Sustainability Potential for Renewable Energy System in Isolated Area that Supports Nantu Boliyohuto Wildlife Reserve

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Abstract. It is still a challenging task to fulfill power demand of Tumba Hamlet in Tamaila Utara Village, which is an isolated area in the buffer zone of Nantu Boliyohuto Wildlife Reserve. The efforts to fulfill the demand had been carried out by the local government by distributing the Solar Home System (SHS) to all households in 2013. However, the SHS performance quickly declined because the solar panels in the rooftop covered by dense and lush trees, and then it did not work at all in 2018. This research performs pre-feasibility in building the micro-hydro powerplant (MHPP) and its sustainability potential in Tumba Hamlet to fulfill the community’s electrical energy needs without disrupting the Nantu Boliyohuto Wildlife Reserve. A basic survey was performed in exploring river resources and topographical conditions in this hamlet. Sustainability study, including technical, social, and environmental aspects, was conducted by interviewing the residents. The results show that the power needs in Tumba Hamlet are 48.5 kW. This demand can be fulfilled by the MHPP with head and water discharge of 10 meters and 0.706 \( \text{m}^3/\text{s} \), respectively. It was found that positive feedback in the technical, social, and environmental aspects of sustainability is dominant.

1. Introduction
Small islands in developing countries face many challenges, ranging from overcoming the effects of climate change to reliance on importing the expensive fuels to meet their energy needs [1]. Based on Law number 23/2014 concerning Regional Government, the authority of government in regency or city level, which had the task in managing the energy and mineral resources, has no more extended authority to run it. The task will be carried out by the provincial government level [2]. Unfortunately, as one of the impacts, supervision, and management at the provincial level is not adequate, causing a new problem for remote and isolated areas in developing the energy system.

Tamaila Utara Village, which is located in Gorontalo Regency, Gorontalo Province, has several hamlets that have no adequate energy system for their demand. Tumba Hamlet is also directly adjacent to the Nantu Boliyohuto Wildlife Reserve, which has rich biodiversity [3-6]. Land fertility in this hamlet
is a magnet for population growth. People move and stay in Tumba Hamlet and then become a farmer. In 2001, there were only seven households in Tumba Hamlet, but in 2018 there were 47 households. The increasing population causes an increase in energy needs.

An effort to fulfill the electricity demand was carried out by the local government by distributing the Solar Home System (SHS) in 2013 for every household in Tumba Hamlet. Unfortunately, since 2018 the SHS only works at the daytime causing by damage. One of the reasons for the battery's damage is imperfect charging [7]. Another cause of the declining SHS performance is the dense and lush tree that covered the solar panel on the rooftop house. People cannot cut the tree because Tumba Hamlet is bordering with wildlife reserve.

![Figure 1. Location of Tumba Hamlet](image)

Other efforts to fulfill the electricity needs made by the community are using a portable generator in their house. This generator is also used for several purposes, such as harvesting, religious holidays, rituals, and other celebrations. The use of a generator is inseparable from the problem of fuel prices. Because of the Dusun Tumba is an isolated area, the cost of fuel there is very high.

Tumba Hamlet has resources suitable to develop micro-hydro powerplant (MHPP). IRENA [8] stated that hydroelectric power plants are currently cheaper and have a significant capacity factor compared to solar power. This hamlet has abundant water resources due to its location in a wildlife reserve so that the preservation of nature is still maintained. The study was conducted to analyze micro-hydro powerplant potential and its sustainability prospect in Tumba Hamlet to meet the electricity needs of the community without disrupting the conservation function of the Nantu Boluyohuto Wildlife Reserve.

2. Material and method

2.1. Materials

This research analyzes the potential of water resources as well as the potential of its sustainability. As this research is aimed at a pre-feasibility study, it applied the current meter and Global Position Sensor (GPS) to measure the river discharge and head in the selected site of the MHPP, respectively. The sustainability study was conducted by interviewing the Tumba Hamlet community as beneficiaries of the system.
The questionnaire was prepared by implementing an indicator which is developed by modifying ones proposed by Buyukozkan and Karabulut [9]. The modification is needed to meet the condition in Tumba Hamlet. Sustainability potential is measured by applying seven indicators, namely:

1. Pollution
2. Resource efficiency
3. Biodiversity and ecological effects
4. Employment
5. Quality of life and society
6. Product use
7. Social governance

Besides, 18 other sub-indicators build those seven indicators.

2.2. Methodology
The methodology that was used in this research can be seen in the following diagram.

![Methodology Diagram](image)

Figure 2. Methodology of research

3. Result and Discussion
This research presents two main outputs, i.e., (1) MHPP pre-feasibility and (2) sustainability potential of the system, including technical, social, and environmental aspects. As part of the pre-feasibility study of the MHPP, this research calculated power demand based on observation in Tumba Hamlet, which is shown in Table 1. The table shows the number of households, social institutions, and small businesses in the hamlet. In total, the community needs 48.5 kW power per day. Electricity needs are still expressed in terms of power, not yet revealed more precisely in energy units.
### Table 1. Total Power Demand in Tumba Hamlet

| Beneficiaries     | Number of beneficiaries [a] | Power equipment (Watt) [b] | Total Power [a] x [b] (Watt) | Function                 |
|-------------------|-----------------------------|---------------------------|-----------------------------|--------------------------|
| Household         | 47                          | 900                       | 42,300                      | Chocolate grinding machine |
| Chocolate business| 1                           | 2,200                     | 2,200                       | Corn sheller machine     |
| Corn business     | 1                           | 2,200                     | 2,200                       |                          |
| School            | 1                           | 900                       | 900                         |                          |
| Mosque            | 1                           | 900                       | 900                         |                          |
| **Power total**   |                             |                           | **48,500**                  |                          |

River discharge and head are needed to design micro-hydro powerplant. Table 2 shows the water discharge measurement results in Tumba Hamlet. The measurement gives an average instantaneous release of 2.91 m³/s. The height difference between the discharge measurement location and the nearest river segment to the resident's house is 19 meters, which is supposed to be a gross head for the MHPP. Based on field conditions, it is presumed that the instantaneous discharge measurement location is suitable for the intake point of the MHPP. In contrast, the area surrounding the resident's house is ideal for the tailrace point.

### Table 2. The results of measurements water discharge

| Measurement point | Velocity (m/s) (V) | Depth (m) [h] | River width (m) [a] | Area (m²) [A = h x a] | Water discharge (m³/s) [Q = V x A] |
|-------------------|-------------------|---------------|----------------------|----------------------|-----------------------------------|
| P1                | 4.3               | 0.5           | 0.5                  | 0.13                 | 1.08                              |
| P2                | 3.2               | 0.3           | 1.375                | 0.41                 | 1.30                              |
| P3                | 6.4               | 0.7           | 1.375                | 0.96                 | 6.18                              |
| P4                | 7.6               | 0.3           | 1.375                | 0.41                 | 3.12                              |
| P5                | 9.7               | 0.35          | 1.375                | 0.48                 | 4.64                              |
| P6                | 9                 | 0.25          | 0.5                  | 0.06                 | 1.13                              |
| **Average discharge** |                |               |                      |                     | **2.91**                          |

Based on community needs, the total power is 48.5 kW. Considering gross head availability and effort in minimizing the budget for building the designed MHPP, this research applied a head value of 10 meters. Total system efficiency is set to 70%. It then gives needed water discharge, which was calculated as follows:

\[ P = \rho_{water} \times Q \times 9.81 \times \frac{m}{s^2} \times head \times \eta \]

\[ 48.5 \text{ kW} = 1.000 \times \frac{kg}{m^3} \times Q \times 9.81 \times \frac{m}{s^2} \times 10 \text{ m} \times 0.7 \]

\[ Q = 0.706 \text{ m}^3/\text{second} \]

It provides that river discharge needed to generate power 48.5 kW is 0.706 m³/s, lower than measured instantaneous release reaching 2.91 m³/sec. It should be noted that if the river is later chosen as the...
location of the MHPP, a more in-depth hydrological analysis must be carried out by involving climate data, watersheds, and other related data. This analysis is needed to obtain long-term discharge availability data that is more robust for the design.

Furthermore, the sustainability survey started with interviewing ten respondents or equal to 21% population as a sample of beneficiaries. These ten respondents answered the question regarding technical and social issues. Technical issues are shown in Figure 3 and Figure 4, while Figure 5 and 6 express social concerns. Figure 3 shows the result of technical issues competencies. Respondents were asked about the willingness to participate in training and assistance programs. The result shows that 63% of respondents are agreed, and 19% strongly agree to support the technical competencies issues. However, 18% of respondents disagree with the idea of increasing professional competencies of the Tumba Hamlet community by developing training and technical skills.

Respondents were asked about the employment issues; for instance, the MHPP project can help communities get a job. Figure 4 shows that more than 50% of respondents believe that the phases of installation, operation, and maintenance (O&M) of the MHPP can help communities get a job. But there are also more than 30% of respondents said that the MHPP project is not able to do that. They do not know how the project will run, and they think the project will cause difficulties in communities.
Respondents were also asked about their opinion on product usability issues, focusing on the impact of the MHPP. Figure 5 shows 76% of respondents believe that the MHPP will provide support for their social activities, and even 16% said very helpful. But there are still about 8% of respondents think that the MHPP will not support their operations. This lack of confidence is probably caused by trauma in using SHS at their house previously. Figure 6 shows the result of an interview on social governance. The indicators are stakeholder relations, social responsibility, and commitment of the community. 64% of respondents said that proper social governance would support MHPP management. It is clearly shown that the community gives their trust to the head of Tumba Hamlet, a cultural patron who always fulfills his commitment and principles.

Sustainability potential in the environmental aspect was asked to 17 respondents or equal to 36% of the population. There are three indicators, i.e., (1) pollution, (2) resource efficiency, and (3) biodiversity and ecological effects. Figure 7 shows that all respondents agree that MHPP will decrease pollution. They already know that MHPP will not cause pollution. Figure 8 presents that more than 50% of respondents said that MHPP would support the resource efficiency in Tumba Hamlet. Indicators of this graph are water consumption, energy use, and fuel use.
Figure 9 presents the analysis of biodiversity and ecological effects indicators. Indicators of biodiversity and environmental effects include sub-indicators of ecosystem vulnerability, critical habitats, and sustainability of agriculture. It is shown that 62% of respondents agree that the positive impact of biodiversity and ecological effects will support the installation, operation, and maintenance of MHPP in their hamlet. The community's awareness makes this situation that their hamlet is the buffer of the Nantu Boliyorhuto Wildlife Reserve, which must be conserved.

4. Conclusion
The Micro Hydro Power Plant (MHPP) has the chance to be built in Tumba Hamlet. To meet the community demand in the power of 48.5 kW, the MHPP can be based on the river water discharge of 0.706 m$^3$/s and the head of 10 m. Moreover, based on a survey on technical, social, and environmental issues, the proposed MHPP shows potential in reaching sustainability during its phases of installation, operation, and maintenance.

Acknowledgments
We gratefully acknowledge the support from USAID through the SHERA program – Centre for Development of Sustainable Region (CDSR). In the year 2017-2021, CDSR is led by the Centre for Energy Studies – UGM. We also gratefully acknowledge the support provided by SGP-UNDP through its grant to UGM.

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