

Techno Economic Analysis Photovoltaic On-Grid System Java Bali to Optimize PLN Energy Consumption

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Abstract. Indonesia's electricity needs are increasing along with population growth. Non-renewable natural resources are insufficient for power generation. Indonesia as a country located on the equator, has 4.8 kWh/m²/day the potential of solar energy, it is time for expanded renewable energy based photovoltaic. The potential development of photovoltaic system in Java Bali is planned to 800 MW based on Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) year 2018-2027. Photovoltaic system on-grid rooftop 2 kWp designed on the Java Bali residence sector based on income of population, number of customers, power sales, and number of population. The energy produced by photovoltaic on-grid system can save the use of coal fuel in 2019 of 1.07 trillion rupiah and until 2027 can save about 11.08 trillion rupiah. The net metering scheme with 30% incentive can be applied for photovoltaic on-grid rooftop 2 kWp system. Photovoltaic on-grid system in the residence sector in Java Bali can save electricity payment for 37.9-41%.

1. Introduction

Indonesia is located in a tropical region having sunlight that can be utilized to build photovoltaic on-grid system. The sun shines from morning to evening with an average daily radiation of 4.80 kWh/m²/day [1]. The photovoltaic on-grid system is a power plant that converts solar thermal energy into electrical energy. One method that can be used is direct way to transfer solar radiation or light energy into electrical energy called photovoltaic.

The Ministry of Energy and Mineral Resources through the Directorate General of Renewable Energy and Energy Conversion has a policy in 2025, the role of renewable energy at least 23%. The potential development of photovoltaic systems in Java Bali has the greatest potential study of 800 MW [2]. Coal fuel need very year has increased, while coal reserves are decreasing. Photovoltaic on-grid system in the household sector can reduce coal fuel need as a source of electrical energy.

2. Methodologi

Based on RUPTL in 2017 [2], photovoltaic on-grid system will be developed in state electricity company with the potential of primary energy in each location and consider the distribution of the population on a very wide geography. Java Bali area has a very large capacity as can be seen in Table 1.

Table 1. Potential of Solar Power

Territory / distribution / system	Capacity MW
Java Bali	800
West Kalimantan	30
East & North Kalimantan	50
Suluttenggo	75
NTB	55
NTT	16
Papua	40

[3]SAM (System Advisor Model) is an application that combines the potential calculation and PV system specifications that have been stored in the SAM database to calculate the production of electricity. The writer choose SAM because free of charge usage. By entering design data system, system cost, electricity tariff and financial parameters, the program will be simulated. Data of simulation result are; LCOE value, Net Present Value (NPV) and Payback Period. In addition, the calculation results can also be presented in graphs, cashflow tables and others. The SAM simulation illustration can be shown in Fig 1.

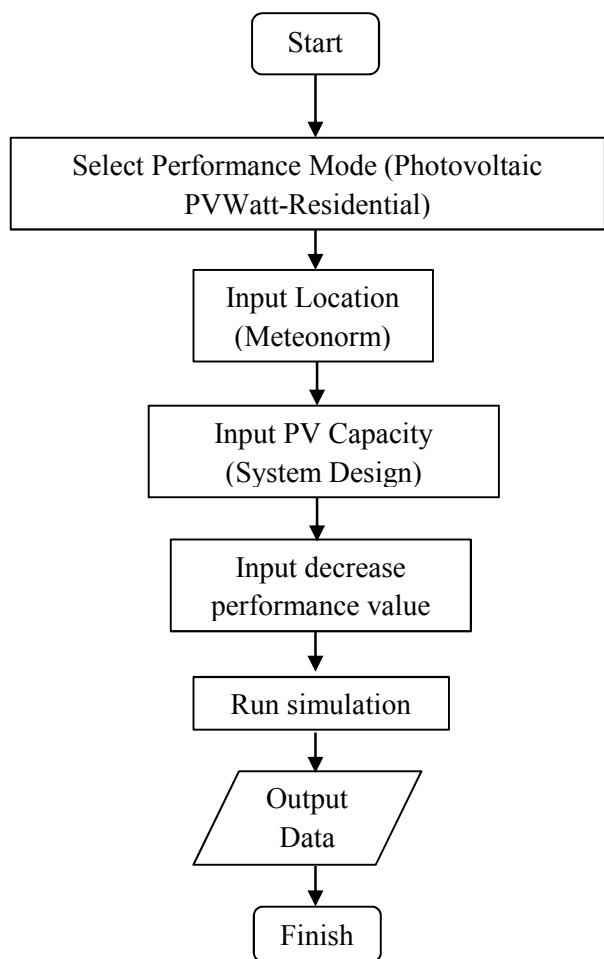


Fig 1. System Advisor Model (SAM) Sceme

[4]Meteonorm were used to determine radiation data by inserting latitude and longitude coordinates. Java-Bali meteonorm data has average radiation and temperature of each city. The average radiation value can be seen at Figure 2.

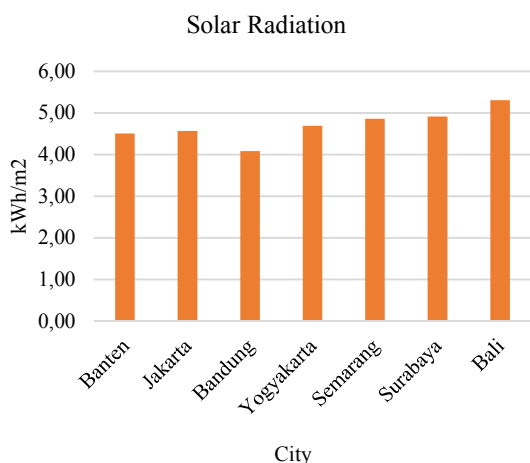


Fig 2. Solar Radiation

Fig 2. The picture above can be seen the largest radiation value in Bali is 5.30 kWh/m²/day and the smallest in Bandung is 4.08 kWh/m²/day.

3. Result and Conclusion

In the SAM simulation, PLTS-PV Rooftop were designed with a life 20 years with 0.5% reduction in device performance annually. PLTS-PV 2 kWp produces different energy each year in each region. The energy produced in one year can be seen in **Fig 3**.

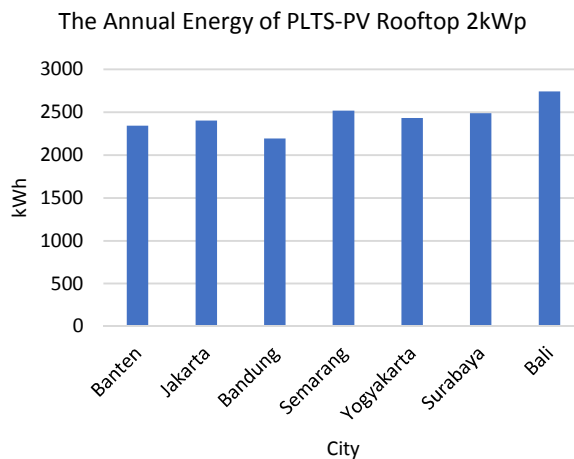


Fig 3. The Annual Energy of PLTS-PV Rooftop 2kWp

Fig 3, the largest energy produced in Bali 2,745 kWh, and Bandung produces the lowest energy of 2,196 kWh. Every year there is a decrease of energy 0.5% due to the degradation of PV device conditions. The difference in energy produced by each region is due to the varying levels of solar radiation.

3.1 Targeting of PLTS Installation

3.1.1 Income of population

Installation of PLTS-PV Rooftop 2 kWp has a large investment value so it can not be sure all the houses can invest into this PV system. In addition, with different of population income will cause uneven PV-Rooftop installation. Considering this, the installation of PLTS-PV is determined based on the magnitude of the regional Gross Regional Domestic Product (GRDP) of population area. There was the number of installation and energy produced by PLTS-PV Rooftop which can be seen in Table 2

Table 2. PLTS-PV Rooftop 800 MW based on income of population

Province	Income of population (Million Rupiah)	Percentage (%)	PLTS Java-Bali 800 MW		
			MW	Unit	GWh
DKI Jakarta	211,8	47,63%	381	190.537	458,24
East Java	47,5	10,68%	85	42.702	106,33
Bali	46,5	10,46%	84	41.841	114,85
Banten	42,3	9,51%	76	38.058	89,21
West Java	34,9	7,84%	63	31.374	68,90
Central Java	32,1	7,22%	58	28.874	72,73
DIY	29,6	6,65%	53	26.615	64,73

Based on the data in **Table 2**, the largest of population income in DKI Jakarta amounted to 211.8 million rupiah, as much as 47.63% of the total energy installed at 190,537 homes will produce 458.24 GWh of energy. While the smallest is located in DIY with population income of 29.6 million rupiah, as much as 6.65% of energy installed in 26,615 homes will produce 64.73 GWh of energy.

3.1.2 Number of Customers

Every province in Java-Bali has different population so that the number of electric power customers also varies. There was the number of installation and energy produced by PLTS-PV Rooftop based on the number of customers of each province which can be seen in **Table 3**.

Table 3. PLTS-PV Rooftop 800 MW based on Customers of Residence

Province	Customer (Million)	Percentage (%)	PLTS Java-Bali 800 MW		
			MW	Unit	GWh
DKI Jakarta	4,76	10,05	80	40.205	96,69
East Java	11,03	23,53	188	94.103	234,27
Bali	1,18	2,52	20	10.097	27,72
Banten	3,26	6,93	55	27.731	65,00
West Java	16,14	34,17	273	136.672	300,13
Central Java	9,51	20,28	162	81.112	204,30
DIY	1,18	2,52	20	10.079	24,51

Based on the **Table 3**, The largest number of residential customers is West Java of 16.14 million, as many as 34.17% of the total energy installed in 136.6 homes will produce energy 300.1 GWh. While the smallest is DIY and Bali with number of residential customers about 1.18 million, as much as 2.52% of energy installed in 10,000 homes will generate energy around 24-27 GWh.

3.1.3 Power Sales

Java-Bali has a different number of customers each city, so the amount of electricity sales also varies. There was number of installation and energy produced by PLTS-PV Rooftop based on the power sales of each province which can be seen in **Table 4**.

Based on the **Table 4**, The largest number of power sales is West Java 25,382 GWh, as much as 29.17% of the total energy installed at 116,681 homes will produce 256.23 GWh of energy. While the smallest is DIY with the number of power sales about 1,763 GWh, as much as 2.06% of the energy installed in 8,249 homes will produce energy around 20.07.

Table 4. PLTS-PV Rooftop 800 MW based on Power Sales

Province	Sales (GWh)	Percentage (%)	PLTS Java-Bali 800 MW		
			MW	Unit	GWh
DKI Jakarta	17.553	20,18	161	80.726	194,14
East Java	17.770	20,44	164	81.772	203,57
Bali	3.116	3,56	29	14.252	39,12
Banten	7.714	8,73	70	34.904	81,81
West Java	25.382	29,17	233	116.681	256,23
Central Java	13.677	15,85	127	63.418	159,73
DIY	1.763	2,06	16	8.249	20,07

3.1.4 Number of Population

There was the number of installation and energy produced by PLTS-PV Rooftop based on the population of each province which can be seen in **Table 5**.

Table 5. PLTS-PV Rooftop 800 MW based on number of population

Province	Population (Million)	Percentage (%)	PLTS Java-Bali 800 MW		
			MW	Atap	GWh
DKI Jakarta	9,61	6,84	55	27.353	65,78
East Java	37,48	26,67	213	106.694	265,62
Bali	3,89	2,77	22	11.077	30,41
Banten	10,63	7,57	61	30.269	70,95
West Java	43,05	30,64	245	122.572	269,17
Central Java	32,38	23,05	184	92.192	232,21
DIY	3,46	2,46	20	9.843	23,94

Based on the **Table 5**, The largest number of population is West Java 43.05 million, as much as 30.64% of total energy installed in 122,572 homes will produce 269.17 GWh of energy. While the smallest is DIY with population of 3.46 million, as much as 2.46% of energy installed in 9,843 homes will produce energy about 23.94 GWh.

3.2 Scenario Analysis

For scenarios based on income of population, DKI Jakarta has the highest capacity of 458 MW. Based on power sales, DKI Jakarta, East Java, West Java, and Central Java have most large capacity. Meanwhile, from the number of residential customers and number of population, the area has a large capacity located in East Java, West Java, and Central Java at 230-300 MW.

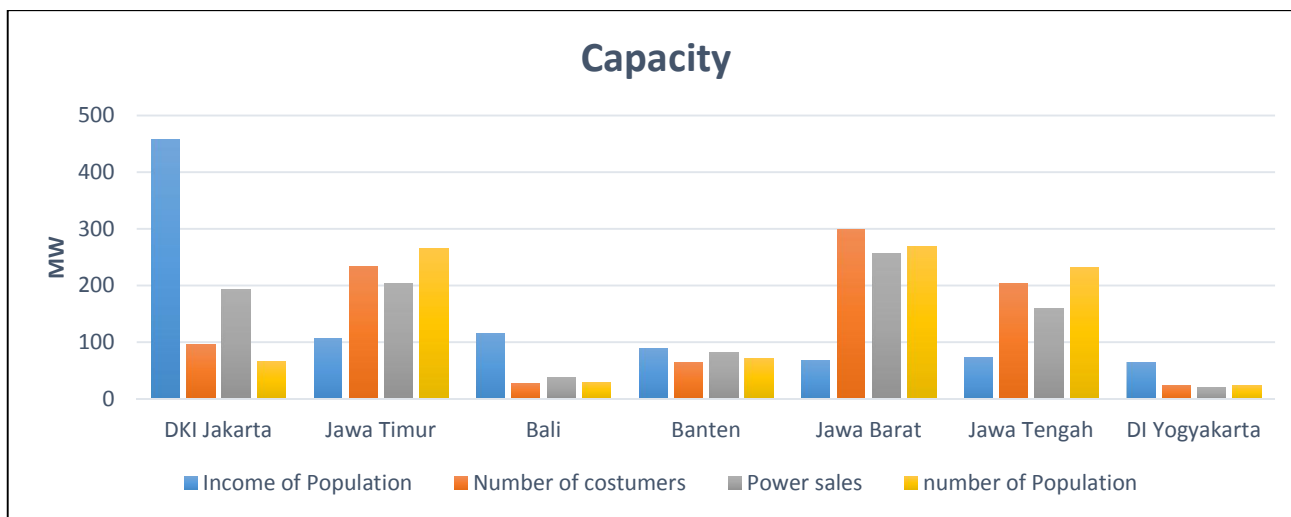


Fig 4. Capacity PLTS Java Bali

3.3 PLTS Savings

PLTS PV-Rooftop 2 kWp installed in residence area of Java Bali can minimize the cost by PLN. The savings were seen from the aspect of coal demand as the largest fuel source that produces electrical energy. The electricity savings is calculated by the percentage of energy produced by the PLTS to the residence electrical needs. The percentage is assumed as the value of coal savings so that it can be calculated in rupiah value. With the installation of 800 MW PLTS in 2018, the cost savings can be seen in **Fig 5 and 6**.

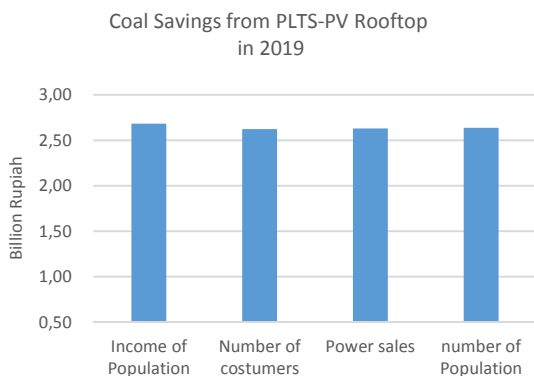


Fig 5. Cost saving PLTS-PV Rooftop 2 kWp

Can be seen in the **fig 5**, in 2019 the biggest savings is 2.68 million earned based on population income. Based on the customer number scenario, savings is 2.62 million; based on total sales, savings is 2.63 million; and by population, savings is 2.64 million.

In the **fig 6**, in the next 9 years, the biggest savings is 11,079 billion earned based on population income. Based on the customer number scenario, savings is 10.825 billion; based on total sales, savings is 10.848 billion; and by population, savings is 10.887 billion

3.4. Saving PLTS-PV Rooftop of Capacity 1 kWp-5 kWp

When viewed from the difference kWp, the energy savings generated by 1.3 million rupiah for the PLTS with capacity of 1 kWp, and energy savings generated by 2.6 million rupiah for PLTS with capacity of 2 kWp. The larger capacity, the greater savings generated by the PLTS. The savings can be seen in **fig-7**.

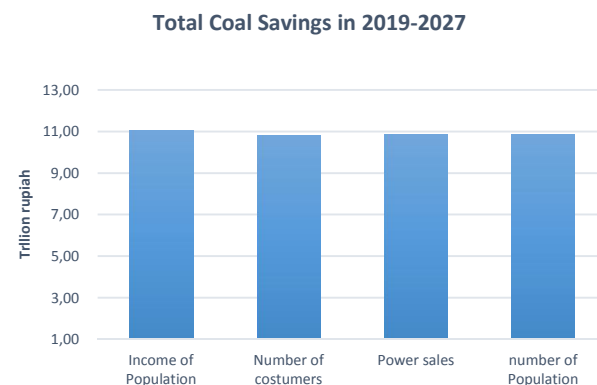


Fig 6. Total saving PLTS 2019-2027

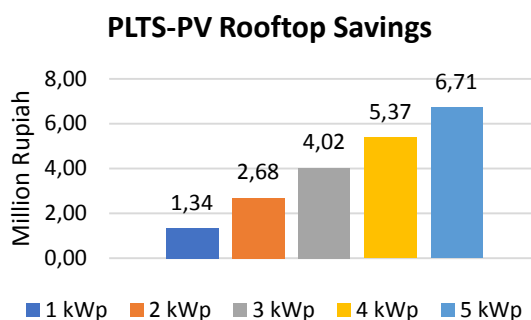


Fig 7. Cost saving PLTS-PV Rooftop capacity of 1 kWp-5 kWp

3.5. Feasibility Analysis of PLTS-PV Rooftop 2 kWp

PLTS-PV Rooftop 2 kWp requires considerable investment for every home. Therefore, it takes considerable effort to attract domestic electricity users to participate in using PLTS. The participation of users will help the government program switch to the use of renewable energy successful and is also beneficial in reducing user electricity costs. In addition, to increase the interest of the community, it can be considered the type of PV installation with incentives. To assess the feasibility of installing PLTS-PV Rooftop 2 kWp, so we doing economic analysis of SAM results area of Jakarta.

Table 6. Economic analysis of the PLTS-PV Rooftop 2 kWp scheme

Metric	Net Metering	Net Metering Incentif
Net present value	\$-370	\$361
Payback period	8,9 years	6.6 years
Incentive	0%	30%

The simulation results of SAM on both payment schemes, it appears that the eligibility of PLTS-PV investment Rooftop 2 kWp is the Net Metering scheme with the incentive from the government. NPV value of \$ 361 or approximately Rp. 5,083,305, with an investment payback period of 6.6 years.

3.6 Advantage Analysis of PLTS-PV Rooftop 2kWp.

PLTS-PV Rooftop 2 kWp in the household sector used to save the energy needs of PLN, so that PV system revenue is assessed from the saving of electric energy paid without the system. Figure 8 shows a graph of annual electricity savings about 41.7% -37.9%

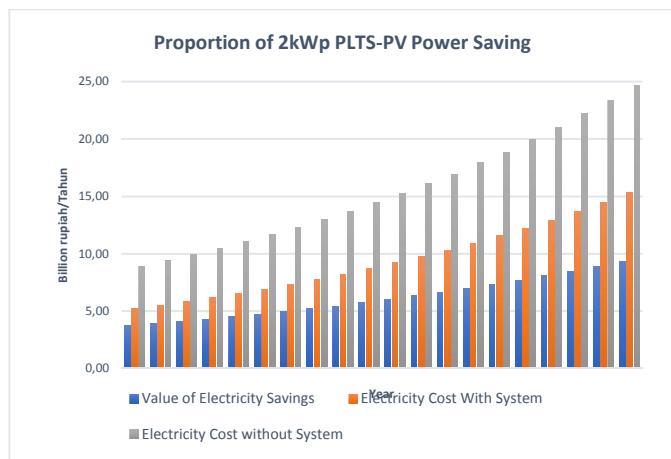


Fig 8. Proportion of electricity savings PLTS-PV Rooftop 2 kWp

4 Conclusion

PLTS-PV Rooftop 2 kWp planned in the household sector in Java Bali is based on of population income, the number of customers, the number of sales, and the number of population. From the results of the research, it was found that high capacity areas for the development of PLTS are located in DKI Jakarta, West Java, Central Java, and East Java. The area with the highest capacity is DKI Jakarta so that it becomes a reference to analyze the energy saving of electricity. The energy generated by PLTS can replace some of the energy resourced from PLN so as to reduce the need for coal fuel. The savings gained in 2019 of about 2.68-2.62 million for each home and until 2027 can save about 11.08 trillion rupiah. The Net Metering scheme with incentives of 30% can be applied to PLTS-PV development of Rooftop 2 kWp. With the installation of the household sector in Java Bali can save household electricity payment for 37.9-41,7%.

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