Feasibility Analysis of a Large Scale Floating Photovoltaic Power Plant Investment Using Financial Modeling with the Consideration of Uncertainties Factors

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Abstract

Indonesia has high potential solar energy, but its utilization is lowest among other renewable energies. To maximize the use of solar energy, Indonesia is planning to have a large-scale solar power plant development program. The main challenge for the large-scale solar power plant in Indonesia is lack of available land. To address this problem, Indonesia plan to build large-scale floating solar power plant above the potential dams in Indonesia. This research aims to analyze the feasibility of large-scale floating solar plant investments by considering the uncertainty factor of energy output and cost requirement using Discounted Cashflow and Monte Carlo simulation with four output indicators which are NPV, Project IRR, Equity IRR, and Discounted Payback Period. The acceptability of the investment indicator is being evaluated using Value at Risk at 95% confidence level. The uncertainty factor will be simulated with the implementation of three option of debt-to-equity proportion with adjusted interest rate and loan tenor. The results show that the use of capital investment scenarios has a significant effect on the results of the feasibility indicators and the uncertainty factors that have the greatest relationship to the uncertainty of the feasibility indicators are annual global horizontal irradiation.

Keywords
Floating Photovoltaic, Monte Carlo, Value at Risk, Techno-Economy Feasibility, and Investment Risk.

1. Introduction
Climate change is still happening and causing negative impacts to all countries include Indonesia. Indonesia is assumed to loss up to 132 trillion rupiah due to climate change at 2030 (USAID, 2016). Climate change is caused by increasing carbon dioxide (CO2) continuously from increased human activity. According to Ministry of energy and minerals Indonesia (2019), the energy sector will produce 2,64 times higher CO2 later on 2030 using the business as usual scenario. Electricity generation activity using coal and oil is the highest contributor of CO2 on the energy sector which is 36% (Enerdata, 2018). Therefore, Indonesia needs to do transformation from coal and oil-oriented electricity into renewable energy which is the main reason of the president declaration number 22/2017 renewable energy should fulfill 23% of Indonesia's energy mix in 2025 and 31% in 2050.

One of the highest renewable energy potentials in Indonesia is solar energy with potential capacity estimated to 207,898 MWp. However, the capacity installed of solar energy have only reached 0.04% of its total potential (Ministry of Energy and Mineral Source, 2019). One of the challenges to solar energy development in Indonesia is the limited amount of available land meanwhile to build 1 MWp solar power plant need at least 1 hectare land (IESR, 2020). Even if there are plenty of available nonproductive land which can be used to build solar power plant, it is located far away from high electricity load and will cause high loss due to far transmission. Aside from the limited appropriate land, renewable energy developer also facing long and complex regulation with land ownership and high price.

Therefore, Indonesia is developing a floating photovoltaic power plant above the hydroelectric powerplant dams to address this problem which is supported by the fact that Indonesia has more than 92 potential dams with total area 86.247 hectare that could have accumulative potential capacity 4.300 MWp. Floating solar power plant is also have some benefits including increased efficiency, reduced evaporation, increased water quality, and potential hybrid with hydroelectricity generation (Sahu et al, 2016).

Even though Indonesia has a very high potential of floating photovoltaic power plant, the investment itself has uncertainty that might cause cost overruns due to uncertainties of investment cost and natural variability (World Bank, 2018). Therefore, the developer needs to take a consideration of those uncertainties factors that could be affect the feasibility investment risk of floating photovoltaic power plant. In addressing those uncertainty factors also increase the bankability of the project from the lender candidate.

1.1 Objectives

This study aims to assess the feasibility investment of a large-scale floating photovoltaic power plant in Indonesia with the consideration of the uncertainty factors, find the most significant uncertain factor, and give recommendation for the project financing.

2. Literature Review

Before building the floating solar power plant, one step that should be went through by the developers is assessing feasibility including its uncertainty factors to minimize the risk of failure due to the technicality and attracting lenders from the lending institution to funding the project. Therefore, the floating solar power plant should meet the standard of feasible project by its technicality and economic aspect. Hence, this paper will conduct technical feasibility for ensuring the performance ratio of energy output compared to the energy input is considered adequate and the investment can meet the set standard by the lenders. Some of the literature about the technical feasibility and economic feasibility has been reviewed as the reference and the literature review will be divided into 4 sections. Subsection 2.1 will discuss about the technical feasibility, subsection 2.2 will discuss about the financial model and indicators for valuing economic feasibility, subsection 2.3 will discuss about Monte Carlo Simulation that considering uncertainty factor that can affect the project feasibility in the future, and subsection 2.4 will discuss about the application of Value at Risk in feasibility analysis considering uncertainty factors.

2.1 Technical Feasibility

The main source of the photovoltaic power plant is the solar irradiation. Solar irradiation is the accumulation of the solar energy per certain area (W/m2). Solar irradiation can be divided into Global Horizontal Irradiation and Plane of Array Irradiation.

2.1.1 Global Horizontal Irradiation (GHI)

Global Horizontal Irradiation is the amount of terastral irradiation that reach a horizontal surface of earth (T.Mahachi, 2016).

$$GHI = DHI + G_n \cos(\theta_z) \ldots\ldots\ldots\ldots (2.1)$$

DHI = Diffuse Horizontal Irradiation or the scattered irradiation on the atmosphere that reach the horizontal surface on earth

G_n = Direct normal Irradiation or the irradiation that directly came from the sun beam.

2.2.2 Plane of Array Irradiation (POA)

Plane of Array Irradiation is the total amount of irradiation that received on the photovoltaic module. Nowadays, there are plenty amount of software to calculate the POA transition from the GHI. Hence, according to Tim Umoette (2006) the formula for POA can be calculated with:

$$G_t = Global\ Horizontal\ Irradiation \times Transposisition\ Factor \ldots (2.2)$$

There are some of the commonly used transposition factors which are Hay, Perez, isotropic, Klucher, and Sandia (T. Mahachi, 2016).

Even though the Plane of Array Irradiation is calculated, not all of the irradiation is effectively absorbed by the photovoltaic system. Therefore, there are potential losses that could reduce the amount of energy output. Losses in photovoltaic system can be divided into three groups that are optical losses, array losses, and system losses (T. Mahachi, 2016).

1. Optical Losses
   Optical Losses is the potential loss that can reduce the total amount of irradiation. Optical losses are divided into far shading, near shading, IAM Shading, and soiling loss.
2. Array Losses
   Array losses is the potential loss that occurred because of the modul specification and configuration between modules. Array losses is divided into irradiation loss, temperature loss, module quality loss, light induced quality loss, mismatch loss, and ohmic wiring loss.
3. System Losses
   System losses is the potential losses occurs from the system component aside the module component which is inverter and transformer. There are three potential system losses before the actual energy injected to the grid which are inverter loss, medium voltage loss, and high voltage loss.

The final energy or actual energy injected to the grid compared to the reference yield that can be received by the system without any losses is called performance ratio. The minimum acceptability of performance ratio is 80% (A.M. Khalid et al, 2016). By the time of the project, the performance ratio will be decreased. The reference yield or reference energy output is calculated by (G.M. Masters, 2004)

$$E = G_t \, . A \, . \eta \ldots\ldots\ldots\ldots\ldots \quad (2.3)$$

G_t= *Plane of Array Radiation*
A = Area
η = Module efficiency

Due to the changing performance ratio throughout the years of operation caused by degradation, the actual energy output can be modified with the consideration of performance ratio into:

$$Actual\ Energy\ Output\ in\ AC_i = \frac{\begin{array}{c} Performance\ Ratio_i\ . \\ DC\ capacity\ Installed\ . \\ Plane\ of\ Array\ Irradiation \end{array}}{Referensi\ Iradiasi\ (1000 \frac{W}{m^2})} \ldots\ldots \quad (2.4)$$

2.2 Financial Model

After calculation of energy output is done, the energy output per year will be multiplied by Power Purchase Agreement Tariff (PPA) to calculate yearly revenue of the project. Despite the yearly revenue, there will be the initial and yearly cost that need to be paid during the project.

1. Initial cost
   Initial cost or cost to purchase the capital needed (capital expenditure) usually calculated using per watt price multiplied by the DC capacity (Ogunnubi et al, 2015).

$$IC_0 = PVC_0 \ x\ DC\ Power\ Rating \ldots\ldots\ldots\ldots \quad (2.5)$$

$NI_0 = IC_0$
$CF_0 = NI_0$
IC_0 = Initial Cost on year 0
NI_0 = Net cash flow on year 0
PVC_0 = Cost requirement

2. Yearly cost
   Yearly cost is usually assumed as annual operational expenditure include the operation and maintenance cost of plant and administration. Due to the inflation, operational expenditure will be increased by the time of the project (Goswami et al, 2019).

$$C_{OM_n} = C_{OM_1}(1 + r_{OM})^{n-1} \ldots\ldots\ldots\ldots \quad (2.6)$$

C_{OM_n} = Operation and Maintenance cost on year n
r_{OM} = O&M escalator or inflation

To calculate the annual net cash flow, there will be an iterative process considering the tax, depreciation, and interest payment (Ogunnubi et al, 2015).

$$Corporate\ Tax = (Revenue - C_{OM_n} - Depreciation - Interest\ Payment)\ x\ \%\ Corporate\ Tax$$

$$Net\ Cash\ Flow\ (C_t) = Revenue - C_{OM_n} - Corporate\ Tax \ldots \quad (2.7)$$

Due to time value of money principle, net cash flow will be discounted using a discounting factor. Usually, the solar power project will need two or more different financing sources which are debt and equity financing. Therefore, the discounting factor can be calculated using WACC (Weighted Average Cost of Capital) to consider the proportion and expected return from each financing source (Steffen, 2020).

$$WACC_{after\ tax} = \delta\ C_D\ (1-\tau) + (1-\delta)\ C_e \ldots\ldots\ldots\ldots\ldots\ldots\ (2.8)$$

δ = *debt to equity ratio(%)*
C_d= *Interest rate* (%)
C_e = Expected *Return on Equity* (%)
τ = *Corporate Tax* (%)

The discounted net cashflow feasibility can be evaluated using Net Present Value (NPV) and Discounted Payback Period (DPBP) while other non-discounted investment indicators is Internal Rate of Return (IRR) which can be divided into Equity IRR that received by the shareholder after annual debt payment and Project IRR that received by the overall project financing before annual debt payment.

1. Net Present Value (NPV)
   Net Present Value is used to evaluate project feasibility if the cumulative positive discounted net cash flow can be balanced all cumulative negative discounted net cash flow. Therefore, if the project is acceptable if the NPV is equal or more than 0.

$$NPV = \sum_{i=1}^{n} \frac{C_t}{(1+i)^t} - IC_0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2.9)$$

C_t= *Net Cash Flow*
i = discounted factor or WACC
IC_0 = Initial cost

2. Internal Rate of Return (IRR)
   While the NPV is used to evaluate amount of net cumulative discounted cash flow, Internal Rate of Return is useful to evaluate the expected return from the project or technically can be said that IRR is the discounted factor that make NPV equal to 0. IRR is acceptable if the value above the WACC for project IRR and above the minimum required return on equity for Equity IRR (Mayes, 2016).

$$IRR = \sum_{i=1}^{n} \frac{C_t}{(1+i)^t} - C_0 = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2.10)$$

3. Discounted Payback Period (DPBP)
   Discounted Payback Period is used to calculate the amount of period needed to cumulative discounted cash flow is equal to the amount of initial cost.

$$Discounted\ Payback\ Period = \frac{C_0}{PV_t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.11)$$

PV_t= *Present Value* or discounted net cash flow

$$PV_t = \frac{C_t}{(1+i)^t}$$

2.3 Monte Carlo Simulation

On the Monte Carlo simulation, uncertain variable is assumed as random variable which have a range of possible values, independent toward each other, and not affected by changing time (F. James, 1980). To conduct an appropriate MCS, there will be some steps to be done according to Raychaudhuri S. (2008) which are:

1. Create deterministic or base model.
2. Choose distribution probability for each uncertain variable.
3. Do iteration using pseudo random number according to each probability distribution function of uncertain variables for n iteration.
4. Conduct sensitivity analysis and decision making based on the model output.

The consideration of distribution probability for each uncertain factor needs to be carefully assessed. The distribution probability can be decided from distribution fitting from the available data. On the other hand, most cases of construction project, the available data of cost and other variable is not available. Therefore, the distribution probability can be decided from the previous study or expert judgment (Spooner, 1974). According to Spooner research, Salling and Leleur (2006) divide uncertain variable into two groups which are epistemic and ontological to make a better understanding of distribution probability decision. Epistemic variable is the uncertain variable due to lack of knowledge and historical data while ontological variable is happened because of the natural variability within the system.

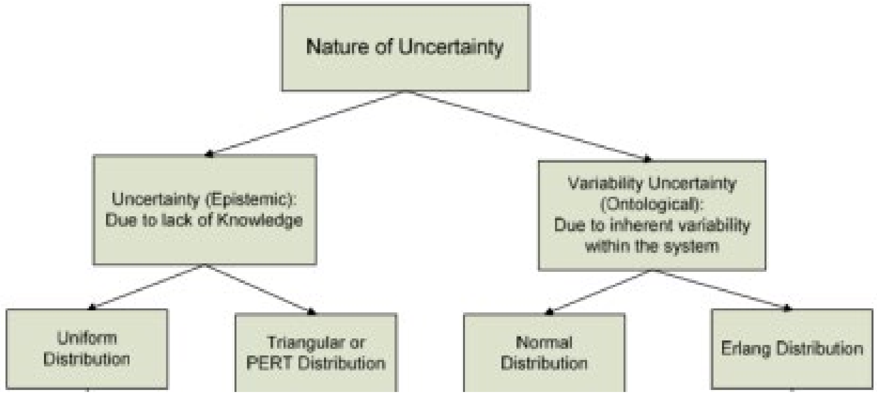

Figure 1. Uncertain Category

2.4 Value at Risk

Aside from used to evaluate the maximum losses that could occur from the portfolio monte carlo simulation, Value at Risk also can be a useful tool to evaluate the project feasibility with the consideration of confidence level to make a better decision making in an uncertain condition. Value at Risk approach to evaluate long term project feasibility investment is researched by Ye et al (2000) which focused only on the NPV at Risk. If the NPV at risk at 95% confidence level is positive, therefore the NPV is acceptable. According to the Ye et al (2000) research, Ke et al (2008) has done research using other investment indicators which are IRR, Debt Service Coverage Ratio (DSCR), Time Interest Earned (TIE), and Self Liquidation Ratio (SLR). VaR calculation according to Borgonovo Gatti (2019):

$$VaR = inf\{z \,\epsilon\, R : \Pr(X \geq x) \leq 1 - c\} \ldots\ldots\ldots\ldots\ldots\ldots \text{(3.1)}$$

c = *confidence level*

$\Pr(X \geq x)$ = Cumulative probability of X

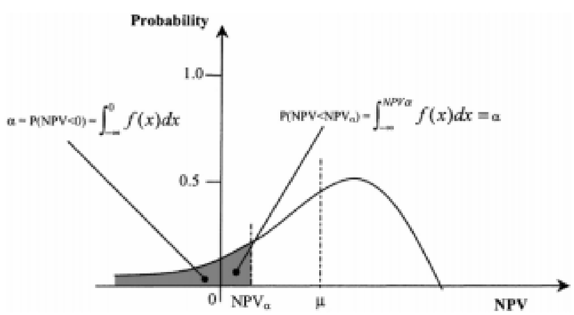

Figure 2. NPV at Risk

2.5 Sensitivity Analysis

Another question from this study aside from the feasibility indicator is which is the most significant factor that affect uncertainty value of output indicator. Therefore, we will conduct sensitivity analysis using Spearman Rank correlation (Spearman, 1904) between input and output value of each MCS iteration (Charnes, 2007).

$$\rho = 1 - \frac{6\sum_{i=1}^{N}(d_i)^2}{n(n-1)} \ldots\ldots\ldots\ldots\ldots\ldots \text{(3.2)}$$

ρ = correlation coefficient

d_i = rank difference between input and output variable

n = total iteration

Based on those literature review which has discussed above, it is expected to be adequate in analyzing current feasibility condition of the solar power plant whether the project is still considered as feasible based on the investment indicators after considering uncertainty factors., identify room for improvement if needed, and creating a recommendation to the developers to minimize its investment risk by the projected uncertainty factors.

3. Methods

The technical aspect including transposition constant, detailed losses from the energy conversion between the process of transforming energy input until generating the actual energy output that injected through the grid is automatically calculated using PVsyst Version 7.7 and the result of the detailed energy losses will be calculated on the Microsoft excel to measure yearly energy output to be sold to the grid. The energy output will be multiplying with the PPA tariff to get the yearly revenue for the developers and the revenue will be subtracted with the yearly cost and initial cost in the beginning of the project before the first revenue occurrence. The flow of the money thorough the project is projected using the Discounted Cash Flow.
Some of the variables on the technical and financial are uncertain. Therefore, aside from building appropriate Discounted Cash Flow (DCF), this study uses Monte Carlo simulation using addIn Crystal Ball on Microsoft Excel. For this study, the iteration will be done in 10.000 iterations based on the previous study by H. Bareto and F. Howland (2006) which stated that 10.000 iterations will result error value less than 2,99%. To evaluate the investment indicators, the decided confidence level is 95% due to low risk appetite and high certainty.

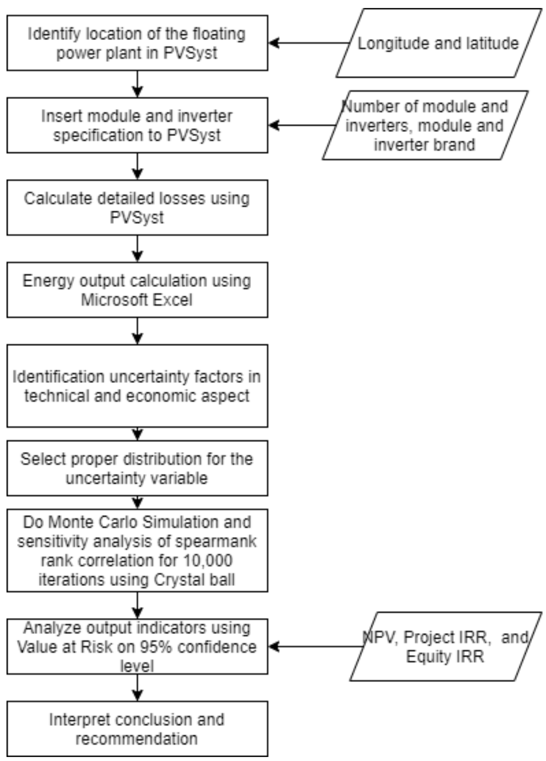

Figure 3. Research Methodology

4. Data Collection

As discussed on the literature review there will be 2 steps of feasibility which are technical and economic feasibility. Therefore, data collection on this study will be divided into technical which is data supporting for calculate energy output and financial data including cost projection for the lifetime project. On the section 4.1, there will be the explanation of the technical data collection and the financial data will be explained on section 4.2.

4.1. Technical Data

1. Geographical Data
   Total area of the dam is 62 km2 and total installed area for floating photovoltaic is 839.978 m^2 with latitude -6.7° S, longitude 107.33° E, and albedo 0.06 which is lower than the most common used value 0.2.
2. Irradiation Data

Irradiation data is being collected using satellite data which are SolarGIS and Meteonorm included in the PVsyst software.The annual global horizontal irradiation is 1776.7 kWh/m^2 and the simulated transposition factor using Perez model from the PVSyst is 1.01 which means the yearly total irradiation or Plane of Array Irradiation (POA) is 1794 kWh/m^2. Even though the POA is quite high, the effective irradiation after optical losses caused by shading are 1719.5 kWh/m^2.

3. Module and Inverter Specification
   a. Module Specification
   Module used in this project is made from mono-crystalline silicone due to its high efficiency and competitive price. The module is tilted into 5 ° facing south due to the sun is on the south of equator at the plant location. The module is divided into 9275 strings, each contain 32 modules.

Table 1. Module Specification

Materials	Mono Crystalline silicone
Power output	590 Wp
Number of Modules	296800
Module tilt	5 °
Total DC capacity installed module	175112 kW

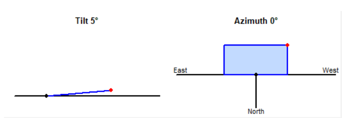

Figure 4. Module Orientation

   b. Inverter Specification
   All of the inverters are placed on the central system. Each of the inverter is 3-phased inverter with total power output 168.750 Kw AC.

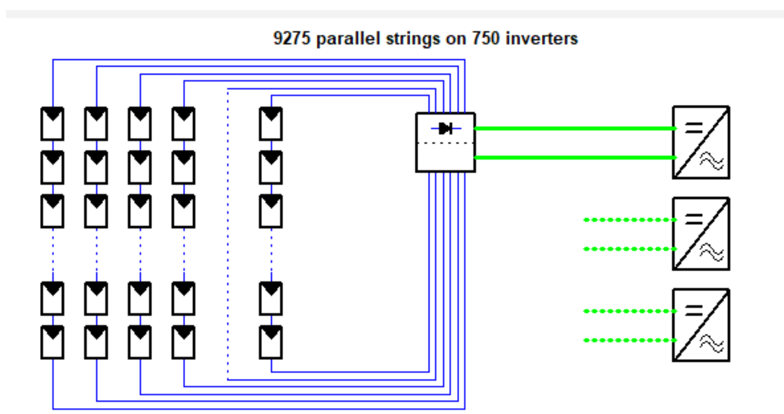

Figure 5. Inverter Configuration

4. Losses Factor
   Losses factor that should be inserted manually on PVsyst are soiling loss, mismatch loss, module quality loss, and LID loss. Other losses are automatically calculated by PVSyst according to the specification of the module and inverter.

Table 2. Potential Loss

Soiling loss	1%
Mismatch loss	0.1%
Module quality loss	0.4%
LID loss	1%
AC wiring loss	0.51%

4.2. Financial Data

Financial data is divided into cash outflow and cash inflow. Cash outflow is stated by using USD/Wp or cost per plant capacity power which is commonly used on the financial model of solar system feasibility study. All financial data are being collected from the internal company interview.

1. Capital and Operational Expenditure

Table 3. Capital and Operational Expenditure

Variable	Unit	Value
Module	USD / Wp	0.256
Inverter	USD / Wp	0.07
Floating dan Anchoring	USD / Wp	0.112
Other electric components	USD / Wp	0.112
Construction tax	USD/Wp	0.066
Development cost	USD/Wp	0.107
Office Operation	USD / kWp / year	1.67
SPV Operation Salary	USD / kWp / year	1.96
Operational and Maintenance cost	USD/kWp/year	2.69
Insurance	USD / kWp / year	3.02

2. Financial Parameter

   Aside from the financial data of cash inflow and outflow along the project, there are some external parameters that could affect the economic feasibility of the floating solar system. These external parameters is affected by the solar trend, government policy, and monetary policy. These parameters will be combined with financial data to analyze the project feasibility using expected indicators output which are NPV, Project IRR, Equity IRR, and Payback Period.

Table 4. Financial Parameter

Variable	Unit	Value
PPA Tariff	USD/kWh	0.058
Minimum *Return on Equity*	%	12
Inflation	%	1.47
Corporate Tax	%	25
Value Added Tax	%	10
Depreciation	Year	25
Project lifetime	Year	25
Commercial Operation Date	-	2022

4.3. Uncertain factors

Uncertain factors on this research are the external variables that independent to each other and time independent. Some of the variable's distribution probability are from the previous study while the site-specific data like annual global horizontal irradiation is being measured by the available historical satellite data on the site location.

Table 5. Uncertain factors

Variable	Probability distribution	Value	References
Annual GHI	Normal	Mean: 1777 kWh/m2, St. Dev: 106.6 kWh/m2	Meteonorm
Degradation Performance	Triangular	Min: 0; Most likely: 0.5, Max: 0.8	Moser et al (2017)
Module price	Triangular	Min: \$0.22/Wp, most likely: \$0.25/Wp, Max: \$0.42/Wp	Sukarso et al(2020)

Inverter price	Triangular	Min: \$0.08/Wp, Most Likely: \$0.1/Wp, Max: \$0.12/Wp	Sukarso et al(2020)
O&M cost of power plant	Normal	Mean: \$2.69/kWp, St.Dev:\$0.135/kWp	Moser et al (2017)

4.4. Alternative Capital Structure

One of the most important things to consider on the renewable energy project financing is the capital structure between the debt and equity proportion. According to World bank (2018), the debt-to-equity ratio for floating photovoltaic power plant is ranging between 70% - 90%. The high percentage of debt-to-equity ratio can be achieved from the development banks. The changing debt to equity ratio will also affect on interest rate given by the lender candidate and loan repayment period or loan tenor. These alternatives contain combination of debt-to-equity ratio, interest rate, and loan repayment period is being collected from the interview with internal special purpose vehicle of the project.

Table 6. Alternative Capital Structure

Alternative	***Debt to equity ratio (DER)***	***Interest Rate***	***Loan Repayment Period***
Alternative 1	90%	2%	16 years
Alternative 2	80%	3%	15 years
Alternative 3	70%	4%	14 years

5.Results and Discussion

5.1 Numerical Results

1. Energy Output
   On the first year of system operation, performance ratio from the PVsyst software is equal to 84% and the actual energy output injected to the grid is 264.102.415 kWh. The annual energy output is decreasing by the time about 0.4% from its current performance ratio because of the degradation performance. In the certain degradation performance, at the end of the system lifetime on the year 25, the annual energy output is 233,789,133 kWh.

2. Investment indicators result without uncertainty consideration.
   Without uncertainty factor consideration, all the alternatives of capital structure can reach minimum expected NPV, Project IRR, and Discounted Payback Period. While in the alternative 3, the equity IRR is less than 12%. Therefore, it cannot fulfill sponsor's minimum return on equity.

Table 7. Investment Indicators without Uncertainty Consideration

Indicator	**Alternative 1**	**Alternative 2**	**Alternative 3**
NPV	\$66.264.736	\$35.414.864	\$13.111.501
Project IRR	6.58%	6,68%	6,73%
Equity IRR	22.03%	12,58%	9,45%
Discounted Payback Period	14,24 years	16,61 years	20 years

3. Investment indicators result with uncertainty consideration at 95% confidence level.
   By using the minimum value at 95% confidence level or 5% significance level from the monte carlo simulation, Alternative 1 and 2 can produce positive NPV and Project IRR above the WACC. Meanwhile, alternative 3 is the only capital structure that results in negative NPV at 95% confidence level. Aside NPV, Project IRR is also below WACC. Therefore, alternative 3 is not suggested to be taken in this project with the consideration of uncertainty effect. However, all the available alternatives cannot meet the minimum required value of return on equity at 12%. To reach 12% of equity IRR, the confidence level is lower than 95% which are 84.68% on alternative 1 and 19.44% on alternative 2.

Table 8. Investment Indicators with Uncertainty Consideration at 95% Confidence Level

Indicator	**Alternative 1**	**Alternative 2**	**Alternative 3**
NPV at risk	\$30,264,736	\$2,607,162	(\$17,567,615)
Project IRR at risk	4.27%	4.37%	4.45%
Equity IRR at risk	9.69%	6.21%	4.86%

4. Sensitivity Analysis
   a. NPV
      The most significant value towards NPV is the uncertainty of annual global horizontal irradiation with positive correlation means the higher annual global horizontal irradiation, the NPV will also be higher.

Table 9. Rank Correlation toward NPV

Uncertain factor	Alternative 1	Alternative 2	Alternative 3
Annual GHI	0.815	0.771	0.724
Module price	-0.458	-0.534	-0.601
Degradation performance	-0.312	-0.260	-0.236
Inverter price	-0.103	-0.105	-0.101
O&M cost	-0.007	-0.024	-0.027

   b. Project IRR
      The most significant value towards Project IRR is the uncertainty of annual global horizontal irradiation with positive correlation means the higher annual global horizontal irradiation, the Project IRR will also be higher. Overall, coefficient correlation of Annual GHI towards project IRR is lower than NPV.

Table 10. Rank Correlation toward Project IRR

Uncertain factor	Alternative 1	Alternative 2	Alternative 3
Annual GHI	0.734	0.729	0.724
Module price	-0.603	-0.602	-0.604
Degradation performance	-0.247	-0.229	-0.234
Inverter price	-0.131	-0.117	-0.103
O&M cost	-0.002	-0.023	-0.027

   c. Equity IRR
      The most significant value towards Equity IRR is the uncertainty of annual global horizontal irradiation with positive correlation means the higher annual global horizontal irradiation, the Equity IRR will also be higher. Overall, from all the alternatives implementation, coefficient correlation of Annual GHI towards project IRR is lower than NPV but higher than Project IRR. Coefficient correlation of Annual GHI is also decreasing towards lower debt to equity ratio of alternative 2 and alternative 3 rather than alternative 1.

Table 11. Rank Correlation toward Equity IRR

Uncertain factor	Alternative 1	Alternative 2	Alternative 3
Annual GHI	0.746	0.736	0.727
Module price	-0.616	-0.609	-0.608
Degradation performance	-0.155	-0.186	-0.215
Inverter price	-0.135	-0.119	-0.104
O&M cost	-0.001	-0.024	-0.027

5.2 Graphical Results of Monte Carlo Simulation

a. Alternative 1

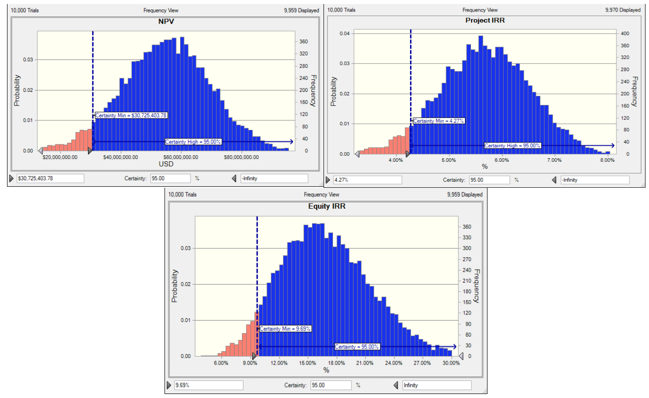

Figure 6. Monte Carlo Simulation Alternative 1

b. Alternative 2

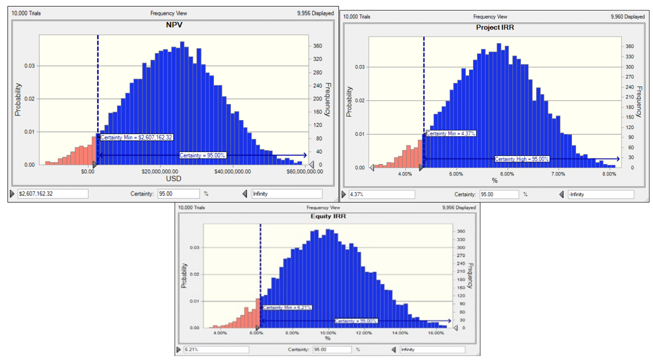

Figure 7. Monte Carlo Simulation Alternative 2

c. Alternative 3

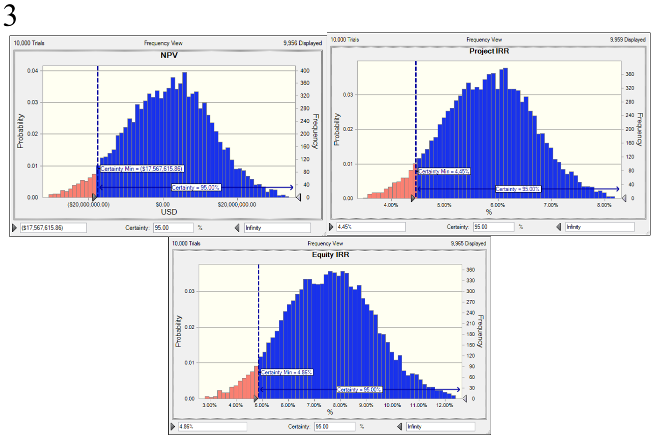

Figure 8. Monte Carlo Simulation Alternative 3

6. Conclusion

From this study, there are few things can be concluded. The first one is the uncertain factors that affect feasibility investment of large-scale floating photovoltaic divided into energy and cost factors. Uncertainty on the energy factors are annual global horizontal irradiation and degradation performance while uncertainty on the cost factors are price of module and inverter and Operation and maintenance cost. Among those uncertain factors, the most significant factors toward all the investment indicators is the amount of annual global horizontal irradiation.

Without the consideration of uncertain factors, all capital structure alternatives will produce acceptable NPV, Project IRR, and Equity IRR. While using the consideration of uncertain factor at 95% confidence level, the alternative capital structure using debt-to-equity ratios 90% and 80% will result acceptable NPV and Project IRR and by using the debt-to equity-ratio 70% will result in unacceptable NPV, Project IRR, and Equity IRR. Therefore, with minimum risk appetite and higher certainty which shows by minimum 95% confidence level, the author is suggested the company to use alternative 1 or alternative 2.

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Biography

Sabrina Putri Kinanti is a final undergraduate student of Industrial and System Engineering, University of Indonesia. She has published one paper indexed in Scopus and won 3rd winner of discrete simulation competition for undergraduate student by IEOM 2020 in Dubai. During the mid-second until third year of the undergraduate program, Arin is being the laboratory assistant of System Engineering, Modeling, and Simulation (SEMS), University of Indonesia and turn into research assistant in the last year of university. Arin has high interest in public policy, renewable energy, and financial risk analysis.

Armand Omar Moeis holds a master degree from Delft University of Technology, the Netherlands, majoring in Engineering and Policy Analysis. Prior to his graduate study, Armand gained his bachelor degree from Industrial Engineering Department, University of Indonesia. His research interests are System Dynamics and Collaborative Analysis and Learning whereas his main application areas are public services and energy. Beside his position at SEMS, Armand also holds positions in several business entities. It helps him to keep up his pace with business and governmental communities.

Dimas Kaharudin really cares about the renewable energy projects at PT PJB Since joining PT PJB in 2006. Long before being assigned as Director of Operations at PT PJB Masdar Solar Energy (PMSE) Dimas Kaharudin together with his team, took part in being part of the first PLTS project in the PLN Group or known as PLTS 1 MW in Cirata. He also became the first team to join the EBT Development Division at PJB in 2017. Until finally Dimas Kaharudin also contributed to the 145 MW Floating PLTS project which became the first Floating PLTS project in Indonesia and the largest in Southeast Asia.