ENERGY SYSTEM DESIGN IN PACITAN REGENCY-EAST JAVA PROVINCE

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Abstract
Planning the construction of renewable energy plants in Pacitan district addresses the increasing electricity needs every year. Pacitan Regency is located on the coast with natural conditions in most of the mountains; there is a lot of renewable energy potentials such as water, wind and sunlight. Based on data from the central statistics agency of Pacitan district with the population increased by 0.18%/year. The energy system planning in this study allocates 70% of renewable energy generation and 30% of fossil plants by 2030.

1. Background
The primary energy used in Indonesia is still derived from fossil energy. Fossil energy is very limited in resources and takes a long time to recover, and the system for processing is not environmentally friendly (Syahputra & Soesanti, 2021) (Panjaitan & Abdur, 2020). So, if demand continues to increase and continues to be used, it can lead to scarcity. The increasing need to be met requires renewable and environmentally friendly energy (Surya et al., 2021) (Tambunan et al., 2020).

Indonesia is an archipelago island country, so each region has different potential resources (Syahputra & Soesanti, 2021) (Reyseliani & Purwanto, 2020). One of them is Pacitan Regency. Pacitan Regency is located in east java province. Pacitan was known as a tourism city or a city of a thousand caves; besides, Pacitan has renewable energy potential such as thermal and wind (Tumiran et al., 2021). It potential resources for fulfilled energy demands (Fikriyyah & Boedoyo, 2021). Furthermore, energy demand were grow speedy. Electricity needs in Pacitan still support coal power plant, while its growth demand have been increasing every year (Erdiwansyah et al., 2021).

2. Methodology
Preliminary Studies, Experiments, and Data Collection data required and collected are: From Secondary Data and seeing the potential in the area for constructing renewable energy power plants (Hariyadi, 2021).

A. Regional Profile
Pacitan Regency is located at the southwestern tip of East Java Province, directly boundary to Ponorogo Regency and Wonogiri Regency (Central Java Province) to the north, Indonesian Ocean to the south, Wonogiri Regency to the west, and Trenggalek Regency to the east. The area of Pacitan Regency is 1,389.87 km² with an average distance of 307.83 km in the area by the district. Most of the area is in hills, mountains, cliffs, and the Thousand Mountains that stretch along with Java. Administratively, Pacitan is divided into 12 districts. Tulakan regency is the largest area, 161.62 km² and Sudimoro District is the smallest area, 71.86 km². Astronomically, the Pacitan district is located between 7.55 ° -8.17 ° S and 110.55 ° - 111.25 ° east java. The average air temperature in 2019 was 32.5°C, and the average humidity was between 24.5%. While the rainfall this year reached 2,154 mm and solar radiation by 38.71 percent.

Figure 1. Map of Pacitan area

B. Population
The population of the Pacitan regency in 2018 amounted to 554,394 people, consisting of 270,708 men and
283,686 women. With an area of 1,389.87 km² each km² is inhabited by 399 people. At the same time, the population growth rate is 0.18%.

Table 1. Total population and population growth rate by the district in Pacitan, 2010, 2016, and 2017

| District       | Population (people) | Annual Population Growth Rate (%) |
|----------------|---------------------|----------------------------------|
|                | 2010                | 2016                | 2017                | 2010-2016 | 2016-2017 |
| 1              | 35,045              | 34,646              | 34,536              | -0.19     | -0.32     |
| 2              | 33,977              | 33,547              | 33,433              | -0.21     | -0.34     |
| 3              | 29,744              | 29,987              | 29,989              | 0.14      | 0.01      |
| 4              | 73,210              | 79,608              | 80,607              | 1.41      | 1.25      |
| 5              | 42,739              | 42,153              | 42,004              | -0.23     | -0.35     |
| 6              | 38,712              | 39,270              | 39,311              | 0.24      | 0.10      |
| 7              | 46,162              | 45,653              | 5,512               | -0.18     | -0.31     |
| 8              | 41,860              | 42,952              | 43,080              | 0.43      | 0.30      |
| 9              | 48,131              | 49,444              | 49,600              | 0.45      | 0.32      |
| 10             | 77,397              | 77,963              | 77,954              | 0.12      | -0.01     |
| 11             | 44,783              | 46,259              | 6,445               | 0.54      | 0.40      |
| 12             | 30,039              | 30,825              | 30,917              | 0.43      | 0.30      |
| Total          | 541,799             | 552,307             | 553,388             | 0.32      | 0.20      |

Source: Indonesia Population Projection 2010–2017

Table 2. Total population and population growth rate by the district in Pacitan district 2017–2018

| Description                  | 2017        | 2018         |
|------------------------------|-------------|--------------|
| Population (people)          | 270,192     | 279,708      |
| Men                          | 283,196     | 283,686      |
| Women                        | 553,388     | 554,394      |
| Total                        | 545,699     | 556,367      |
| Population density (Person/km²) | 398         | 399          |
| Population Growth Rate (%)   | 0.20        | 0.18         |
| Gender Ratio                 | 95.41       | 95.43        |
| Age Composition              |             |              |
| 0-14 Years Old               | 17,338      | 17,524       |
| 15-65 Years Old              | 69,863      | 70,520       |
| ≥ 65 Years                   | 66,187      | 66,350       |
| Dependency Free Number       | 49.62       | 49.63        |

Source: Indonesia Population Projection 2010–2017

Total population and population growth rate in Pacitan based on gender and age-prone grouping to project electrical energy needs. Comparison value of population growth with growth rate grouped by sub-district in Pacitan Regency.

Table 3. Total population and population growth rate by the district in Pacitan 2018-2019

| District       | Population (thousands) | Annual Population Growth Rate (%) |
|----------------|------------------------|----------------------------------|
|                | 2019                   | 2018-2019                         |
| 1              | 38.30                  | -0.29                             |
| 2              | 33.22                  | 0.04                              |
| 3              | 37.23                  | -0.90                             |
| 4              | 77.95                  | 1.08                              |
| 5              | 47.12                  | -0.33                             |
| 6              | 42.11                  | 0.50                              |
| 7              | 51.85                  | 1.02                              |
| 8              | 45.10                  | 1.30                              |
| 9              | 53.25                  | 1.03                              |
| 10             | 86.68                  | 0.32                              |
| 11             | 48.92                  | 0.40                              |
| 12             | 34.84                  | 1.27                              |
| Total          | 596.55                 | 0.51                              |
| Pacitan Regency | 555.30                 | 0.16                              |

Source: Pacitan Regency in Figures 2019

Table 4. Electricity profile of Pacitan Regency

| Description                  | Value     | Unit  | Statement                      |
|------------------------------|-----------|-------|--------------------------------|
| Electricity                  | 554,394   | Person| BPS and PLN                    |
| Electrificatio n Ratio       | 99.56     | %     | BPS 2019 (Pacitan in number)   |
| Resources                    | Pln       |       | BPS 2019 (Pacitan in number)   |
| Number of Electricity Sold   | 146,052   | Kwh   | BPS 2019 (Pacitan in number)   |
| 2017-2018                    | 228,710   |       |                                |
| kWh per capita               | 842.65    | Kwh/capita/year | Calculation of BPS and PLN data |
| Request                      | 16,000    | Kilowatt| Household                      |
| Customers in 2019            | 129,091   | Household| BPS and calculation |

C. Electricity Profile of Pacitan Regency

Electricity and power plant data in meeting electricity needs in Pacitan as a reference for carrying out energy planning scenarios.
Energy supply by 2030 can meet 100% of electricity needs. In that year, 70% of the supply came from two renewable energy resources, while 30% came from coal-fired power plants.

D. Estimating install renewable energy power plant:

The largest renewable energy power plant supply in 2025 installs of Pump power plant storage 1,000 MW in Pacitan Regency (following PLN RUPTL, 2017), while in 2050, the most significant renewable power plant provision will be develop of a solar power plant which is estimated at 5,000 MW. East Java has considerable solar potential (Riansyah, Septi & Chalid, Dony A., 2020). The river in Pacitan Regency is an alternative source of hydropower.

The river has located in the upper part of the Pacitan Regency and has many mountainous areas. Some of the government’s efforts have been building dams for various purposes such as rice irrigation, flood prevention, and tourism. Pacitan Regency has a Tikul dam built in the Arjosari area with a potential of 0.64 MWH/Year, Construction Implementation in 2013-2017.

Table 5. Potential of debit-based hydropower in Pacitan 2012

| Village   | District | Debit (l/s) |
|-----------|----------|-------------|
| Karang gede | Arjosari | 4200        |
| Sembowo   | Sudimoro | 2,000       |
| Bomo      | Punung   | 20,000      |

Table 6. Potential power plants that can be used in Pacitan 2012

| Village    | District | Potency (kW) |
|------------|----------|--------------|
| Karang gede| Arjosari | 50           |
| Sembowo    | Sudimoro | 15           |
| Bomo       | Punung   | 60           |
| Tinatar    | Punung   | 10           |
| Mlati      | Arjosari | 15           |
| Mlati      | Arjosari | 9            |
| Tinatar    | Punung   | 7            |
| Kebonsari  | Punung   | 11           |
| Tremas     | Arjosari | 6            |
| Karangrejo | Kebonagung| 9            |
| Jetis lor  | Nawangan | 1            |
| Karanganyar| Kebonagung| 1            |
| Gunungsari | Arjosari | 33           |
| Jetis kidul| Arjosari | 9            |
| Kebondalem | Tegalombo | 13           |

Source: Energy Planning East Java 2019-2050

Hydropower development with a total target of at least 412 MW by 2025 and PLT Pump Storage with a total target of at least 1,000 MW by 2025. The potential of solar for the development of solar power plants in Pacitan regency has the potential of renewable energy that is quite promising but not yet maximized for the benefit of the citizens. One of them is a solar power plant. Radiation Intensity in Pacitan is 4,300 Wh/m² [5], and the average air temperature is 32.5 °C. Solar Radiation is 38.71%.

If it can be appropriately used, this alternative energy source can be a solution to meet the energy needs in remote areas. The head of the Energy and Ground Water Office of the Pacitan Priharto Mining Office confirmed on Wednesday (22/6) that there are still 152 hamlets that have not been able to enjoy according to the current data electricity. The reason is due to geographical conditions.

Such as Panjing Village, Bandar Village, Bandar District, Ngemplak Hamlet, Sugihwaras Village, Pringkuku Subdistrict, and Wonosobo Village area, Ngadirojo Subdistrict. Installation costs will be more expensive when using power from the National power plant (PLN) of Indonesia. Infrastructure is needed than in any other area. In 2002, the government rolled out the solar power plant renewable energy program through central and provincial assistance.

However, many solar power plant devices currently do not work due to the high cost of maintenance. Of the 751 households that have used solar power plants, 20% are no longer used. Most of the damage is to electrical energy storage panels. In addition to outdated usage issues,
damage to the power device is estimated due to minimal maintenance. The battery will last between 3-4 years with a recorded maintenance record according to the life span. As an illustration, to buy an electrical device in a 12-volt battery, solar power plant users must pay between Rp 800-Rp 900.

That much value is certainly large enough for residents who live in remote areas and only make a living as farmers or laborers. Install waste to energy power plant and biomass fuel development with a total target capacity of at least 84 Megawatt. by 2025 for the whole of East Java. A micro-hydro power plant has been installed in Tokawi Village, Nawangan subdistrict with 18 kva and five kva. Install wind turbine power plant, Pacitan wind speed has considerable potential because it is located in coastal areas.

Table 7. Average air pressure, wind speed, and solar radiation on the year in Pacitan district 2016

| Months   | Air pressure | Wind Speed (km/h) | Solar Radiation |
|----------|--------------|-------------------|-----------------|
| January  | 33.65        | 36.87             | 33.80           |
| February | 34.26        | 25.27             | 33.60           |
| March    | 34.00        | 25.03             | 38.25           |
| April    | 34.15        | 23.70             | 40.95           |
| May      | 35.50        | 22.93             | 37.74           |
| June     | 35.00        | 12.16             | 32.62           |
| July     | 35.50        | 9.75              | 36.61           |
| August   | 35.00        | 13.86             | 38.46           |
| September| 35.00        | 16.71             | 36.98           |
| October  | 35.00        | 9.91              | 38.76           |
| November | 35.00        | 10.53             | 32.83           |
| December | 35.00        | 19.50             | 24.19           |

Source: Department of Highways and Irrigation

Wind potency to install power plant has capacity 89,600 Watt around south beach. The potential small-scale wind power plant can use a horizontal wind turbine model (Widiyanto et al., 2021).

Table 8. Data specific wind power plant development

| Wind speed | 30 km/h-35 km/h |
|------------|-----------------|
| Average Wind Speed | 9 m/s |
| Capacity Factor | 0.35 |
| Operating hours | 13 hours/day, 335 days/year |
| Power Rate | 50 KW |
| Cut wind speed | 3 m/s |
| Cut-out wind speed | 12 m/s |
| Diameter rotor | 18 m |
| Hub Height | 25 m |
| Wind grade | IEC IIA, IIIA |
| Wind power rate | 9.1 m/s |
| Number of turbines | Five turbines |

Source: Department of Highways and Irrigation

Cross section area \( A = \frac{1}{4} \pi d^2 = \frac{1}{4} \times 3.14 \times (9)^2 = 55.624 \) m². Power \( P = \frac{1}{2} \pi r D^3 = 1/2 \times 1.2 \times 254.34 \times 0.5 = 55,624 \) kW. Power = 55624 kW x 5 pieces = 278 MW Construction of wind turbine power plant with a total capacity target of at least 70 MW on 2025 and 300 MW on 2050.

Table 9. Geothermal potential

| Data                  | Value | Unit |
|-----------------------|-------|------|
| Tukul Dam (Arjosari)  | 0.64  | MWH  |
| Karanggede            | 50    | KW   |
| Sembowo               | 15    | KW   |
| Bomo                  | 60    | KW   |
| Tinatar               | 10    | KW   |
| Milati                | 15    | KW   |
| Milati                | 9     | KW   |
| Tinatar               | 7     | KW   |
| Kebosari              | 11    | KW   |
| Tremas                | 6     | KW   |
| Karangrejo            | 9     | KW   |
| Jetis Lor             | 1     | KW   |
| Karanganyar           | 1     | KW   |
| Gunungsi             | 33    | KW   |
| Jetis Kidul           | 9     | KW   |
| Kebondalem            | 13    | KW   |
| Total: 249            |       | KW→249+640=889 |
| Microhydro:           |       |      |
| Tokawi, Nawangan     | 23    | Kva→18.4 W |
| Total up to 412 MW   | 443.7 | KW   |
|                       | 5     | Kva→4 W |
|                       | 244.7 | KW   |
|                       | 0.688 | MW   |
| Wind                  | 89.600| Watt |
|                       | 5562x5| 278 MW |
| Solar                 | 4300  | Wh/m² |
| Geothermal            | 50    | MWe   |

Source: Energy Planning East Java 2019-2050

Result based on RUED, its scenario to meet 70%, EBT 30% power plant can be used hydropower and hydropower so that the construction of hydropower with a total target of at least 412 MW in 2025 and Pump Storage with a total target of at least 1000 MW by 2025. Construction of wind turbine power plant with a total capacity target of at least 70 Megawatt in 2025 and 300 megawatts in 2050.

E. Projected energy fulfillment until 2030

Design an energy system that can supply 100% of the region’s electricity needs by 2030. In that year, 70% of the supply came from two renewable energy resources, while 0% from coal power plants. Estimate the investment cost of renewable energy-based power plants. Pacitan have a steam power plant existing that an installed capacity of 2 x 315 MW, a power capable of 560 MW that supplies other areas
Pattern population growth was calculated:

$$P_t = P_0 (1 + r)^t$$  \hspace{1cm} (1)

Based on above,

$$r = \left( \frac{P_t}{P_0} \right)^{\frac{1}{t}} - 1$$  \hspace{1cm} (2)

So $P_t$ is total population in year $t$, $P_0$ is first year population, $r$ is population growth rate, $t$ is period time.

Table 10. The formula obtained population projection

| No | Year | Total People |
|----|------|--------------|
| 1  | 2016 | 552,307      |
| 2  | 2017 | 553,388      |
| 3  | 2018 | 554,394      |
| 4  | 2019 | 555,300      |
| 5  | 2020 | 556,301      |
| 6  | 2021 | 557,304      |
| 7  | 2022 | 558,309      |
| 8  | 2023 | 559,315      |
| 9  | 2024 | 560,342      |
| 10 | 2025 | 561,334      |
| 11 | 2026 | 562,346      |
| 12 | 2027 | 563,360      |
| 13 | 2028 | 564,376      |
| 14 | 2029 | 565,394      |
| 15 | 2030 | 566,413      |

Calculated household consumption

$$Total\ household = PRT_{-1} \left( 1 + CFH \frac{9E}{100} \right)$$  \hspace{1cm} (3)

So, $PRT_{-1}$ is household first growth in the year, $CFH$ is coeffisien factor household.

$$Energy = C_f \cdot Power \cdot .8760$$  \hspace{1cm} (4)

Where, $C_f$ for Coal, Wind and Solar power plant is 0.7 –0.8, 0.3-0.35 and 0.3.

3. Results & Discussions

Projection electricity based on data for the calculation power plant, which is shown below:

Comparison electricity Projection for 70% renewable energy power plant and 30% coal power plant. The power plant will estimate a decrease in reductions $CO_2$ emissions as a result of the system by 2030 compared to conditions if this area is 100% supplied by renewable energy. Emission Factors for Power Plants= 955 g/kwh. The survey shows that more than 80% of Pacitan experienced a turn-off power outage that lasted an average of 5.8 hours per outage, with the number of outages reaching 5.6 times per year.
In comparison, electricity is the driving force of Indonesia’s economic growth and one way to double the amount of GDP per capita to 5,500 US dollars in 2019. It needs to increase its electricity capacity. Moreover, capacity needs to be improved because Indonesia is currently faced with the reality of growing electricity needs. The acceleration of the electricity capacity increase cannot offset the rise. Furthermore, this can start from the district if each region is committed to harnessing the potential of renewable energy that will help the government install independence in terms of power.

In 2030, the population of Pacitan district will reach 566,413 people, with energy consumption in 2030 of 843.85 kWh/capita. The demand required in the population by 2030 is 187,613 MWh. Based on energy savings from the economic side affected by the utilization of new and renewable energy resources, it is necessary to calculate operating costs. It is assumed that operating costs are created simultaneously, and analysis is limited to fuel costs for two scenarios: Mix energy 70% + 30% steam from steam power plant 100%.

| Power plant | Total fulfillment energy demand | kWh |
|-------------|---------------------------------|-----|
| Steam       | 100%                            | 187,613.150 |

Scenario Table 12 steam power plant 30%, mix (wind + hydro) 70%.

| Energi Mix | Total fulfillment energy demand | kWh |
|-----------|---------------------------------|-----|
| Steam     | 30%                             | 56,283.945 |
| Wind      | 35%                             | 65,664.602 |
| Hydro     | 35%                             | 65,664.602 |
| Total     |                                 | 187,613.150 |

Mix energy scenario are above give more reducing the use of power plants from 100% to 30% can reduce CO₂ emissions to 125,419,390,667 Tons.

| No | Year | People (total) | Customer | Energy (MWh) | Demand (MW) |
|----|------|---------------|----------|--------------|-------------|
| 1  | 2016 | 552.307       | 111.259  | 93.752       | 13          |
| 2  | 2017 | 553.388       | 116.911  | 98.515       | 14          |
| 3  | 2018 | 554.394       | 122.850  | 103.520      | 15          |
| 4  | 2019 | 555.300       | 129.091  | 108.778      | 15          |
| 5  | 2020 | 556.301       | 135.649  | 114.304      | 16          |
| 6  | 2021 | 557.304       | 142.540  | 120.111      | 17          |
| 7  | 2022 | 558.309       | 149.781  | 126.213      | 18          |
| 8  | 2023 | 559.315       | 157.389  | 132.624      | 19          |
| 9  | 2024 | 560.342       | 165.385  | 139.362      | 20          |
| 10 | 2025 | 561.334       | 173.786  | 146.441      | 21          |
| 11 | 2026 | 562.346       | 182.615  | 153.880      | 22          |
| 12 | 2027 | 563.360       | 191.892  | 161.697      | 23          |
| 13 | 2028 | 564.376       | 201.640  | 169.912      | 24          |
| 14 | 2029 | 565.394       | 211.883  | 178.543      | 25          |
| 15 | 2030 | 566.413       | 222.647  | 187.613      | 27          |

4. Conclusion

Energy planning in Pacitan with population growth increasing every year. Energy potential mapping includes micro-hydro, solar, wind, and biomass. Steam power plants still supply the fulfillment of energy in Pacitan for now. Energy planning scenarios include 100% steam power plants, 30% steam power plants with 70% renewable energy in 2030. Pump storage and wind power plants are the mainstay of renewable energy generation; on the other hand, solar power plants have an essential role in developing renewable energy. The largest consumption in the household sector from the simulation results is a decrease in the impact of emissions.

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