Modeling and simulation for optimizing renewable energy utilization in the South Sulawesi region to meet the target of the renewable energy mix

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Modeling and simulation for optimizing renewable energy utilization in the South Sulawesi Region to meet the target of the renewable energy mix

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Abstract.

The challenges in developing renewable energy for electricity in Indonesia are indeed still very complex. In terms of policy, energy use development in Indonesia is mostly still based on the least-cost electricity. The problem of high technological cost used to generate electricity from renewable energy when compared to electricity generation from fossil energy sources takes part burdening the development of renewable energy in Indonesia. This study aims to determine electricity demand projections and fulfillment of using renewable energy (RE) in South Sulawesi. Electricity demand projection is obtained from the time series model based on historical data. The results show that from 2017 to 2025 the public sector is the highest percentage increase (78 %), while the highest nominal increase is the household sector (971 GWh). In total, there is an addition of 2,285 GWh (43%) of electricity demand in South Sulawesi. Renewable Energy available in South Sulawesi has been able to meet the target of fulfilling electricity demand and the energy mix with the most optimum type of RE is Hydropower at a cost of USD 168,242,725 and the fulfillment of the electricity demand meet from Renewable Energy are 52% from the total electricity demand at year 2025.

*Keywords***:** Energy mix; Least cost; Optimization model; Renewable energy; Simulation

1. 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 EBT compared to electricity generation from fossil energy sources also contributes to the burden of RE development in Indonesia. In addition to

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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 also 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.

With the great potential of RE and the government's commitment to continue to develop the use of RE for electricity generation, strategic steps from various stakeholders are needed to make the RE energy mix proportion target in the RUEN (National Energy General Plan) achieved and provide many benefits to the community. One step that can be done is to make this RE competitive. In this regard, the modeling and optimization of the model is needed to get the best solutions related to the utilization of potential RE in each region in Indonesia, especially for remote areas that are not optimally affordable electricity from the National Grid electricity grid. This research were focusing on South Sulawesi Region as the pilot project due to its various RE potency and utilization. Optimization is done by looking at the energy potential of RE, the projected cost trend of RE for electricity generation in Indonesia, and projections of the development of demand for electricity.

2. LITERATURE REVIEW

In terms of optimizing the supply of RE energy there are several previous studies that have been carried out. El Kafazi, et. al (2017) [3] explained about the model and optimization of production costs for RE generation with the aim of finding solutions to supply electricity to certain demand. Talotis, et. al (2017) [4] explained about the provision of electricity in Cyprus while still using fossil fuels as the main supply coupled with the potential of RE available. Han and Kim (2017) [5] examined the optimization of RE utilization for the residential / residential electricity sector with various existing scenarios. In 2016, the Ministry of Energy and Mineral Resources conducted a research on the capability of the electricity system in several regions with the scenario of using conventional plants along with RE plants.

The purpose of this research is to carry out simulations and find out the optimization of the utilization of RE energy sources and RE technology so that the cost of electricity generation from RE energy sources can be competitive for certain regions in Indonesia. By using the results of the optimization of this study, interested parties, whether from Regulators, Private Sector, etc. who will invest, can find out how to use appropriate RE technology based on regional potential, challenges faced by each region, and existing technological developments .

3. MODELING OF ELECTRICITY COST

The model of electricity generation costs developed is aimed at knowing the total cost of electricity generation needed to supply electricity needs in aggregate in South Sulawesi. The modeling problem regarding the cost of electricity generation needed to meet the demand for electricity in South Sulawesi Province is to obtain optimal costs to meet the additional demand. This mathematical model involves the variable cost of electricity generation per kWh or Least Cost of Electricity (LcoE) for energy from fossils and from Renewable Energy namely Onshore Wind, Hydropower, and Solar (Solar PV) energy. The model is listed in the following formula

$$Min\ Total\ Cost = \sum_{i=1}^{n} CF_i \times DF_i + \sum_{i=1}^{n} CRB_i \times DRB_i + \sum_{i=1}^{n} CRA_i \times DRA_i + \sum_{i=1}^{n} CRS_i \times DRS_i \qquad (1)$$

- CF = Fossil Based Electricity Generation Costs (USD / kWh)
- CRB = Costs for Renewable Energy Power Generation from Wind (onshore) (USD / kWh)
- CRA = Costs for Generating Renewable Energy from Water (USD / kWh)
- CRS = Costs of Solar Renewable Energy Generation (USD / kWh)
- DF = Addition of Fossil Based Electricity Demand (GWh/year)
- DRB = Addition of Bayu's Renewable Energy Electricity Demand (GWh/year)
- DRA = Addition of Electricity Demand for Renewable Energy Water (GWh/year)
- DRS = Addition of Solar Energy Renewable Energy Demand (GWh/year)
- Addition of Total Electrical Energy Demand = DF + DRB + DRA + DRS (GWh/year)

4. SIMULATION

4.1 Electricity Demand

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. 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.

Table 1 is a summary of the Southern Sulawesi Region electricity demand data from 2009 to 2017 and it's projection from 2018 to 2025. The electricity data are counted with the formula for calculating PLN electricity sales added with the assumption that the needs of households that have not been served by PLN in one year are concerned. From the data on PLN electricity sales, it can be seen that the demand for electricity from each group of customers has a tendency to increase every year. The projection data were calculated using the electricity demand data trend that can be seen on figure 1.

TABLE 1. Southern Sulawesi Region Electricity Demand History and Projection

Year	Residential (GWh)	Industrial (GWh)	Commercial (GWh)	Public (GWh)	Total (GWh)	Total (MTOE)
2008	2026.87	685.14	548.18	245.98	3506.17	0.30
2009	2021.88	614.90	554.41	267.66	3458.85	0.30
2010	2350.35	641.13	620.52	293.46	3905.46	0.34
2011	2280.46	686.78	663.51	307.76	3938.51	0.34
2012	2478.02	754.87	780.97	323.87	4337.73	0.37
2013	2574.12	741.28	1075.61	353.76	4744.77	0.41
2014	2786.71	803.00	1004.00	385.00	4978.71	0.43
2015	2741.24	824.86	927.83	411.46	4905.39	0.42
2016	2915.34	904.35	1011.71	453.95	5285.35	0.45
2017	2782.92	958.73	1068.01	487.04	5296.70	0.46
2018	3048.70	965.76	1183.14	516.61	5714.21	0.49
2019	3149.40	1010.21	1248.18	556.29	5964.08	0.51
2020	3250.10	1056.71	1313.22	599.01	6219.05	0.53
2021	3350.80	1105.35	1378.26	645.02	6479.43	0.56
2022	3451.50	1156.23	1443.30	694.56	6745.59	0.58
2023	3552.20	1209.44	1508.34	747.91	7017.90	0.60
2024	3652.90	1265.11	1573.38	805.36	7296.75	0.63
2025	3753.60	1323.34	1638.42	867.21	7582.58	0.65

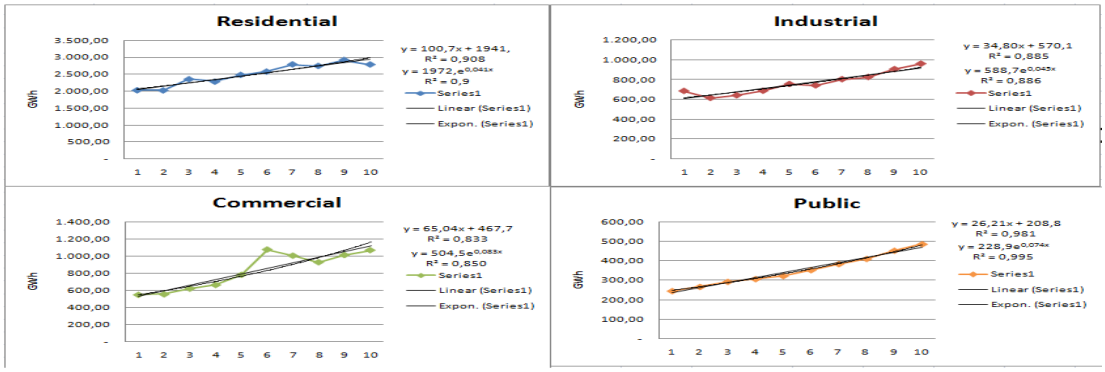

FIGURE 1. Southern Sulawesi Electricity Demand Data (2008-2017) Trend

4.2 RE Electricity Demand

South Sulawesi has the potential for abundant renewable energy to be utilized especially for electricity generation. Table 2 shows data on potential RE in South Sulawesi issued by the Ministry of Energy and Mineral Resources (MEMR) in the 2016 EBTKE Statistics Book.

TABLE 2. Southern Sulawesi Region RE Potency

RE Type	Energy Potency (MW)	Yearly Energy Potency (GWh)
Hydro	762	5,340.10
Solar PV	7,588	15,509.87
Onshore Wind	4,193	29,384.54

For these three types of potential RE that are relatively easy to use, for Minihydro and Microhydro power has an Annual Capacity of 5,340 GWh, for annual Solar Power capacity of 15,509 GWh, and annual Onshore Wind Power Capacity of 29,384 GWh. Annual capacity is determined by calculating the energy that can be produced in one year by multiplying the potential with the efficiency and time available in one year of operation.

The growth of renewable energy utilization in South Sulawesi is entering a new phase with the construction of two wind power plants (PLTB), namely the Sidrap PLTB with a capacity of 75 MW and the Jeneponto Tolo PLTB with a capacity of 72 MW. The construction of the two PLTBs made the total energy from RE electricity generation in South Sulawesi increase significantly. In total, for the base of simulation, RE electricity generation in South Sulawesi was recorded as a table 3 below.

TABLE 3. Southern Sulawesi Region RE Demand & Capacity for base (year 2018)

RE Type	Capacity of Electricity (GWh)
Hydro	1,047.67
Solar PV	2.66
Onshore Wind	1,030.18

4.3 Levelized Cost of Electricity (LCoE)

The cost of generating RE electricity in Indonesia is still varied and shows a decline from year to year. In general, when compared to the generation of plants other than RE, it is clear that the electricity generation from RE has enormous potential to be developed in view of the increasingly competitive costs of its generation [7]. The cost of generating (Non-RE) electricity varies from 6 cents to 15 cents per kWh [7]. For electricity generation from Wind Energy (onshore) the weighted average generation costs are around 9.5 cents USD per kWh. RE electricity generation with Solar PV the cost of generating a weighted average is around 20 cents USD per kWh. Meanwhile for RE electricity generation with hydropower around 7 cents USD per kWh

From year to year the data shows that the trend of electricity generation costs for some types of REs shows a significant decline[7]. This provides a huge opportunity that actually RE electricity costs can and will excel compared to electricity from conventional or non-RE sources, considering that electricity costs from conventional sources will not change significantly or can even increase significantly due to the decline in primary energy sources from fossil [8]

The cost of electricity generation for conventional power plants that are already mature in this study is taken from the average conventional power plant cost of generation (BPP) according to the region. In general, indeed for this type of generator does not have a trend or tendency to rise or fall because of the established technology and its application. For the generation cost (BPP) of South Sulawesi, this study uses data from the Ministry of Energy and Mineral Resources based on Minister of Energy and Mineral Resources Decree No. 1404 K / 20 / MEM / 2017 which is equal to 8.1 cents USD / kWh.

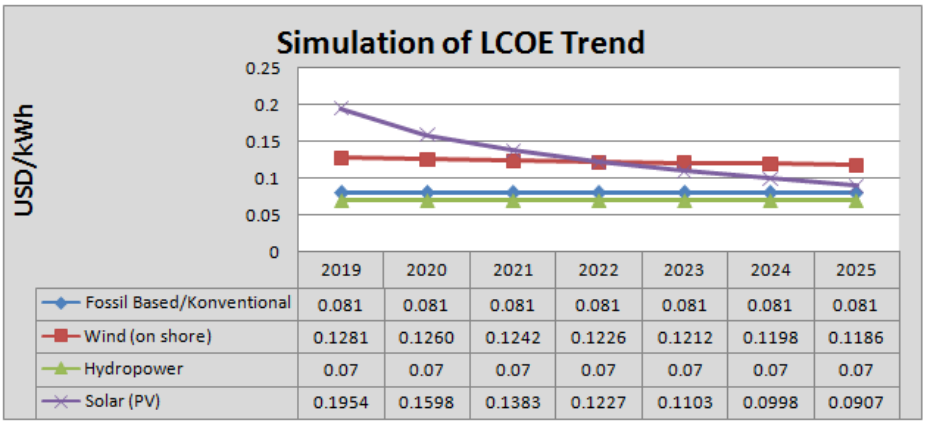

FIGURE 2 : LCOE Learning Curve and Trend

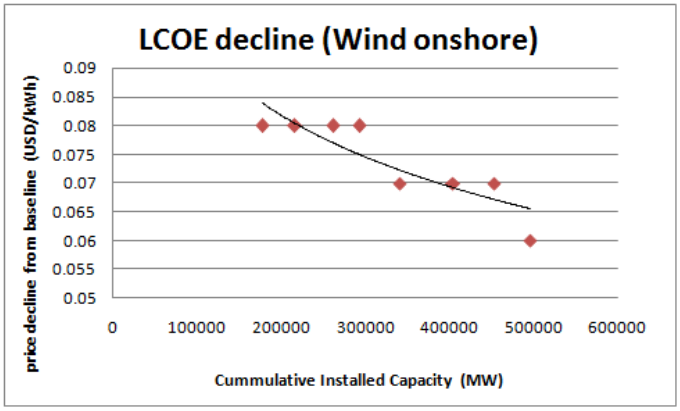

FIGURE 3 : LCOE Learning Curve for Wind Onshore

Costs of RE electricity generation for Wind Onshore and Solar PV have a tendency to declining along with the increase in installed capacity. The projection of LCOE of Wind Onshore uses historical data from IRENA [8]. Figure 3 shows the Learning Curve of the LCOE of Wind Onshore calculated with the model of Rubin et al (2015) [10]. The price of electricity generation (LCOE) for Solar energy (Solar PV) in this study uses data from the ASEAN Center of Energy (ACE) [9]. The data used is the price of electricity generation [LCOE] from Solar PV compared to the accumulative capacity installed. The Trend of LCOE decline can be seen in figure 2.

4.4 Simulation Running

This study use 4 scenarios to simulate the cost of generation. The result are as shown in table 4 as follows:

Table 4 : Simulation Result

No	Scenario	Total Cost of Electricity (USD)
1	Additional electricity demand is fulfilled from fossil energy	194,680,867
2	Additional electricity demand is met from wind energy	215,964,772
3	Additional electricity demand is met from hydro energy	168,242,725
4	Additional electricity demand is met from Solar PV	296,044,616

5 CONCLUSION

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

1. Total growth and projected demand for electricity in South Sulawesi are shown in Table 2. The household sector increased electricity demand by 971 GWh (35%) from 2,783 GWh in 2017 to 3,754 GWh, the industrial sector increased by 364 GWh (38%), the commercial sector amounted to 570 GWh (53%), and the public sector amounted to 380 GWh (78%). The public sector is the highest increase in percentage, while the highest increase in nominal is the household sector. In total, there is an addition of 2,285 GWh (43%) of electricity demand in South Sulawesi.
2. By carrying out the disaggregation process, the target of 23% of the mix of renewable energy in the South Sulawesi region were fulfilled. The fulfillment of the Electricity Demand meet from Renewable Energy are 52% from the total electricity demand. Then the decision to use Hydropower is the most efficient at a cost of USD 168,242,725
3. In 2025 the hydropower capacity installed will be 2916.04 GWh which is still below the potency itself (5,340 GWh)

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