A progressive alternative of energy planning for West Sumatera province

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Abstract. To ensure energy security for people, the Government develops energy planning, a plan that contains the baseline condition and projected energy consumption and energy supply in specific years. In West Sumatera Province's Regional Energy Plan (RUED), The Local Government targeted 70.9% renewable energy share in its primary energy mix in 2050. The alternative scenario of power plant generation in West Sumatera base on the Regional Energy Plan Document for 2050 is developed in this paper. The share of renewable energy in the alternative scenario in 2050 is 100%. The alternative energy planning we design meet the expected electricity consumption each year. The Levelized Cost of energy for the alternative scenario cheaper than the RUED scenario in present value. With the rapid development of renewable energy technology, West Sumatera can achieve 100% renewable energy electricity in 2050 and give reasonable energy security confidence.

1. Introduction

There are several forms of energy that use directly by households or industries in their daily life. Electricity is one of the most widely used forms of energy. Electricity uses as an intermediary from the primary source of energy, like coal and gas, into our electronic devices. So that electricity access and electricity security is an essential parameter for taking account of the Government. On another hand, energy consumption is blamed for one of the leading causes of global warming [1]. Renewable energy is proven to contradict that claim because renewable energy sources did not produce greenhouse gas emissions while operating. Shifting to renewable energy be one of the efforts to stop global warming. The Government of Indonesia ratified Paris Agreement and promise to cut its emission by 29% from the baseline before 2030 [2].

Indonesia plans to deploy renewable energy not only on national bases but also on Local bases. Provincial governments have to develop their Regional Energy Planning based on National Energy Planning [3]. West Sumatra Province is one of the few provinces that already release their Regional Energy Planning. Their Regional Energy Planning already accommodates strategy to deploy more renewable energy technology in electricity generation. However, with a large number of renewable energy resources, West Sumatra Province can rely on renewable energy for their electricity supply.

In this paper, a progressive alternate scenario of West Sumatera Province Electricity Planning is examined to adopt more renewable energy. The alternate scenario is based on West Sumatra's renewable energy potential and economic viability.

2. Role of Local Energy Planning and Energy Security

Energy security is an Essential issue for every ruler in a country. There are many definitions and interpretations of energy security. The International Energy Agency (IEA) defines energy security as "the uninterrupted availability of energy sources at an affordable price" in a short period and long period [4]. Conceptually, energy security as old as fire when the early stone age people tend to live in an area that has adequate supplies of flammable material that could be produced without requiring more effort and excessive safety risk. The foundation of energy security since that day can be described as availability to meet the demand affordability [5].
To ensure energy security for people, the Government develops a plan that contains the baseline condition and projected energy consumption and energy supply in specific years. This plan helps the policymaker and another stakeholder to plan the next step of supplying energy for its people. In Indonesia, Energy Planning divides into the national level, National Energy Planning (RUEN), and provincial level, Local Energy Planning (RUED). The Regional Energy Plan (RUED) is the Provincial Government's policy regarding the provincial level energy management plan, which is an elaboration and a plan for implementing the National Energy Plan (RUEN) and cross-sectoral to achieve the targets of the RUEN [6]. In The RUED, The Government calculates its energy consumption and its inclination per year and plan the energy supply to meet the consumption. In RUEN and RUED, Indonesia Government and local Government already considering the renewable energy source as an essential energy supply, particularly for electricity needs.

Relying on electricity only from renewable energy is not an impossibility; Costa Rica already proved it. In 2016, Costa Rica ran its electricity 100% from renewable energy resources for 76 straight days, starting from 17 June 2016. Hydropower providing about 80.27% of total electricity, 12.62% from Geothermal, 7.1% from wind turbines, and 0.01% from solar [7]. Many countries and region already pledge to achieve 100% renewable energy in their area such as Denmark with 100% renewable energy by 2050, Sweden with 100% renewable electricity by 2040, Costa Rica with 100% renewable energy by 2030, the California State of The U.S. with 100% Clean Electricity by 2045, and Hawaii of The U.S. with 100% renewable Electricity by 2045 [8].

3. West Sumatra Electricity Current Condition and Planning

West Sumatera Province is blessed by tremendous resources. Located on the west coast of Sumatera Island, West Sumatera Province has four big lakes, volcano mountains, and dozens of big rivers. West Sumatera Province's Government also already ratified its regional energy planning into a Local Government Regulation number 11/2019.

To calculate the supply and demand side of the energy, The RUED arranged with some assumptions and models. The RUED use Long-Range Energy Alternative Planning (LEAP) software in modeling and calculation. Some several assumptions used namely Annual Population Growth 1.2% in 2015, 1% in 2025, and 0.7% in 2050, Annual Economic Growth 5.5% in 2015, 4.9% in 2025, and 6% in 2050. The Economic condition, population, and Energy condition in 2015 were used as the baseline for modeling and calculation. From the calculation and simulation, the primary energy mix as follow.

| Energy Sources | 2015   | 2025   | 2050   |
|----------------|--------|--------|--------|
| Coal           | 30.30% | 14.90% | 7.60%  |
| Gas            | 3.50%  | 9.40%  | 9.30%  |
| Oil            | 46.60% | 24%    | 12.20% |
| Renewable Energy| 19.60% | 51.70% | 70.90% |

The energy consumption mix dominates by the transportation and industry sector, while the percentage of household consumption will decline every year due to the energy efficiency program. Detail of the energy consumption mix shown below.
Figure 1. The projection of Energy Consumption share for each sector in West Sumatera RUED

Table 2. Energy Consumption per sector in Ton Oil Equivalent

| Sector     | Energy consumption (thousand TOE) |
|------------|-----------------------------------|
|            | 2015    | 2025    | 2040    | 2050    |
| Industry   | 199.4   | 457.3   | 1009.7  | 1789    |
| Transportation | 988.6   | 11352   | 1816.5  | 2208.4  |
| Household  | 847.4   | 545.3   | 845.5   | 1044.6  |
| Commercial | 75.6    | 183.6   | 380.1   | 682.8   |
| others     | 30.4    | 45.6    | 83.1    | 132.1   |
| Total      | 2141    | 12584   | 4135    | 5857    |

The RUED targeted kerosene and diesel oil already substitute by "bio solar" and other plant base oil in 2050, but coal dan gas still take some share. The total energy supply in RUED is shown below.

Table 3. Energy Supply per Energy Sources in Ton Oil Equivalent

| Energy Sources | Energy Supply (thousand TOE) |
|----------------|-----------------------------|
|                | 2015    | 2025    | 2040    | 2050    |
| Coal           | 758.6   | 659.7   | 663.7   | 915.5   |
| Gas            | 87.3    | 415.9   | 742.4   | 1123.2  |
| Oil            | 1167.8  | 1064.3  | 1232.2  | 1465.5  |
| Renewable Energy | 409.5 | 2286.5  | 5446.3  | 8546    |
| Total          | 2504.2  | 4426.4  | 8084.6  | 12050.2 |

Focusing on electricity, The RUED expects the annual electricity consumption per capita to rise from 573.4 kWh in 2015 to 3612.1 kWh in 2050 to compensate for the projected economic growth. Large-hydro power plants are targeted to be the main backbone for its system and plan to remove all diesel generators. The power generation projection is shown in the below table.
Table 4. The Power Plant projection capacity from The RUED (in MW)

| Power Plant Type    | 2015  | 2025  | 2040  | 2050  |
|---------------------|-------|-------|-------|-------|
| Coal - steam PP     | 414   | 424   | 424   | 414   |
| Gas combustion PP   | -     | 148   | 400   | 500   |
| Oil combustion PP   | 52.5  | 52    | 35    | -     |
| Diesel Gen PP       | 33.4  | 15.9  | 15.9  | -     |
| Large-hydro PP      | 254   | 450   | 800   | 1100  |
| Micro-hydro PP      | 9.8   | 124.6 | 600   | 800   |
| Geothermal PP       | -     | 250   | 650   | 950   |
| Biomass PP          | -     | 150   | 550   | 700   |
| Solar PV PP         | 0.2   | 250   | 550   | 750   |
| Wind Turbine PP     | -     | 20    | 280   | 350   |
| **Total**           | 763.9 | 1884.5| 4304.9| 5564  |

Fortunately, the RUED also gives information about the Potency of energy resources in The West Sumatera Province, which refers to several studies from the government and another party. The potency of energy resources in West Sumatera is shown below.

Table 5. The potency of energy resources in The West Sumatera Province base on the RUED

| Energy Type      | unit   | Potency |
|------------------|--------|---------|
| Large hydro      | MW     | 3607*   |
| Geothermal       | MW     | 1035    |
| Micro-hydro      | MW     | 1353    |
| Biomass          | MW     | 923.1   |
| Solar            | MW     | 5898    |
| Wind             | MW     | 428     |
| Coal             | Million Ton | 795.5 |

*Together with Riau Province

From the RUED data, we can see that The West Sumatera Provinces Government has goodwill to utilize green energy and secure the energy need with their local resources as we can see their projection align with potency.

4. West Sumatra Electricity Progressive Alternative Planning: Rely on Renewable Energy

4.1 Boundary
The alternative planning for RUED 2050 design focusing only on electricity generation and power plant share. The alternative electricity generation planning for 2050 has to produce electricity as much as the expected electricity consumption in 2050 in RUED, which is 25.1 TWh per year because we assume there is no declining demand in 2050. The electricity production calculates based on the capacity factor. Capacity factor is the ratio of the net electricity generated, for the time considered, in this study for one year, to the energy that could have been generated at the continuous full-power operation during the same period [9]. It represents in the below equation.
Actual \( P(t) = CF \times Potential \ P(t) \)  \hspace{1cm} (1)

\( Actual \ P(t) \) = Actual electricity power generation in a period (i.e. one year)
\( CF \) = capacity factor
\( Potential \ P(t) \) = potential electricity power generation if the power plan running full time in a period (i.e., one year)

In this paper, the value of the capacity factor of all designated power plant types came from several sources. The capacity factor for the coal power plant and the gas combustion power plant refers to the EIA report [10]. The diesel power plant’s capacity factor refers from Nathan Green’s paper [11]. The capacity factor of renewable energy power plants refers to several reports from IRENA, NREL, and DECC. The capacity factor for each type of power plant is shown in the below table.

| Power Plant Type        | Capacity Factor |
|------------------------|-----------------|
| Coal - steam PP        | 0.6             |
| Gas combustion PP      | 0.55            |
| Diesel Gen PP          | 0.25            |
| Large-hydro PP         | 0.5             |
| Micro-hydro PP         | 0.5             |
| Geothermal PP          | 0.85            |
| Biomass PP             | 0.58            |
| Solar PV PP            | 0.1             |
| Wind Turbine PP        | 0.32            |
| Tidal Current PP       | 0.097           |
| Fuel Cell PP           | 0.8             |

Alternative electricity generation planning also has to economically reasonable. To check the economic reasonability for the alternative scenario, the Levelized Cost of Energy (LCOE) is compared between the alternative plan with the original RUED scenario. LCOE is a measure of the average net present cost of electricity generation for a generating plant over its lifetime to the total electricity production in its lifetime. The LCOE can be simplified in the below equation [12].

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LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} E_t \cdot (1+r)^t}
\]

\( I_t \) = Investment Expenditure in year \( t \)
\( M_t \) = Operation and Maintenance Expenditure in year \( t \)
\( F_t \) = Fuel Expenditure in year \( t \)
\( E_t \) = Energy generation in year \( t \)
\( r \) = Discount rate
\( n \) = Life of The System

The electricity generation cost will calculate with the Levelized Cost of Energy (LCOE) Calculator software from the Danish Energy Agency (DEA). The DEA LCOE Calculator is based on internationally acknowledged methodology and permits comparing different electricity production technologies and considering the socio-economic electricity production costs. This LCOE Calculator consists of an Excel-based model and manual discussing different aspects [13]. Furthermore, the power plant size in the alternative scenario also has to below West Sumatera’s potency of energy so that all the power plants in the scenario utilize its own resources.
4.2 The Scenario

The alternative electricity generation planning developed from the initial RUED generation planning by taking all fossil power plants out and add two new types of renewable energy, the tidal power plant, and the fuel cell power plant. Tidal power plant technology and fuel cell technology are believed will play a significant role in energy supply soon [14] [15]. Even though not described in the RUED, West Sumatera has a good potency of tidal energy since they have a long coastline and facing the Indian Ocean. Regarding the fuel cell power plant, the primary fuel source of this power plant is the hydrogen gas that available in every area on the earth, so this kind of power plant can be operated in West Sumatera Province as well. In the alternative generation planning, the other renewable energy power plant's share also increases but still below West Sumatera's potential. The large-hydro power plant is being the primary baseload supplier replacing the coal power plant function, and the micro-hydropower plant can be the peak load supplier replacing the gas turbine generator. The composition of the power plant in RUED's alternative scenario is shown below.

Table 7. Power plant capacity for each type in The RUED scenario in 2050 and the alternative RUED scenario in 2050

| Power Plant Type     | The RUED scenario in 2050 (MW) | The alternative generation planning in 2050 (MW) |
|----------------------|--------------------------------|-----------------------------------------------|
| Coal - steam PP      | 414.0                          | -                                             |
| Gas combustion PP    | 500.0                          | -                                             |
| Oil combustion PP    | -                              | -                                             |
| Diesel Gen PP        | -                              | -                                             |
| Large-hydro PP       | 1,100.0                        | 1,600                                         |
| Micro-hydro PP       | 800.0                          | 900                                           |
| Geothermal PP        | 950.0                          | 1,050                                         |
| Biomass PP           | 700.0                          | 800                                           |
| Solar PV PP          | 750.0                          | 1,000                                         |
| Wind Turbine PP      | 350.0                          | 350                                           |
| Tidal Current PP     | -                              | 250                                           |
| Fuel Cell PP         | -                              | 64                                            |
| **Total Power**      | **5,564.0**                    | **6,014.0**                                   |

4.3 Result

By using the capacity factor in Table 6, the annual electricity production in 2050 from the RUED scenario is 25.1 TWh, and annual electricity production in 2050 from the alternative generation planning RUED scenario is 25.2 TWh. While the RUED expects the electricity consumption in West Sumatera Province in 2050 is 25.1 TWh. The expected electricity consumption in 2050 will fulfill by the alternative generation planning RUED scenario. The Levelized Cost of Energy (LCOE) for each scenario is calculated by using the DEA LCOE calculator. The DEA LCOE calculator's database for coal power plants and gas combustion power plants use in this calculation. While, for the renewable energy power plant, The data of the cost of life cycle refer to several reports from IRENA [16,17], ADB [18] (ADB, n.d.), and Batelle [19]. The LCOE for The RUED scenario is Rp 1110.17 / kWh, and the alternative RUED scenario is Rp 983.15 /kWh with using Euro - Rupiah Exchange rate on 13 April 2020. Those LCOE values are a present value, as technology will going mature for renewable energy, the construction and operation cost might be decrease, and the LCOE will decrease too.
5. Conclusion and discussion
Renewable Energy Technology is a solution for available, affordable, and resilient sources of energy for energy security. Renewable energy sources are almost equally available in every country and region. Relying on our electrification only by renewable energy is not an impossibility. Many countries and region already pledge their commitment and construct some strategy to achieve that goal. In some countries, renewable energy technology is the majority source of electricity for an extended period.

West Sumatera Province also has a plan to maximize renewable energy share in its energy mix. In West Sumatera Province’s Regional Energy Plan (RUED), the local Government targeted 70.9% renewable energy share in its primary energy mix in 2050. The alternative scenario of power plant generation in West Sumatera base on the Regional Energy Plan Document for 2050 is shown in this paper. The share of renewable energy in the alternative scenario in 2050 is 100%. It means, West Sumatera Province can rely on their electricity need in green and sustainable renewable energy. The alternative energy planning we design meet the expected electricity consumption each year.

The Levelized Cost of energy for the alternative scenario cheaper than RUED scenario in present value. the RUED scenario in 2050, the LCOE is Rp 1110.17 / kWh, and for the alternative 2050 RUED scenario, the LCOE is Rp 983.15 /kWh. Those values indicate that the alternative scenario is economically viable. With the rapid development of renewable energy technology, West Sumatera can achieve 100% renewable energy electricity in 2050 and give reasonable energy security confidence. The designed alternative scenario still a preliminary design of renewable energy power plant deployment of an electricity system. It needs an advanced study to check the impact of the scenario on electricity conditions like grid impact study.

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