Evaluation of 35 kWp on grid solar power plant based on economic and environmental factors in ESDM office Jawa Tengah, Indonesia

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Abstract. The existence of Solar Power Plant is very much needed in supplying clean, cheap and sustainable electricity. New renewable energy power plants are very important to replace power plants that use fossil fuels. Therefore, it is necessary to evaluate the performance of Solar Power Plant that is how much the operational costs and how much CO2 emissions can be reduced. This study describes an investment feasibility assessment or economic analysis using the calculation of NPV (Net Present Value), PI (Probability Index) and DPP (Discount Payback Period) and environmental analysis, that is knowing the amount of CO2 emission reduction from the use of Solar Power Plant analysed using criteria according to IPCC standards (Intergovernmental Panel on Climate Change). The research location of Solar Power Plant on Grid 35 KWP Office of the Energi and Sumber Daya Mineral (ESDM), Jawa Tengah, Indonesia. The results of this study indicate that the NPV of this PV mini-grid > 0 is Rp. 3,331,537.- PI, 1.0039, DPP 24 years 6 months and Payback Period 8.74 years, which means this investment is feasible to continue. Meanwhile, the CO2 emission that can be reduced is 44.718.42 kgCO2/year. These results indicate that Solar Power Plant on Grid 35 KWP the ESDM office location in Central Java is feasible and profitable from an economic and environmental criterion.

1. Introduction

The problem of decreasing fossil fuel reserves today is feared that the world will soon run out of energy sources. This is a concern for developing countries whose economies are highly dependent on energy use. Under these conditions, it is highly expected that new and renewable energy resources can be utilized with maximum conversion efficiency in order to supply the increasing energy demand. The environmental advantage factor, renewable energy sources generate electricity with a low/insignificant contribution of carbon dioxide (CO2) or other greenhouse gases (GHG) to the atmosphere and do not result in the release of pollutants to water or soil and therefore generating electricity [1]. Electricity from renewable energy becomes very important. Economic analysis was carried out to realize the advantages of stand-alone systems. Size and techno-economic optimization of PV/autonomous energy systems with battery storage [2]. In IEA 2018, data from 2016 shows that renewable energy along with several other non-fossil sources provides around 19% of the world's energy needs with a contribution of 1% of global carbon emissions [3]. Meanwhile, the coal used by power plants with the amount of energy reaching 27% actually contributes 44% of carbon emissions. On the other hand, 32% of the amount of oil
contributes 35% of carbon emissions. Based on the 2015 Electricity Indonesia is around 4.80 kWh/m²/day [4].

The ESDM Office has Solar Power Plant which is considered feasible to be implemented and is certain to provide economic benefits. Where the NPV of Rp 3.331.537, - which means > 0, with a payback period or payback period of 8.7 years and DPP for 24 years and 6 months [5], which means it is smaller than the project age of 25 years. Economic evaluation is carried out to assess and calculate the benefits obtained by using Solar Power Plant as an alternative energy source at the ESDM Office of Central Java Province every year [6].

2. Literature Review
The research location of Solar Power Plant which is the object of this research is Solar Power Plant Rooftop on Grid 35kWp [7, 8] which is located at the ESDM office Jawa Tengah, Indonesia (Figure 1). Figure 2 show that Solar panel laying plan.

![Figure 1. Map ESDM Office Semarang Jawa Tengah](image1)

![Figure 2. Solar Panel Laying Plan](image2)

Methods of data collection is done by interview, observation and document study [9]. Interviews were conducted with several parties related to the object of research, namely the field of new and renewable energy, the electricity sector as well as the general sector and staffing. Observation to see Solar Power Plant rooftop directly and see equipment such as AC panels, combiner panels and inverters. Document study by reading PV mini-grid planning books and related journals [10]. After data collection, it can be seen that the Department of Energy and Mineral Resources of Central Java Province consists of two parts of the building, namely an office building or main building and a dormitory building. Where for electricity the two buildings use PLN electricity with each transformer capacity of 105kVA and 66kVA. In addition, there are also two generators with a size of 100kVA as backup power in case of a power outage from PLN [11]. The investment feasibility assessment method in this study uses the analysis of Net Present Value (NPV), Probability Index (PI), Discount Payback Period and Payback Period. Meanwhile, the calculation process is assisted with Microsoft Excel 2010 software [12]. To find out the amount of carbon emissions that are reduced by using the guidelines from the (Intergovernmental Panel on Climate Change).
3. Result and Discussion

The results of the study can be known by calculating the investment feasibility analysis and calculating CO2 emissions that can be reduced by investment cost. The investment cost for the Solar Power Plant ESDM Office Jawa Tengah includes the cost of PV mini-grid components, installation service fees and PPN [13].

Maintenance and Operational Budget Meanwhile, the maintenance and maintenance budget is usually 1% of the investment cost for a country with two seasons like Indonesia because it does not have to incur large maintenance costs for solar panels [14]. The maintenance and operational budget (M) per year is as follows:

\[
M = 1\% \times \text{Total Investment} = 1\% \times \text{Rp. 851,903,000}.
\]

\[
= \text{Rp. 8,519,030.}- \text{rounded to Rp. 8,519,000}.-
\]

\[
= \text{Rp. 8,519,000} \times \frac{(1+i)^{25}-1}{(1+i)^{25}}
\]

\[
= \text{Rp. 8,519,000} \times 0.105(1+0.105)^{25}
\]

\[
= \text{Rp. 8,519,000} \times 8,740
\]

\[
= \text{Rp. 74,456,060}.-
\]

Solar Power Plant Energy Cost (Cost of Energy) COE is the ratio of the total cost required to produce energy with the energy produced in the same time period [15]. Calculation of energy costs (cost of energy) Solar Power Plant ESDM Jawa Tengah Indonesia is determined by the capital recovery factor (CRF), life cycle costs (LCC) and annual production kWh is calculated based on the formula:

\[
\text{CRF} = \frac{1}{(1+i)^{25}} = \frac{1.274}{11.135} = 0.1144
\]

### Table 1. Initial Costs for Installation Solar Power Plant ESDM Jawa Tengah

| Goods Shopping | Costs (IDR) |
|----------------|-------------|
| A Solar Modul Polycrystalline capacity of 35 kWp | 322,547,000.00 |
| B System Inverter dan Communication | 130,276,475.00 |
| C Installation, Protection, Power Cable | 64,134,250.00 |
| D Module Support Frame | 64,199,850.00 |
| E Monitoring System | 10,608,750.00 |
| F Grounding | 5,490,925.00 |
| Service Shopping A | 177,200,000.40 |
| Total Shopping for Goods and Services | 774,457,250.40 |
| **PPN 10%** | 77,445,725.04 |
| **Total Overall Budget** | 851,902,975.44 |
| **Rounding** | 851,903,000.00 |

The annual kWh production of Solar Power Plant on ESDM office is as follows (table 2). Amount of COE for Solar Power Plant ESDM office to calculate the annual kWh production cost [16, 17, 18, 19], the authors use 2018 data as the first year, because 2017 starts operating in the final months and the availability of incomplete data [20]. The amount of COE for Solar Power Plant ESDM Office Semarang, Jawa Tengah Indonesia is as follows:

\[
\text{COE} = \frac{\text{LCC} \times \text{CRF}}{\text{A kWh annual}}
\]

\[
= \frac{926,359.060 \times 0.1144}{39.226.69} = \text{Rp. 2,702}.-
\]
Table 2. Production power (kWh) of Solar Power Plant on ESDM office

| Month     | Inverter 1 | Inverter 2 | Inverter 1 | Inverter 2 | Inverter 1 | Inverter 2 |
|-----------|------------|------------|------------|------------|------------|------------|
| January   | No data    | No data    | 1792.24    | 1014.95    | 1819.96    | 1008.63    |
| February  | No data    | No data    | 1855.13    | 1019.2     | 2020.86    | 1101.34    |
| March     | No data    | No data    | 2079.71    | 1149.31    | 2017.85    | 599.46     |
| April     | No data    | No data    | 2022.8     | 1228.97    | 2162.09    | 644.97     |
| May       | No data    | No data    | 2180.03    | 1212.49    | 2289       | 830.6      |
| June      | No data    | No data    | 2100.01    | 1160.97    | 2123.72    | 836.45     |
| July      | No data    | No data    | 2245.49    | 1248.53    | 2242.25    | 863.38     |
| August    | No data    | No data    | 2251.27    | 1280.05    | 2404.7     | 815.06     |
| September | No data    | No data    | 2228.15    | 1236.63    | 2387.91    | 654.67     |
| October   | No data    | No data    | 2359.68    | 1285.99    | 2578.77    | 528.04     |
| November  | No data    | 3.12       | 2094.14    | 1143.52    | 2176.34    | 347.53     |
| December  | 633.83     | 434.84     | 1956.37    | 1081.06    | 2176.01    | 344.83     |

| Total     | Inverter 1 | Inverter 2 | 633.83     | 437.96     | 25165.02   | 14061.67   | 26399.46   | 8574.96    |

The investment feasibility assessment process must calculate the annual cash inflow [21], annual cash outflow and net cash flow. To calculate the annual cash inflow rate by multiplying the annual kWh production of Solar Power Plant by COE (cost of energy) [22, 23, 24, 25, 26]. The annual cash outflow represents the budget for maintenance and operations. While net cash flow is the difference between annual cash inflows and annual cash outflows.

To determine the feasibility of an investment, several economic analyses must be used, including: Net Present Value (NPV) the total current value of the net cash rate which is the result of multiplying the net flow with the discount factor is Rp. 855,234,537.- if the initial investment is Rp. 851,903 million, - then the value of the NPV is: \[ \text{NPV} = \text{Rp. 855,234,537.} - \text{Rp. 851,903 million, = Rp. 3,331,537.} \]

The calculation of the positive NPV is: \[ \text{NPV} = \text{Rp. 3,331,537.} ( > 0) \]

Shows that the Solar Power Plant investment from the ESDM Office of Jawa Tengah is indeed feasible to carry out. Probability Index (PI) With a total present value of net cash flows of Rp. 855,234,537.- and initial investment cost of Rp. 851.903 million, - then the PI value is: \[ \text{PI} = \frac{855,234,537}{851,903,000} = 1.0039 \]
Table 3. PVNCF Calculation Result

| P  | Costs       | Cash in flow | Cash out flow | Net Cash Flow NCF | DF | Present Value NCF | Cumulative PVNCF |
|----|-------------|--------------|---------------|-------------------|----|-------------------|------------------|
| 0  | 851,903,000 |              |               |                   |    |                   |                  |
| 1  | 105,990,516 | 8,519,000    | 97,471,516    | 0.9049            |    | 88,201,975        | 88,201,975       |
| 2  | 105,990,516 | 8,519,000    | 97,471,516    | 0.8911            |    | 86,856,868        | 175,058,843      |
| 3  | 105,990,516 | 8,519,000    | 97,471,516    | 0.7411            |    | 53,541,104        | 247,294,983      |
| 4  | 105,990,516 | 8,519,000    | 97,471,516    | 0.6707            |    | 43,852,435        | 312,669,129      |
| 5  | 105,990,516 | 8,519,000    | 97,471,516    | 0.6070            |    | 35,908,506        | 371,834,339      |
| 6  | 105,990,516 | 8,519,000    | 97,471,516    | 0.5493            |    | 29,407,156        | 425,375,443      |
| 7  | 105,990,516 | 8,519,000    | 97,471,516    | 0.4971            |    | 23,100,749        | 473,828,534      |
| 8  | 105,990,516 | 8,519,000    | 97,471,516    | 0.4499            |    | 19,728,235        | 517,680,969      |
| 9  | 105,990,516 | 8,519,000    | 97,471,516    | 0.4071            |    | 17,847,034        | 557,361,623      |
| 10 | 105,990,516 | 8,519,000    | 97,471,516    | 0.3684            |    | 16,151,030        | 593,270,129      |
| 11 | 105,990,516 | 8,519,000    | 97,471,516    | 0.3334            |    | 14,620,727        | 625,767,132      |
| 12 | 105,990,516 | 8,519,000    | 97,471,516    | 0.3017            |    | 13,226,885        | 655,174,288      |
| 13 | 105,990,516 | 8,519,000    | 97,471,516    | 0.2730            |    | 11,969,502        | 687,257,037      |
| 14 | 105,990,516 | 8,519,000    | 97,471,516    | 0.2471            |    | 10,829,085        | 702,360,249      |
| 15 | 105,990,516 | 8,519,000    | 97,471,516    | 0.2236            |    | 9,805,634         | 724,154,880      |
| 16 | 105,990,516 | 8,519,000    | 97,471,516    | 0.2024            |    | 8,869,908         | 743,883,115      |
| 17 | 105,990,516 | 8,519,000    | 97,471,516    | 0.1831            |    | 8,031,653         | 761,730,149      |
| 18 | 105,990,516 | 8,519,000    | 97,471,516    | 0.1657            |    | 7,778,181         | 777,881,179      |
| 19 | 105,990,516 | 8,519,000    | 97,471,516    | 0.1500            |    | 7,720,501         | 792,501,906      |
| 20 | 105,990,516 | 8,519,000    | 97,471,516    | 0.1357            |    | 7,085,634         | 805,728,791      |
| 21 | 105,990,516 | 8,519,000    | 97,471,516    | 0.1238            |    | 6,349,502         | 817,698,293      |
| 22 | 105,990,516 | 8,519,000    | 97,471,516    | 0.1111            |    | 5,609,085         | 828,527,378      |
| 23 | 105,990,516 | 8,519,000    | 97,471,516    | 0.1006            |    | 4,869,908         | 838,333,012      |
| 24 | 105,990,516 | 8,519,000    | 97,471,516    | 0.0910            |    | 4,129,908         | 847,202,920      |
| 25 | 105,990,516 | 8,519,000    | 97,471,516    | 0.0824            |    | 3,430,653         | 855,234,573      |

Table 4. CO₂ Emission Coefficient from Solar Power Plant

| Electrical Power Plant | Fuel | Emission Factor CO₂ (kg/kWh) |
|------------------------|------|-----------------------------|
| PLTU                   | Coal | 1.1400                      |
|                        | HSD  | 0.6780                      |
|                        | MFO  | 10530                       |
| PLTG                   | Natural gas | 1.0020                     |
|                        | HSD  | 1.0910                      |
| PLTGU                  | Natural gas | 0.5050                     |
|                        | HSD  | 0.7090                      |
| PLTD                   | HSD  | 0.7860                      |
|                        | MFO/I | 0.7280                     |
| PLTP                   | -    | 0.2000                      |
| PLTA                   | -    | 0.0000                      |

The results of the PI calculation which is worth 1.0039 (>1) indicate that the Solar Power Plant investment from the ESDM Office of Jawa Tengah, Indonesia is indeed feasible to carry out. Discount
Payback Period Discount Payback Period (DPP) is obtained by calculating how many years the present value of cumulative net cash flows will be equal to the value of the initial investment. The results of the PVNCF calculation show that in year 24 the present value of cumulative net cash flows is close to the initial investment value with a shortfall of Rp. 851,903 million, \(-\ Rp. 847,202,902 = \ Rp. 4,700,098,\) - Rp. 847,202,902 = Rp. 4,700,098.

In the 25th year the net cash rate value is Rp. 8,031,653, - Rp. 8,031,653, = 0.58 of 12 months or 6 months). The resulting DPP of 24 years and 6 months, shows that the Solar Power Plant investment operating in the ESDM Office of Jawa Tengah years [26, 27]. Meanwhile, the payback period can be calculated by dividing the initial investment by the cash flow, which is the payback period of 8.74 years. Carbon dioxide emissions that can be reduced in 2018 are 44,718.42 kg CO\(_2\) various activities, including from power plants using fossil fuels. The role of new and renewable energy such as Solar Power Plant will be the right choice because it is capable of. Based on table V, the use of PLN electricity generally utilizes coal-fired PLTU so that the emission factor is 1.1400 kg/kWh with energy produced by Solar Power Plant ESDM Office of Jawa Tengah Indonesia in 2018 of 39,226.69 so that the potential for carbon dioxide gas emissions can be reduced in one year by:

\[
\text{CO}_2 \text{ emission} = \text{Emission Factor } \times \text{Electrical Production} \\
= 1.1400 \text{ kg/kWh} \times 39,226.69 \text{ kWh} \\
= 44,718.42 \text{ kgCO}_2/\text{annual}
\]

From the calculations above, it can be seen that in 2018 the Solar Power Plant of the ESDM Office of Jawa Tengah Indonesia could reduce CO\(_2\) emissions by 44,718.42 kg CO\(_2\) or 44,71842 tons CO\(_2\). However, the amount of CO\(_2\) emissions that can be reduced depends on the size of the Solar Power Plant [29].

4. Conclusion

Based on the calculations carried out, Solar Power Plant of ESDM office investment project is considered feasible to be implemented and is certain to provide economic benefits. Where the NPV of Rp. 3,331,537, - which means > 0, with a payback period or payback period of 8.7 years and DPP for 24 years 6 months, which means it is smaller than the project age of 25 years. As well as the cost of selling and buying Solar Power Plant electricity by PT. PLN Persero changes from time to time, so the results of savings will also fluctuate. The results of these sales and purchases are also accumulated to the next month's payment so that the results per month are not too visible. Economic evaluation is carried out to assess and calculate the benefits obtained by using Solar Power Plant SDM Office of Central Java Indonesia every year. While the environmental aspect, carbon dioxide emissions that can be reduced from the use of Solar Power Plant depend on the production of Solar Power Plant, which means it is influenced by the weather. The use of energy in the future is expected to be able to shift from energy based on natural resources (resource-based energy) to energy based on technology (technology-based energy).

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