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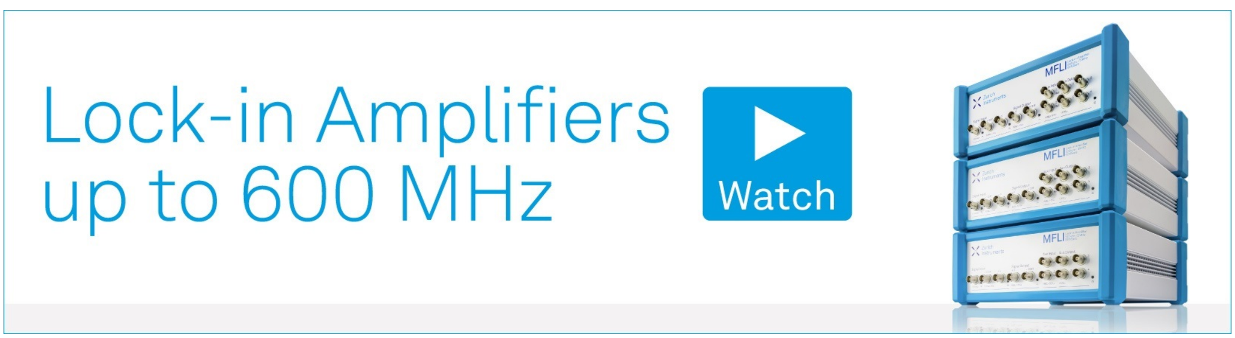

The use of Solar Energy (Solar PV) to meet the increase in electricity demand in South Sulawesi from 2019 to 2025 : Development Analysis

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Abstract. Indonesia has committed to the National Energy Policy (KEN) or the National Energy General Plan (RUEN) to increase the Renewable Energy Mix which is at least 23% by 2025. Given that Indonesia is a tropical country, the energy from solar using Solar PV (Photovoltaic) has great potential to be developed and utilized. In this study we conducted an analysis of the application of Solar PV to meet the additional electricity demand for residential sector in South Sulawesi from 2019 to 2025 with certain scenarios. The results of calculations using the center of gravity method show that Makassar is the best location for development of centralized power plant in South Sulawesi. The demand of residential sector increase by 34,88% from 2019-2025. The best option for developing Solar PV Power plant is by individual scale Solar PV rooftop power plant.

INTRODUCTION

Data from the Ministry of Energy and Mineral Resources (MEMR) shows that conventional energy sources (fossil based) still dominate Indonesia's energy mix. According to the MEMR's National Energy Council data, until 2015 the energy portion of fossils (petroleum, gas and coal) reached a total of 95% of the total energy mix while the energy portion of the Renewable Energy (RE) only reached 5%. A large portion of conventional energy sources makes the sector still holds the main key related to the provision of energy for electricity needs in Indonesia because electricity generation is the biggest need for primary energy use. Contributions from conventional energy sources for electricity are 87.48 % while contributions from RE are 12.52% [1].

The challenges in developing RE for electricity in Indonesia are indeed still very complex. In terms of policy, energy development in Indonesia is mostly still based on the lowest cost without considering environmental factors [2] The problem is that the high technology used for electricity generation from RE compared to electricity generation from fossil energy sources also contributes to the burden of RE development in Indonesia. In addition to these problems, Indonesia's geography in the form of islands poses its own challenges for the development of RE. This natural condition in Indonesia makes the cost of installing equipment high and presents challenges in terms of durability of the equipment itself due to the problem of availability of components and qualified human resources to treat them.

As a tropical country, Indonesia has the potential of renewable energy from solar energy using Solar PV which is high considering that solar radiation is relatively stable throughout the year. This study presents an optimal calculation process to find out the best solutions for solar energy utilization in particular region in Indonesia, namely South Sulawesi. The process of determining the optimal solution is to compare alternative solutions that can be done in terms of solar energy utilization, namely roof top mounting solutions for each residence, regional (district) centralized use of solar power plants, and use of centralized solar power plants on a province scale to meet the

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projected increase in electricity demand in South Sulawesi by looking at the total generation costs (LCOE) and transmission costs.

METHODOLOGY

This research was conducted by comparing several alternative solutions to meet the projected increase in electricity demand from 2019-2025 using energy from solar (Solar PV).

Model Structure and Assumption

Power transmission

Electric power distribution is a matter that affects the total cost of fulfilling the addition of electricity in South Sulawesi. The model developed in this study is the process of transmission or distribution of electricity generated from solar energy (Solar PV) can be:

1. The process of sending electricity from a Provincial Power Plant to the district's central point (Transmission)
2. The process of sending electricity from the district center to the final customer (Distribution)

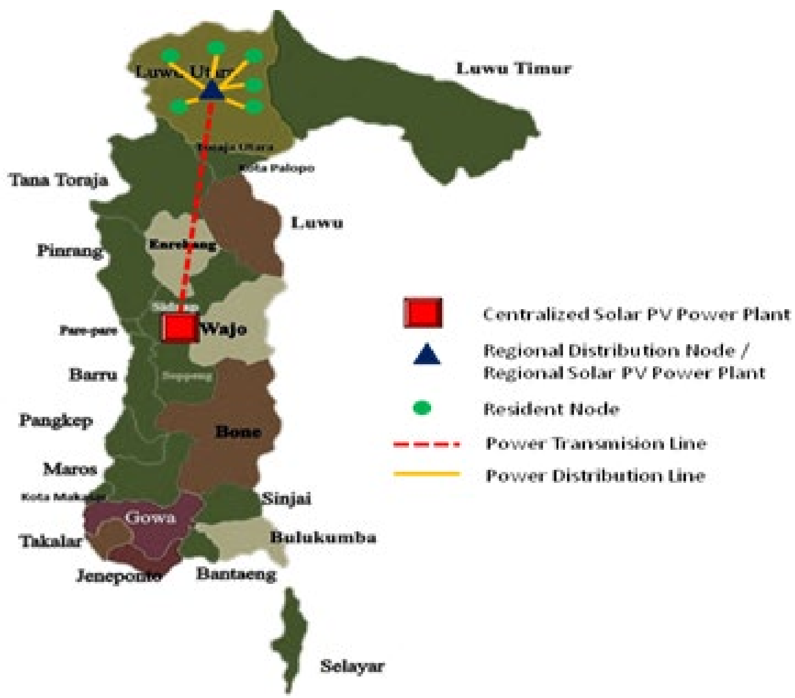

FIGURE 1. Illustration of the Power Transmission in South Sulawesi Region

Figure 1 shows the model of electricity transmission or distribution in the South Sulawesi Region. That figure shows some example the process of transmitting or distributing the electricity for Luwu District/Regency. For the scenario 1 which is generating Solar PV by individual resident's solar PV rooftop, there is no transmitting and distributing process to send the electricity to customer. For the scenario 2 which is generating the electricity by centralized power plant for each District/Regency, there is cost for distributing the electricity from power plant to the customer (residential sector). For the scenario 3 which is generating the electricity by centralized power plant for all District/Regency, there is cost for transmitting and distributing the electricity.

Power plant location for scenario 3

In the case of scenario 3, there are 2 district / city choices that are an alternative to be used as large-scale power plants in Makassar and in Wajo. Both places were chosen because in Makassar the demand for electricity was highest among the other districts in South Sulawesi, while Wajo was chosen because it was the midpoint of South Sulawesi Province. Determination method uses Center of Gravity Method [3]. The objective function to be achieved is minimizing the distance multiplied by the needs of each electricity demand point (district/city) [3].

TABLE 1. Determination of Power Plant Location for Skenario 3

District/City	Resident (Person)	Resident (%)	Demand (GWh)	Distance from Makasar (km)	Distance from Wajo (km)	Z Makasar	Z Maros
01. Kepulauan Selayar	127,220	1.53%	42.44	171.78	235.5	7,290.5	9,996.5
02. Bulukumba	404,896	4.85%	135.07	89.86	157.5	12,137.7	21,268.7
03. Bantaeng	181,006	2.17%	60.38	68.11	166.2	4,112.7	10,038.2
04. Jeneponto	351,111	4.21%	117.13	51.69	176.0	6,054.5	20,616.3
05. Takalar	280,590	3.36%	93.61	36.4	167.9	3,407.2	15,719.1
06. Gowa	696,096	8.34%	232.22	38.14	` 147.8	8,856.8	34,312.6
07. Sinjai	234,886	2.82%	78.36	74.64	133.1	5,848.7	10,431.8
08. Maros	331,796	3.98%	110.69	19.25	122.1	2,130.7	13,510.5
09. Pangkep	317,110	3.80%	105.79	35.39	107.4	3,743.9	11,360.6
10. Barru	169,302	2.03%	56.48	81.34	65.3	4,594.0	3,685.3
11. Bone	734,119	8.80%	244.90	81.05	80.3	19,849.4	19,668.2
12. Soppeng	225,512	2.70%	75.23	102.73	40.1	7,728.5	3,017.5
13. Wajo	390,603	4.68%	130.31	142.14	-	18,521.7	-
14. Sidrap	283,307	3.40%	94.51	164.61	28.3	15,557.6	2,675.6
15. Pinrang	361,293	4.33%	120.53	166.43	69.9	20,059.5	8,423.7
16. Enrekang	196,394	2.35%	65.52	192.89	65.9	12,637.6	4,317.6
17. Luwu	343,793	4.12%	114.69	222.56	82.4	25,525.4	9,447.0
18. Tana Toraja	226,212	2.71%	75.46	231.87	111.5	17,498.0	8,410.5
19. Luwu Utara	297,313	3.56%	99.18	323.84	194.9	32,119.8	19,334.9
20. Luwu Timur	263,012	3.15%	87.74	343.07	202.0	30,101.4	17,722.8
21. Toraja Utara	222,393	2.67%	74.19	256.77	131.3	19,049.9	9,741.2
22. Makassar	1,408,072	16.88%	469.74	0	142.1	-	66,768.1
23. Pare-Pare	135,192	1.62%	45.10	127.18	48.4	5,735.9	2,183.3
24. Palopo	160,819	1.93%	53.65	251.94	114.7	13,516.4	6,151.4
					Total :	296.077,8	328.801,9

$$\min: Z = \sum_{i=1}^{m} \sum_{j=1}^{n} \sqrt{Wj[(Xi - aj)^2 + (Yi - bj)^2} \tag{1}$$

Where,

m	: Total Alternative of Location
n	: Total District to be supplied with electricity
Xi,Yi	: Coordinate of City/District Power Plant to be located
aj, bj	: Coordinate of City/District to be supplied with electricity
Wj	: Electricity Demand in the City /District to be supplied.

The first thing that will be done is to determine the demand of each district / city by using the historical demand data of South Sulawesi in one year in 2017 [4] as the basis for the calculation divided by the proportion of the population in each district / city [5]. Table 1 shows that Makassar is the best location option to place the Power Plant.

Cost of transmission

The cost for distributing electricity from the power plant to the customer (residential sector) are 5% from LCOE [6].

Power generation

Component of generating electricity cost that being calculated for this research is Levelized Cost of Electricity for Solar PV Plant. It is known that the LCOE of Solar PV plant are decreasing year by year. The development of the solar Panel technology pushes the decreasing. For the Southeast Asia region, the average generation cost (LCOE) is below 0.16 USD / kWh [7].

The Asean Center for Energy classified Solar PV as follows : small-scale (<100KWp), medium-scale (100-1000kWp), dan large-scale (>1000kWp)[7]. Scenario 1 will use the data of small-scale plant, Scenario 2 will use the data of medium-scale plant, Scenario 3 will use the data of large-scale plant .

The price of electricity generation (LCOE) from Solar energy (Solar PV) in this study uses data from the ASEAN Center of Energy (ACE) [7]. On average, the small-, medium-, and large-scale solar PV plants had an LCOE of USD 0.187, USD 0.181, and USD 0.182/kWh, respectively. Most of the solar PV plants in the ASEAN countries were installed in the six years after 2012. This data will be used for the basis year (2017).

Mathematical Formulation

The purpose of this study is to know which scenario the best is to implement the solar PV plant in South Sulawesi by calculating the transmission/distribution cost and the generating cost.

$$z = \sum_{i=1}^{m} [(TC_i \ x \ D_i) + (DC_i \ x \ D_i) + (LCOE_i \ x \ D_i)] \tag{2}$$

Where,

i	: District/City of South Sulawesi Region
TC	: Transmission Cost for distributing electricity from the Large Centralized Power Plant to the District/City node (USD/kWH)
DC	: Distribution Cost for distributing electricity from the Regional node/Regional Power Plant to the resident (USD/kWH)
LCOE	: Levelized Cost of Electricity for generating electricity (USD/kWH)
D	: Demand for residential sector

Key parameters and assumptions

Electricity Demand for Resident Sector

Data on Electricity Demand in South Sulawesi is obtained from electricity statistics that are issued annually by the Directorate General of Electricity at the Ministry of Energy and Mineral Resources [4]. One component of electricity demand data is the amount of use or sale of electricity by PLN (National Electricity Company) to each customer within a period of one year. Another component is the calculation of the number of households that have not yet obtained electricity based on the electrification ratio of the year multiplied by the assumption of the average electricity demand per household within one year.

Learning Curve for LCOE

Year by year the LCOE of electricity from Solar PV are decreasing. In this paper, we use the projection data of LCOE from Asean Center of Energy [9] for projecting the future LCOE for small, medium, and large scale of Solar PV plant. Figure 2 are the graphical of the LCOE decline and the equation that will used to predict the LCOE of 2019-2025. The equation of regression line of the data is y = -0,01ln(x) + 0,241

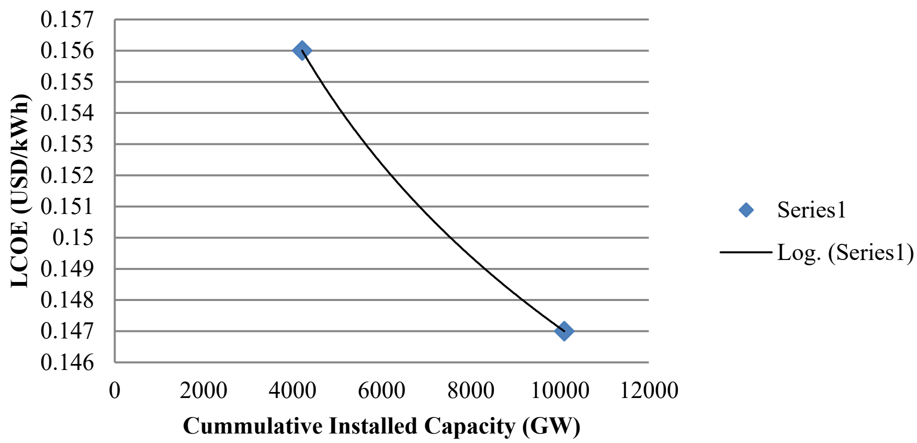

FIGURE 2. LCOE Decline (Solar PV)

RESULTS AND DISCUSSION

Electricity Demand

In the PLN electricity sales data, the demand for electricity from residential sector tends to increase every year. The projection data were calculated using the electricity demand data trend that can be seen on figure 3. For the residential sectors, the electricity demand projection used is projected with linear regression (time series) approach because it has a smaller Mean Square Error (MSE) parameter compared to exponential regression approach. The linear regression equation is y = 100.7x + 1941

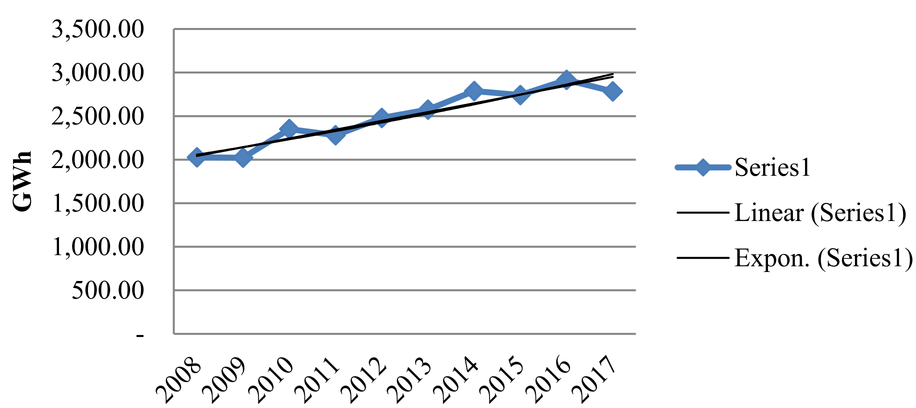

FIGURE 3. Residential Curve

Table 2 is a summary of the Southern Sulawesi Region electricity demand data from 2009 to 2017 and its projection from 2018 to 2025. The electricity data are counted with the formula for calculating PLN electricity sales [4] added with the assumption that the needs of households that have not been served by PLN in one year are concerned.

TABLE 2. Southern Sulawesi Region Electricity Demand History and Projection

Year	Demand (GWh)	Additional from Previous Year (GWh)
2008	2,026.87	
2009	2,021.88	(4.98)
2010	2,350.35	328.47
2011	2,280.46	(69.89)
2012	2,478.02	197.56
2013	2,574.12	96.10
2014	2,786.71	212.59
2015	2,741.24	(45.47)
2016	2,915.34	174.10
2017	2,782.92	(132.42)
2018	3,048.70	265.78
2019	3,149.40	100.70
2020	3,250.10	100.70
2021	3,350.80	100.70
2022	3,451.50	100.70
2023	3,552.20	100.70
2024	3,652.90	100.70
2025	3,753.60	100.70

Levelized Cost of Electricity (LCOE) projections

The price of electricity generation (LCOE) from Solar energy (Solar PV) in this study uses data from the ASEAN Center of Energy (ACE) [7]. The data used is the price of electricity generation [LCOE] from Solar PV compared to the accumulative capacity installed.

Calculation of the Scenario

TABLE 3. Southern Sulawesi Region Electricity Demand History and Projection

Year	Residential Demand (GWh)	Demand Addition Year (GWh)	Capacity (GW)	Accumulative Installed Capacity (GW)	LCOE Small (USD/kWh)	LCOE Medium (USD/kWh)	LCOE Large (USD/kWh)	Scenario 1 (USD)	Scenario 2 (USD)	Scenario 3 (USD)
2017	2,782.92	(132.42)	1.5248852		0.187	0.181	0.182			
2019	3,149.40	100.70	0.0551781	0.2008	0.203	0.197	0.198	19,425,140.81	19,843,316.64	20042543.53
2020	3,250.10	100.70	0.0551781	0.2560	0.201	0.195	0.196	19,192,896.78	19,598,849.25	19796862.3
2021	3,350.80	100.70	0.0551781	0.3112	0.199	0.193	0.194	19,006,164.64	19,402,289.10	19599326.18
2022	3,451.50	100.70	0.0551781	0.3663	0.197	0.191	0.192	18,849,996.57	19,237,901.65	19434122.52

TABLE 3. Southern Sulawesi Region Electricity Demand History and Projection (continued)

Year	Residential Demand (GWh)	Demand Addition Year (GWh)	Capacity (GW)	Accumulative Installed Capacity (GW)	LCOE Small (USD/kWh)	LCOE Medium (USD/kWh)	LCOE Large (USD/kWh)	Scenario 1 (USD)	Scenario 2 (USD)	Scenario 3 (USD)
2023	3,552.20	100.70	0.0551781	0.4215	0.196	0.190	0.191	18,715,780.42	19,096,621.50	19292140.87
2024	3,652.90	100.70	0.0551781	0.4767	0.194	0.188	0.189	18,598,098.57	18,972,745.87	19167650.17
2025	3,753.60	100.70	0.0551781	0.5319	0.193	0.187	0.188	18,493,320.43	18,862,453.09	19056809.76
								132,281,398.24	**135,014,177.09**	**136,389,455.33**

Table 3 shows the calculation based on equation (2) which Scenario 1 become the best scenario which has total cost USD 132,281,398.24.

CONCLUSION

This study present calculation of several scenario of the use of Solar PV to meet the addition of electricity demand in South Sulawesi region. The conclusion are as follows:

1. The electricity demand from residential sector in South Sulawesi Region increased by 34.88% from year 2017 to year 2025 according to the projections calculated
2. Makassar are the best location to place the Centralized power plant based on Center of Gravity Method
3. The best development scenario is developing Solar PV Power plant by residential rooftop.

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