Economic study in simulating 5 MWp solar farm planning with 2 technologies under Indonesia Feed-in Tariff in Weh Island-Aceh, Indonesia

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Abstract. Up to now in Weh Island-Aceh, the power energy used comes from the Diesel Power Plant (PLTD) only, where the cost of this electricity production (BPP) reached more than Rp 2,500/kWh. This price is currently higher than the requirement set by the Minister of Energy and Mineral Resources of Rp 1,733/kWh. Because of these significant differences, special attention is needed to examine the natural resources that can be converted into electrical energy with the aim that the energy offered can reduce the price of electricity production. The purpose of this research is to conduct a study that analyses the economic feasibility of investment by considering all economic aspects using HOMER Software. The result shows that the overall value of an investment with Indonesia's feed-in tariff is feasible. The cost of energy production with si-mono and si-poly technologies was Rp 1,051/kWh and Rp 914/kWh respectively. By the capacity of 5000 kWp, return on investment (ROI) can occur in 10.73 years with si-mono technology and in 8.87 using si-poly technology from 25 years of the current system period. Using the Bank's interest rate of 5.25%, the Internal Rate of Return (IRR) is considered feasible to apply because these two technologies illustrated the greater number than the general bank interest rate prevailing in Indonesia.

1. Introduction
Currently, the primary source of electrical energy used in the world comes from fossils, which are known to be environmentally unfriendly and are limited in capacity. Electricity demand continues to increase every year; therefore, the energy crisis becomes one of the significant issues of concern in the world. Up to 2016, Aceh had a peak load of 325 megawatts (MW) derived from fossils such as gas power plants (PLTGs) and some from steam power plants (PLTU), which are distributed from the Sumatra region. The availability of electricity in this region should be able to reach 50% of the peak load requirement, or there must be around 500 MW, yet currently, there are only 340 MW available. This condition causes the importance of additional electricity supply; one alternative is to propose environmentally friendly and renewable energy. In addition, it was also carried out to support the achievement of the ASEAN target to increase the energy mix of renewable energy (EBT) by 23% in the coming year 2025, where the world's EBT has supplied 24.5% of the total energy needs consisting
of 16.6% hydro, 4% wind, 2% biopower and 1.5% solar PV [1]. Also considering that Indonesia's potential with two seasons is very supportive of this EBT procurement, one of which is a solar plant with the utilization of solar radiation, where the light obtained from the sun can then be converted into electrical energy using PV panels.

In fact, the investment in EBT implementation, especially in Indonesia, is still costly [2]. The amount of EBT investment costs will significantly affect investors' interest to invest, whereas, on the other hand, Indonesia's target is severe enough to be able to develop EBT. Therefore, one of the reasons for the Indonesian government to support the achievement of this EBT target is to impose a Feed in Tariff (FiT) rule as a benchmark for the purchase price of EBT by the State Electricity Company (PLN). The regulation stipulated by the Minister of Energy and Mineral Resources (ESDM) No. 17 of 2013 [3] is that the FiT for the Aceh region is $ 17 cents and can reach up to $ 30 cents if using products manufactured or assembled domestically. The next most recent regulation is No.12 in 2017 [3] where FiT is set at 85% of the electricity production cost (BPP) in the local area.

The following are projections of electricity demand by sector and electricity production until the year 2050 in Indonesia:

![Projections for electricity demand by sector and electricity production by 2050 in Indonesia](image)

*Figure 1. Projections for electricity demand by sector and electricity production by 2050 in Indonesia (Source: Indonesia’s energy outlook 2016, BPPT)*

The economic analysis on this project, especially solar farm, aims at producing information needed as a reference for investors to determine the feasibility of an investment today and in the future [4,5,6,7]. In this study, the planning will be simulated based on the real electricity peak of Weh Island. The fact that the use of EBT, especially solar energy farming on Weh Island, has been developed four years ago, some obstacles make this electrical energy plan fail and be left out. Such obstacles include the condition of the grass that grows tall, lack of skilled technicians, and the lack of socialization about the maintenance of the PV system, so that the impact makes PLTS inoperable [8].
2. Methodology

In this study, all data were taken in Weh Island located at the coordinate point of 5.84° N 95.28° East, where average radiation is 5.1 kwh/m2/day, simulated in 2 technologies of panels, si-Monocrystalline, and si-Polycrystalline. Designed for 5 MWp (grid-connected system) based on the peak of electricity daily load in this location. Information for this economic analysis, management planning, and price of all materials needs (e.g., solar PV module (si-mono and si-poly), inverter, land acquisition) was gathered from a consultant solar PV company (PT. Rekasurya Prima Daya). The FiT rates use of 85% from the real cost of electricity from diesel power (set by the government).

Figure 2. Daily load curve of PLTD Weh Island for the past year (April 2017-March 2018) [8]

2.1. HOMER (Hybrid Optimization of Multiple Electric Renewables)

HOMER software was developed by The National Renewable Energy Laboratory (NREL), USA in collaboration with Mistaya Engineering, where copyright is protected by the Midwest Research Institute (MRI) and used by the United States Department of Energy (DOE). HOMER is used to design hybrid power generation systems by combining conventional energy and renewable energy [9]. Homer Energy software used to analyse the Simulation, optimization of the systems offered along with the sensitivity analysis of all Renewable Energy (EBT) systems. The three main objectives HOMER can do are simulation, optimization and sensitivity analysis. HOMER is designed specifically to analyse and optimize the renewable energy industry system, as implemented by [4], [10]. HOMER is widely used to study, measure and analyse the performance of grid-connected PV systems.

Figure 3. Map of Weh-Aceh Island Location for Solar Farm Planning
2.2. Data simulation

2.2.1 Solar radiation
Data by the National Aeronautics and Space Administration (NASA) [11] shows the average annual radiation on this island is 5.1 kWh/m²/day. The highest solar radiation usually occurs in February to April about 5.75 kWh/m²/day, while the lowest radiation occurred in October and November of 4.66 - 4.67 kWh/m²/day.

Table 1. Data on the potential of solar radiation in Weh Island - Aceh (kWh/m²/day)

| Solar radiation in Weh Island | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Avg |
|------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Monthly radiation (kWh/m²/month) | 167.1 | 161 | 179.5 | 169.2 | 155.3 | 149.7 | 151.9 | 149.1 | 142.2 | 144.8 | 139.8 | 151.3 | 155.1 |
| Daily radiation (kWh/m²/day) | 5.39 | 3.75 | 5.79 | 5.64 | 5.01 | 4.99 | 4.9 | 4.81 | 4.74 | 4.67 | 4.66 | 4.88 | 5.1 |

2.2.2. Sizing of solar farm

2.2.2.1. Using PVsyst for Sizing All Capacity Needs for 5 MWp Solar Farm
Optimization of material required for 5 MWp has been calculated by PVSYST software in the previous study by Rahmawati et al., 2019, [12]. This 5MWp solar farm planning is based on the geographical location of Weh Island - Indonesia, which is at latitude 5.830 North - longitude 95.320 East with a time zone of UT + 7, the altitude of 95 m and Albedo at the point of 0.20. Meteo data were obtained from NASA-SESE satellites from 1983-2003. The slope design of the panel was set at an angle of 100 eastward and the Azimut 00 provision with fixed tilt, and the model used in the simulation is the Perez transposition by ignoring the Shading factor.

2.2.2.2. HOMER simulation

Figure 4. Input for HOMER model simulation

2.2.2.3. PV Generation
The number of materials required for 5 MWp solar farm was 16,668 panels with utilizing 300 Wp [12] with 25 years of life time and different specification. Si-mono technology with the efficiency of 16.4% costs Rp. 134.062.550.000 while si-poly technology with an efficiency of 15% costs Rp. 118.022.795.000
2.2.2.4. Inverter model
The inverter used in this study is a grid-connected inverter type. The capacity of the inverter was adjusted to the capacity of available power, i.e. 5,000 kWp. The inverter has a capacity of 20 k with Maximum Efficiency > 98.2% [12]. The cost of this inverter was Rp. 14,961,375,000.

2.2.2.5. Economic analysis
This study [13] states that there are several factors that can help investors assess the feasibility of an investment, as follows:

Life cycle analysis (LCC); LCC refers to the sum of all costs, both recurrent and non-recurring with respect to products, structures, systems, or services, during their lifetime. LCC calculation is as follows [4]:

\[
\text{LCC} = C_{\text{capital}} + C_{\text{O&M}} + C_{\text{replacement}} - C_{\text{salvage}} \tag{1}
\]

The capital cost \((C_{\text{capital}})\) is the overall price of expenditure to manage the whole system. Capital costs include all prices of components, installation and project design. The costs for operational and maintenance \((C_{\text{O&M}})\) include salaries for workers, maintenance costs for each solar farm product and system monitoring during the system operation. Replacement cost \((C_{\text{replacement}})\) is the cost to replace the product at a certain period of the lifetime product, for instance, the replacement of a converter where the lifetime of this product is 15 years. Salvage cost is the residual value of an item or the residual value of an investment. An item that has expired can still be resold. In the calculation of HOMER software, it is estimated that the salvage or residual value of this investment is 20% of the initial investment.

**Table 2.** Detail cost for 5 MWp solar power generations (si-Mono technology)

| No | Description                             | Weh Island (Rp) | Percentage |
|----|-----------------------------------------|----------------|------------|
| 1  | Management Cost                         | Rp 3,400,000,000 | 2.3%       |
| 2  | Land Acquisition                        | Rp 10,500,000,000 | 7.0%       |
| 3  | Building, Infra and Civil Work          | Rp 21,064,000,000 | 14.1%      |
| 4  | Solar Module                            | Rp 75,000,000,000 | 50.3%      |
| 5  | Inverters                               | Rp 14,961,375,000 | 10.0%      |
| 6  | Installation Cost                       | Rp 14,000,000,000 | 9.4%       |
| 7  | Electrical Equipment and Asset          | Rp 8,092,550,000  | 5.4%       |
| 8  | Others (Legal Fees/ General)            | Rp 2,000,000,000  | 1.3%       |
|    | Total                                   | Rp 149,017,925,000 | 100.0%   |

**Table 3.** Detail cost for 5 MWp solar power generations (si-poly technology)

| No | Description                             | Weh Island (Rp) | Percentage |
|----|-----------------------------------------|----------------|------------|
| 1  | Management Cost                         | Rp 3,400,000,000 | 2.6%       |
| 2  | Land Acquisition                        | Rp 10,500,000,000 | 7.9%       |
| 3  | Building, Infra and Civil Work          | Rp 21,064,000,000 | 15.8%      |
| 4  | Solar Module                            | Rp 59,166,666,667 | 44.4%      |
| 5  | Inverters                               | Rp 14,961,375,000 | 11.2%      |
| 6  | Installation Cost                       | Rp 14,000,000,000 | 10.5%      |
| 7  | Electrical Equipment and Asset          | Rp 8,092,550,000  | 6.1%       |
| 8  | Others (Legal Fees/ General)            | Rp 2,000,000,000  | 1.5%       |
|    | Total                                   | Rp 133,184,591,667 | 100.0%   |
Net Present Value (NPV); The NPV shows a lump-sum with a certain discounted current which gives a figure of how much the current business value (Rp) is. In this method, the NPV includes a time value factor, to consider all project cash flows, measuring absolute amounts, so that it is easy to follow its contribution to efforts to increase company revenue [13]. To calculate the NPV, we need data about estimated investment costs, operating costs, and maintenance, as well as estimated benefits from the planned project, NPV is explained in the equation as follows [14].

\[
NPV = \frac{TAC}{CRF}
\]  
(2)

Where, TAC- total annual cost includes the sum of the annual costs of each system component (Rp), CRF - capital recovery factor (%).

After these costs were calculated, the unit of CoE produced by the generating electricity system could be calculated. The cost of energy (in Rp) is the ratio between the total costs per year of the system with the energy it produces during the same time period [4]. To calculate the price for the energy generated by the system, the following formula was used:

\[
CoE = \frac{LCC}{\sum Ppv}
\]  
(3)

Levelized Cost of Energy (LCoE); Levelized Cost of Energy is the price at which electrical energy is generated from certain energy sources and stops functioning even during a certain period of time [13]. LCoE can also be considered the average minimum cost of electricity that can be offered during the duration of the project. LCoE calculations are shown in the following equation:

\[
LCoE = \frac{\sum_{t=1}^{n} LCC_{t}}{\sum_{t=1}^{n} E_{t}}
\]  
(4)

Pay Back Period (PBP); Payback period is a parameter that calculates how fast an investment is needed to be returned, so the units used are years, months and days [13].

\[
Payback\ period = \frac{Initial\ Investment}{Cash\ In\ Flow\ Per\ Period}
\]  
(5)

Internal Rate of Return (IRR); Internal Rate of Return (IRR) is a parameter used to obtain an interest rate that equates the total present value of the expected cash flow recipient with the total present value required for investment [15]. The IRR decision criteria are, if the IRR value is greater than the general interest rate in effect, the project is accepted, but if it is the opposite, the project will be rejected. The general interest rate applicable in Indonesia is based on the benchmark interest of all banks, namely, Bank Indonesia, i.e. 5.25% [16]. The formula used is provided in the following [13]:

\[
IRR = i + \left(\frac{NPV}{NPV^1-NPV^2}\left(i^1 - i^2\right)\right)
\]  
(6)

Where (i) is the interest rate, \(i^1\) is interest rates that produce a positive NPV value, \(i^2\) is Interest rates that produce a positive NPV, \(NPV^1\) is a positive of net present value, and \(NPV^2\) is a negative of net present value.
3. Result and discussion

3.1. Technical analysis

The simulation was conducted after calculating the sizes of all components for 5 MWp, and the use of the components is illustrated in Table 5. The output of the electricity produced by the system with these 2 technologies, as illustrated in Figure 9, gave differences in electricity output, although the technologies used have different efficiency.

| Sizing Simulation | 5000 MW (300 Wp @panel) |
|-------------------|--------------------------|
| Number of Modules | 16.668                   |
| Number of inverters (20kW) | 250                    |
| Configuration     | 18 modules in series with 926 string |
| The area of land required by the panel | 32.309 m² |

Figure 5. Total energy generated by the systems with 2 different technology

5000 kWp si-Monocrystalline technology

With an investment of Rp. 149,023,925,000, this project is calculated to have an NPV (Net Present Cost) value of Rp. 171,741,079,862. The costs to be incurred annually for the system are Rp. 8,347,640,000, where Energy of as much as 7,991,000 kWh is generated per year with a project life of 25 years. The minimum price that can be offered (LCoE) from Homer simulations is Rp. 1,035, which shows the profit from sales per kWh, and thus the minimum selling price that can be offered is Rp. 1,065 / kWh. The IRR interest rate where NPV = 0 will be obtained at 9.8%, which is greater than the bank interest rate of 5.25%; thus, it is considered feasible. Return on Investment (ROI) generated is 6.4%. Simple payback period, i.e. cash flow with profit without considering the value of money, will occur in year 9.63. Return on capital will occur in year 10.73.

Figure 6. HOMER result of cost summary for 5 MWp si-mono technology
5000 kWp si-polycrystalline technology

With an investment cost of Rp.133,189,325,000, this project has an NPV (Net Present Cost) value of Rp. 192,021,200,400, costs to be incurred per year for the system are Rp. 9,314,790,000. The energy that rose annually is 7,852,000 kWh with a project life of 25 years. With a sales tariff of 85% from BPH Weh Island, the results show that the minimum price that can be offered (Levelized cost of energy) from Homer's simulation shows an LCOE figure of Rp. 1,177. The minimum selling price that can be offered to the public is Rp. 923 / kWh. The IRR interest rate where NPV = 0 will be obtained is at 11%, which is greater than the bank interest requirement of 5.25% so that it is considered feasible.

Return on Investment (ROI) generated is 7.9%. A simple payback period, i.e. cash flow with profit without considering the value of money, will occur in year 8.32. Return on capital will occur in year 8.85. More information can be seen in Table 6.

Figure 7. Life cycle cost of 5000 kWp si-monocrystalline technology

Figure 8. The total cost of the system for 25 years

5000 kWp si-polycrystalline technology

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Figure 9. HOMER result of cost summary for 5 MWp si-mono technology
Figure 10. Life cycle cost of 5000 kWp silicon-poly crystalline technology

Figure 11. The total cost of the system runs for 25 years

Table 5. The result of economic analysis for 5000 kWp solar farm

| Decision Variable          | Standart | E_output (kWh/year) | Total Investment (Rp) | Fit (Rp) | CoE (Rp) | LCoE (Rp) | NPV (Rp) | Annual Cost (Rp) | ROI (%) | IRR (%) | simple PBP (year) | Discounted PBP (year) |
|----------------------------|----------|---------------------|-----------------------|----------|----------|----------|----------|-------------------|---------|----------|------------------|------------------------|
| E_output (kWh/year)        | Standart | 7991                | 149,023,925,000       | 2100     | 1,035    | 900      | 172,866,400,000  | 8,347,640,000    | 6.4     | 5.25%   | 25               | 25                     |
| Total Investment (Rp)      | Standart |                     | 133,189,325,000       | 2100     | 1,177    | 923      | 193,146,600,000  | 9,326,958,000    |         |         |                  |                        |
| Fit (Rp)                   | Standart | 2100                |                       | 2100     |          |          | 25          |                  |         |         |                  |                        |
| CoE (Rp)                   | Standart | 1,035               |                       | 1,177    |          |          | 25          |                  |         |         |                  |                        |
| LCoE (Rp)                  | Standart | 900                 |                       | 923      |          |          | 25          |                  |         |         |                  |                        |
| NPV (Rp)                   | Standart | 172,866,400,000     |                       | 193,146,600,000 |          |          | 25          |                  |         |         |                  |                        |
| Annual Cost (Rp)           | Standart | 8,347,640,000       |                       | 9,326,958,000    |          |          | 25          |                  |         |         |                  |                        |
| ROI (%)                    |          |                     |                       |          |          | 6.4      | 9.8       | 5.25%             | 9.8     | 11       |                  |                        |
| IRR (%)                    |          |                     |                       |          |          | 7.9      | 11        | 9.8               | 11      |          |                  |                        |
| simple PBP (year)          |          |                     |                       |          |          | 25       | 9.63      | 25                | 9.63    | 8.32     |                  |                        |
| Discounted PBP (year)      |          |                     |                       |          |          | 25       | 10.73     | 25                | 10.73   | 8.85     |                  |                        |

4. Summary
In this economic study, several important factors that determine investment decisions have been analysed. This is to provide more detailed information on business actors. The two technologies used were the feasibility information in this project. However, several factors contributed to the decision. Based on return on investment, with FiT sales of Rp. 2,100, -. Although solar farm with silicon mono technology produces higher electricity output, cheaper of CoE and greater LCoE, the fastest return on investment was with a solar farm system with 5000 kWp capacity of silicon-poly crystalline technology. Overall, capital recovery in this system occurred in 8.32 with an IRR of 11%.
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