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Feasibility Analysis of The Bribin Pump-As-Turbine in Semanu District, Gunungkidul Regency

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ABSTRACT

The 2025–2034 Electricity Supply Business Plan (RUPTL) prioritises the development of renewable energy based on base load technology, such as hydroelectric power plants (PLTA) and pumped storage systems. A similar pumped storage concept was previously introduced through a collaborative initiative between Germany and Indonesia, involving the Karlsruhe Institute of Technology (KIT) and the University of Giessen. The project, known as Indonesian Integrated Water Resources Management (IWRM), began in 2004 in the karst region of Gunung Kidul, Special Region of Yogyakarta. This project implemented a pump-as-turbine system in Bribin Cave to supply clean water to rural communities, with financial support from the German Federal Ministry of Education and Research (BMBF) within the framework of international collaborative research. However, in 2017, the Bribin PAT system was damaged by Cyclone Cempaka, rendering it inoperable. This study aims to assess the feasibility of revitalising PAT Bribin II through technical and economic analysis, while maintaining the original module design with a module configuration that is estimated to produce a water flow of 100 litres per second. The economic evaluation is based on estimated indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit-Cost Ratio (BCR). The findings show that the NPV remains positive and the BCR exceeds one at discount rates of 10%, 11%, 12%, and 13%, indicating the project's feasibility. This analysis confirms that the benefits exceed the costs. Overall, this study shows that the Bribin PAT revitalisation project is financially feasible and is expected to provide a solid foundation for policymakers to increase the benefits of Bribin PAT II in various financing scenarios.

INTRODUCTION

Integrated Water Resources Management (IWRM) in Indonesia began in 2004 in Gunung Kidul, a karst area in the Special Region of Yogyakarta, Java Island, Indonesia (Nestmann et al., 2013). The Karlsruhe Institute of Technology (KIT) and the University of Giessen initiated this project in collaboration with Germany and Indonesia, funded by the German Federal Ministry of Education and Research (BMBF). The Bribin II pump-as-turbine (PAT) development project is located in the Gunungsewu Karst region. Gunungsewu is an area covering 1,300 km² and stretching 10 km to 29 km (north to south) and 85 km (west to east). This karst region consists mainly of limestone, which is easily permeable to water and forms rivers and underground caves. This region has underground rivers formed by groundwater seepage, especially in areas without vegetation. This karst region has many interconnected caves. However, the geography of karst regions often causes drinking water shortages and droughts (Cahyadi et al., 2019).
Sir MacDonald and his colleagues (1979, 1984) have conducted research on the hydrogeology and potential of the karst underground river system in Gunungkidul. The research shows that the Bribin underground aquifer originates from non-karst volcanic highlands. This hydrological system enters through a ponor in the Sawahombo area and then exits at the Bribin cave, causing a significant increase in the amount of water flowing downstream. This study explains that the Bribin and Seropan water systems intersect at

the Baron spring and other beaches in Gunungkidul. This research is a key indicator that water resources in Gunungkidul are abundant and require further exploration (Nestmann et al., 2013).

Oberle et al. (2016) explain how the first underground water supply system project was built in Bribin Cave. The project was based on a report by MacDonald and Partners, followed by in-depth exploration of groundwater resources in the Gunungkidul karst region in the early 2000s. This project has made a significant contribution to the development of long-term water supply solutions for the Bribin region, covering 21 surrounding villages by designing an underground dam using PAT technology. The PAT system module is located 100 metres below the surface. Access to the module is via a lift with multi-angle concrete that dams the underground river flow. The success of PAT Bribin has made it a model for similar initiatives in other regions. It can also be a good way to obtain water in karst areas using renewable energy.

In 2017, PAT Bribin II suffered severe damage due to Typhoon Cempaka, resulting in the PAT not operating as usual. This disrupted research activities in the area. The latest research on PAT Bribin II was conducted by Rekinagara et al. (2018) focusing on the potential for developing micro-hydro power plants in the Bribin Underground River as an energy efficiency measure. According to the study, it was found that the Bribin underground river has a water level of 240 metres and can flow at up to 1,500 litres per second. This means that, theoretically, it can generate 3.53 MW of hydraulic power. Since 2018, no similar studies have been conducted, resulting in a lack of data and recent findings related to the development of PAT Bribin II. As a replacement for the damaged Bribin II PAT, the Regional Water Company (PDAM) Tirta Handayani has expanded the new water distribution system from Bribin I using high-pressure pumps with electricity supplied by PLN.

The Central Government, through the Ministry of Public Works and Public Housing, the Directorate General of Water Resources, and the Serayu Opak River Basin Agency, has undertaken redesign and revitalisation efforts to optimally utilise the potential of the Bribin II PAT to meet raw water needs as before. This study is expected to provide an analysis of the feasibility of revitalising PAT Bribin II using a techno-economic approach that considers technological, economic, and social aspects. In addition, the results of this study can also be used as a strategy by relevant parties to optimise the operation of PAT Bribin II in supporting the achievement of renewable energy targets in Indonesia.

RESEARCH METHOD

This chapter will discuss the research stages, including a detailed explanation of the research flow chart. The research methods to be used will be explained in full in this subchapter to determine the feasibility of the revitalisation and redesign plan for Bribin II from a technological and economic perspective by optimally implementing the pump-as-turbine system.

1.1 Research Step

Data collection for this study began with interviews with local communities and the PAT II Bribin management team. In addition, secondary data was also collected from various sources: the Serayu Opak River Basin Agency (BBWSSO) for the completeness of the redesign of PAT Bribin II, the Gunungkidul Regency Government and the Gunungkidul Regency Statistics Agency for geolocation information, and PDAM Tirta Handayani Gunungkidul Regency for operational data on PAT Bribin II while it was still active. This data includes water production capacity, population served, water consumption by the surrounding community, service coverage, and the ratio of water supply to demand capacity of the Bribin Branch of PDAM Tirta Handayani. This study also uses supporting data from the Final Report on the redesign and revitalisation of PAT Bribin II obtained from BBWSSO. Data sources include project budget estimates (RAB) for redesign and revitalisation, as well as analysis of the water treatment plant technology to be used. The water sales tariff and revenue modelling for the Bribin II water treatment plant was determined by comparing the operational costs when it was still in operation, which covered 21 beneficiary villages.

Secondary data from PDAM Tirta Handayani will be used to make projections until 2050 using Microsoft Excel software. The data will then be analysed using a techno-economic analysis based on the BBWSSO Final Report, which contains the RAB for the PAT Bribin II project with several changes to obtain optimal values. This data is expected to provide an assessment of the feasibility of the redesign and revitalisation initiative for PAT Bribin II. The conclusion-drawing process is expected to answer the research objectives and provide a basis for policymakers to improve the utilisation of PAT Bribin II under various financing conditions.

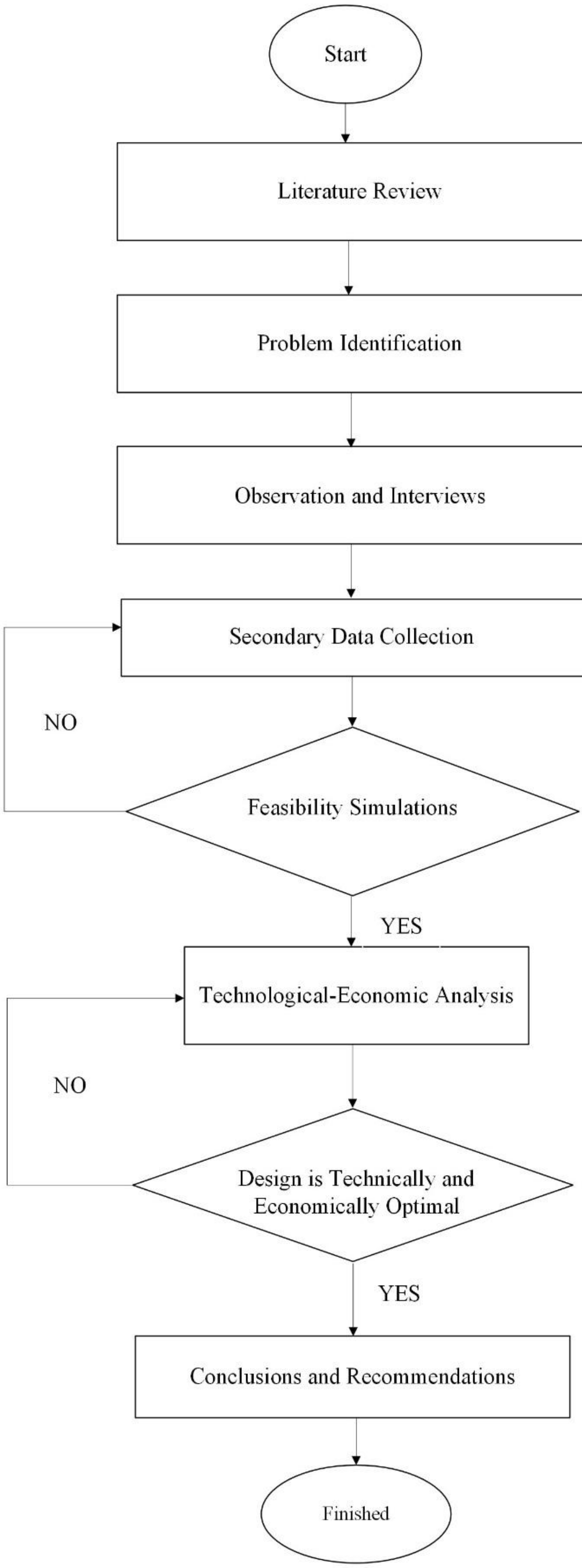

Figure 1. Feasibility Study Flowchart.

RESULTS AND DISCUSSION

1.2 Pump-as-Turbine Model

PAT Bribin II is located on the Bribin river, which according to previous research has a flow rate of 800-1500 litres/second (Subratayati, 2008). This hydraulic potential utilises pump-as-turbine (PAT) technology, which means that centrifugal pumps operate in reverse as turbines to drive high-pressure pumps that transfer water to the distribution reservoir. The high flow rate in Bribin requires the PAT design to be able to divert water during peak flow and flooding. The water diverter in the PAT model needs to be carefully reviewed so that damage such as that caused by Typhoon Cempaka in 2017 can be minimised. According to Oberle (2016), Figure 1 shows the modules that have been installed in the Bribin II PAT, namely five modules with a flow rate range of 400 to 2000 litres/second. The PAT pumps used are Multitec D 65/9 6.1 high-pressure feed pumps and single-flow Etanorm-R 300-340 pumps. The PAT pump operates at 1,200 revolutions per minute, while the pump has a higher speed of 2,200 revolutions per minute. This system is designed for durability, minimal maintenance, and cost-efficiency.

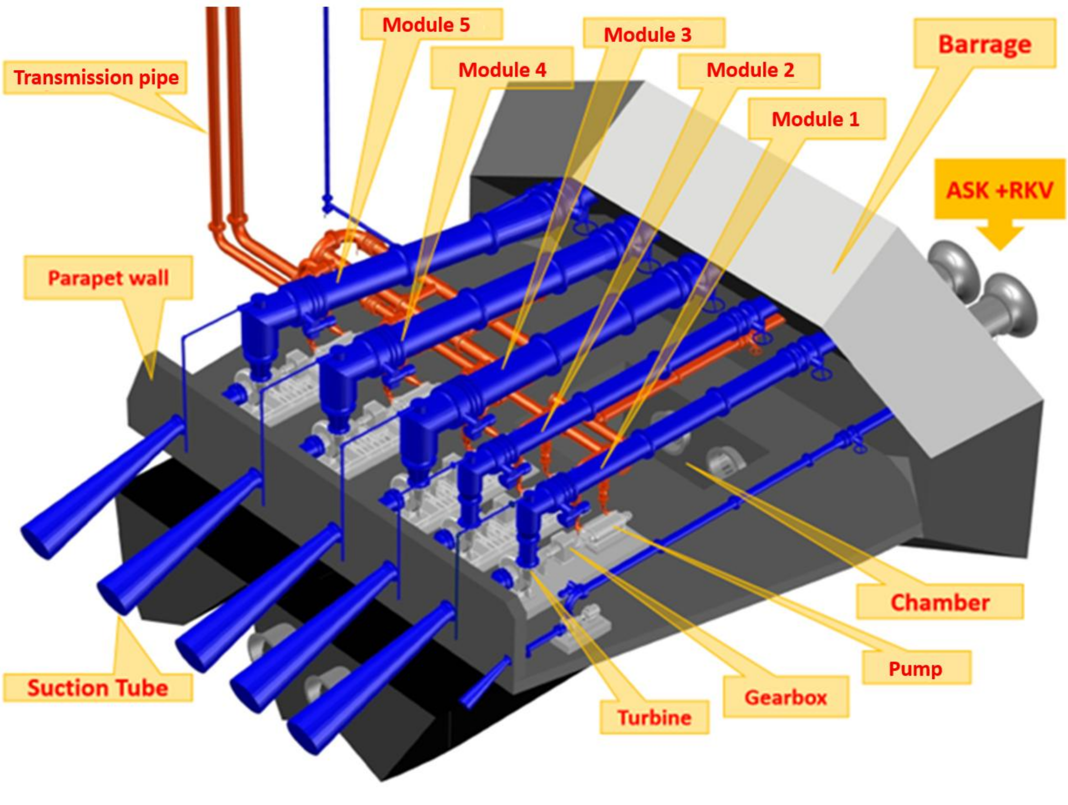

Figure 2. Modular layout of the PAT Bribin II (modified) (Oberle et al, 2016).

The latest revitalisation plan carried out by BBWSSO in the Final Report analysis states that the five existing modules will be modified using PAT DN 700 and PAT DN 450 configurations. The use of these types of modules is expected to provide effective flood control when there is a significant rise in groundwater levels, especially during the rainy season.

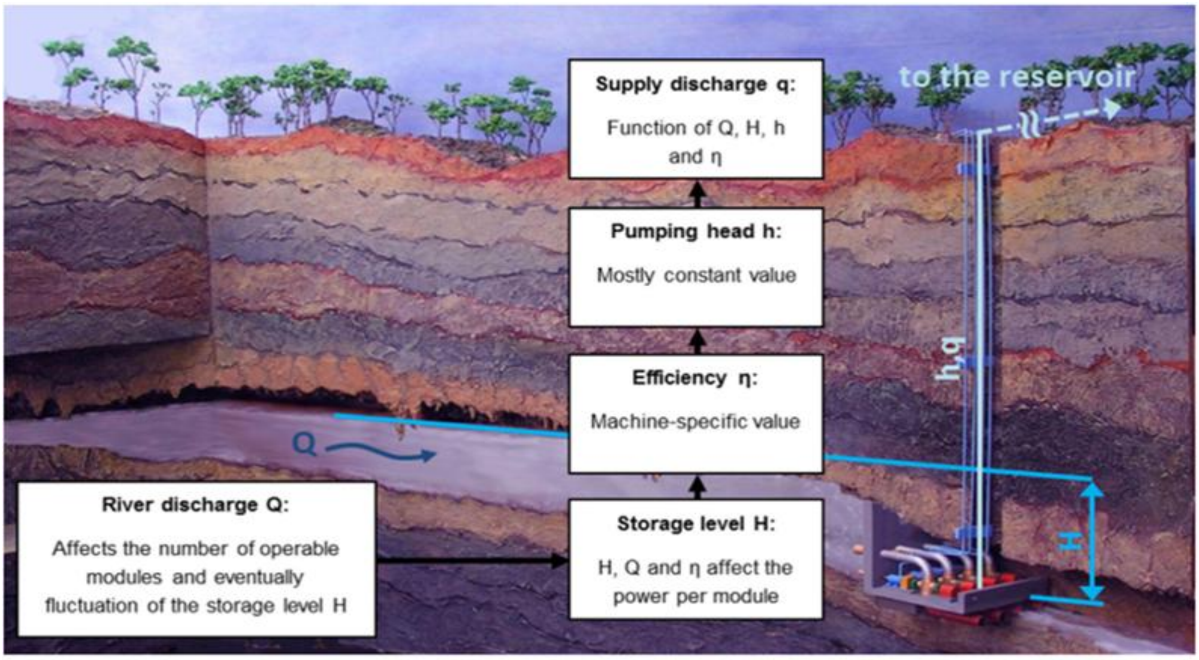

Figure 3. Main Design PAT Bribin II
(modified from Nestmann et al. 2009) (Oberle et al. 2016).

The hydraulic power of PAT Bribin II can be assessed based on the volume of water flowing. This power is an important aspect in assessing the ability of a water flow to absorb power as energy. Purece et al. (2016) states that the efficiency of a hydraulic turbine is the ratio between the mechanical power generated by the turbine shaft at the coupling point and the hydraulic power received by the shaft. In other words, this efficiency indicates the proportion of hydraulic energy entering the turbine that is successfully converted into mechanical power that can be utilised from the turbine shaft output. The hydraulic power equation can be written as:

$$P_h = \gamma \cdot Q \cdot H$$

Q is the discharge,
γ is the specific weight of water (9810 N/m3), and
H the turbine gross head.

According to the latest research from Rekinagara (2018), the Bribin river, which flows into PAT Bribin II, has a flow volume (Q) of 1,500 litres/second. Based on the Final

Report, the gross head (H) is 270 metres (*Laporan Akhir Desain Rehabilitasi Air Baku Dan Jaringan Pemanfaatan Sungai Bawah Tanah Bribin*, 2021). The hydraulic power of PAT Bribin II is 3.97 MW. Klein & Fox (2022) explains in his research that hydraulic power capacity below 10 MW can be categorised as small hydropower plants (SHP).

1.3 Techno-Economic Analysis of Pump-As-Turbine

The techno-economic analysis conducted in this study was calculated using a project period of 25 years, from 2025 to 2050. The use of a Discounted Factor (DF) ranging from 10% to 20% assumes that this project is a private infrastructure project with limited revenue and risk exposure (not a direct government project) (Spohr et al., 2024). This project is also expected to generate an Internal Rate of Return (IRR) on equity in the range of 10–20% to compensate for private investor risk.

1.4 Net Present Value

Net present value (NPV) is a method used to assess the feasibility of an investment by comparing the present value of cash inflows with the present value of cash outflows (Ernawati et al., 2020). In this study, discounted factor (DF) calculations were performed ranging from 10% to 20%. NPV can be categorised as feasible to proceed when the NPV value is > 0 or positive. In this study, it was found that at DF 10%, 11%, 12%, and 13%, the NPV value was positive, so the DF in the project should be within that range to indicate feasibility.

Table 1. NPV value at ten discounted factor positions.

DF (%)	NPV (Rp)
10%	Rp9.694.451.986,59
11%	Rp6.415.497.223,86
12%	Rp3.564.887.305,75
13%	Rp1.075.499.639,40
14%	-Rp1.108.030.386,25
15%	-Rp3.031.538.073,51
16%	-Rp4.733.109.079,23
17%	-Rp6.244.505.170,73
18%	-Rp7.592.310.155,18
19%	-Rp8.798.853.865,65
20%	-Rp9.882.959.568,63

1.5 Benefit Cost Ratio (BCR)

The Benefit Cost Ratio (BCR) is the ratio between the net benefit (B_k) obtained and the costs or losses incurred (C_k). A project is considered feasible if BCR ≥ 1, whereas if BCR < 1, the project is considered unfeasible (Ernawati et al., 2020). The equation below explains the calculation of BCR (Wijaya et al., 2012):

$$BCR = \frac{\sum_{k=0}^{N} B_k}{\sum_{k=0}^{N} C_k}$$

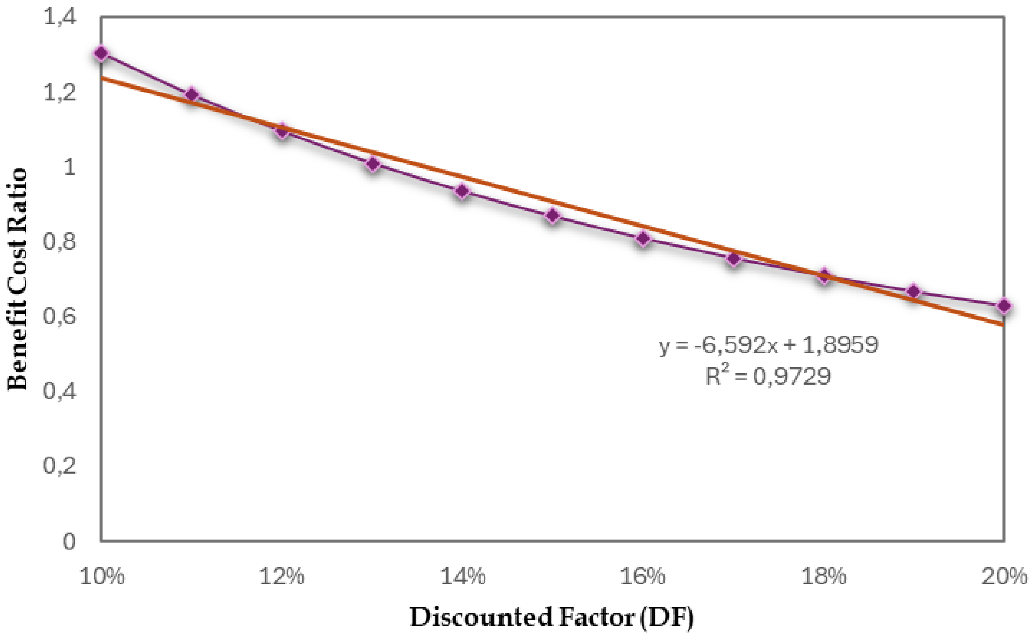

Figure 4. Changes in IRR in line with changes in Discounted Factor (DF).

Based on Figure 5, it can be seen that the BCR value is greater than one for DF less than 14%. When calculated in detail, the following results are obtained:

Table 2. BCR value at ten discounted factor positions.

DF (%)	BCR
10%	1,30
11%	1,19
12%	1,10
13%	1,01
14%	0,94
15%	0,87
16%	0,81
17%	0,76
18%	0,71
19%	0,67
20%	0,63

1.6 Internal Rate Return (IRR)

From the NPV and BCR calculations above, the IRR value is then calculated, where the IRR value is the value that causes the NPV value to be zero. The IRR value of the project needs to be calculated to assess the feasibility of the business by setting a discount rate that equates the present value of cash inflows and the present value of cash outflows (Ernawati et al., 2020).

$$NPV = 0$$

$$NPV = -27.429.954.898{,}82 + \sum_{t=1}^{25} \frac{CF_t}{(1+r)^t} = 0$$

with $CF_1 = 2.603.726.177{,}71$; $CF_2 = 2.813.810.285{,}22$; ⋯; $CF_3 = 7.645.744.757{,}96$

Based on the calculation results, the NPV value obtained is 0 with the r or DF value being the IRR value of 13.48%. This value is supported by linear regression analysis which obtained a parabolic curve function of y = -2E+11x + 3E+10 with an R^2 value of 0.9709, which is close to 1, meaning it is accurate. This value indicates that the feasibility of the techno-economic analysis can be considered feasible and can be continued when the IRR value is greater than the project's discounted factor.

CONCLUSION

From the results of the techno-economic analysis, it was found that the DF value was in the range of 10%–13.48% in the medium to high risk project category. The project's feasibility can be assessed primarily based on the NPV value, which tends to decline until it reaches the IRR. These results provide an updated picture of the revitalisation of PAT Bribin II by reviewing the potential of the Bribin underground river. There are enormous project benefits if the revitalisation of PAT Bribin II is continued in support of Indonesia's Net Zero Emission (NZE) target in 2060. The revitalisation of PAT Bribin II will be an example of Integrated Water Resources Management (IWRM) with the aim of achieving equitable economic and social welfare while maintaining the sustainability of vital ecosystems. The data obtained is expected to be the main basis for the government in making decisions regarding the sustainability of PAT Bribin II in the future. This research needs to be continued to analyse the Life Cycle Assessment (LCA) in order to review the environmental impact on the surrounding community.

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