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.

Projected availability of steam power plants with installed capacity of 2 x 315 MW, power capable of 560 MW. The distribution of renewable energy power plants is spread in the Pacitan area with hydroelectric power plants with a total target of at least 412 MW by 2025 and Pump Storage power plants with a total target of at least 1000 MW by 2025. Solar power plants have the potential of intensity radiation 4300 Wh/m2; the average air temperature is 32.5 0C and Solar Radiation 38.71%. Electricity generation waste power with a total target capacity of at least 84 MW. Wind potential with an average speed of 9 m/s. By 2030, the population of Pacitan district will reach 566,413 people, with an energy consumption of 843.85 kWh/capita; the demand required is 187,613 Mwh. By reducing the use of power plants from 100% to 30% can reduce CO^2 emissions to 125,419,390,667 Tons.

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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 & Abduh, 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, 2021). 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 speedly. 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 $km^{2,}$ 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 $km^{2,}$ and Sudimoro District is the smallest area, 71.86 $km^{2.}$ 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.

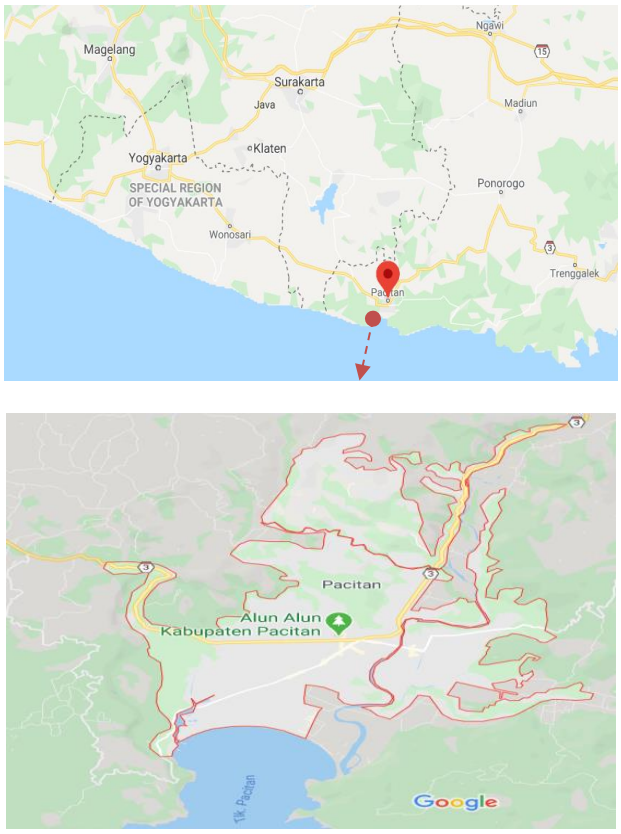

Figure 1. Map of Pacitan area

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 $km^{2,}$ each km^2 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

Population growth rate by sub-district in Pacitan, 2010, 2016, and 2017						
District		***Population (people)***			***Annual Population Growth Rate* (%)**	
		2010	**2016**	**2017**	**2010-2016**	**2016-2017**
1		2	3	4	5	6
1	Donorojo	35,045	34,646	34,536	- 0.19	- 0.32
2	Punung	33,977	33,547	33,433	- 0.21	- 0.34
3	Pringkuku	29,744	29,987	29,989	0.14	0.01
4	Pacitan	73,210	79,608	80,607	1.41	1.25
5	Kebon agung	42,739	42,153	42,004	- 0.23	- 0.35
6	Arjosari	38,712	39,270	39,311	0.24	0.10
7	Nawangan	46,162	45,653	5,512	- 0.18	- 0.31
8	Pacitan	41,860	42,952	43,080	0.43	0.30
9	Tegalombo	48,131	49,444	49,600	0.45	0.32
10	Tulakan	77,397	77,963	77,954	0.12	- 0.01
11	Ngadirojo	44,783	46,259	6,445	0.54	0.40
12	Sudimoro	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 2010–2035						

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

Description	**2017**	**2018**
Population (people) Men Women Total	 270,192 283,196 553,388	 279,708 283,686 554,394
Population density (Person/$km^{2)}$	398	399
Population Growth Rate (%)	0.20	0.18
Gender Ratio	95.41	95.43
Age Composition 0-14 Years Old 15-65 Years Old ≥ 65 Years	 17,338 69,863 66,187	 17,524 70,520 66,350
Dependency Free Number	49.62	49.63
Source: Indonesia Population Projection 2010–2035		

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		2	3
1	Donorojo	38.30	-0.29
2	Punung	33.22	0.04
3	Pringkuku	37.23	-0.90
4	Pacitan	77.95	1.08
5	Kebonagung	47.12	-0.33
6	Arjosari	42.11	0.50
7	Nawangan	51.85	1.02
8	Pacitan ciity	45.10	1.30
9	Tegalombo	53.25	1.03
10	Tulakan	86.68	0.32
11	Ngadirojo	48.92	0.40
12	Sudimoro	34.84	1.27
Pacitan Regency Register Results Projection Results		 596.55 555.30	 0.51 0.16
Source: Pacitan Regency in Figures 2019			

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

Table 4. Electricity profile of Pacitan Regency

Description	**Value**	**Unit**	**Statement**
Electricity	554,394	Person	BPS and PLN
Electrification Ratio	99.56	%	BPS 2019 (Pacitan in number)
Resources	Pln		BPS 2019 (Pacitan in number)
Number of Electricity Sold 2017-2018	146.052.228 138.238.710	Kwh Kwh	BPS 2019 (Pacitan in number)
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 calculations

Electricity Growth per year	8.39	%	BPS and PLN
Load factor	83.29	%	Load factor East Java - PLN
Installed Power			
- Steam Power Supply	120	Mw	Year 2019
Total Generating Capacity		Mw	
- Wind power Capacity	206	MW	Customized Local Regulations
- Hydropower capacity	70	Mw	Request
Total CO_2 emissions			
- Steam power emissions	179,170,558	Ton / Year	Year 2030
- Emissions Mix	5,5622,608.6	Ton / Year	Year 2030

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 Tukul 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	20000
Tinatar	Punung	80
Mlati	Arjosaro	220
Source: Energy Planning East Java 2019- 2050		

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 1000 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/m^2 [5], and the average air temperature is 32.5 ^{0}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	:	9m/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) = $\frac{1}{4}$ π d^2 = $\frac{1}{4}$* 3.14 * (18) 2 = 254.34 m^2. Power =$\frac{1}{2}$. r. π. D^3 = 1/2 * 1.2 *254.34 * (9)3 * 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
-Mlati	15	KW
-Mlati	9	KW
-Tinatar	7	KW
-Kebosari	11	KW
-Tremas	6	KW
-Karangrejo	9	KW
-Jetis Lor	1	KW
-Karanganyar	1	KW
-Gunungsari	33	KW
-Jetis Kidul	9	KW
-Kebondalem	13	KW
Total:	249	KW→249+640=889
Microhydro:		
- Tokawi, Nawangan	23	Kva→18,4 W
	443,7	KW
Total up to 412 MW	5	Kva→4 W
	244,7	KW
	0,688	MW
Wind	89.600	Watt
	5562x5	278 MW
Solar	4300	Wh/m^2
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

(Dewayana et al., 2011). Pattern population growth was calculated:

$$P_t = P_0 (1 + r)^r \quad (1)$$

Based on above,

$$r = \left(\frac{p_t}{p_0}\right)^{\frac{1}{t}} - 1 \quad (2)$$

So P_t is total population in year t , P_0 is first year population, r is population growt rate, t is periode 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

$$Total\ household = PRT_{-1}\left(1 + CFH \cdot \frac{g_E}{100}\right) \quad (3)$$

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

$$Energy = C_f . Power . 8760 \quad (4)$$

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:

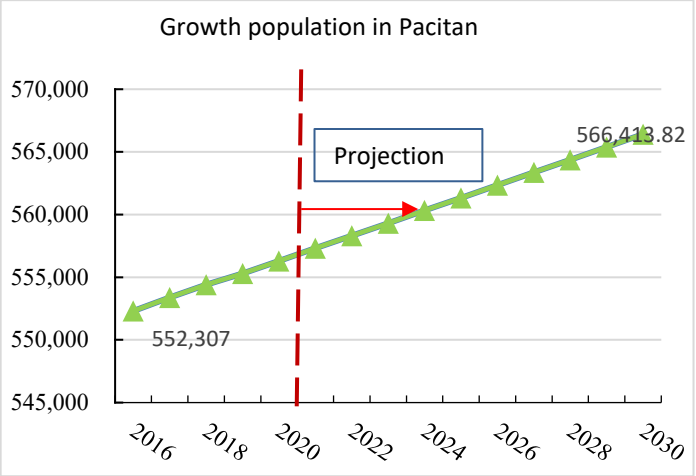

Figure 2. Projection of population growth in Pacitan regency

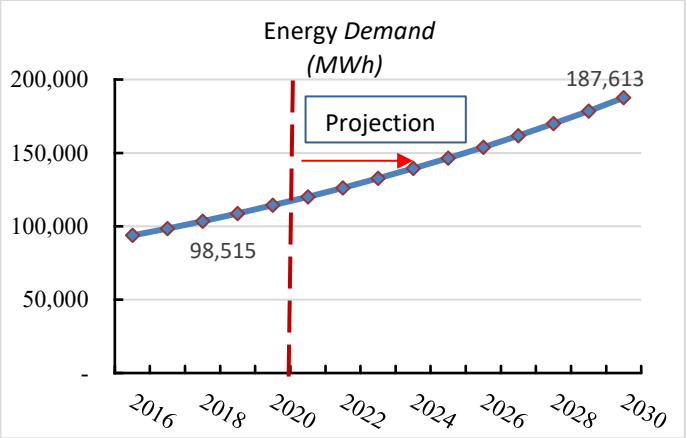

Figure 3. Projection energy demand

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.

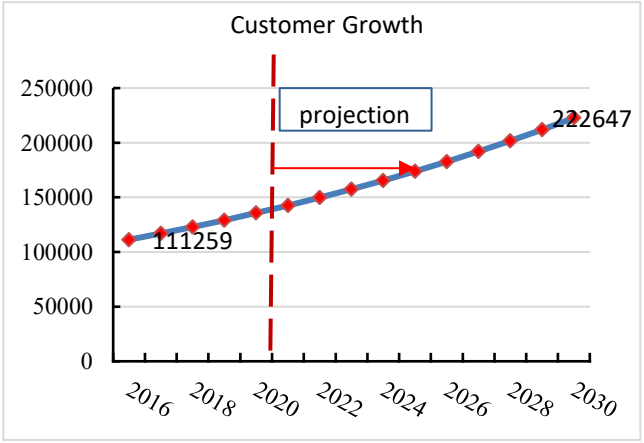

Figure 4. Total customers growth

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%.

Table 11. Scenario 1 coal power plant 100 % capacity (without renewable energy)

Power plant	Total fulfillment energy demand		
Steam	100%	187.613.150	kWh

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

Table 12. Efficiency mix energy

Energi Mix	Total fulfillment energy demand		
Steam	30%	56.283.945	kWh
Wind	35%	65.664.602	kWh
Hydro	35%	65.664.602	kWh
	Total	187.613.150	kWh

Mix energy scenario are above give more reducing the use of power plants from 100% to 30% can reduce CO_2 emissions to 125,419,390,667 Tons.

Table 13. Calculated household electricity growth

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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