Renewable Energy Development to Realize Sustainable Development in Jatiluwih Tourism Area, Tabanan Regency

I Nyoman Sedana Triadi[1], Ketut Wiwin Andayani[2] , Made Mudhina[3], I Gusti Lanang Made Parwita[4], and I Nyoman Anom Purwa Winaya[5]

[1,2,3,4,5] Civil Engineering Department, Politeknik Negeri Bali, Bali, Indonesia
nyomansedanatriadi@pnb.ac.id

Abstract. In the use of energy, it is necessary to pay attention to the impact on the environment. Environmental impacts due to energy use such as climate change and global warming. It is necessary to develop renewable energy that does not damage the environment and ecosystem. Indonesia itself has many sources for the development of renewable energy such as water, solar, geothermal, biomass, and wind. Regional development is very closely related to the availability of water sources in an area. Water is one of the natural resources that is very important to be fulfilled to support human survival, therefore efforts to develop water sources and their management are part of the highest priority related to sustainable development efforts. Jatiluwih Village is located in Penebel District, Tabanan Regency, Bali. Jatiluwih Village is a highland village located at the foot of Mount Batukaru. This village is located at an altitude of 500-1500 meters above sea level and has an average rainfall of 2500 mm/year. Most of the population in the Jatiluwih area still relies on the economy of planting rice, with a good irrigation system. Research on renewable energy is needed in the Jatiluwih Area which implements environmentally friendly tourism. The potential of renewable energy in the Jatiluwih area will be developed to meet limited electrical energy including, micro hydropower plants and solar power plants. Energy is used to meet the electrical energy of the Jatiluwih Village community and meet the needs of electrical energy in the Jatiluwih Dam and Aya Dam.

Keywords: Environmentally Friendly, Renewable Energy, Sustainable

1 Introduction

Indonesia has many sources for developing renewable energy, including water, solar, geothermal, biomass, and wind (Adzikri, 2017). Renewable energy can reduce pollution and environmental damage. Renewable energy means energy that comes from sources that can be continuously renewed and has environmentally friendly properties (Azhar, 2018).

A. A. N. G. Sapteka et al. (eds.), *Proceedings of the International Conference on Sustainable Green Tourism Applied Science - Engineering Applied Science 2024 (ICoSTAS-EAS 2024)*, Advances in Engineering Research 249,
https://doi.org/10.2991/978-94-6463-587-4_13

The government's General National Energy Plan has targeted New Renewable Energy from 11.9% to 23% by 2025 (BPPT. Indonesia Energy Outlook, 2016). Until now, the role of new renewable energy in Bali Province is very small. Approximately 1% of Bali's total electricity capacity comes from renewable energy, consisting of 2.1 MW of solar power, 736 kW of wind power, 45 kW of micro-hydro, and 4.17 MW of waste and waste power (Arimbawa, 2016).

The United Nations Educational, Scientific and Cultural Organization (UNESCO) has designated Jatiluwih and Subak Jatiluwih Villages, Penebel District, Tabanan Regency, Bali as part of the World Cultural Heritage (WBD) called the *subak* Catur Angga Batukaru Landscape.

Rice fields in the Subak Jatiluwih area need protection and preservation so that their area does not decrease. This priority is necessary because the meaning of land, including paddy fields is very important for humans, not only to own but also to live their lives. The destruction of *subak* can be caused by the loss of one or more elements as a feature in the *subak* system. The elements referred to are the loss of the physical system including paddy fields, planting arrangements, irrigation network facilities, and infrastructure, also the loss of the social system due to paddy fields, the status of farmers, and even land ownership changes.

2 Methodology

This section must be written out briefly and concisely but adequately so that it can be replicated. This section comprises an explanation of the research approach, tools and objects under study, use of materials or components and instruments, conducts of the research procedure, the parameters observed, data collection, the design or approach, and analysis techniques (Duckworth et al., 2019). These are not theories. Any specific criteria used by the researcher in collecting and analyzing the research data should be completely described to produce clear basics for the study under similar conditions. The research was conducted in the Jatiluwih area, Tabanan Regency, using quantitative descriptive research methods. The quantitative descriptive method aims to create a systematic, factual and accurate description or picture of a phenomenon or the relationship between the phenomena being investigated.

2.1. Data Source

Primary data is the data obtained based on direct observation of the location research, including the height of the waterfall (head), depth of irrigation channels, water speed, width of irrigation canals, canal water discharge irrigation, and interviews with the device village. Secondary data is data obtained through the study of literature such as books, journal articles, and other literature relevant to research.

2.2. Data Collection Method

Observation Method. The observation method is defined as an activity towards a process or object which means feeling and understanding knowledge of the phenomenon. The observation method used is to observe directly by coming to the study location, such as observing the layout of the micro hydro power plant at the location, and measuring the speed of river flow and the cross-section of the river.

Interview method. The interview method is to conduct discussions and ask questions with related parties or managers of the Jatiluwih tourist attraction regarding the required planning information.

Literature study method. The literature study method was carried out to obtain standards for calculation, installation, and operation as well as looking for journal references regarding micro hydropower plants and solar power plants.

2.3. Data Analysis Method

Measurement with Current Meter. The river discharge is obtained after measuring the water speed with a current measuring device and then multiplying it by the cross-sectional area at the measurement location as stated in Equations (1).

$$Q = \sum_{n-1}^{n} Vi \times Ai \tag{1}$$

Capacity Calculation. The installed capacity and electrical energy produced each year are calculated as stated in Equations (2) and (3).

$$P = \eta t \times \eta g \times g \times Qd \times Hn \tag{2}$$

$$E = \xi \times P \times 8760 \tag{3}$$

Solar Power Plant System and Capacity. From the calculation of the array area, the amount of power generated by the solar power plant (wattpeak) can be calculated using the following formula (Winardi et al., 2019) as stated in Equations (4).

$$Pwattpeak = PV\ Area \times PSI \times nPV \tag{4}$$

Where:
PV Area = Solar panel surface area (m^2)
PSI = Peak solar insolation is 1000 W/ m^2
nPV = Solar panel efficiency (%)

Calculating solar charge controller (SCC) capacity. The Solar Charge Controller is determined using the following formula as stated in Equations (5).

$$SCC\ capacity\ =\ (Demand\ watts\ \times\ safety\ factor)/\ (System\ Voltage) \qquad (5)$$

Where:
Demand watts = peak power needed for home energy (kW)
Safety factor = 1.25 %
System voltage = Volts

Battery calculation. The battery capacity required to meet daily energy consumption can be calculated using the following formula as stated in Equations (6).

$$C = (N\ \times\ ed)/(VS\ \times\ Dod\ \times\ n) \qquad (6)$$

Where:
C = Battery capacity
N = Number of autonomous days
Ed = Daily energy consumption
VS = Battery voltage (v)
Dod = Maximum depth for battery discharge [%]
n = Battery efficiency x Inverter efficiency

Inverter calculation. The calculated capacity of the inverter is determined by the formula as stated in Equations (7).

$$\text{Inverter capacity} = \text{Demand watts} \times \text{safety factor} \qquad (7)$$

Demand watts = peak power for home energy need

3 Result and Discussion

3.1 Irradiation and Temperature Data

The highest solar irradiation was in October with a total of 6.96 kWh/m^2 and the lowest was in June with a total of 4.96 kWh/m^2, the average solar irradiation was 5.88 kWh/m^2. The average temperature in the Jatiluwih area is 27.3°C, the highest is 27.9°C and the lowest is 26.2°C.

The value of solar irradiation is a factor that influences the output power of solar P because the performance of solar PV is very dependent on the quality of solar radiation in the area. The following is solar irradiation data in the Jatiluwih area, Penebel District, Tabanan Regency, Bali.

Table 1. Solar irradiation

Month	Solar irradiation ($kWh/m^2/mth$)	Solar irradiation (kWh/m^2)
January	174.53	5.63
February	174.53	5.63
March	180.73	5.83
April	186.62	6.02
Mey	164.3	5.3
June	153.76	4.96
July	159.65	5.15
August	176.7	5.7
September	192.2	6.2
October	215.76	6.96
November	208.94	6.74
December	197.78	6.38
Avarage	182.12	5.87

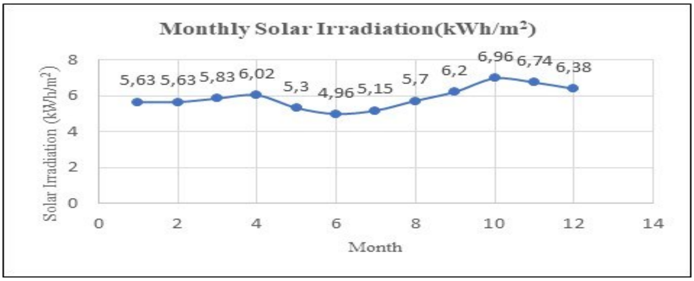

Figure 1. Graph of solar irradiation values of the dam guard house

3.2 Water Discharge Measurement

The river discharge is obtained after measuring the water speed with a current measuring device, and then multiplying it by the cross-sectional area at the measurement location.

Table 2. Discharge and high fall

Site	Width (m)	Heigh (m)	Speed avarage (m/dt)	Discharge (m^3/dt)	High fall (m)
BAY3	0.750	0.500	0.612	0.230	12
BAY4	1.200	0.300	0.618	0.222	12

3.3 Micro Hydro Power Plant Planning

Micro Hydro or what is referred to as a Micro Hydropower plant is a small-scale generator that uses water power as its driving force, such as irrigation canals, rivers, natural waterfalls, and water that is stored in tanks by utilizing the height of the waterfall and fall of the water as well as the amount of water discharge. The following is the plan for a micro-hydraulic power plant:

Rapid Pipe (Penstock). In the rapid pipe, the maximum discharge will be calculated through the rapid pipe. The maximum discharge through this rapid pipe is calculated using as stated in Equations (9) and (10).

Equation 9

$$Qmax = (D/0.75)^2 \tag{9}$$

$$Qmax = (0.35/0.75)^2$$

$$Qmax = 0.236\ m^3/s$$

Equation 10

$$D = 2.69\ \times\ ((n\text{^}2\ Q\text{^}2\ L)/H)\text{^}0.1875 \tag{10}$$

$$0.35 = 2.69 \times ((0.009\text{^}2\ Q\text{^}2\ 50)/12)\text{^}0.1875$$

Q max = 0.236 m^3/s

So it is planned:

D = penstock diameter = 0.35 m
n = Manning coefficient = 0.009
Q = maximum flow through the penstock (m^3/s) = 0.236 m^3/s
L = length of penstock pipe = 50 m
H = fall height (m) = 12 m

Table 3. Penstock planning

Site	L (m)	H (m)	n	D (m)	Qmax (m^3/s)
BAY3	50	12	0.009	0.35	0.236
BAY4	35	12	0.009	0.30	0.174

Effective Fall Height (H_{eff}). The basic working principle of Micro Hydro is utilizing the potential energy it has by water flow at a certain height distance from the power plant installation site. The effective fall height (H_{eff}) is obtained from the gross fall height (H_{gross}) minus the fall height from the lost water pressure.
The area of the pipe circle :

$$A = 1/\ 4 \times 3.14 \times D2 \tag{11}$$

A = 1/ 4 × 3.14 × 0.352

A = 0.096 m^2

Low velocity in the pipe :

V = Q/A (12)

V = 0.230/0.096 = 2.391 m/dt

Primary energy losses: $hf_1 = f \times \frac{Lv^2}{D \times 2g}$ (13)

$hf_1 = 0.003 \times 50 \times 2.391\text{^}2/0.35 \times 2 \times 9.81$ = 0.1245 m

Energy loss at the beginning of the pipe : $hf_2 = kV^2/2g$ (14)

$hf_2 = \frac{0.5\ (2.391)^2}{2} \times 9.81$ = 0.1457 m

Effective fall height Heff = H – (hf1 + hf2) (15)

= 12 m – (0.1245 + 0.1457)

= 11.729 m

So the effective fall height at location BAY3 = 11.729 m

Energy Potential. Installed capacity is calculated as as stated in Equations (2)

P = ηt . ηg. g. Qd . Heff

P = 95 x 90 x 9.81 x 0.230 x 11.729

P = 22.627 kW

Electrical energy produced each year as stated in Equations (3)

E = ξ× P ×8760

E = 75% × 22.627 × 8760

E = 146,625.124 kWh

So the electrical energy produced annually at BAY 3 is 146,625 kWh. The calculation of energy potential at each location is presented in the following Table 4.

Table 4. Energy potential

Site	μt	μg	g (m/s²)	Q (m³/dt)	H eff (m)	P (kW)	E (kWh)
BAY 3	0.95	0.900	9.810	0.230	11.729	22.62	146.625
BAY 4	0.95	0.900	9.810	2.228	11.737	21.93	142.128
Total energy						44.55	288.753

3.4 Solar Power Plant Planning

Energy is a basic human need to carry out daily activities. Rapid technological and industrial developments will encourage an increase in energy demand. One of enormous energy. The use is electrical energy. The use of electrical energy continues to increase starting from households, companies, factories, offices, and so on.

Calculating Solar Power Plant Capacity. The loads that will be supplied are 3 street lighting lamps with a power of 50 W each, 5 indoor light points with a power of 10 W, a Shimizu semijet 250 bit water pump with a power of 850 W and 2 sockets with a power of 100 W. The daily amount of energy that will be supplied by the solar power plant is 13,000 Wh.

The daily solar insolation value (GAV) used is the smallest daily solar insolation value of 4.96 kWh/m2, the efficiency of the solar module (ηPV) is 21.33%, and for efficiency, ηout uses an inverter efficiency of 85%.

$$PV\ Area = \ (13\ kWh)/4.96 \times 0.2133 \times 0.98x \times 0.85 \tag{16}$$

$PV\ Area$ = 15.24 m^2

The PV Area value obtained was 15.24 m^2. The value obtained is the area of PV placement area needed to generate daily energy needs.

Table 5. Total power required per day

No	Burden	Amount	Power (W)	Operating time (jam)	Total power (Wh)
1	Water pump	1	850	12	10.200
2	Street lighting	3	50	11	1.650
3	Loom lights	5	10	11	550
4	Electric socket	2	100	3	600
	Total daily energy				13.000

Calculating the Power that SOLAR PV Will Generate. After carrying out calculations on the PV area, you can calculate the amount of power that will be generated by Solar PV using as stated in Equation (4).
P Watt Peak = PV Area × PSI × "npv"
P Watt Peak = 15.24 × 1000 × 0.2133
P Watt Peak = 3,251 Wp or 3.25 kWp
The amount of power that will be generated by Solar PV is 3.25 kWp.

Calculating the Number of Solar Modules. The solar module used is the JKM550M-72HL4 Monocrystalline solar module. In this research, the total planned SOLAR PV capacity is 3,251 Wp or 3.25 kWp.
Number of PV Modules = 3,251 Wp/550 Wp
Number of PV Modules = 5.91 or rounded up to 6 modules
So the number of solar modules needed in this research is 6 modules with a capacity of 550 Wp of the monocrystalline type.

Inverter Calculation and Selection. The inverter capacity can be calculated as below:
Inverter capacity = Demand watts × Safety Factor (17)
= 1,250 W × 1.25
= 1,562.5 W
The choice of inverter capacity will be 1,562.5 W. The inverter used is the Kenika Inverter brand with a capacity of 1.6 kW.

Calculating solar charge capacity (SCC). The capacity of the Solar Charge Controller (SCC) can be calculated using as stated in Equation (5): SCC capacity=(Demand watts x safety factor)/(System Voltage)
= (1,250 × 1.25)/83.92
= 18.61 A
So, the capacity of the Solar Charge Controller that will be used is rounded up to 20A

Calculating Battery Capacity. The battery that will be used is Lifepo 4 type, the capacity can be calculated using the following formula:
Battery Capacity = (N × ed)/(VS × Dod × n) (18)
Battery Capacity = (3 × 13,000)/(48 × 0.80 × 0.95)
= 1.069 Ah
The battery that will be used is 48V100 Ah, so the total number of batteries needed is 11 pieces.

4 Conclusion

Conclusions from this research: a. Total Energy Potential for Micro Hydro Power Plants in the Jatiluwih area is 44,561 kW; b. Planning for a Micro Hydro Power Plant in the Jatiluwih area is For BAY3 location: Design discharge (Q) = 0.236 m^3/s, Pipe diameter (D) = 0.35 m, Height (H)= 12 m, Effective height (H_{eff}) = 11.729 m, Length of penstock pipe (L)= 50 m, Flow speed in penstock pipe (V)= 2.391 m/s, Energy (P) = 22,627 kW, For BAY4 Location: Design discharge (Q)= 0.174 m^3/s, Pipe diameter (D) = 0.30 m, Height (H) = 12 m, Effective height (H_{eff}) = 11.737 m, Length of rapid pipe (L) = 35 m, Flow speed in the penstock pipe (V)= 2,462 m/s, Energy (P) = 21,933 kW; c. Planning for the solar power plant at Aya Dam House : Energy = 1,010 W, Total Power = 13,000 Wh, PV area = 15.24 m, Power generated by SOLAR PV = 3,251 kWp., Number of solar modules = 6 modules with, solar module capacity = 550 Wp, module type = monocrystalline, inverter capacity = 1.6 kW, brand Kenika Inverter, SCC capacity 20 A, number of batteries = 11 pieces, with type Lifepo 4.

Acknowledgment

This research was made possible thanks to the support of all parties. Gratitude is expressed to the Bali State Polytechnic for providing research funds, and gratitude is expressed to the Bali Penida River Basin Office, the Head of Jatiluwih Village, the Head of Senganan Village, and the community who have provided information about the condition of the *subak* in their area.

References

Adzikri, F., Notosudjono, D., & Suhendi, D. (2017). Renewable energy development strategy in Indonesia. *Student Online Journal (JOM)Electrical Engineering, 1*(1), 1–13.

Arimbawa, P. A. R., Kumara, I. N. S., & Hartati, R. S. (2016). Studi pemanfaatan Catu Daya Hibrida PLTS 3, 7 kWp dan PLN pada instalasi pengolahan air limbah Desa Pemecutan Kaja Denpasar Bali. *Majalah Ilmiah Teknologi Elektro*, *15*(2), 33-38.

Azhar, M., & Satriawan, D. A. (2018). Implementasi kebijakan energi baru dan energi terbarukan dalam rangka ketahanan energi nasional. *Administrative Law and Governance Journal*, *1*(4), 398-412.

Darma, S. (2017). Analisa perkiraan kemampuan daya yang dibutuhkan untuk perencanaan pembangkit listrik tenaga surya (PLTS). *Jurnal Ampere*, *2*(1), 39-53.

Dewi, M. H. U. (2013). Pengembangan desa wisata berbasis partisipasi masyarakat lokal di Desa Wisata Jatiluwih Tabanan, Bali. *Jurnal Kawistara*, *3*(2).

Ni Made Wiasti (2012), Environmental wisdom of Jatiluwih Village Community: Its relevance to the conservation of world cultural heritage. *Bumi Lestari Journal, Anthropology Study Program, Faculty of Letters and Culture, Udayana University, Denpasar*.

Norken, I Nyoman., (2003). Integrated and sustainable water resources development and management (a challenge in water resources management in Indonesia). *Seminar on Integrated and Sustainable Water Resources Development and Management, Faculty of Engineering, UNUD, Denpasar.*

Riadi, M. (2016). Pembangkit Listrik Tenaga Mikrohidro (PLTMH). *data diperoleh melalui situs internet: www. kajianpustaka. com. Diunduh pada tanggal*, *14*.

Sugiri, A., & Risano, A. Y. E. (2013). Studi Potensi Pembangkit Listrik Tenaga Mikrohidro (PLTMH) Di Sungai Cikawat Desa Talang Mulia Kecamatan Padang Cermin Kabupaten Pesawaran Propinsi Lampung. *Jurnal Ilmiah Teknik Mesin*, *1*(1).

Sulistyono, S. (2012). Pemanasan global (Global Warming) dan hubungannya dengan penggunaan bahan bakar fosil. *Swara Patra: Majalah Ilmiah PPSDM Migas*, *2*(2).

Winardi, B., Nugroho, A., & Dolphina, E. (2019). perencanaan dan analisis ekonomi Pembangkit Listrik Tenaga Surya (PLTS) terpusat untuk desa mandiri. *Jurnal Tekno*, *16*(2), 1-11.