Prahastono, Iswan; Paradongan, Hendry Timotiyas; Aditya, Indra Ardhanayudha et al.

Article

Photovoltaic power plant feasibility study based on Indonesia's renewable energy tariffs : a study of Nusa Penida solar power plant

Reference: Prahastono, Iswan/Paradongan, Hendry Timotiyas et. al. (2023). Photovoltaic power plant feasibility study based on Indonesia's renewable energy tariffs : a study of Nusa Penida solar power plant. In: International Journal of Energy Economics and Policy 13 (5), S. 221 - 228. https://www.econjournals.com/index.php/ijeep/article/download/14659/7470/34219. doi:10.32479/ijeep.14659.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(5), 221-228.

Photovoltaic Power Plant Feasibility Study Based on Indonesia's Renewable Energy Tariffs: A Study of Nusa Penida Solar Power Plant

Iswan Prahastono[1], Hendry Timotiyas Paradongan[2]*, Indra A. Aditya[1], Kevin M. Banjarnahor[3], Ngapuli Irmea Sinisuka[3]

[1]PLN Research Institute, PT PLN (Persero), Jakarta, Indonesia, [2]School of Business and Management, Bandung Institute of Technology, Bandung, Indonesia, [3]School of Electrical Engineering and Informatics, Bandung Institute of Technology, Bandung, Indonesia. *Email: hendry_timotiyas@sbm-itb.ac.id

Received: 14 May 2023 **Accepted:** 16 August 2023 **DOI:** https://doi.org/10.32479/ijeep.14659

ABSTRACT

This study conducts feasibility study on 3.5 MW photovoltaic (PV) power plant in Nusa Penida based on Indonesia's existing renewable energy tariffs. Three scenarios were developed utilizing RET screen software, according to the power plant specification. Base case scenario was developed to determine the feasibility of the PV power plant based on independent power producer perspective. PLN scenario was developed to determine the feasibility of the PV power plant based on Indonesia's state-owned electricity company. Clean-energy scenario was developed to determine the feasibility of the PV power plant if there was a \$20/tCO_2 emission reduction incentive in Indonesia. The base case scenario results showed that the existing PV tariffs for PV power plant project was not sufficient to make the project financially viable based on the IPPs perspective. The PLN scenario results showed that the PV power plant project is very profitable based on PLN perspective due to high cost-savings. The clean-energy scenario results showed that \$20/tCO_2 emission reduction incentive was sufficient to make the PV power plant project financially viable based on the IPPs perspective. Based on those results, this study recommends emission-reduction incentives as a mean of attracting more investors. This study also recommends PLN to utilize more PV power plant, especially if the region have high generation cost as a means to lower Indonesia's energy cost thus making energy more accessible for everyone.

Keywords: Photovoltaic Power Plant, Feasibility Study, Indonesia's Renewable Energy Tariffs, RET Screen
JEL Classifications: G32, Q42, Q48, Q58

1. INTRODUCTION

In recent years there has been a rising trend toward renewable energies usage all around the globe, including Indonesia. Indonesia's electricity consumption has grown about 75% from 2010 to 2020 or about 7.5% annually (IEA, 2020). Indonesia's government is targeting to have 23% renewable energy mix by the end of 2025 (MOF, 2022). In 2021, Indonesia's renewable energy contributes to 11.5 of its energy mix (ESDM, 2022). In 4 years, Indonesia needs to double its renewable energy mix to achieve the 23% renewable energy mix target in 2025.

Solar energy is a renewable energy source whose potential is largely unexploited. According to Indonesia's Ministry of Energy and Mineral Resources there is 112,000 GWp of solar energy potential in Indonesia (ESDM, 2012). Although Indonesia's solar potential is great, solar energy utilization in Indonesia is still lacking. Indonesia's solar power plant utilization in 2020 is 147.28 MW (ESDM, 2021). One reason has been Indonesia's dependency with coal due to its availability and affordability, since coal contributes to 62% of Indonesia's energy mix in 2021 (PLN, 2021c).

Photovoltaic power plants are becoming increasingly popular as a clean and renewable source of energy. The conversion of sunlight into electricity using photovoltaic cells has made it possible to generate electricity without the use of fossil fuels, thereby reducing carbon emissions (EPA, 2019) and reduce dependency on fossil fuels usage. Power generated by photovoltaic panels (PV), electronic device that convert sunlight to electricity and presently are one of the fastest growing renewable energy technologies (Rynska, 2022). There is a tendency to increase the implementation rate of PV systems worldwide (Mirzahosseini and Taheri, 2012). Their advantages are little maintenance, environmentally friendly and does not use fossil fuel. One weakness of PV systems is their high initial costs (IESR, 2019).

Indonesia's archipelago condition brings a complex situation in its electricity system condition. Many of Indonesia's region power system is not inter-connected (PLN, 2021b), thus Indonesia's electricity production cost can be varied from one region to another. Production cost can be immensely high due to its remote location and high cost of fuel transportation. PV power plant seems to be suitable solution for remote areas in Indonesia due to the availability of solar energy all around Indonesia.

In order to accelerate Indonesia's renewable energy mix, Indonesian government introduce new renewable energy tariffs including PV tariffs as a means to increase Indonesia's renewable energy mix and accelerate its energy transition. Unfortunately, according to author's knowledge there is still no academic literature focusing on the feasibility of PV power plant based on the renewable energy tariffs. Therefore, this research aims to provide a comprehensive feasibility study of PLN's 3.5 MW PV power plant in Nusa Penida which hopefully helped Indonesia in increasing its renewable energy mix.

2. MATERIALS AND METHODS

In the review of effectiveness of the renewable energy tariffs, from the viewpoint of financial viability for the construction of photovoltaic power plants, a financial analysis of the project was developed in consisting three scenarios which included periodic cost of the power plant components replacement such as batteries. In all three scenarios, the inflation rates were 5.71% based on Indonesia's average inflation rates in the last 20 years (Bank Indonesia, n.d.).

In addition to the financial analysis, sensitivity analysis was carried out in order to determine the impact of changes in variables on project viability. Lastly, emission analysis was carried to understand the impact of PV power plant in reducing greenhouse gas (GHG) emission.

2.1. Indonesia PV Tariffs

In 2022, Indonesia's government release regulation about renewable energy development acceleration that regulates tariff for renewable energies in Indonesia (President Regulation Number 112, 2022) including solar PV power plant. The tariffs include power plant capacity, location, and the years of operation in the calculation. A summary of existing PV tariffs for Tiga Nusa region was shown in Table 1.

Three scenarios were developed to evaluate the viability of the PV power plant. First scenario, known as base case scenario represents the independent power producer (IPPs) perspective which utilizes the existing renewable energy tariffs. Second scenario, referred to as PLN scenario represents the PLN perspective, which included PLN's cost-savings in the calculation. Third scenario, referred to as clean-energy scenario was developed as a hypothetical scenario to explore the implications of a \$10/tCO_2 emission incentives for every green-house gas (GHG) emission reduction.

The USD currency will be converted using Central Bank of Indonesia's (BI) Jakarta Interbank Spot Dollar Rate (JISDOR) (Bank Indonesia, 2022). It is worth mentioning that tariffs for PV power plant that includes for battery facilities or other electricity storage as referred in the existing regulation (President Regulation Number 112, 2022) for more than 60% from its rates needs to obtain price approval from Indonesia's energy and mineral resources minister.

In order to assess the feasibility of the power plant based on different perspectives, 3 scenarios were developed. The first scenario, namely base case scenario was developed in order to assess the feasibility of the PV power plant based on existing renewable energy tariffs. This scenario was done in order to assess the feasibility of the PV power plant based on the IPPs perspective. The second scenario, also known as PLN scenario was developed in order to understand the feasibility of the PV power plant based on PLN perspective. This scenario includes PLN's electricity selling price and diesel generation cost in the feasibility calculation (Table 2). The third scenario, also known as clean-energy scenario was developed in order to assess the feasibility of the PV power plant if there was a \$20/tCO_2 emission incentives. A summary for all scenarios was shown in Table 3.

2.2. De-dieselization Program

The second scenario was designed with the objective of assessing the feasibility of the PV power plant project, in alignment with PLN's de-dieselization program. The de-dieselization program as specified by PLN (PLN, 2021a), is focused on the transition from diesel-based power plants to renewable energy-based power plants. By conducting a comprehensive feasibility study of the PV power plant project, this research endeavours to provide valuable insights into the effectiveness and potential implications of the de-dieselization program. The analysis on Nusa Penida's 3.5 MW PV power plant aims to contribute to the broader understanding

Table 1: PV (excluding BESS) tariffs for Tiga Nusa region

Capacity	Year 1-10	Year 11-30
≤1 MW	0.126 USD	0.069 USD
>1 MW-3 MW	0.109 USD	0.597 USD
>3 MW-5 MW	0.965 USD	0.526 USD
>5 MW-10 MW	0.909 USD	0.496 USD
>10MW-20 MW	0.873 USD	0.476 USD
>20 MW	0.764 USD	0.417 USD

Table 2: PLN average generation cost

Parameter	IGeneration cost diesel PP	Generation cost solar PP
Rp/kWh	5.906	1284
\$/kWh	0.397	0.0863

Table 3: Tariffs scenario

Scenario	Capacity (kW)	Average Tariffs ($/kWh)	Cost-savings ($/kWh)	GHG reduction incentives ($/tCO$_2$)
Base case	3.500 kW	0.112		
PLN	3.500 kW	0.084	0.188	
Clean energy	3.500 kW	0.112		20

Table 4: Kutampi diesel power plant data

Engine	Installed capacity	Production capacity
1	1.700 kW	1.531 kW
2	1.700 kW	1.531 kW
3	1.700 kW	1.531 kW
4	1.700 kW	1.531 kW
5	1.700 kW	1.531 kW
6	1.700 kW	1.531 kW
7	1.700 kW	1.531 kW
Total capacity	11.900 kW	10.717 kW

of the program's viability and facilitate all stakeholders regarding the adoption of renewable energy sources in the power generation sector.

Nusa Penida's power system is part of Tiga Nusa grid. Tiga Nusa is a group of small islands in the southeast of Bali separated by Badung Straits, and their power system is not connected with Bali. The group consists of Nusa Penida, Nusa Ceningan and Nusa Lembongan islands. The power system of Tiga Nusa is isolated from Bali.

In addition to the 3.5 MW solar PV power plant facility, the power system of Nusa Penida incorporates a diesel power plant called Kutampi Diesel Power Plant, from which it also obtains electrical energy. As shown in Table 4, Kutampi Diesel Power Plant installed capacity is 11.900 kW or equivalently 11.9 MW, with a corresponding production capacity of 11.717 kW or around 11.7 MW.

2.3. RET Screen Software

Renewable-energy and Energy-efficiency Technology Screening (RET screen) is a software developed by the government of Canada that allows comprehensive identification, assessment and optimization of the technical, financial viability and risk of potential renewable energy, energy efficiency and cogeneration projects. RET Screen can be used world-wide to calculate the energy production, life-cycle costs and greenhouse gas emission reduction.

The analysis was performed using RET Screen software which is capable of performing energy production analysis, financial analysis, risk analysis and GHG emission analysis. RET Screen software takes into account details such as availability of energy resource at the project site, equipment performance, initial project costs, "base case" credits, ongoing and recurring project costs, avoided cost of energy, financing, equipment taxes and sales, environmental characteristics of alternative energy, environmental credits and subsidies, and decision maker's definition of cost-effective (Iacobescu and Badescu, 2012; Natural Resources Canada, 2023). RET Screen allows the project evaluation process easier for decision-makers. A summary of the input data for the RET Screen calculation in this research is summarized in Table 5.

Table 5: Data for RET Screen calculation

Power plant location	8.7133°S, 115.5843°E
Elevation	120 m
Power plant capacity	3,500 kW
COD	2022
Daily solar radiation	5.34 kWh/m^2
Electricity output to grid	6,189 MWh/year
Initial costs	$1,765/kW
Annual O&M costs	$16/kW
Periodic cost (per 15 years)	$1,000,000
Discount rate	7%
Inflation rate	5.71%
Project life	25 years
Debt ratio	70%
Debt interest rate	10%
Debt term	15 years
Capacity factor	19.8%
Electricity tariff escalation rate	0%

Net present value (NPV):

$$NPV = \sum_{n=0}^{N} \frac{Cn}{(1+r)^n} \tag{1}$$

Levelized cost of electricity (LCOE):

$$\text{LCOE} = \frac{\text{Sum of cost over lifetime}}{\text{Sum of electricity generated over lifetime}} \tag{2}$$

Simple payback (SP):

$$SP = \frac{C - IG}{(Cener + Capa + CRE + CGHG) - (CO \text{ and } M + Cfuel)} \tag{3}$$

Equity payback (EP):

$$EP = \sum_{n=0}^{N} Cn \tag{4}$$

The internal rate of return (IRR):

$$0 = \sum_{n=0}^{N} \frac{Cn}{(1+IRR)^n} \tag{5}$$

Benefit-cost ratio (B-C):

$$B - C = \frac{NPV + 1(1 - fd)c}{(1 - fd)c} \tag{6}$$

Annual emission reduction (ΔGHG):

$$\Delta GHG = ABCE – APCE \tag{7}$$

Capacity factor:

$$\text{CF} = \frac{\text{Net annual generated electical energy}}{\text{Nominal Capacity}} \tag{8}$$

GHG emission reduction revenue (GRR):

$$GRR = \Delta GHG \times GHG \text{ emission incentives} \quad (9)$$

Where N is the project life in years, Cn is the after-tax cash flow in year n, r is the discount rate, C is the initial cost of the project, fd is the debt ratio, B is the total benefit of the project, IG is incentives and grants, $Cener$ is the annual energy savings or income, $Ccapa$ is the annual capacity savings or income, CRE is the annual renewable energy (RE) production credit income, $CGHG$ is the GHG reduction income, $CO\&M$ is the annual operation and maintenance cost incurred by the project, $Cfuel$ is the annual cost of fuel, which is zero for this PV project, ΔGHG is the annual emission reduction, $ABCE$ is the annual base case emission, $APCE$ is the annual proposed case emission.

This study employs Monte Carlo simulations conducted with the RET Screen software to perform risk analysis. Monte Carlo simulations is a highly effective technique for enhancing the precision of estimators regarding the performance of the model (Rubinstein and Kroese, 2016). The risk associated with the project was assessed to gain an understanding of its implications. Multiple parameters, as outlined in Table 6, were employed as inputs for the risk analysis using the RET Screen software. By evaluating the impact of these input parameters on the net present value (NPV), an estimation was made regarding the risk entailed by the project, along with the probabilities of success and identification of the most influential parameters.

2.4. PV Power Plant

Solar power plants are essential to human beings (Makkiabadi et al., 2021), not only for the potential to supply electricity, but also for their help to mitigate CO_2 emissions (Al Garni and Awasthi, 2017; Hirbodi et al., 2020; Nili et al., 2021; Wyban, 2020). Countries near the equator have the highest solar radiation level, the construction of various types of solar power plant in these countries has been expanding rapidly in recent years (Ali et al., 2019; Makkiabadi et al., 2021; Reddy and Veershetty, 2013). Based on those considerations, PV power plant seems to be suitable solution for Indonesia's future energy.

The configuration of grid-connected PV system consists of PV panels, converter, electricity meter, AC breaker panel and fuses, safety switches and cabling, the electrical grid, and the home sockets are the main parts of a grid-connected PV system. To enable greater power from the PV arrays, the PV panels should be chosen with high cell efficiency and high working temperatures (Rehman et al., 2017). The PV panels specification for this research is shown in Table 7. In order to feed into the grid or power loads, inverter extracts the direct current (DC) electricity from the PV array and converts it into alternating current (AC) electricity at the proper voltage and frequency. The inverter specification is summarized in Table 8. Electricity meters or kilowatt hours are used to measure the flow of electricity to and from the grid. It is also important to mention, this PV power plant employs battery energy storage system (BESS) that acts as excess energy storage for later use, in order to balance energy supply and demand, and to provide grid stability. The battery specification for the PV power plant is shown in Table 9.

3. RESULTS AND DISCUSSION

3.1. Economic and Financial Analysis

In the first scenario the average rates for PV based electricity of \$0.112/kWh was assumed, and any credit for the reduction of greenhouse emissions was not considered. PV systems technical conditions of 6.189 MWh electricity exported to grid annually was considered for the scenario. As shown in Figure 1, equity payback period of 21.4 years and cumulative cash flows of \$1,762,000 could be achieved. Equity payback period signifies the time required to recover the investment solely from equity. The pre-tax internal rate of return equals to 3.4%, simple payback period of 9.5 years, NPV of −\$830,336 and 0.54 benefit-cost ratio.

In the PLN scenario, average rates for PV based electricity of \$0.084/kWh was assumed with the addition of \$0.188/kWh cost savings. Any credit for the reduction of greenhouse emissions was not considered in the calculation. PV systems technical conditions of 6.189MWh electricity exported to grid annually was considered for the scenario. Figure 2 showed that the equity payback of 1.7 years and cumulative cash flows of \$26,517,728 could be achieved. The pre-tax internal rate of return equals to 58.6%, simple payback period of 3.7 years, NPV of \$10,709,335 and 6.9 benefit-cost ratio.

On the clean energy scenario, the average rates for PV based electricity of \$0.112/kWh was assumed, and \$20/tCO_2 credit for the reduction of greenhouse gas emissions was considered. PV system technical conditions of 6,189 MWh electricity exported

Table 6: Risk parameters

Parameter	Unit	Value	Range (%)	Minimum	Maximum
Initial costs	\$	6,040,000	25	4,530,000	7,550,000
O&M costs	\$	56,00	25	42,000	70,000
Electricity exported to grid	MWh	6,189.44	25	4,642.08	7,736.80
Electricity tariffs #1	\$/MWh	112	25	84	140
Electricity tariffs #2	\$/MWh	84	25	63	105
Net GHG reduction	tCO_2	119,944	25	89,958	149,930
GHG reduction incentives	\$/tCO_2	20	25	15	25
Cost-savings	\$	1,163,532	25	872,649	1,454,415
Debt ratio	%	70	25	52.50	87.50
Debt interest rate	%	10	25	7.50	12.50
Debt term	year	15	25	11	19

to grid annually was considered for the scenario. Based on the achieved results shown in Figure 3, equity payback period of 18 years and cumulative cash flows of $4,160,909. The internal rate of return equals to 8.3%, NPV of $287,854, payback period of 8.2 years and cost-benefit ratio of 1.2.

Energy production cost or levelized cost of electricity (LCOE) was $0.124/kWh or Rp. 2.067/kWh based on the average JISDOR currency in 2022 (Bank Indonesia, 2022).

3.2. Risk and Sensitivity Analysis

Figure 4 shows that the most sensitive input in the base case scenario is the electricity export rate, the higher the electricity export rate the more profitable the project is, vice versa. The second most sensitive is electricity exported to grid, followed by initial costs, debt interest rate, operation and maintenance cost, debt ratio and lastly debt term.

Figure 5 shows that the most sensitive input in PLN scenario is other revenue (cost savings), the higher the cost-savings, the more profitable the project is, and vice versa. The second most sensitive is initial cost, followed by electricity export rate, electricity exported to grid, debt interest rate, operation and maintenance cost, debt rate and lastly debt term.

Figure 6 shows that the most sensitive input in clean-energy scenario is electricity export rate, the higher the electricity rate, the more profitable the project is, and vice versa. The second most sensitive input is the electricity exported to grid, followed by initial cost, debt interest rate, net GHG reduction, oepration and maintenance cost, GHG reduction credit rate, debt ratio, and lastly debt term.

Table 7: PV panel specification

PV panel type	Mono-crystalline
Solar tracking mode	Fixed
Slope	9°
Azimuth	180°
Capacity	540 Wp
Efficiency	20.9%
Lifetime expectancy	25 years
Dimension	2.584 m^2

Table 8: Inverter specification

Capacity	26.000 kW
Efficiency	99%
Lifetime expectancy	25 years

Table 9: Battery specification

Rated energy	372.7 kWh
Rated voltage	1331.2 V
Lifetime expectancy	15 years
Number of modules	8

Figure 1: Cash flows of base case scenario

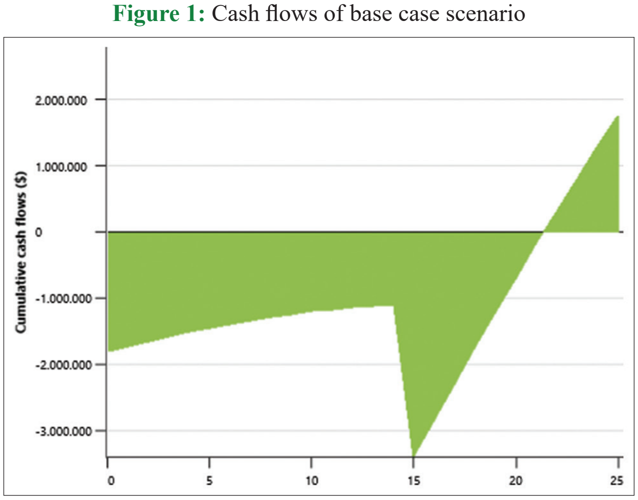


Figure 2: Cash flows of PLN scenario

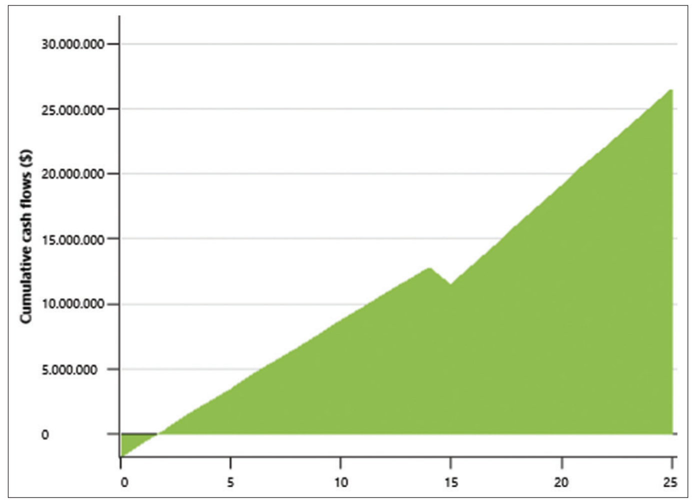


Figure 3: Cash flows of clean-energy scenario

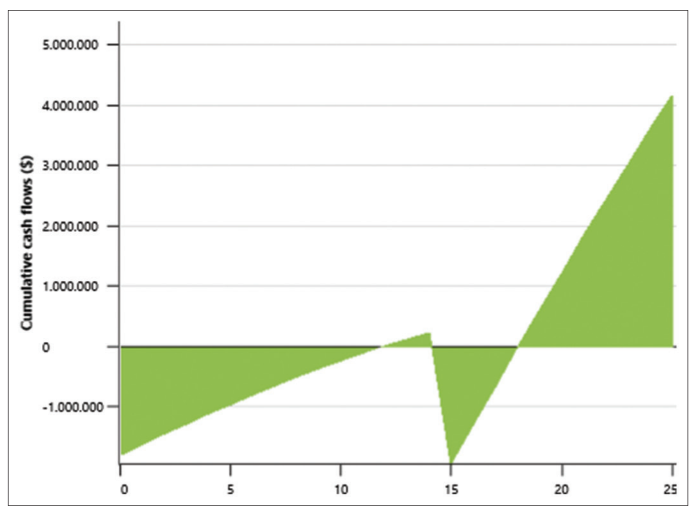
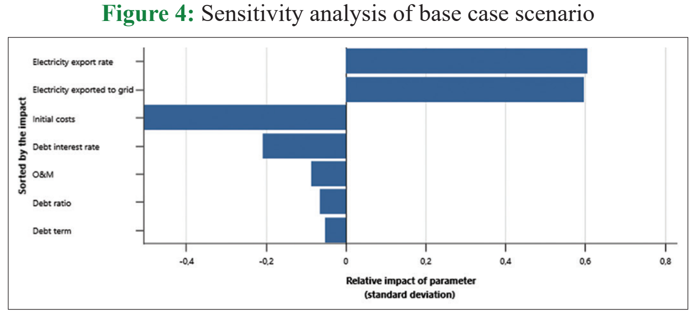


Figure 4: Sensitivity analysis of base case scenario



As shown in Figure 7, the probabilities of NPV <0 tends to locate on the far right from the center, which indicates the project tends to be unprofitable based on the base case scenario. From 1000 Monte Carlo simulations, the base case scenario NPV range from −$2,598,023 to $987,735, with $853,513 median.

Figure 5: Sensitivity analysis of PLN scenario

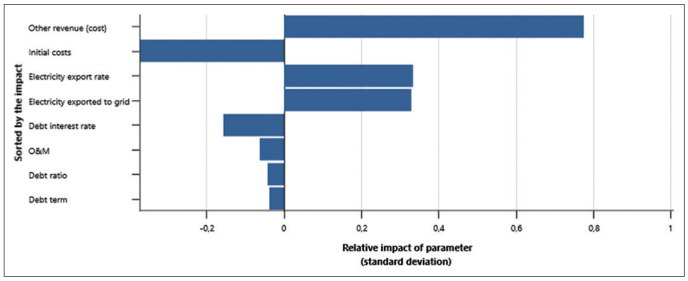


Figure 6: Sensitivity analysis of clean-energy scenario

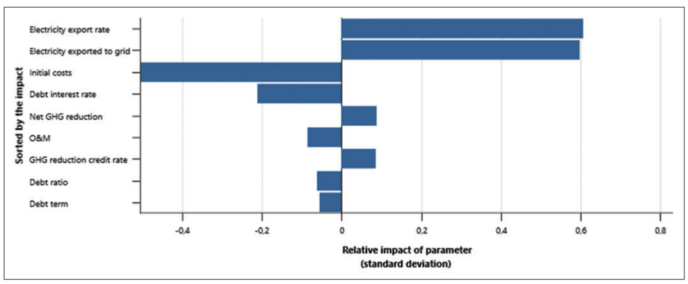


Figure 8 shows that from 1000 Monte Carlo simulations, there is no probabilities of NPV <0, which indicates the project tends to be highly profitable based on the PLN scenario. The PLN scenario NPV range from $8,211,371 to $987.735, with median of $853,513.

Figure 9 shows that the probabilities of NPV <0 tends to locate on the middle-left part from the Center, which indicates that the project tends to be profitable based on clean-energy scenario. From 1000 Monte Carlo simulations, the base case scenario NPV range from −$1,551,156 to $2,034,643, with $270,397 median.

A summary of risk analysis results from base case scenario, PLN scenario, and clean-energy scenario is presented in Table 10.

3.3. Emission Analysis

Other than the PV power plant, Tiga Nusa power system is also powered by Kutampi diesel power plant. Hence in the emission analysis Figure 10, it is assumed that in the base case is the amount of GHG emission produced by diesel power plant in Indonesia using RET Screen data, 9% transmission and distribution (T&D) is also included in the calculation. The base case in this study is electricity system by oil based in Indonesia with 0.758 tCO_2/MWh emission factor, 9% T&D losses which equals to 0.833 tCO_2/MWh emission factor calculated using RET screen. The proposed case is the 3.5 MW power plant in all three scenarios with 4,797.8 tCO_2 gross annual GHG emission reduction or equal to 2,061,460 L of gasoline not consumed annually.

Figure 7: Distribution of net present value-base case

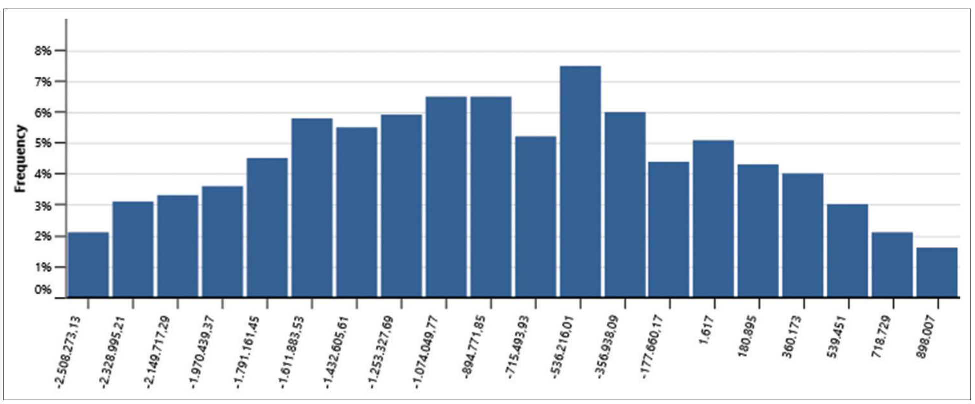


Figure 8: Distribution of net present value-PLN scenario

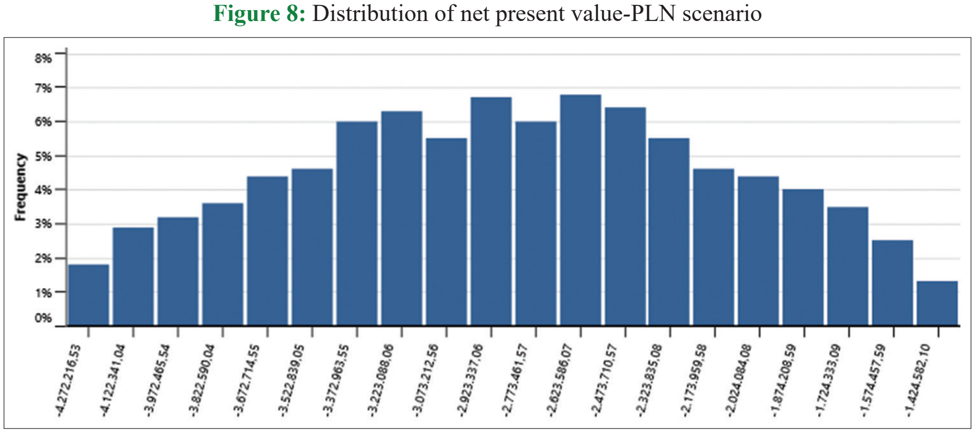


Figure 9: Distribution of net present value-Clean energy scenario

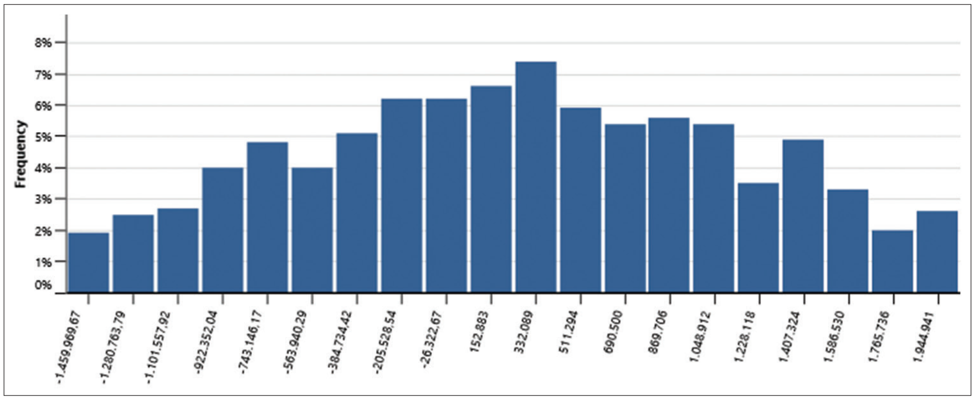


Figure 10: Annual greenhouse gas emission reduction

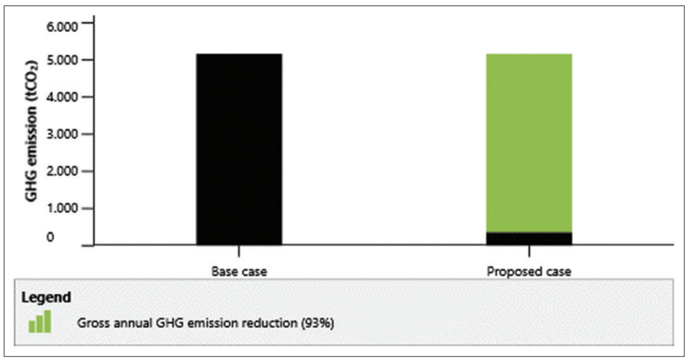


Table 10: Risk analysis results of all scenarios

Scenario	Probabilities of success (NPV>0) (%)	Probabilities of failure (NPV<0) (%)
Base case	20	80
PLN	100	0
Clean energy	62	38

4. CONCLUSION

Based on the economic and financial analysis results, risk and sensitivity analysis results analysis results, and emission analysis results, the PLN scenario is considered feasible. In order to decrease PLN's average generation cost, PV power plant seems to be an adequate solution for other area that still mainly powered by diesel power plant. However, based on the IPPs perspective, which represented in the base case scenario, the project is not feasible due to its negative NPV result. Therefore, other incentives such as GHG emission reduction incentives should be considered. Considering 12.5% of Indonesia's power system is still powered by diesel-fuel (PLN, 2021c) with an average generation cost of $0.397/kWh which is far higher compared to existing renewable energy tariffs.

Based on the clean-energy scenario results, this research suggests the government to implement GHG emission reduction incentives to increase the profitability of renewable energy project, in order to helped in attracting investors to invest in Indonesia's renewable energy market. As part of government's commitment to achieve energy transition, clean energy incentives should be applied to make renewable energy projects more feasible financially. Other alternatives that is also suggested is emissions trading system, which based on "cap and trade" principle, where the overall volume of particular greenhouse gases that can be emitted by power plants, factories and aviation sector is limited by a "cap" on the number of emission allowance which proven by many literatures to be effective in lowering green-house gas emissions (European Commisions, 2023; NCEE, 2001; OECD, 2004).

The existing renewable energy tariff policy in Indonesia stipulates that the tariff for photovoltaic power plants with battery storage systems is set at 60% increase from the basic tariff. However, any tariff rate exceeding 60% must receive approval from the Minister of Energy and Mineral Resources. This regulation introduces an element of uncertainty in tariff rates, which could potentially undermine investor confidence in solar PV projects. Consequently, the lack of certainty in PV with BESS tariff may deter prospective investors from committing to renewable energy initiatives in the country.

There are several suggestions for further research in order to provide more insights. The author suggests further research to include climate analysis data gathered from full-year survey, as it will provide more accurate estimation in terms of energy produced by the power plant, and the realistic condition of the environment. More technical approach such as including the PV panels efficiency decrease over its lifetime period is also suggested, in order to measure the reliability and the true cost of PV power plant. The author also suggests further study in other location and other renewable energy technology, to provide more insights about Indonesia's renewable energy tariffs. Nevertheless, one does expect the findings in this paper hold in other locations, that specific renewable energy does matter in lowering energy production cost and making energy more accessible for everyone, which hopefully helped to achieve Indonesia energy transition.

REFERENCES

Al Garni, H.Z., Awasthi, A. (2017), Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia. Applied Energy, 206, 1225-1240.

Ali, T., Ma, H., Nahian, A.J. (2019), An analysis of the renewable energy technology selection in the southern region of Bangladesh using a hybrid multi-criteria decision making (MCDM) method. International Journal of Renewable Energy Research, 9(4), 1838-1848.

Bank Indonesia. (2022), Informasi Kurs JISDOR. Available from: https://www.bi.go.id/id/statistik/informasi-kurs/jisdor/default.aspx

Bank Indonesia. (n.d.), Data Inflasi. Available from: https://www.bi.go.id/id/statistik/indikator/data-inflasi.aspx [Last accessed on 2023 Jan 28].

EPA. (2019), Greenhouse Gas Reporting Program: Industrial Profile: Power Plants Sector. U.S. Environmental Protection Agency. Available from: https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2

ESDM. (2012), Sun for Photovoltaic Power Plant in Indonesia. Ministry of Energy and Mineral Resources. Available from: https://www.esdm.go.id/id/media-center/arsip-berita/matahari-untuk-plts-di-indonesia

ESDM. (2021), Statistik Ketenagalistrikan Tahun 2020. In: Ministry of Energy and Mineral Resources. 34th ed. Sekretariat Direktorat Jenderal Ketenagalistrikan. Agartala: ESDM.

ESDM. (2022), Government Supervises the COD of Renewable Energy Power Plant According to Target. ESDM. Available from: https://www.esdm.go.id/en/media-center/news-archives/renewables-power-plants-cod-within-target-says-official

European Commisions. (2023), EU Emissions Trading System (EU ETS). Available from: https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en

Hirbodi, K., Enjavi-Arsanjani, M., Yaghoubi, M. (2020), Techno-economic assessment and environmental impact of concentrating solar power plants in Iran. Renewable and Sustainable Energy Reviews, 120, 109642.

Iacobescu, F., Badescu, V. (2012), The potential of the local administration as driving force for the implementation of the National PV systems Strategy in Romania. Renewable Energy, 38(1), 117-125.

IEA. (2020), World Key Energy Statistics. Paris, France: International Energy Agency (IEA). Available from: https://www.iea.org/countries/indonesia

IESR. (2019), Levelized Cost of Electricity in Indonesia. Institute for Essential Services Reform. Jakarta, Indonesia: Institute for Essential Services Reform.

Makkiabadi, M., Hoseinzadeh, S., Taghavirashidizadeh, A., Soleimaninezhad, M., Kamyabi, M., Hajabdollahi, H., Nezhad, M.M., Piras, G. (2021), Performance evaluation of solar power plants: A review and a case study. Processes, 9(12), 1-26.

Makkiabadi, M., Hosseinzadeh, S., Nezhad, M.M., Sohani, A., Groppi, D. (2021), Techno-economic study of a new hybrid solar desalination system for producing fresh water in a hot-arid climate. Sustainability, 13(22), 12676.

Mirzahosseini, A.H., Taheri, T. (2012), Environmental, technical and financial feasibility study of solar power plants by RETScreen, according to the targeting of energy subsidies in Iran. Renewable and Sustainable Energy Reviews, 16(5), 2806-2811.

MOF. (2022), Government Committed to Achieve 23% Renewable Energy Mix in 2025. Indonesia Ministry of Finance. Available from: https://www.kemenkeu.go.id/informasi-publik/publikasi/berita-utama/pemerintah-berkomitmen-capai-bauran-23

Natural Resources Canada. (2023), RETScreen. Available from: https://natural-resources.canada.ca/maps-tools-and-publications/tools/modelling-tools/retscreen/7465

NCEE. (2001), The United States Experience with Economic Incentives for Protecting the Environment. United States: U.S. Environmental Protection Agency. p230.

Nili, M., Seyedhosseini, S.M., Jabalameli, M.S., Dehghani, E. (2021), A multi-objective optimization model to sustainable closed-loop solar photovoltaic supply chain network design: A case study in Iran. Renewable and Sustainable Energy Reviews, 150, 111428.

OECD. (2004), Policies to Reduce Greenhouse Gas Emissions in Industry: Successful Approaches and Lessons Learned: Workshop Report. OECD Papers, Vol. 4. p51.

PLN. (2021a), Optimalisasi Strategi Mewujudkan Transisi Energi Berkelanjutan Optimizing Strategy in Realizing Sustainable Energy Transition. Available from: https://web.pln.co.id/statics/uploads/2023/02/sr-pln-2021-low-revisi-0111.pdf

PLN. (2021b), Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2021-2030. In: PT PLN (Persero). Available from: https://web.pln.co.id/statics/uploads/2021/10/ruptl-2021-2030.pdf

PLN. (2021c), Statistik PLN 2021. In: PT PLN (Persero) (Vols. 01001-2206). Available from: https://web.pln.co.id/stakeholder/laporan-statistik

President Regulation Number 112. (2022), Acceleration of Renewable Energy Development for Electricity Provision. Available from: https://drive.esdm.go.id/wl/?id=o8wdm5f2axpp9awt2y4cfnvb3t2jdoaf

Reddy, K.S., Veershetty, G. (2013), Viability analysis of solar parabolic dish stand-alone power plant for Indian conditions. Applied Energy, 102, 908-922.

Rehman, S., Ahmed, M.A., Mohamed, M.H., Al-Sulaiman, F.A. (2017), Feasibility study of the grid connected 10MW installed capacity PV power plants in Saudi Arabia. Renewable and Sustainable Energy Reviews, 80, 319-329.

Rubinstein, R.Y., Kroese, D.P. (2016), Simulation and the Monte Carlo Method. 3rd ed. Hoboken: John Wiley and Sons, Inc.

Rynska, E. (2022), Review of PV solar energy development 2011-2021 in central European countries. Energies, 15(21), 8307.

Wyban, C.A. (2020), Resource assessment. Tide and Current, 7, 13-25.