TECHNO-ECONOMIC ANALYSIS OF THE POTENTIAL FOR HYBRID POWER PLANT IN GUNUNG SEWU GEOPARK, PACITAN REGENCY

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Abstract

Gunung Sewu has been designated as a Global Geopark Area by The United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2015. In the preparation of the Gunung Sewu Masterplan as a UNESCO Global Geopark (UGGp), the provision of environmentally friendly and sustainable electricity is one of the strategies to utilize the renewable energy. The application of Hybrid Power Plants (HPP) that utilize wind and solar energy in the industrial and tourism sectors can have a positive impact on regional income where economic growth is one of the strategic issues of Pacitan Regency.

The average wind speed in Pacitan is 3.41 m/s and the average solar radiation reaches 5.69 kWh/m^2/day so that it can be said that the potential for solar and wind energy in the Gunung Sewu Pacitan Geopark is reliable and feasible to be used as an environmentally friendly energy source. The simulation of HPP that will be implemented at Buyutan Beach illustrates that the system could produce an output of 7,519 kWh/yr. This result is able to meet the annual demand of 4,107 kWh/yr and even exceed the annual requirement.

The economic analysis of the simulated HPP system produces a negative Net Present Value (NPV). This could be due to the large value of Operational Expenditure (OpEx) and Capital Expenditure (CapEx) and the low purchase price (National Electricity Company's feed in tariff). However, this research also proposes a scenario so that the HPP system can still be applied by dividing the cost components contained in the budget plan into two parts. In the proposal obtained cash inflows of Rp. 8,640,834.80/year and a positive or feasible NPV.

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1. Introduction

World heritage includes cultural and natural heritage which are valuable assets for all human beings, have a major role in science, history and culture. Currently, geopark is the best concept that can integrate all natural resources around areas that have unique geology with the aim of protecting and improving the welfare of the surrounding community by prioritizing the concept of sustainable spatial management and development that combines biodiversity, geodiversity and cultural-diversity.

Based on the Decree of the Minister of Energy and Mineral Resources No. 3045 K/40/MEM/2014, Gunung Sewu has been designated as a Global Geopark Area by The United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2015 and stretches for 85 km in three different administrative areas, ranging from Gunung Kidul Regency (Yogyakarta Province), Wonogiri Regency (Central Java Province) and Pacitan Regency (East Java Province). Pacitan is one of the regencies in East Java Province which is located on the south coast of Java Island with an area of 1,389.87 km^2 and has a population growth rate of 0.51% (in 2018 – 2019) (BPS, 2021).

In the Geopark Area, there are locations designated as protected areas or commonly referred to geosites, and their distribution locations in the Gunung Sewu Pacitan Geopark Area can be seen in Figure 1:

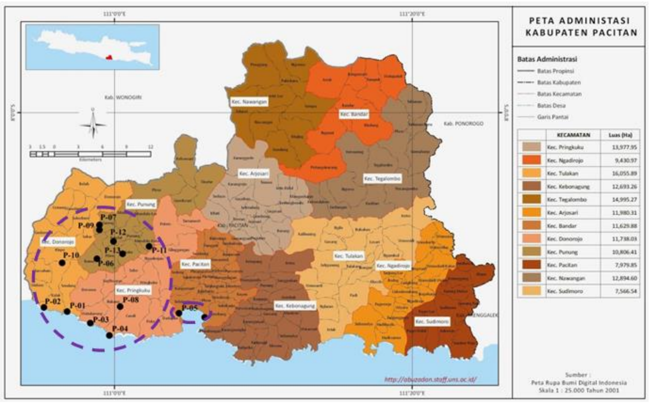

Figure 1. Geosite Delineation of the Gunung Sewu Pacitan Geopark Area in Pacitan Regency

The geosites are included in the National Tourism Strategic Area which is expected to be a lever for regional economic development in Pacitan Regency. However, with the mountainous, remote, and the relatively far distance between houses, a high investment cost is required to attract the electricity network in these locations so that infrastructure development in order to achieve regional economic improvement in this area needs to be a concern.

The application of Hybrid Power Plants (HPP) that utilizes wind energy and solar energy in the industrial and tourism sectors in the Gunung Sewu Geopark Area of Pacitan can have a positive impact on regional income, where economic growth is one of the strategic issues of Pacitan Regency, as stated in the Pacitan Regency Spatial Plan (2022 – 2042). Generally, the implementation of HPP in the region is also in line with one of the points in the Sustainable Development Goals (SDGs) agenda, namely clean and affordable energy. This research will analyze how the utilization of power plants using solar and wind energy in the Pacitan Geopark Area is reviewed from a technical and economic point of view.

2. Methodology

a. Data Collection

The research uses primary and secondary data as shown in Table 1. Primary data was taken at Buyutan Beach with coordinates 8°13'12"S - 110°55'15"E which is one of the geosites in the Gunung Sewu Pacitan Geopark Area. While secondary data such as wind speed, HPP system specifications, data ion regional spatial planning are taken from government institutions, product manufacturers, literature studies and others related to research.

Table 1. Data Used In Research

No.	Data	Data Source
1	Wind Speed	Pacitan Air Force Detachment
2	Sunlight Intensity	Meteonorm Software
3	Number of Geosite Tourist Visits	Tourism, Youth and Sports Department of Pacitan Regency
4	Electricity Demand Load	Residents around the geosite point
5	Data on Regional Spatial Planning, Map of Protected Rice Fields	Regional Development Planning Agency of Pacitan Regency
6	HPP's Component Specification, HPP's Operational&Maintenance	WindStream Energy Technologies India Pvt Ltd., Literature Study
7	Economic Scenario	Bank Indonesia, National Electricity Company, Literature Study

The research flow is mainly described through the flowchart as seen on Figure 2:

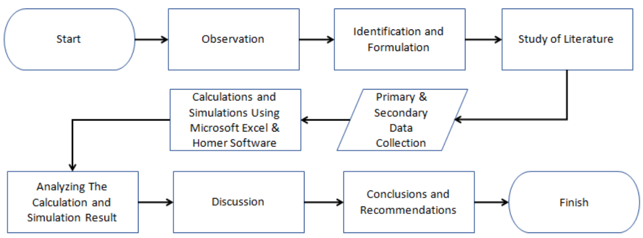

Figure 2. Research Flowchart

b. Calculation and analysis of the potential application of HPP

The first step to start the calculation and analyze the HPP system which can be applied to the Geopark Area, is determining a point in the Gunung Sewu Pacitan Geopark Area then followed by calculating how much electricity demand load is needed. Determination of the location is determined from the analysis obtained from the data on the number of geosite tourist visits.

Microsoft Excel and HOMER software are used as tools to calculate and analyze the production simulation of the HPP system output and how much HPP is effective to be implemented on site, according to the required load.

c. Economic Feasibility

One of the considerations for implementing a system is economic feasibility. Before the feasibility study is carried out, the aspects that will specify the system investment need to be calculated to determine whether the investment is feasible or not. Many economic approaches are available to analyze the economic feasibility, one of those is the Net Present Value (NPV) approach. The NPV method is an economic method that is used as an evaluation and indicator of how worthy the investment value of a project is. NPV is equalizing technique between the discounted cash flows with the initial investment (Kerzner, 2009).

$$NPV = \sum_{t=1}^{n}\left[\frac{FV_t}{(1+k)^t}\right] - II$$

NPV = Net Present Value
FV_t = Future value at t year
n = Number of periods
k = Discount rate
II = Initial Investment
t = Year period

3. Results& Discussion

a. Potency and Output Power of Wind and Solar Energy in the Gunung Sewu Pacitan Geopark Area

Based on data from the Indonesian Air Force Detachment – Pacitan, the average wind speed for a period of 10 years (2012 – 2021) can be seen in Table 2:

Table 2. Wind Speed in Pacitan Regency in 2012 – 2021

Month	Wind Speed (m/s)	Temperature (°C)
January	3.20	26.80
February	2.93	26.90
March	3.07	26.90
April	3.04	27.20
Mei	3.24	26.80
June	3.28	26.10
July	3.59	25.10
August	3.83	25.00
September	4.06	25.50
October	3.90	26.50
November	3.50	27.10
December	3.26	27.10
Average	3.41	26.40

Meanwhile, the solar radiation data taken from the Meteonorm Software is shown in Table 3 below:

Table 3. Pacitan Regency Solar Radiation in 2021

Month	Solar Radiation (kWh/m^2/day)	Temperature (°C)
January	5.40	26.00
February	5.17	25.90
March	5.80	26.30
April	5.73	26.80
Mei	5.40	27.00
June	5.17	26.40
July	5.47	26.00
August	5.87	25.90
September	5.93	26.50
October	6.53	27.20
November	5.70	27.00
December	6.13	26.30
Average	5.69	24.77

By assuming that wind speed and solar radiation are the same throughout the Geopark Area, it can be seen that these data can be applied to HPP with a combination of Vertical Axis Wind Turbine (VAWT) Savonius type and solar cells. The Savonius VAWT can produce electrical power if the turbine rotates due to wind gusts with a minimum speed of 2 m/s. From Table 2, the lowest wind speed occurred in February, which was 2.93 m/s, which indicates that the wind speed in the Gunung Sewu Pacitan Geopark Area can be used to generate electricity, of course, by choosing the right type of wind turbine.

Based on the Ministry of Research and Technology of the Republic of Indonesia (2006), the estimated average solar radiation in Indonesia is 4.8 kWh/m2/day. Table 3 shows that solar radiation in the Gunung Sewu Pacitan Geopark area is in the range of 5.17 – 6.53 kWh/m^2/day, which is higher than the average forecast for solar radiation in Indonesia. The amount of solar radiation will affect the output power of solar cells, therefore the application of solar cells by utilizing the potential of solar energy in the area can be relied upon to help increase electrification in Pacitan Regency.

b. Potential Application of HPP in the Gunung Sewu Pacitan Geopark Area

According to data taken from the Tourism, Youth and Sports Department of Pacitan Regency, the number of tourist visits throughout 2021 reached 309,000 people. The contribution of visitors to each geosite is shown in Figure 3 below:

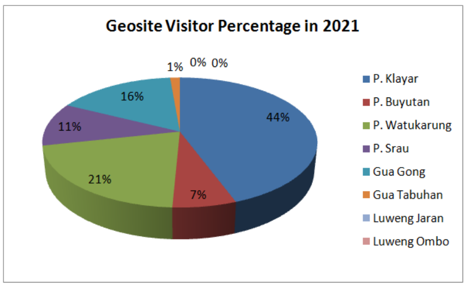

Figure 3. Visitor Contribution of Several Geosites in the Gunung Sewu Pacitan Geopark Area in 2021

Unlike other geosites whose management has been managed by The State, the management of Buyutan Beach is still operated by the local community tourism awareness group which is fostered by the Regional Government through the Tourism, Youth and Sports Department. With a contribution of 7% of the total number of visitors in 2021 and management that is still independent, making Buyutan Beach feasible to be chosen as the location for the implementation of HPP. Buyutan Beach has facilities which are divided into two areas, namely the upper area and the lower area with details as shown in Table 4.

Table 4. Facilities at Buyutan Beach (July 2022)

Facility	Area	Number (location)
Lodging	Lower	1
Kiosk	Upper	6
	Lower	43
Toilet	Upper	2
	Lower	8
Prayer Room	Upper	2
	Lower	6
Parking Area	Upper	1
	Lower	2

From of all the existing facilities, lodging is the only facility that has been electrified, while the others have not. The electricity requirement for lodging is 4,107 kWh/yr, not including the need for kiosks or other facilities that generally require electricity such as charging devices, refrigerators, lights and plans for the development of various tourist areas such as the construction of glamp camps and other facilities. Thus, the electricity demand in the Buyutan Beach area certainly exceeds this value.

The simulation using the SolarMill SM2-6P HPP system in the input process is divided into two parts, that are solar cells and wind turbines. HPP type SM2-6P is shown in Figure 4.

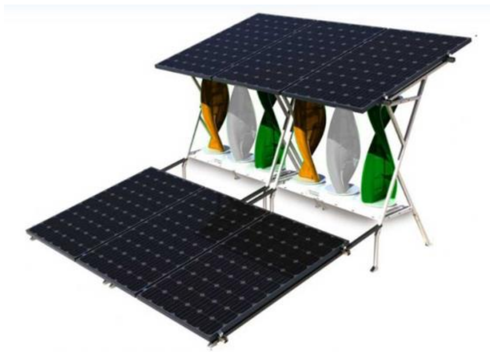

Figure 4. SolarMill SM2-6P PLTH System

The architectural scheme of the HPP system is installed off-grid or not connected to the National Electric Company's network, therefore battery and inverter components are added to the system. Quoting from Mousavi, S.A., et all., (2021), the technical and economic characteristics of the Leonics inverter type S-219Cp 5kW and Surette battery type 4 KS 25P are informed in Table 5.

Table 5. Technical and Economic Characteristics of Components Used in Simulation

Component	Type	Capital Cost ($)	Replacement Cost ($)	O&M Cost ($)	Life Time
Battery	Surette 4KS 25P	1,259	1,100	10/yr	12 yr
Inverter	Generic (Leonics S-219Cp 5kW)	600	600	10/yr	10 yr

By using Homer Software, the scheme of the HPP system designed and the load of electricity needs in the Buyutan Beach area are shown in Figures 5 (a) and (b):

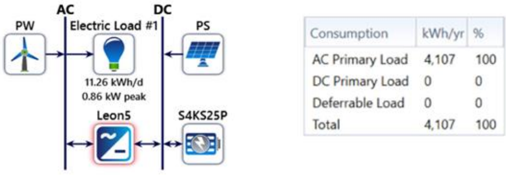

Figure 5. (a) Schematic of HPP System Design;
(b) Electricity Demand for Buyutan Beach

The output simulation of electricity from each power plant and total output throughout the year is shown in Figure 6:

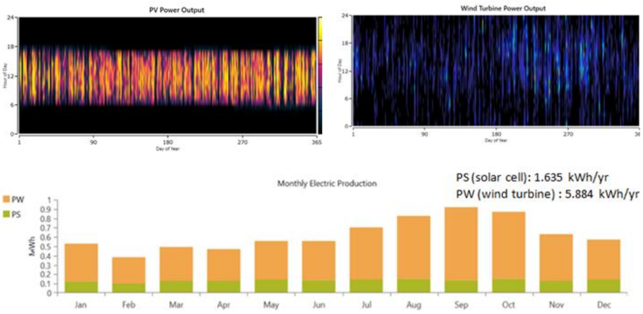

Figure 6. Output Simulation

From the simulations obtained, the total HPP system are capable of generating electrical power of 7,519 kWh/yr. This result meets the annual electricity demand in the Buyutan Beach area which is 4,107 kWh/yr. To produce an electric power of 7,519 kWh/yr, the number of components used in the system is shown in Table 6.

Tabel 6. Number of Components Used in the PLTH System

Component	Total Units
HPP SolarMill tipe SM2-6P	5
Inverter Leonics tipe S-219Cp 5kW	1
Battery Surrette tipe 4 KS 25P	10

Referring to the Pacitan Regency Spatial Plan 2009 – 2028 : Pacitan Regency Spatial Pattern Plan, the majority of spatial patterns in Geopark Area are still planned as reserve land, then followed by as land for agriculture and as residential areas. Most of the land in the area has a slope of more than 40% and is used as community forest. The Buyutan Beach area also has areas that are designated as reserve land and agricultural land so that the application of HPP should follow the spatial pattern that has been planned. The lands that are designated as agricultural land or often referred to Map of Protected Rice Fields in the Buyutan Beach area as shown in Figure 7.

Figure 7. Protected Rice Fields in Buyutan Beach Area

By adjusting the Protected Rice Fields's Map of the Buyutan Beach area, the proposed location for the implementation of the HPP system that has been calculated is illustrated as shown in Figure 8.

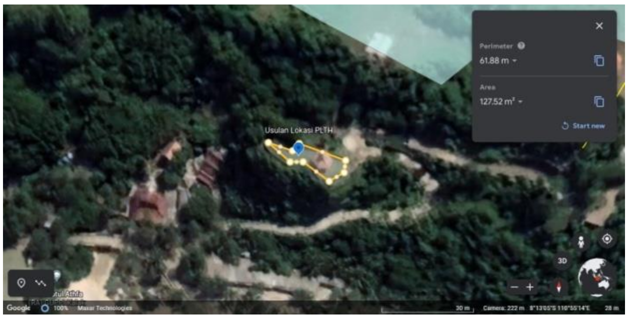

Figure 8. Proposed HPP Implementation Area

c. Economic Feasibility Analysis Using NPV

The implementation of the HPP system that has been simulated and calculated needs to be reviewed for its economic aspects. This is necessary so that policy makers can assess whether this application is feasible or not, one of the method is by using NPV. The calculation starts from calculating all the components involved in planning the implementation of the HPP system, such as start-up costs, engineering consultant fees, environmental consultant fees, licensing fees, equipment investment costs to all the equipment which will be used on the installation (initial investment), then jump into the calculation of the purchase price of electricity output from HPP as cash inflow that will be obtained and the last is calculating the NPV. Calculation of initial investment is stated in the form of an estimate of the Budget Plan as seen on Table 7.

Table 7. Budget Plan Forecast

Description	Price (Rp.)
Start Up Cost	585,005,748
Engineering Consultant Fee	304,800,000
Environment Consultant Fee	139,400,000
Direct Non-Personnel Costs	103,318,750
Land Rental Cost	0
HPP Cost (5 units)	309,602,625
Battery Cost (10 unit)	77,998,332
Inverter Cost (1 unit)	24,423,000
Operation & Maintenance (OM) Cost	4,120,420
Equipments Cost	18,020,000
Total Budget Plan Forecast	1,566,706,875

Based on Presidential Regulation No. 112 of 2022 concerning the Acceleration of Renewable Energy Development for Electricity Supply, the purchase price of electricity (feed in tariff) from solar and wind power plants is obtained as shown in Table 8.

Table 8. Electricity Purchase Price From Power Plants

	Year 1 – 10	Year 6 – 30
Purchase Price From Solar Power Plant (cent USD/ kWh)	9.94 x F	5.97
Purchase Price From Wind Turbine Power Plants (cent USD/ kWh)	10.26 x F	6.15

The location factor number (F) for the Java, Madura, Bali (Jamali) area has been set in the Presidential Regulation of 1.00. As the result, cash inflows for the HPP system are obtained as shown in Table 9.

Table 9. Cash Inflows Forecast

	Year 1 - 10	Year 6 – 30	
Cash Inflows From Solar Power Plants	16,252	9,760.95	cent USD/ kWh
Cash Inflows From Wind Turbine Power Plants	60,370	36,186.60	cent USD/ kWh
Total	76,662	45,947.55	cent USD/ kWh
	12,259,478	7,351,608	Rp./kWh

By using the reference interest rate from Bank Indonesia of 4.75% (Bank Indonesia, 2022) and a period of 25 years as the lifetime of the HPP system, the NPV is obtained as shown in Table 10.

Table 10. NPV Calculation

Present Value of Cash Inflows (Rp.)	:	144,621,571.45
Initial Investment (Rp.)	:	1,566,706,875.00
NPV (Rp.)	:	(1,422,085,303.12)

From these calculations, a negative NPV value was obtained. Some of the contributing factors are the size of Operational Expenditure (OpEx) such as employee wages, the amount of Capital Expenditure (CapEx) such as the cost of HPP system and the low feed in tariff.

Indeed, electricity does not only provide lighting, but also opens civilization and encourages economic development. For this reason, in order to improve the quality of people's lives so that they become better, easier and more prosperous, electricity must be enjoyed by all Indonesians wherever they are, that is equitable energy. The requirements for the realization of equitable energy are that electricity must be available, its supply must be sufficient, its distribution must reach all regions and the tariff is affordable by all levels of society. When the economic perspective shows improper calculation, then we should look for the other side so that energy justice could be realized.

The proposed scenario for the implementation of a power plant, especially in the Buyutan Beach area which has enormous potential, is to adapt the Community-Based Drinking Water and Sanitation Provision Program which has succeeded in increasing the availability of drinking water and water facilities for proper sanitation needs for 12,000 villages spread over 32 provinces (at the time) in Indonesia. This program has helped at least 10.4 million people to get clean water facilities and improve public health levels by getting access to proper sanitation.

As the Village Owned Enterprises and community groups can form separate divisions for electricity management. With a huge initial investment value as described in Table 7, the funding for the implementation needs to be divided into two parts where the first part is regarding consultant fees, purchase of equipment and installation costs submitted to The State in accordance with the Minister of Energy and Mineral Resources Regulation Number 12 of 2018. Meanwhile, the second part is that the OM costs are handed over to the village party, for example by using village funds or Village Owned Enterprises's profit. Apart from the cost of OM, the village is also in charge of carrying out its OM activities, so as in the description shown in Table 11 below, the OM cost component needs to be added to the cost of the technician assigned to carry out the daily activities of OM, or it can be said to be an estimate of the budget plan (initial investment) for the village.

Table 11. Budget Plan Forecast for Proposed Scenario

Description	Price (Rp.)
Operation & Maintenance Cost	4,120,420
Man Power Fee	105,011,496
Total of Budget Plan Forecast	109,131,915

Assuming that the system can only be absorbed by local residents by 85% of the total production capacity of the HPP system and by using the Basic Electricity Tariff on October – December 2022 (basic electricity tariff for the class (R-1/TR) limit power 900 VA, regular and prepaid usage fees is Rp. 1,352/kWh). Thus, cash inflows from electricity production are 6,391 kWh (85% of 7,519 kWh) which if the electricity is purchased by the local community, the amount obtained is Rp. 8,640,834.80/year. The calculation of NPV in this proposed scenario is shown in Table 12.

Table 12. NPV Calculation for Proposed Scenario

Present Value of Cash Inflows (Rp.)	:	124,894,400.60
Initial Investment (Rp.)	:	109,131,915.57
NPV (Rp.)	:	15,762,485.03

With this scenario, a positive NPV is obtained or is feasible to apply. However, one of the challenges in this proposed scenario is the transfer of technology. Therefore, the transfer of technology must be given to the village as a whole with good supervision so that the program can be useful, accountable and sustainable.

4. Conclusion

Some essential points that can be drawn from this research are:

1. The PLTH design simulation that will be implemented at Buyutan Beach uses 5 units of PLTH Solarmill type SM2-6P, 1 unit of Inverter Leonics type S-219Cp 5kW and 10 units of Battery Surrette type 4 KS 25P by following the spatial pattern contained in the Pacitan Regency Spatial Plan 2009 – 2028 and Map of Protected Rice Fields. The simulation illustrates that the system produces an output from solar cells of 1,635 kWh/yr and wind turbines of 5,884 kWh/yr and are able to meet the annual needs of the Buyutan Beach area.
2. The economic analysis of the simulated HPP system produces a negative NPV which means it is not feasible to run from the current business side. This can be caused by several factors such as the large value of OpEx and CapEx and the low purchase price (National Electricity Company's feed in tariff). Therefore, the proposed scenario needs to be made as an alternative perspective.
3. In the proposed scenario, it is assumed that the electricity costs paid by the community for the use of HPP as cash inflows, where the tariff is the same as the basic electricity tariff for class (R-1/TR) power limit of 900 VA is Rp. 1,352/kWh, then the cash inflows from the electricity production of 6,391 kWh are Rp. 8,640,834.80/year. With an estimated budget plan of Rp. 109,131,915, obtained a positive NPV. However, the proposed scenario has a challenge, namely technology transfer issues. It is necessary to have a very good and complete supervision and technology transfer system so that the application of HPP can be useful, accountable and sustainable.

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