Feasibility study of installation photovoltaic system at a university in Indonesia: A case study

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Abstract. Universitas Samudra (UNSAM) is one of the new state universities in Indonesia, located in Langsa City, Aceh Province. The masterplan for developing UNSAM projected to expanding access to higher education for secondary school graduates in the province by increasing the capacity through the construction of new buildings. The plan to construct green buildings inside the campus complex is simply an effort to achieve the UNSAM mission, which is, to become a green campus. There are nine buildings on the UNSAM campus with a total roof area reaching 11,232 m\textsuperscript{2}, which is structurally suitable for solar photovoltaic installation. In Langsa City, for one year, the average exposure to sunlight is equivalent to about 7,860 hours. The average annual insulation at this location is around 5.0 to 6.5 kWh / m\textsuperscript{2} / day. This study focuses on the economic feasibility of solar photovoltaic systems on the UNSAM campus. Electricity production costs, which might have economic benefits, are obtained for Rp. 1,990 / kWh. The results of the analysis concluded that the economic potential of installing a PV system is very dependent on the geography of the building and the direction of PV installation.

1. Introduction
Universitas Samudra (UNSAM) noticeable as one of the oldest private universities in Aceh, founded in 1985. After successfully serving the higher education needs for more than 40 years, it then officially became a state university in May 2013. Since becoming a state university until now, UNSAM is starting to improve several key sectors, especially in the development of 14 new departments. Currently, UNSAM is focusing on the implementation of programs to improve the quality of human resources and supporting facilities. UNSAM consists of five faculties, i.e., Faculty of Teacher Training and Education (10 Departments), Faculty of Engineering (8 Departments), Faculty of Agriculture (3 Departments), Faculty of Economy (3 Departments), and Faculty of Law (1 Department). The UNSAM campus occupies a land area of 49.8 hectares, located in Meurandeh Village, Langsa City, Aceh Province, Indonesia. Starting in 2016, UNSAM expanding the access capacity for high school graduates. The masterplan expected to become a guideline for the construction of the green building, which finally might support UNSAM's mission to become a green campus complex.

Many studies have been carried out to make the green campus, like the study by Jinyoung Song and Yosoon Choi through the study of the feasibility of using the photovoltaic system as a power plant [1].
Jin H et al., conducted a study related to the implementation of a large-scale photovoltaic scheme at a higher education institution in Illinois, USA [2]. The analysis conducted using software System Advisor Model (SAM) developed by National Renewable Energy Laboratory (NREL). Sujoy Barua and R. Arun Prasath has conducted a study aimed at designing and evaluating solar roof-photovoltaic systems connected to the network for academic campuses [3]. The feasibility analysis of the solar photovoltaic roofing system project is carried out using PV Syst software. Many other studies have been carried out individually for feasibility studies using photovoltaic systems for electricity supply in the campus [4-6].

Pre-feasibility studies on the use of photovoltaic systems for power generation are often carried out with the help of software. Gardenio Diogo Pimentel da Silva using System Advisor Model (SAM) developed by National Renewable Energy Laboratory (NREL) for Electricity Generation by Grid-Connected Photovoltaic Projects in all Regions of Brazil [7]. Ana Palmero et al., has made a comparison of the use of some software as a tool for analyzing the feasibility of using the PV system [8].

The goal of this study is to assess the economic feasibility of using solar PV systems at the campus of Universitas Samudra (UNSAM) as an effort to introduce the utilization of renewable energy sources. At this stage, the feasibility analysis of the photovoltaic system application on the roof of an existing building is carried out. The results of the analysis are prepared to become an essential guide for the utilization of PV systems in building construction in the future.

2. Methods
This study conducted in two stages. First, initiating the data collection of rooftop area in all building inside the complex of UNSAM, and data on the use of electrical energy in each building. Currently, UNSAM has nine buildings suitable for application PV roof systems. This stage includes the calculation of the available area and roof area of each building. The results of the initial data collection shown in Table 1.

| No. | Building name                               | Rooftop area (m²) | Annual electrical demand (kWh) |
|-----|--------------------------------------------|-------------------|--------------------------------|
| 1   | Academic Service Center Building           | 2,960             | 240,000                        |
| 2   | Faculty of Engineering Building            | 1,480             | 87,500                         |
| 3   | Faculty of Teacher Training and Education Building | 1,184           | 67,560                         |
| 4   | Faculty of Agriculture Building            | 675               | 24,500                         |
| 5   | Law Faculty Building                       | 638               | 26,400                         |
| 6   | Faculty of Economics Building              | 638               | 28,430                         |
| 7   | Multipurpose building                      | 2,730             | 257,040                        |
| 8   | Basic Laboratory Building                  | 543               | 30,250                         |
| 9   | Student Activity Building                  | 384               | 12,400                         |
|     | Total                                      | 11,232            | 774,080                        |

In the second stage, an analysis of the use of PV systems on the roof of the building was carried out. The analysis is conducted using software System Advisor Model (SAM) developed by National Renewable Energy Laboratory (NREL).
3. Result and discussion

The initial stage of the analysis is to determine the intensity of the sun at the position of each building. In this study, the sun intensity data was determined based on the coordinates of the position of Universitas Samudra. The monthly solar radiation at coordinates latitude 4.458 and longitude 97.971, is as shown in Figure 1. While the monthly average temperature is given in Figure 2.

![Figure 1. Solar intensity data at the UNSAM location.](image1)

![Figure 2. Diagram of monthly temperature.](image2)

The analysis then followed by calculation the power capacity that can be produced by the PV-system installed in each building. The type of PV and inverter used in this analysis are as shown in Table 2.

The results of the analysis depict the optimal number of PV modules for each building, which highly determined by the direction of the roof of the building. Table 3 shows the complete calculation results. The table portrays that multipurpose building can be used to produce sizeable electrical power compared to other buildings. It is because the building has no semi-circular shape. Therefore, the entire roof is installable with PV modules. The total electricity production produced by the PV system is expected to
satisfy 15.5% out of total energy required at the peak of the campus complex during fully operational. Compared to government regulations for green building criteria, therefore, each building should deliver 25% of its required energy from green sources.

**Table 2. PV module and inverter used in the analysis.**

| PV Modules |  |
|------------|---|
| Model      | SunPower SPR-205-NX-BLK-D |
| Material   | c-Si |
| Module area| 1.2 m² |
| Module capacity | 249.9 DC Watts |
| Efficiency | 16.5% |

| Inverters |  |
|-----------|---|
| Model     | SMA America SB 240-US-10 (240V) |
| Unit capacity | 2AC kW |
| Input voltage | 250-480 VDC |
| Efficiency | 96% |
| AC rate factor | 0.99 |

**Table 3. Calculation results of PV system power.**

| Building No, | Rooftop area (m²) | Number of PV Modules | Capacity (kW) | Annual electricity production (kWh/year) |
|-------------|--------------------|----------------------|---------------|----------------------------------------|
| 1           | 2,960              | 84                   | 17.25         | 17,336,10                              |
| 2           | 1,480              | 60                   | 12.31         | 14,648,80                              |
| 3           | 1,184              | 60                   | 12.31         | 14,648,80                              |
| 4           | 675                | 48                   | 9.85          | 9,591,90                               |
| 5           | 638                | 72                   | 14.78         | 15,103,60                              |
| 6           | 638                | 72                   | 14.78         | 15,103,60                              |
| 7           | 2,730              | 168                  | 34.47         | 23,370,50                              |
| 8           | 543                | 12                   | 2.46          | 2,684,60                               |
| 9           | 384                | 36                   | 7.39          | 7,857,80                               |
| **Total**   | **11,232**         | **612**              | **125.6**     | **120,345,70**                         |

The calculation continued with the calculation of the installation costs and operational costs of the PV system. The data on prices for PV modules and inverters is completed by collecting data on the website and comparing it with several analyzes that have been carried out at different locations [9-11]. Whereas for operational and maintenance costs are based on the difficulty of implementing maintenance. Table 4 shows the results of the analysis of the initial installation expenses and total maintenance costs.
Table 4. Results of calculation of installation costs and operational and maintenance costs.

| Building No. | Installation cost (IDR) | Operation and maintenance cost (IDR/year) |
|--------------|-------------------------|------------------------------------------|
| 1            | 636,728,250             | 5,918,535                                |
| 2            | 454,805,895             | 4,227,525                                |
| 3            | 454,805,895             | 4,227,525                                |
| 4            | 363,844,710             | 3,382,020                                |
| 5            | 545,767,080             | 5,073,030                                |
| 6            | 545,767,080             | 5,073,030                                |
| 7            | 1,273,456,515           | 11,837,085                               |
| 8            | 90,961,185              | 845,505                                  |
| 9            | 272,883,540             | 2,536,515                                |
| Total        | 4,639,020,150           | 43,120,770                               |

The analysis then followed by the calculation of the NPV value based on the cost of electricity production by the PV system with an inflation rate at around 4%, and 20 years operational period. Figure 3 depicts the results of the analysis.

![Figure 3. The value of NPV analysis based on electricity production costs.](image)

The graphs show that the cost of producing electricity is around Rp. 1,990/kWh, which gives a positive NPV value. Therefore, the results of the analysis, when compared to the current electricity bills paid by UNSAM, shows the viability of using PV system as a source of electricity for college buildings.
4. Conclusion
The whole analysis that has been carried out for an assumption of the operational period at 20 years, with current electricity costs and inflation rate, therefore, the net present value (NPV) shows that the PV installation at the rooftop of UNSAM campus building is economically beneficial. Electricity production costs also projected an economic payback, which obtained at the price of Rp. 1,990/kWh. The analysis results also depict that the potential economic advantages depend on the installation of modules according to the geography and direction of the PV.

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