600,000
2	Inverter	1	Pcs	16,374,500	16,374,500
3	Cable $4mm^2$	250	meters	3,587,000	3,000,000
4	Batteries	24	pcs	2,850 .000	68.400,000
5	Installation Services	1	Package	4,000,000	20,000,000
6	MPPT	1	Pcs	222,000	222,000
7	Ba network	1	package	587,000	587,000
		Total		176,183,500	

3.6.3 Cost Operational and Repair

Table 5 O&M Off grid

Component	Number of Units		Reference	Cost Monthly	Cost Annual	Escalation 20 years
Fix Cost						
Technical Employee	1	Person/ Month	UMR	Rp 4,000,000	Rp 48,000,000	Rp 960,000,000
Office Operations		Per month		Rp 1,000,000	Rp 12,000,000	Rp 240,000,000
			Total Cost			Rp 1,200,000,000
Variable Cost						
Battery (per 5 years)						Rp 23,684,000
Inverter (per 15 years)						Rp 18,093,792
			Total Variable Cost			Rp 41,777,792
			Total O&M Cost			Rp 1,241,777,792
			O&M/Year			Rp 62,088,890

This PLTS is planned to work for 20 years based on the assumption of a lifetime of panels and other equipment that supports the PLTS system[12]. The interest rate used to determine the present value is 10.95% (Government Bank in 2022)

MPW(10.95 20) $= O\&M\ x\ \frac{(1+i)^N-1}{i(1+i)^N}$

$= 62{,}088{,}890\ x\ \frac{6.9}{0{,}87}$

$= 62{,}088{,}890\ x\ 7{,}9$

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= Rp 490,502,231

After knowing the investment costs and operational and repair costs, you can find out the LCC value with the formula

$$LCC = II + MPW$$

$$= 176{,}183{,}500 + 490{,}502{,}231 = 666{,}685{,}731$$

3.6.4 Cost Calculation Energy

Calculation of energy costs (cost of energy) of a PV mini-grid is determined by the cost of Life Cycle Cost (LCC), capital recovery factor (CRF), and the amount of energy produced in one year. The cost of energy for PV mini-grid is calculated by the following formula:

$$COE = \frac{LCC \ x \ CRF}{A \ kWh}$$

Capital recovery factor to convert cash flow Life Cycle Cost into a series of annual costs, calculated by the following formula:

$$\text{CRF} = \frac{i(1+i)^N}{(1+i)^N-1}$$

$$\text{CRF} = \frac{0.87}{6.9}$$

$$\text{CRF} = 0.12$$

Based on the calculation results of LCC, CRF, and energy estimates in one year, the cost of energy for PV mini-grid which will be developed at Lemah Abang Station for the Off Grid type solar panels as follows.

$$\text{COE} = \frac{LCC \ x \ CRF}{A \ kWh}$$

$$= \frac{666{,}685{,}731 \ x \ 0.12}{36{,}792}$$

$$= 2{,}174\text{/kWh}$$

3.6.5 Feasibility Investment

Initial

investment Off Grid Capital = Rp 176,183,500

(Discount rate Bank Indonesia) = 10.95%

Life Cycle = 20 Years

Capital recovery factor = 0.12

Electricity generated = 36,792 KWh/year

Fee

Billing Fee at Lemah Abang Station = Rp 9,158,048

Expenditure Cost

Per year = Rp 62,088,890 /year

Table 6 Off Grid Investment Feasibility

Solar Panel Classification	Method	Value	Description
Off Grid	NPV	IDR 46,977,602	Eligible
	PI	1	Eligible

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	IRR	13.26%	Eligible
	DPP	2	Feasible

3.7. Hybird/substitution

3.7.1 Solar cell design

Figure 5. *Hybrid*

3.7.2 Total cost of Solar Cell Requirements

Table 7 Details of Manufacturing Costs Solar Panel On Grid

No	Name of Material	Qty	Unit Unit	Price (Rp)	Total Price (Rp)
1	Solar Panel	26	Pcs	631.726	67.600,000
2	Inverter	1	Pcs	4,813,152	16,374,500
3	Cable $4mm^2$	250	meters	3,587,000	3,000,000
4	kWh Meter	1	Pcs	450.378	450.378
5	Battery	24	pcs	4.300.000	68.400,000
6	Installation Services	1	Package	4,000,000	20,000,000
7	MPPT	1	Pcs	222,000	222,000
8	Mild steel	1	package	587,000	587,000
	Total			176.633,878	

3.7.3 Operational and Repair Cost

Table 8 Hybrid O&M

Components	Number of Units	Reference	Cost Monthly	Cost Annual	Escalation 20 years
			Fix Cost		

DOI: https://doi.org/10.71225/jstn.v1i3.69

Technical Employee	1	Person/ Month	UMR	Rp 4,000,000	Rp 48,000,000	Rp 960,000,000
Office Operations		Per month		Rp 1,000,000	Rp 12,000,000	Rp 240,000,000
			Total Cost			Rp 1,200,000,0 00
			Variable Cost			
Battery (per 5 years)						Rp 23,684,000
Inverter (per 15 years)						Rp 18,093,792
			Total Variable Cost			Rp 41,777,792
			Total O&M Cost			Rp 1,241,777,7 92
			O&M/Year			Rp 62,088,890

This PLTS is planned to work for 20 years based on the assumption of a lifetime of panels and other equipment that supports the PLTS system. The interest rate used to determine the present value is 10.95% (Government Bank in 2022)

MPW(10.95% 20) $= O\&M\ x\ \frac{(1+i)^N-1}{i(1+i)^N}$

$= \ 62{,}088{,}890\ x\ \frac{6.9}{0.87}$

$= \ 62{,}088{,}890\ x\ 7{,}9$

= Rp 490,502,231

After knowing the investment costs and operational and repair costs, you can find out the LCC value with the formula

LCC $= \ II + O\&M$

$= 176.633{,}878 + 490.502{,}231$

$= 667{,}136{,}109$

3.7.4 Calculations Energy Cost

Calculation of energy costs (cost of energy) of a PLTS is determined by the cost of Life Cycle Cost (LCC), capital recovery factor (CRF), and the amount of energy produced in one year. The cost of energy for PLTS is calculated by calculating the cost of energy for a PLTS determined by the cost of Life Cycle Cost (LCC), capital recovery factor (CRF), and the amount of energy produced in one year. The cost of energy for PLTS is calculated by the following formula.

$$COE = \frac{LCC\ x\ CRF}{A\ kWh}$$

Capital recovery factor to convert the cash flow Life Cycle Cost into a series of annual costs calculated by the following formula

DOI: https://doi.org/10.71225/jstn.v1i3.69

$$CRF = \frac{i(1+i)^N}{(1+i)^N - 1}$$
$$= \frac{0.87}{6.9}$$
$$= 0.12$$

Based on the results of the calculation of LCC, CRF, and energy estimates in one year, the cost of energy for PLTS to be developed at Lemah Abang Station for On Grid solar panels is as follows

$$COE = \frac{LCC\ x\ CRF}{A\ kWh}$$
$$= \frac{667{,}136{,}109\ x\ 0.12}{36{,}792}$$
$$= 2{,}175/kWh$$

3.7.5 Feasibility Investment

Initial

investment Hybrid Capital = Rp 176.633,878
Discount rate (Bank Indonesia) = 10.95%
Life cycle = 20 Years
Capital recovery factor = 0.12
Electricity generated = 36,792 kWh/year

Cost

Billing Fees at Lemah Abang Station = Rp 9,158,048

Expenditure Costs

Per year = $Rp\ 62{,}088{,}890/yr$

Table 9 Eligibility of Hybrid Investment

Classification of Solar Panels	Method	Value	Description
Hybrid	NPV	Rp 256,241,714	Eligible
	PI	5	Eligible
	IRR	12%	Eligible
	DPP	2the	be

4. Conclusion

Results of this research is

1. that the solar panel design that was developed at Lemah Abang Station as a substitute for PLN has several classifications including on grid, off grid, and hybrid where the three designs have their respective differences. -each where
2. the on grid has a grid/power pole, solar panels, inverter, and kWh Exim but does not have a battery
3. off the grid has a solar panel, kWh meter, battery, and inverter but does not have a grid/pole
4. hybrid has solar panels, kWh Exim ,battery, inverter, and grid/electric pole
5. Efficiency of solar panels at the weak brother station reached 77.8%
6. Estimated energy produced by solar panels at the weak station a bang is 36,792kWh/Year
7. Based on the economic analysis, the lowest energy cost is obtained by using on grid which is Rp. 1762/kWh, the feasibility of the investment made shows the NPV value of Rp. 291.182.607. PI of 6, IRR of 13%, DPP for 2 years

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