

Techno-Economic analysis of solar photovoltaic power plant for small scale fish processing in Kota Langsa - a case study

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Abstract. In Langsa, fisheries are the sector leaders by fulfilling a capacity of about 6,050 tons per year and on the other hand, fish-aquaculture reaches 1,200 tons per year on average. The fish processing is conducted through catches and aquaculture. The facilities on which this processing takes place are divided into an ice factory unit, a gutting and cutting unit, a drying unit and a curing unit. However, the energy and electricity costs during the production process has become major constraint because of the increase in the fishermen's production and income. In this study, the potential and cost-effectiveness of photovoltaic solar power plant to meet the energy demands of fish processing units have been analysed. The energy requirements of fish processing units have reached an estimate of 130 kW, while the proposed design of solar photovoltaic electricity generation is of 200 kW in an area of 0,75 hectares. In this analysis, given the closeness between the location of the processing units and the fish supply auctions, the assumption is made that the photovoltaic plants (OTR) were installed on the roof of the building as compared to the solar power plants (OTL) installed on the outside of the location. The results shows that the levelized cost of OTR instalation is IDR 1.115 per kWh, considering 25 years of plant life-span at 10% of discount rate, with a simple payback period of 13.2 years. OTL levelized energy, on the other hand, is at IDR 997.5 per kWh with a simple payback period of 9.6 years. Blood is an essential component of living creatures in the vascular space. For possible disease identification, it can be tested through a blood test, one of which can be seen from the form of red blood cells. The normal and abnormal morphology of the red blood cells of a patient is very helpful to doctors in detecting a disease. With the advancement of digital image processing technology can be used to identify normal and abnormal blood cells of a patient. This research used self-organizing map method to classify the normal and abnormal form of red blood cells in the digital image. The use of self-organizing map neural network method can be implemented to classify the normal and abnormal form of red blood cells in the input image with 93,78% accuracy testing.

1. Introduction

Langsa is a municipality located in the province of Aceh, Northern Sumatra that covers 262.41 km² of land and it's formed by 5 districts and 66 villages. The policy of the city government of Langsa is to boost the marine resources available through the improvement of the fishing industry, aquaculture, the processing industry and the marine industry, while relying on science and technology. Marine resources



are the backbone of the sustainable economic development in the region. The growth of the fisheries in the sector and the efforts to support them are constantly encouraged given that the local government is fully aware of the positive economic impact they can provide. In table 1, the production rate of the Langsa fisheries throughout the year 2015 can be observed.

Based on the data, it can be noted that the fisheries that generate the most production are located in the Langsa Timur and Langsa Barat district. Meanwhile, the largest aquaculture production belongs to Langsa Timur. In a fishing group there's a total of 80 members divided into 45 fishermen and 35 aquaculture business owners who specialize in milkfish aquaculture. Added value of the fisheries products has been a great issue for years. They haven't been successful to bring fish production into a wider market because ice factories and post-harvest fish processing technology are not available. Moreover, there is an energy shortage in the region that poses a constraint. Therefore, this paper will analyze how the solar energy is an option to deal with the energy shortage in the fish processing units.

Table 1. The production capacity of marine and inland fisheries in Langsa [2]

| No. | Districts | Inland Fisheries (Ton) | Marine Fisheries (Ton) |
|------------|--------------|---------------------------|---------------------------|
| 1 | Langsa Timur | 420.50 | 3,019.00 |
| 2 | Langsa Barat | 80.51 | 2,022.00 |
| 3 | Langsa Kota | 74.03 | 1,009.00 |
| 4 | Langsa Lama | 245.05 | - |
| 5 | Langsa Baro | 380.05 | - |
| Sum | | 1200.14 | 6,050.00 |

The solar market for power generation is still relatively new and it's still being studied. There are a limited number of technology providers and the access to technical data is restricted. In addition, it's necessary to analyze the energy impact of these new technologies before considering using them on a large scale. A photovoltaic system converts solar energy into DC power and the system consists of a PV array, a battery, and elements for power conditioning. There are two types of PV systems: grid connected and standalone. The grid connected type feeds electricity directly into the electrical network and operates parallel to the conventional energy source. These types of grid systems create clean electricity without transmission or distribution losses and without a need for batteries; its performance relies on the local climate, the orientation and inclination of the PV array, and inverter performance. By contrast, a standalone system has no interaction with a network grid and it's directly connected to the load; the use of a battery becomes necessary. The battery stores energy when the power supplied by the PV modules exceeds the load demand and it returns it when the PV supply is deficient [9]. There are a large number of researches focused on the analysis of the feasibility of solar energy use for power plants with PV panels, i.e. [1,4-7,10]. One of these studies was conducted in Serbia [8] to figure out the possibilities of generating electrical energy through 1MW PV power plants by using the different types of solar PV modules. They concluded that using CdTe solar modules generates more electricity.

Chandel et. al [3] analysed the potential and cost-effectiveness of a solar photovoltaic power plant to fulfil the energy demand of a garment zone in Jaipur, India. It was estimated that the energy demands of the zone for the year 2011 were at 2.21 MW, and the design of the solar PV power plant had a capacity of 2.5 MW. This requires an approximate of 13.14 acres of land. The on-site solar PV power plant internal rate of return (IRR) is 11.88%, NPV at a 10% discount rate and of 119.52 million INR; the simple payback period is 7.73 years and the discounted payback period is at 10% in 15.53 years, while the off-site power plant represents an IRR of 15.10%, NPV of 249.78 million INR, simple payback period of 6.29 years and discounted payback period of 10.14 years. Levelized energy cost is Rs. 14.94 and Rs. 11.40 per kWh for on-site and off-site solar PV plants respectively at a 10% discount rate, which is quite attractive.

Grid connected and standalone photovoltaic systems can be analysed and dimensioned by using a wide array of tools. System designers and installers tend to use simpler tools for sizing the PV system. On the other hand, most scientists and engineers typically use more involved simulation tools for optimization. Software tools related to photovoltaic systems can be classified into pre-feasibility analysis, sizing, and simulation. PVSYST is a dedicated PC software package for PV systems developed by the University of Geneva. It integrates pre-feasibility, sizing and simulation support for PV systems. After defining the location and loads, the user selects the different components from a product database and the software automatically calculates the size of the system [9].

In this work, PVSYST 5.41 is used to perform the simulations of standalone solar PV systems by comparing the energy production, performance ratio, efficiency and cost. Throughout this project, the potential and the cost-effectiveness of a solar photovoltaic power plant is analysed for meeting the energy demand of fish processing at a small scale in Kota Langsa; this process makes use of an ice factory unit, a gutting and cutting unit, a drying unit, and a curing unit.

2. Method

Location: The geographic location where the project was conducted is Kuala Langsa which is situated at: 04° 31' 4.98" N, 98° 0' 54.3" E, and elevation at 2 m (a.s.l.) shows figure 1. PVSYST includes its own solar data for some locations. The general architecture of our proposed method is shown in figure 1.

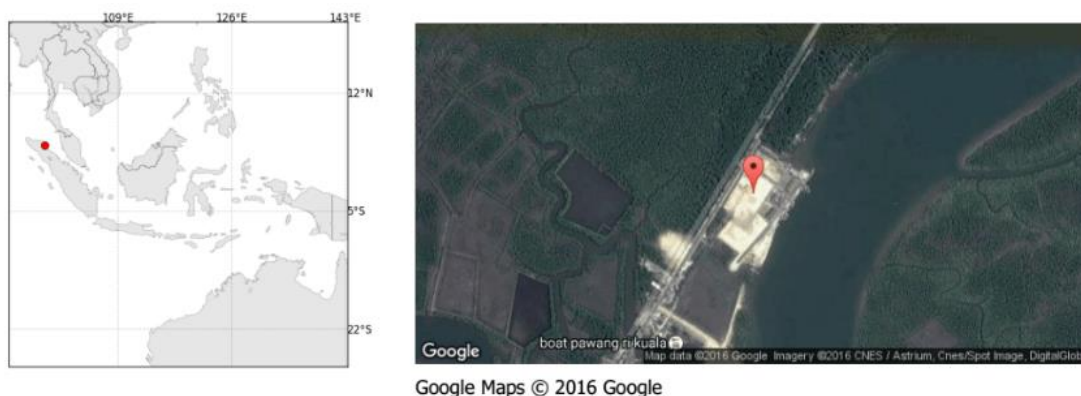


Figure 1. Location of small scale fish processing plant in Kota Langsa

In figure 2 the global horizontal irradiation and air temperature during a year can be observed. The global radiation components are direct, diffuse and reflected. The average daily sum of global irradiation on the horizontal surface is of 4.73 kWh/m² per day with a maximum value of 5.50 kWh/m² (March) and a minimum value of 3,852 kWh/m² (December). The diffuse component of radiation proved to be significant, especially during the months of Feb-Sept, while reflected radiation stayed relatively reduced throughout the rest of the year. The average yearly component of diffuse radiation is of 46.5 % of total global radiation.

Designing a standalone PV system doesn't entail many steps, but the preferred ones are as follows. Determination of the load defines the sum of electrical power used in the process of fisheries. Figure 3 shows the layout of equipment inside the fisheries' unit processing. Inside the unit, there are two unit freezers, one unit ice machine, one unit chiller, two units of fresh water pumps, a gutting and cutting unit, a drying unit, and a curing unit. The whole equipment will need 130 kW of electrical power, putting the daily average energy requirement at 3120 kWh.

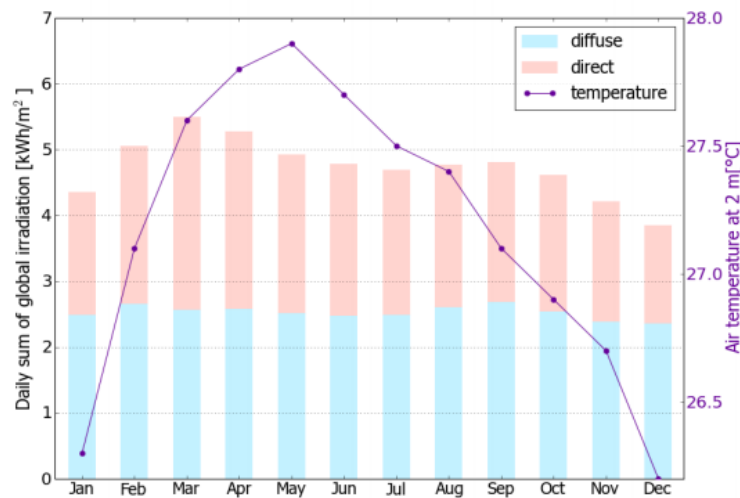


Figure 2. Global horizontal irradiation on site

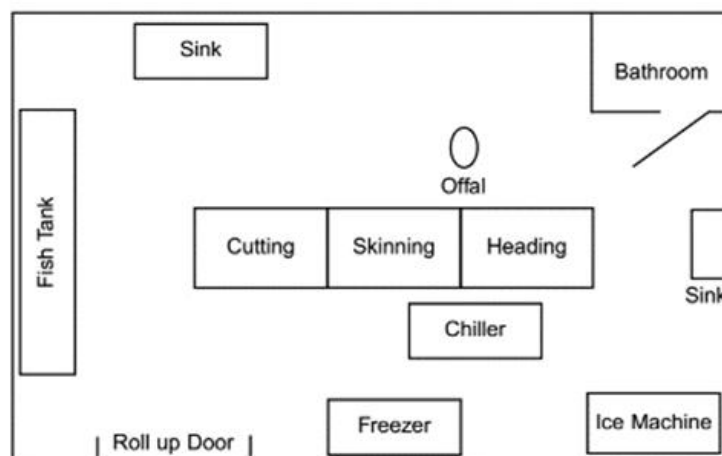


Figure 3. Layout of small-scale fish processing facility in Kota Langsa

The next step is to calculate the number of PV, battery and method of controller. The system defining parameter which was used is shown in table 2.

Table 2. System Defining Parameters

| Module type | Standard |
|--------------|------------------|
| Technology | Poly-crystalline |
| PV module | 120 Wp 28 V |
| Battery pack | Open 12 V/100 Ah |

Using the aforementioned PVSYST software it was shown that the number of PV panels that should be provided to meet the energy demands was 935 modules, with the requirement of an area of about 0.75 hectares (1.85 acres).

Orientation: The panels are facing south (in this study), and the angle of the panels form an inclination with the ground. The energy usage between winter time and summer time is quite large at this latitude; on the contrary, the solar resource gap between winter and summer is not that considerable. That is the

reason why the inclination needs to be optimized for the summer months. In this example, the plane tilt is about 15° and azimuth is about 0°, as shown in figure 4.

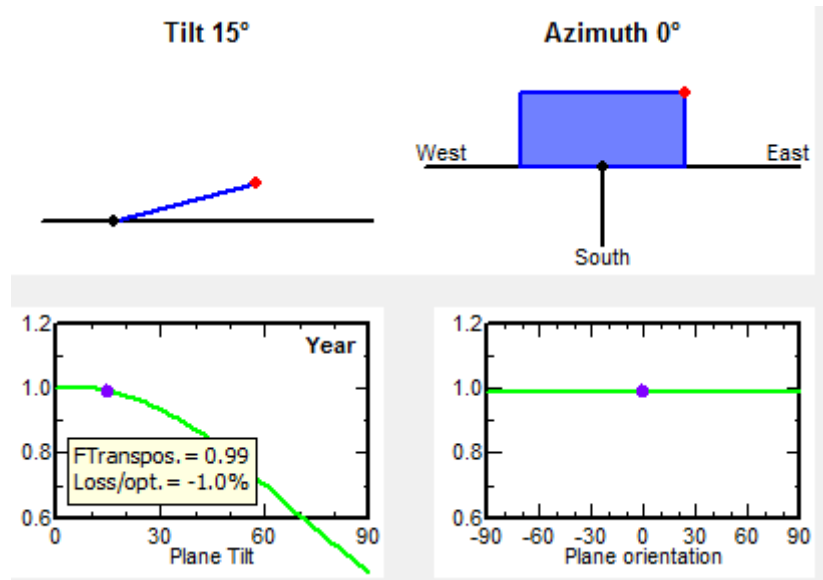


Figure 4. Orientation

The path of the sun in Kota Langsa throughout the year is represented in figure 5. The figure shows the terrain horizon, the module horizon, and an active area with civil and solar time. The module horizon, however, may have a shading effect on solar radiation.

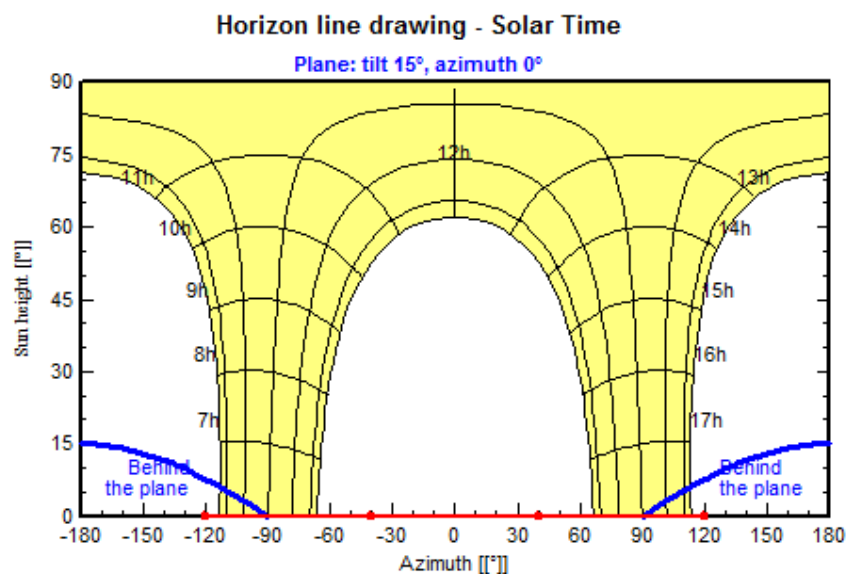


Figure 5. Insolation at location

System: A standalone PV system will depend on the demand of the user; the user has to input the desired nominal power, or the area that's available for installing PV modules. In the off-grid PV system, a battery needs to be chosen from the database. All the strings of PV modules should be homogeneously connected; this means that they should be identical modules, with the same number of modules in a series, the same orientation, etc. Figure 6 shows the schematic diagram of a standalone system. The

diode shown here is the bypass diode used for the purpose of protecting and a back-up generator is used for emergency purposes.

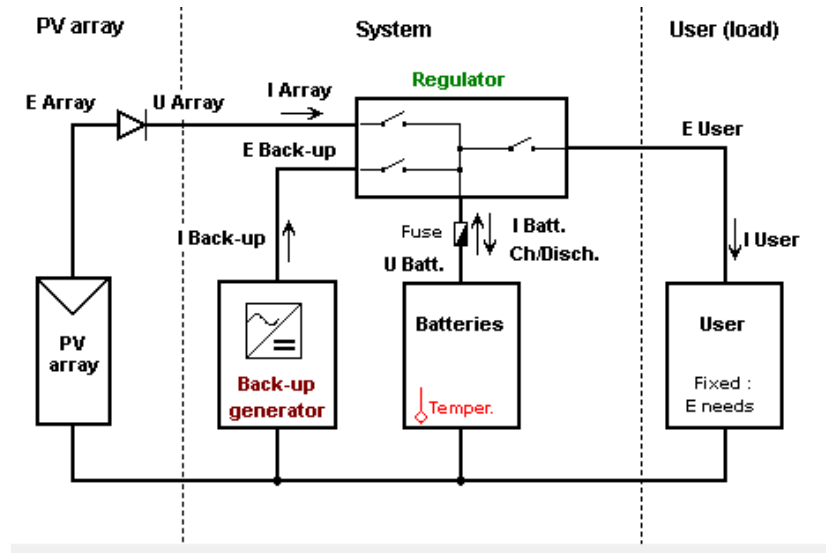


Figure 6. Schematic of the system

3. Result and discussion

This research is totally based on the PVSYST software and for modelling purposes. All the figures and tables depicted in this paper were generated during the simulation process. This paper only depicts the computational modelling, so that's why there's only the presentation of the results of the simulation rather than the description of it. Performance ratio (PR) is the ratio of the final PV system yield (Y_f) and the reference yield (Y_r). Table 3 shows the performance ratio of a grid connected system designed for the Kuala Langsa site. The yearly average performance ratio is 0.764.

Table 3. Normalized Performance Coefficients

| | Y_r kWh/m ² .day | L_u | Y_u kWh/kWp/day | L_c | Y_a kWh/kWp/day | L_s | Y_f kWh/kWp/day | PR |
|-----------|----------------------------------|-------|----------------------|-------|----------------------|-------|----------------------|-------|
| January | 4.30 | 0.139 | 4.30 | 0.956 | 3.35 | 0.240 | 3.11 | 0.722 |
| February | 4.68 | 0.444 | 4.68 | 1.392 | 3.29 | 0.182 | 3.11 | 0.664 |
| March | 5.11 | 0.433 | 5.11 | 1.463 | 3.65 | 0.545 | 3.11 | 0.607 |
| April | 4.51 | 0.306 | 4.51 | 1.180 | 3.33 | 0.224 | 3.11 | 0.689 |
| May | 4.20 | 0.091 | 4.20 | 0.910 | 3.29 | 0.187 | 3.11 | 0.739 |
| June | 4.05 | 0.016 | 4.05 | 0.776 | 3.27 | 0.166 | 3.11 | 0.767 |
| July | 4.14 | 0.000 | 4.14 | 0.788 | 3.36 | 0.249 | 3.11 | 0.750 |
| August | 4.16 | 0.000 | 4.15 | 0.792 | 3.36 | 0.257 | 3.11 | 0.748 |
| September | 4.29 | 0.236 | 4.29 | 1.061 | 3.23 | 0.120 | 3.11 | 0.724 |
| October | 4.61 | 0.253 | 4.61 | 1.166 | 3.44 | 0.483 | 2.96 | 0.642 |
| November | 4.13 | 0.112 | 4.13 | 0.883 | 3.24 | 0.137 | 3.11 | 0.753 |
| December | 3.72 | 0.053 | 3.72 | 0.749 | 2.97 | 0.359 | 2.61 | 0.702 |
| Year | 4.32 | 0.171 | 4.32 | 1.007 | 3.32 | 0.264 | 3.05 | 0.706 |

Table 4 shows the meteorological and incident energy of the PV system. The global horizontal irradiation (GlobHor) is of 1598.3 kWh/m²/year. The horizontal diffuse irradiation (DiffHor) is of 965.11 kWh/m². The overall global incident energy on the collector plane is of 1578.0 kWh/m².

Table 4. Meteor and Incident Energy

| | GlobHor | DiffHor | T Amb | WindVel | GlobInc | DiffSInc | Alb Inc | DifS/GI |
|-----------|--------------------|--------------------|-------|---------|--------------------|--------------------|--------------------|---------|
| | kWh/m ² | kWh/m ² | °C | m/s | kWh/m ² | kWh/m ² | kWh/m ² | |
| January | 125.5 | 80.52 | 27.05 | 2.0 | 133.4 | 82.15 | 0.428 | 0.000 |
| February | 125.0 | 68.34 | 27.47 | 1.9 | 131.1 | 69.81 | 0.426 | 0.000 |
| March | 158.5 | 90.05 | 27.91 | 2.0 | 158.6 | 89.73 | 0.540 | 0.000 |
| April | 141.4 | 87.07 | 27.80 | 1.8 | 135.3 | 84.33 | 0.482 | 0.000 |
| May | 141.8 | 80.30 | 28.28 | 1.9 | 130.3 | 76.45 | 0.483 | 0.000 |
| June | 133.7 | 81.74 | 27.88 | 1.9 | 121.5 | 77.19 | 0.456 | 0.000 |
| July | 140.7 | 83.24 | 28.01 | 2.0 | 128.5 | 78.84 | 0.480 | 0.000 |
| August | 136.2 | 86.50 | 27.86 | 1.9 | 128.8 | 83.27 | 0.464 | 0.000 |
| September | 131.5 | 79.89 | 27.00 | 1.9 | 128.6 | 78.47 | 0.448 | 0.000 |
| October | 138.7 | 79.80 | 27.16 | 1.8 | 142.8 | 80.70 | 0.473 | 0.000 |
| November | 117.1 | 75.95 | 26.70 | 1.7 | 123.8 | 77.52 | 0.399 | 0.000 |
| December | 108.1 | 71.70 | 26.89 | 1.9 | 115.3 | 73.26 | 0.368 | 0.000 |
| Year | 1598.3 | 965.11 | 27.50 | 1.9 | 1578.0 | 951.72 | 5.446 | 0.000 |

Table 5 shows the detailed monthly average system losses in kWh. Module quality loss (ModQual) is of 33,515 kWh/year. Module mismatch loss (MisLoss) is of 13,071 kWh/year. Ohmic wiring loss (Ohm Loss) is of 15,543 kWh/ year. Array virtual energy at Maximum Power Point (MPP), EArrMPP is of 1,278,478 kWh/Year.

Table 5. Detailed system Losses

| | ModQual | MisLoss | OhmLoss | EArrMPP | EArUfix | EUnused | EArray |
|-----------|---------|---------|---------|---------|---------|---------|---------|
| | kWh | kWh | kWh | kWh | kWh | kWh | kWh |
| January | 2845 | 1110 | 1319 | 108536 | 108536 | 4317 | 104219 |
| February | 2757 | 1075 | 1449 | 104989 | 104989 | 12495 | 92492 |
| March | 3338 | 1302 | 1710 | 127164 | 127164 | 13472 | 113692 |
| April | 2872 | 1120 | 1321 | 109554 | 109560 | 9205 | 100349 |
| May | 2761 | 1077 | 1224 | 105378 | 105378 | 2820 | 102557 |
| June | 2594 | 1011 | 1065 | 99072 | 99078 | 463 | 98609 |
| July | 2737 | 1067 | 1165 | 104502 | 104502 | 0 | 104502 |
| August | 2743 | 1070 | 1193 | 104728 | 104734 | 5 | 104723 |
| September | 2736 | 1067 | 1285 | 104357 | 104357 | 7112 | 97244 |
| October | 3016 | 1176 | 1524 | 114941 | 114947 | 7860 | 107081 |
| November | 2650 | 1033 | 1195 | 101116 | 101116 | 3367 | 97749 |
| December | 2467 | 962 | 1093 | 94141 | 94141 | 1644 | 92497 |
| Year | 33515 | 13071 | 15543 | 1278478 | 1278500 | 62762 | 1215714 |

Table 6 shows the balances and main results of the PV system employed. Yearly global horizontal irradiation is of 1,598.3 kWh/m². The yearly global incident energy on the collector plane is of 1,521.1 kWh/m². Energy available at the output of the PV array is of 1.223.697 kWh. The energy supplied to

the user is of 1,118,857 kWh. Energy the user needed = 1.138.971. SolFrac Solar fraction ($E_{\text{Used}} / E_{\text{Load}}$) = 98.2 %.

Table 6. Balances and main results

| | GlobHor kWh/m ² | GlobEff kWh/m ² | E Avail kWh | EUnused kWh | E Miss kWh | E User kWh | E Load kWh | SolFrac |
|-----------|-------------------------------|-------------------------------|----------------|----------------|---------------|---------------|---------------|---------|
| January | 125.5 | 128.9 | 103854 | 4317 | 0 | 96735 | 96735 | 1.000 |
| February | 125.0 | 127.0 | 100687 | 12495 | 0 | 87373 | 87373 | 1.000 |
| March | 158.5 | 153.2 | 122470 | 13472 | 0 | 96735 | 96735 | 1.000 |
| April | 141.4 | 130.3 | 105233 | 9205 | 0 | 93614 | 93614 | 1.000 |
| May | 141.8 | 125.2 | 100707 | 2820 | 0 | 96735 | 96735 | 1.000 |
| June | 133.7 | 116.4 | 94685 | 463 | 0 | 93614 | 93614 | 1.000 |
| July | 140.7 | 123.3 | 99838 | 0 | 0 | 96735 | 96735 | 1.000 |
| August | 136.2 | 123.9 | 100057 | 5 | 0 | 96735 | 96735 | 1.000 |
| September | 131.5 | 124.1 | 99920 | 7112 | 0 | 93614 | 93614 | 1.000 |
| October | 138.7 | 138.1 | 110069 | 7860 | 4707 | 92027 | 96735 | 0.951 |
| November | 117.1 | 119.4 | 96648 | 3367 | 0 | 93614 | 93614 | 1.000 |
| December | 108.1 | 111.3 | 89528 | 1644 | 15407 | 81328 | 96735 | 0.841 |
| Year | 1598.3 | 1521.1 | 1223697 | 62762 | 20114 | 1118857 | 1138971 | 0.982 |

Figure 7 shows a graphic the Performance Ratio of the Incident energy for the entire month. The average Performance ratio is 0.706.

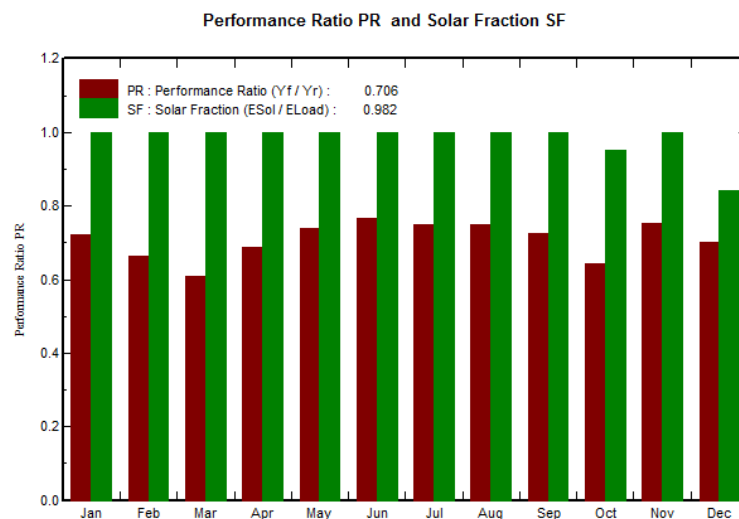


Figure 7. Performance Ratio PR and Solar Fraction

Figure 8 represents the overall system loss diagram for small scale fish processing at Kota Langsa. The horizontal global irradiation is of 1,598 kWh/m². The effective irradiation on the collector plane is of 1,521 kWh/m². Then the PV cell converts solar energy into electrical energy. After PV conversion, array nominal energy is of 1,528 MWh. Effective energy at the output of the array is of 1,216 MWh. After the inverter loss, the battery storage was of 1,161 MWh. Therefore the energy injected into the fish processing plant is 1,119 MWh.

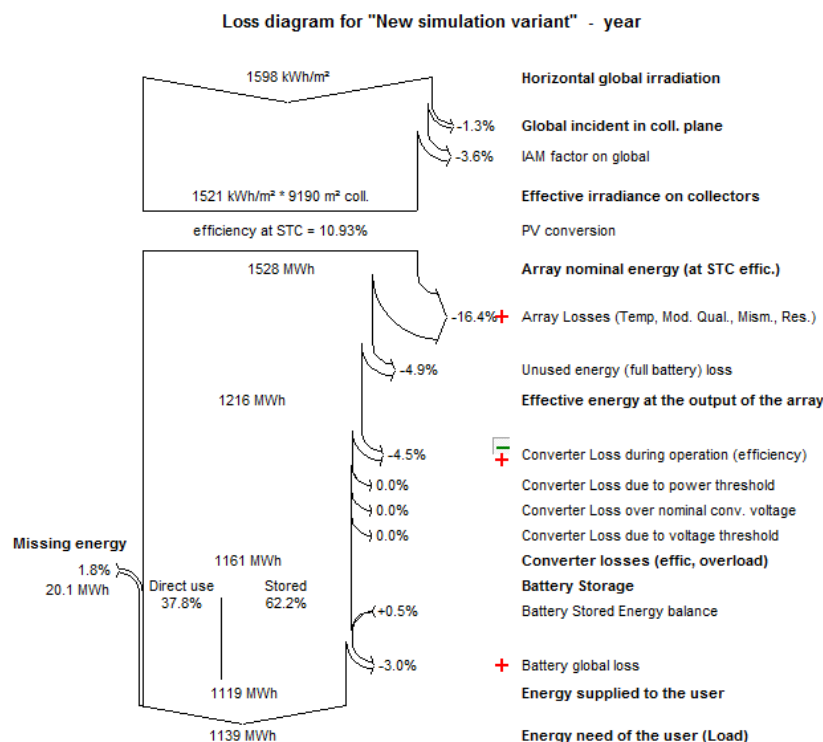


Figure 8. The overall system loss diagram for small scale fish processing at Kota Langsa.

4. Conclusion

Fisheries are leading sectors in the municipality of Langsa; the fish processing industry comprises an ice factory unit, a gutting and cutting unit, a drying unit, and a curing unit. However, the energy and electricity costs during the production process have become major constraints. In this paper, the solar energy as an option to deal with the energy shortage is studied. PVSYST 5.41 is used to perform the simulations of standalone solar PV system by comparing the energy production, performance ratio, efficiency and cost. The potential and the cost-effectiveness of a solar photovoltaic power plant can likewise be estimated.

The result of the analysis shows that for the installation of OTR, the levelized cost is IDR. 1,115 per kWh, taking into consideration the 25 years of life-span at a 10% of discount rate, with a simple payback period of 13.2 years. As for OTL, levelized energy was obtained at IDR.997.5 per kWh, with a simple payback period of 9.6 years.

Acknowledgement

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