Jurnal Polimesin
Department of Mechanical Engineering
State Polytechnic of Lhokseumawe
http://e-jurnal.pnl.ac.id/polimesin

e-ISSN	: 2549-1999	No.	: 4	Month	: August
p-ISSN	: 1693-5462	Volume	: 21	Year	: 2023

Article Processing Dates: Received on 2022-01-26, Reviewed on 2022-02-01, Revised on 2022-02-08, Accepted on 2022-06-21 and Available online on 2023-08-30

Planning analysis of solar power plant utilization using the PLN network grid system interconnection on Samudra University roof building

Ferri Festika*, Ahmad Syuhada, Hamdani Umar, Poppy Irawan Arif
Master of Mechanical Engineering Study Program, Syiah Kuala University, Banda Aceh 23111, Indonesia
*Corresponding author: ferri@mhs.unsyiah.ac.id

Abstract

Solar power plants can be applied in various forms of installation, either centralised or distributed, with each configuration system installation being either on-grid or off-grid. Samudra University plans to install a solar power plant for environmentally friendly applications and energy savings. The purpose of this study is to investigate the feasibility and benefits of Samudra University installing solar power generation capacity using a single-owner system on campus using SAM (System Advisor Model) applications using two axes with PV energy. The method used is to model the photovoltaic results with the System Advisor Model (SAM), which can develop new renewable energy photovoltaics. The use of solar energy as a producer of electrical energy in buildings at the ocean university by using the System Advisor Model application on the Single Owner (Grid) system in collaboration with local electricity (PLN) to continue the energy needs produced as much as 32,652,394 kWh will cost IDR. 372,864,450,000, and with an area of 105,179.9 m2 or ± 11 hectares of the total area of 49.8 hectares, it only uses ± 20% of the total area.

Keywords:
Solar Energy, System Advisor Model, Single Owner system, Grid, Local Electricity (PLN).

1 Introduction

Indonesia has an abundance of solar power. On the basis of solar radiation data collected from 18 locations in Indonesia, it has been determined that solar radiation in Indonesia can be successively classified for the western and eastern regions of Indonesia based on the radiation distribution.[1]. Western Indonesia (KBI) has = 4.5 kWh/m2/day, which varies by about 10% each month. Eastern Indonesia (KTI) = 5.1 kWh/m2 per day, with a monthly change of 9 percent. Indonesia uses an average of 4.8 kWh per square metre per day. This number changes by about 9% each month.

Replacing fossil energy has become a world priority because it makes the most carbon dioxide (CO_2), while solar energy does not. Indonesia's needs for energy are always growing because of economic needs, education, transportation, and other things. Energy is an important sector because it drives economic growth at home and is also a valuable export commodity. With the growth of the economy as a whole, there are consequences of energy use that can pollute the environment, such as solid waste, liquid waste, and pollution from burning fossil fuels.

Indonesia's oil reserves are only 9.09 x BOE (which is the same as a barrel of oil), and the country's natural gas reserves are 137.79 TSCF (Tera Standard Cubic Feet). Most of the electricity in Indonesia comes from fossil fuels.[2]

In order to keep energy freedom and security, the government is putting more and more emphasis on new and renewable energy. This is because the production of fossil fuels, especially oil, is going down, and the world has agreed to reduce greenhouse gas emissions. PP No. 79 of 2014, which is the National Energy Policy, says that the mix of new and green energy should be at least 23% and 31% in 2025 and 2050, respectively [3]. The technology for converting solar energy into electricity is the conversion of radiation into electrical energy, which is commonly referred to as a solar power plant, a power generation system whose energy is derived from solar radiation via photovoltaic cell changes, where this photovoltaic system converts solar radiation into electricity[4].

Rooftop photovoltaic solar power plants around the world, including the one at Arizona Western College in the U.S. Under real-world conditions, Yale University in the United States has a capacity of 6.07 kWh/m2/d, for a total of 4616 kWp. Capacity of 4,01 kWh/m2/d and 1250 kWp, USA 4.75 kWh/m2/d total capacity of 2,000 kWp when placed at Oregon University [5]. In addition to the United States, there are several other countries, such as Spain, where the University of Murcia has a total installed capacity of 5.04 kWh/m2/d and the University of Jaen has a total installed capacity of 5.11 kWh/m2/d. The University of Queensland in Australia has a total capacity of 1220 kWp, which is 5.50 kWh/m2/d. In a country with four seasons, solar energy is not used all year long. Because of this, it is more profitable to study the use of solar energy for a big building with a large capacity at Samudra University, which has only two seasons.

Several previous studies have been carried out on the use of Solar Power Plants[6][7][8][9]. Research conducted by Kassahun Y. Kebede, this study explores the potential of grid-connected solar PV power plants in Ethiopia. a total of 35 locations have been assessed for their technical potential by considering a 5 MW PV power plant. Research data sources are from the Ethiopian National Meteorological Agency and NASA's Solar Energy and Surface Meteorological Data Collection. The software used is HOMER and RETScreen in this study. The results show that the average value of the PV power plant capacity factor from the various locations considered is 19.8%, and the average value of electricity exported to the grid is 8674 MWh/year[10]. Research conducted by K. Padmavathi, about performance analysis of a 3 MWp grid connected solar photovoltaic power plant in India. This paper presents performance analysis of a 3 MW grid connected SPV plant located in Karnataka State, India as per International Electro-technical Commission (IEC) Standard 61724, using monitored data. Annual average energy generated by the plant was 1372 kWh per kWp of the installed capacity. Performance of the plant is satisfactory in comparison with that reported from other countries[6].

The goal of this study is to find out if Samudra University could build a single-owner solar power system on campus SAM applications using two axes with PV energy and what the benefits would be.

2 Materials and Methods

Solar power plants can be set up in different ways. They can be centralised or spread out, and each system setup can be either on-grid or off-grid. The difference between these two methods is:

1. Off-Grid

Off-grid refers to a system that is not connected to the local electricity network (PLN) and instead uses a battery. Most off-grid systems have a battery that can still provide electricity at night or when there is no sun, but some applications, like a solar water pump, can be set up without a battery. Can be used at any time of day.

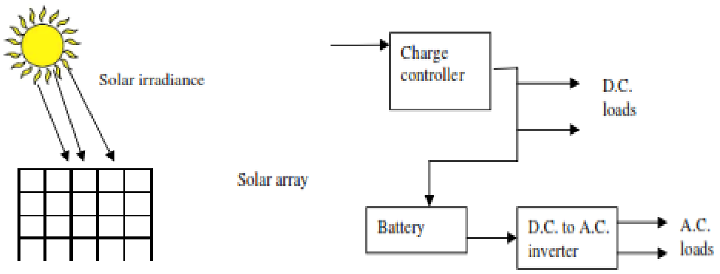

Fig. 1. Off Grid

Fig. 1 shows that Indonesia divides Off-Grid, namely:[11]

a) Be able to work on its own without being connected to the PLN network. For this method to work, the electricity made during the day needs to be stored in a battery so that it can be used at night. Direct current, or DC, is different from alternating current, or AC. Coupling is the name for the point where the system connects. The DC-coupling system connects a set of photovoltaic modules to the DC side of the PV mini-grid system using a solar charge controller.
b) The AC-coupling system connects a series of solar panels and batteries to the AC side using grid inverters and battery inverters. If the load doesn't use all of the power, the battery inverter will turn the extra power back into DC and store it in the battery.

Both configurations use the same components except for the solar charge controller (SCC), a component mounted on the side after the combiner box. The use of SCC in the DC-coupling system is replaced by a network inverter in the AC-coupling system.

2. On Grid

Meanwhile, on-grid is a system that is connected to a distribution network that gets power from other power plants, such as the PLN network. There is no battery so it cannot work at night or if it is not connected to a network such as the PLN network as in Figure 2[12].

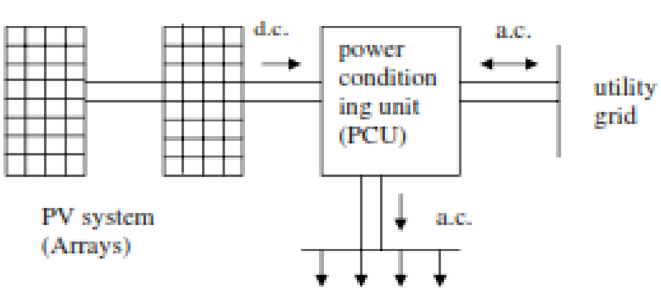

Figure 2. On Grid

2.1 Photovoltaic

Photovoltaic is the direct conversion of light into power using semiconducting materials. The solar cell is the most important part of a PV system. The solar panel gives off DC power and has no moving parts or pollutant emissions, which is a good thing about this PV installation method. This PV is flexible, easy to work with, and quick to put together into solar energy-generating panels. There are three types of PV panels on the market, and they are made with different kinds of silicon :[4].

1. Modules made of amorphous silicon are not made of silicon that has been shaped into crystals.
2. Monocrystalline solar cells are made of wafer-thin, bluish-black pieces of big single crystals of silicon.
3. Polycrystalline solar cells are plates made up of several blocks of crystalline silicon.

Some software, like the SYSTEM ADVISOR MODEL (SAM), can be used to model the effects of photovoltaic. This can help a number of researchers come up with new renewable energy sources that use photovoltaic.

SAM is a performance and financial model that was made to make it easier to figure out how much energy will cost and how it will be used. The SAM programme includes information about photovoltaic modules, inverters, weather conditions, and radiation levels that can be found on the international radiation network through the PVGIS application. The SAM performance model figures out how well the system works hour by hour. The electrical output of the power system creates a set number of hours, which is equal to the system's annual energy output. SAM is also a good technical tool for doing statistical analysis and figuring out the possibilities for photovoltaic projects in a given area before they are built. SAM can also be used to do a financial study of the Levelized Cost of Electricity (LCOE) [13].

2.2 Methods

The design that uses a PV generating system is shown in Figure 3.

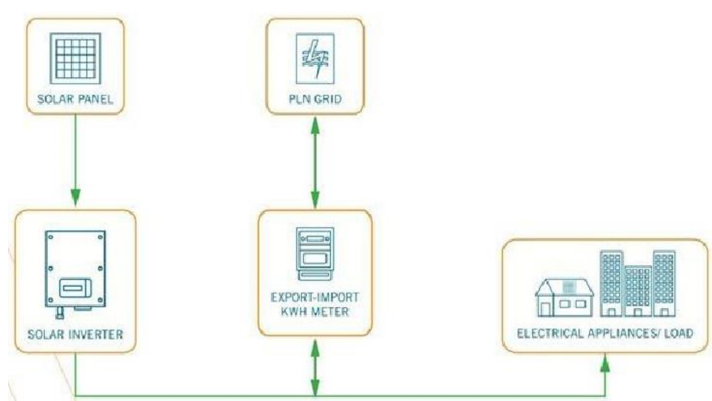

Figure 3. Mechanism of Solar Power Generation (GRID)

Photovoltaic is the direct conversion of light into power using semiconducting materials. The solar cell is the most important part of a PV system. The solar panel gives off DC power and has no moving parts or pollutant emissions, which is a good thing about this PV installation method. This PV is flexible, easy to work with, and quick to put together into solar energy-generating panels. There are three types of PV panels on the market, and they are made with different kinds of silicon [4].

There are different kinds of solar rooftop equipment on the market, and they have been used in a wide range of power plants and businesses. Polycrystalline photovoltaic (PV) panels are thought to break down at a rate of 0.5% per year. This makes them one of the most popular types of equipment [6].

Some software can be used to model the results of photovoltaic, one of which is the SYSTEM ADVISOR MODEL (SAM, which can help several researchers to be able to develop photovoltaic development of new renewable energy.

SAM is a performance and financial model that was made to make it easier to figure out how much energy will cost and how it will be used. The SAM programme includes information about photovoltaic modules, inverters, weather conditions, and radiation levels that can be found on the international radiation network through the PVGIS application. The SAM performance model figures out how well the system works hour by hour. The electrical output of the power system creates a set number of hours, which is equal to the system's annual energy output. SAM is also a good technical tool for doing statistical analysis and figuring out the possibilities for photovoltaic projects in a given area before they are built. SAM can also be used to do a financial study of the Levelized Cost of Electricity (LCOE) [13].

The SAM application will generate multiple results based on the quantity of energy produced by considering the area obtained and the number of PV panels that can be installed; if the roof area is known, the SAM application will calculate the number of panels that can be included in the solar power plant. 11 Ha in the planning of buildings at Samudra university by accumulating weather data with the help of the international application PVGIS Weather.

The amount of use where when power is measured in watt-hours show in Eq. 1 [14]

$$W = P\,xt \qquad (1)$$

where P is power in watts, t is time in hours, and W is energy in watt-hours

Therefore, the author argues that the power requirements have not been calculated based on the assumption that 25 to 35% of the total equipment used simultaneously requires electrical power for administration, while 35 to 50% of the equipment requires laboratory power and only 20% is used at night. with electric power at the industrial rate of IDR. 996.7 per kWh

Power load for input photovoltaic input shown in Eq. 2[15]:

$$(P_{in} = \text{x}A) I_r \qquad (2)$$

Where P_{in} is Solar radiation input power (Watts), I_r is Intensity of solar radiation (Watts/)m^2, A is Surface area of the photovoltaic module m^2

Where the Power Load with this Solar power calculation load will be calculated directly with the SAM application

3 Results and Discussion

In the Samudra University Strategic Plan, there is an agreement to build a 49.8-hectare, three-story building for teaching elementary school teachers. Acceleration programme for the development of Samudra university in 2020 can be recommended for the construction of a building with enough space to use photovoltaic (PV) panels, which are very helpful in reducing the need for open space and can be installed on the roof of the new building [16].

Funding with a Single Owner system is a great way to get money because this system makes it much easier to make the needed amount of energy. So, the researcher gives a few examples that can be used as guides for PV standards in Samudra university's funding needs.Researchers have found that the business has to pay 38,476,608 kWh/year at a price of IDR. 996.7/kWh. The results are shown in Table 1:

Table 1. Price Assumptions

No	Amount	Unit	IDR	Information
1	38.476.608.00	kWh		
2	996.7	IDR		
	Amount		IDR 38,349,635,193.60	year
			IDR 3,195,802,932.80	month

The use of options in the SAM Application has been effectively regulated so that it can be utilised by a variety of groups by adjusting to regional requirements and funds for the implementation of PV.

Researchers utilising the SAM application will make the following modifications to meet the energy and funding requirements of Samudra university in order to create PV energy for ocean universities:

1. Modify module and inverter with the current cost
2. Adapting to the type of axis used. 3. Obtaining the requisite number of kWh, or nearly so.
3. Adjusting the total area to be: 105,179.9 or 11 hectares per square metre
4. Module 64,488 units with the maximum market price of 0.60 dollars per watt-hour
5. Inverter 22 units with the greatest cost per unit of $1,800

By spending the amount shown in Fig.4:

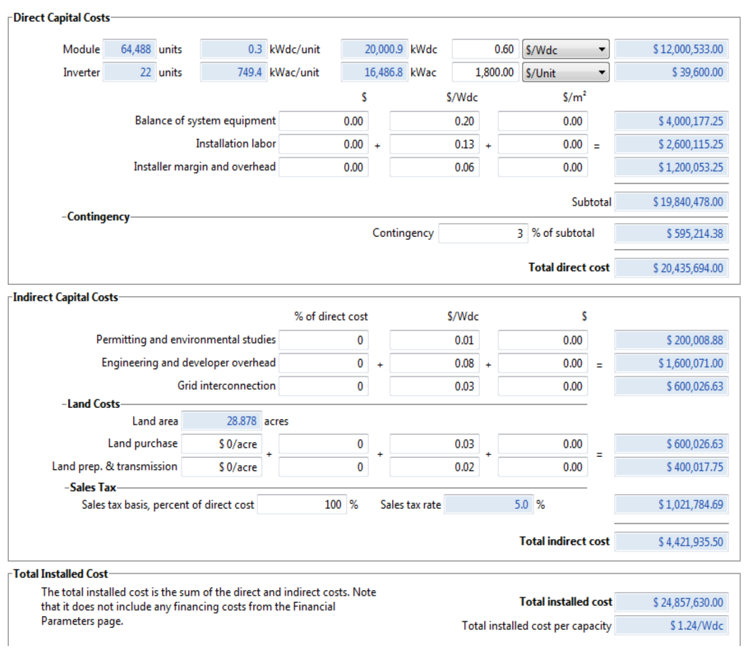

Figure 4. Single Owner Investment Cost

3.1 Funding Analysis Finding Amount of kWh

3.1.1 No Axis

The SAM application for Samudra university uses a sun power module type with the highest price being 0.60 $/Wdc with an inverter used in the KACO type market[17]. Meanwhile, the module uses the sun power spr-E19-310-COM which is easily available online market prices[18]

The type of Kaco brand inverter for 3 phases with an inverter price plus a shipping price of 1800 $ / unit will produce a power of 24,477,636 kWh, shown in Table. 2. The investment costs for PV planning are shown in Fig. 4

Tabel 2. The amount of energy produced

Metric	Value
Annual energy (year 1)	24,477,636 kWh
Capacity factor (year 1)	14.0%
Energy yield (year 1)	1.,224 kWh/kW
Performance ratio (year 1)	0.75
PPA price (year 1)	12.22 c/kWH
PPA price escalation	1.00%/year
Levelized PPA price (nominal)	13.21 c/kWH
Levelized PPA price (real)	10.54 c/kWh
Levelized COE (nominal)	12.44 c/kWh
Levelized COE (real)	9.93 c/kWh
Net present value	$1,767,327
Internal rate of return (IRR)	11.00%
Year IRR is achieved	20
IRR at end of project	12,94%
Net capital cost	$27,225,608
Equity	$11,364,852
Size of debt	$15,860,757

3.1.2 One Axis

The use of the SAM application using 1 axis will produce 31,550,114 kWh show in Table 3.

Table 3. The amount of energy produced

Metric	**Value**
Annual energy (year 1)	31,550,114 kWh
Capacity factor (year 1)	18.0%
Energy yield (year 1)	1,577 kWh/kW
Performance ratio (year 1)	0.72
PPA price (year 1)	9.48 c/kWH
PPA price escalation	1.00 %/year
Levelized PPA price (nominal)	10.25 c/kWH
Levelized PPA price (real)	8.18 c/kWh
Levelized COE (nominal)	9.65 c/kWh
Levelized COE (real)	7.70 c/kWh
Net present value	$1,767,627
Internal rate of return (IRR)	11.00%
Year IRR is achieved	20
IRR at end of project	12,94%
Net capital cost	$27,225,518
Equity	$11,364,898
Size of debt	$15,860,620

By ground coverage ratio a good slope than for one axis will be better in generating energy. assuming the same funding will produce more energy using one axis

3.1.3 Two Axes

The use of the SAM application using 2 axes will produce 32,652,394 kWh with greater results than without axes and one axis show in Table 4.

Table 4. The amount of energy produced by 2 axes

Metric	**Value**
Annual energy (year 1)	32,652,394 kWh
Capacity factor (year 1)	18.6%
Energy yield (year 1)	1,633 kWh/kW
Performance ratio (year 1)	0.71
PPA price (year 1)	9.16 c/kWH
PPA price escalation	1.00 %/year
Levelized PPA price (nominal)	9.90 c/kWH
Levelized PPA price (real)	7.90 c/kWh
Levelized COE (nominal)	9.32 c/kWh
Levelized COE (real)	7,44 c/kWh
Net present value	$1,767,756
Internal rate of return (IRR)	11.00%
Year IRR is achieved	20
IRR at end of project	12,94%
Net capital cost	$27,225,430
Equity	$11,364,883
Size of debt	$15,860,548

Consequently, each axis can produce more energy based on anticipated requirements. Using this energy comes closer to meeting the total energy needs of the University of Samudra and the city of Langsa. Samudra University's Recapitulation of Funding Sources Plans for 2020 to 2024 funding (Table 5)[19].

Table 5. Samudra University Funding Sources

No	Source of Funds	Year				
		2020	2021	2022	2023	2024
1	PNBP	IDR 17,585,980,000.00	IDR 19,425,285,000.00	IDR 21,367,813,500.00	IDR 23,504,594,850.00	IDR 25,855,054,335.00
2	BOPTN	IDR 16,959,745,000.00	IDR 16,959,745,000.00	IDR 18,655,719,500.00	IDR 20,521,291,450.00	IDR 22,573,420,595.00
3	RM Salary and Operations	IDR 25,546,879,000.00	IDR 28,101,566,900.00	IDR 28,944,613,907.00	IDR 29,812,952,324.00	IDR 30,707,340,894.00
4	SBSN or PHLN	IDR 34,426,600,0000.00	IDR 39,590,590,000.00	IDR 45,529,178,500.00	IDR 52,358,555,275.00	IDR 60,212,338,566.00
		IDR 94,519,204,000.00	IDR 104,077,186,900.00	IDR 114,497,325,407.00	IDR 126,197,393,899.00	IDR 139,348,154,390.00

Table 6. Samudra University Funding Allocation

No	Quantity Allocation Fund	Allocation of Funds
1	45%	Payment of salaries/honorariums for educators and education staff as well as other structural benefits
2	10%	Procurement/maintenance of physical facilities (lecture rooms, offices and laboratory)
3	10%	Office Operations
4	10%	Educational facilities (college equipment, office and others)
5	10%	Academic/lecture activities
6	3%	Preparation of higher education administration and curriculum
7	2.5%	Research activities and community service
8	2.5%	Scientific activities, training, workshops, seminars
9	2.5%	Student activities
10	2.5%	The need for library books
11	2%	Other Budget

The policy and level of funding at Samudra University means that it will take 15 years to reach the required amount of IDR 372,864,500,000.

The researchers used a two-axis system with the allocation funds in Table 6 in 2022 of IDR. 114,497,325,407.00 to determine the amount of energy required by Samudra University after conducting research from no axes to each number of axes required. Realize the single owner system by allocating 5% to the acquisition/maintenance of physical facilities (lecture rooms, offices, and laboratories), 5% to office operations, 5% to educational facilities (lecture tools, office, and others), 5% to academic/lecture activities, and 2% to other budgets. Thus, a total of IDR. 25,189,411,589.54 (22% of the total amount owed) has been collected from the financing for Samudra university, and the University of Samudra will be debt-free within approximately 15 years. As much as 32,652,394 kWh of energy produced will cost IDR. 372,864,450,000, and with an area of 105179.9m2 or 11 hectares of the total area of 50 hectares, Samudra university will only use 20% of its total land area for future energy independence.

32,652,394 kWh =IDR. 372,864,450,000 for Initial Capital
Energy Use at Local Electricity Prices:
Total Energy Per Year: 32,652,394 kWh x IDR 996.7 =IDR 32,521,784,431.00.
Total Energy Per Month: 2,721,032.83 kWh x IDR 996.7 =IDR 2,710,148,709.00.
Total Energy Per Day of 89,458.6 kWh x IDR 996.7 =IDR 89,100,786.24
Electrical Power Assumptions show in Table 7

For energy use using energy storage, further analysis is needed using battery storage where it will help to use energy simultaneously by using a single owner PV battery storage system.

Table 7. Electrical Power Assumptions (Concurrent Use)

No	Daily Power/kWh (1 Day)	Daytime Usage/kWh		Night Usage/kWh
		ADM	Lab	Lighting
	89458.6137	25%	50%	20%
1		22364.65342	44729.30685	17891.72274
	IDR	IDR 22,290,850.07	IDR 44,581,700.14	IDR 17,832,680.05

4. Conclusion

The End This study looked into whether it would be possible and beneficial for Samudra University to build a single-owner system with two axes and PV energy to generate solar power on campus. Based on the assumption that Samudra University already has these funds, these findings show that solar energy can provide up to 22% of the university's funds right now. The PV Project will cost up to IDR 372,864,500,000, making it one of the most expensive projects. This project will use room in every new building on campus that is less than 50 ha in size.

It will take 15 years for this big project to reach a point where it pays for itself. If power prices rise faster than expected, the break-even point could come sooner.

References

[1] A. Lubis, "Renewable Energy In Sustainable Development," *BPPT Environ. Technol. J.*, vol. 8, no. 2, 2007.

[2] M. I. Alhamid, Y. Daud, A. Surachman, A. Sugiyono, H. B. Aditya, and T. M. I. Mahlia, "Potential of geothermal energy for electricity generation in Indonesia: A review," *Renew. Sustain. Energy Rev.*, vol. 53, pp. 733–740, 2016.

[3] K. E. S. D. Mineral, "outlook energi Indonesia," in *outlook energi Indonesia*, 2019.

[4] A. F. Zobaa and R. C. Bansal, *Handbook of renewable energy technology*. World Scientific, 2011.

[5] V. Collini, "The potential of photovoltaic energy production: a detailed assessment for Politecnico di Milano," 2020.

[6] K. Padmavathi and S. A. Daniel, "Performance analysis of a 3 MWp grid connected solar photovoltaic power plant in India," *Energy Sustain. Dev.*, vol. 17, no. 6, pp. 615–625, 2013.

[7] H. Umar, M. Amudy, and T. A. Rizal, "Feasibility study of installation photovoltaic system at a university in Indonesia: A case study," in *Journal of Physics: Conference Series*, IOP Publishing, 2019, p. 44035.

[8] B. S. Kumar and K. Sudhakar, "Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India," *Energy reports*, vol. 1, pp. 184–192, 2015.

[9] M. H. Hasan, T. M. I. Mahlia, and H. Nur, "A review on energy scenario and sustainable energy in Indonesia," *Renew. Sustain. energy Rev.*, vol. 16, no. 4, pp. 2316–2328, 2012.

[10] K. Y. Kebede, "Viability study of grid-connected solar PV

system in Ethiopia," *Sustain. Energy Technol. Assessments*, vol. 10, pp. 63–70, 2015.

[11] R. E. and E. C. (DJ E. Director General of New, *PLTS Installation*. 2018.

[12] *Guide to planning and utilization of PLTS Roof in Indonesia Indonesia Clean Energy Development*. 2020.

[13] G. D. P. da Silva, "Utilisation of the System Advisor Model to estimate electricity generation by grid-connected photovoltaic projects in all regions of Brazil," *Int. J. Softw. Eng. its Appl.*, vol. 11, no. 7, pp. 1–12, 2017.

[14] A. Wahid, "Analysis of the capacity and demand for electrical power to save the use of electrical energy at the engineering faculty of the University of Tanjungpura," *J. Electr. Eng.*, vol. 2, no. 1, 2014.

[15] B. A. Syuhada, A., Fuadi, Z., Satari, "Analysis of Solar Energy Potential for Electrical Energy in Banda Aceh and Surrounding Areas," *J. Mech. Eng.*, vol. 7, no. 1, 2019.

[16] H. Umar, "Study of the Use of Rooftop Photovoltaic Power Plants as an Effort to Implement Green Campus," in *Seminar Nasional Poliiteknik Negeri Lhokseumawe*, 2019, p. 254.

[17] "solar inverter," *Kaco*, 2021. https://www.europe-solarstore.com/solar-inverters/kaco/kaco-blueplanet-tl3/kaco-blueplanet-7-5-tl3.html

[18] "solar photovoltaic system," *Sun Power*, 2021. https://www.alibaba.com/product-detail/High-quality-solar-cell-AUO-sunpower_60799247555.html

[19] [Samudra University, "Samudra university Strategic Plan 2020-2024," 2020.