FEASIBILITY STUDY OF A MINI HYDROELECTRIC POWER PLANT DEVELOPMENT AT CIKAMUNDING VILLAGE

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Abstract**—***Indonesia's national energy policy prioritizes renewable resources to increase the electrification rate and reduce carbon emissions. In Banten Province, Lebak Regency faces a significant electricity deficit, creating an urgent need for new, sustainable power sources. This thesis conducts a comprehensive feasibility study for the development of the Cikamunding Mini Hydroelectric Power Plant (MHPP), a proposed 6.17 MW run-of-river project by PT. XYZ. The study evaluates the project's viability through an in-depth analysis of its market, technical, and financial aspects. The market analysis confirms a secure demand, guaranteed by a Power Purchase Agreement with PT PLN. The technical analysis validates the site's suitability and the robustness of the engineering design, which is projected to generate 35.17 GW annually. The financial evaluation demonstrates the project's strong profitability, yielding a positive Net Present Value (NPV) of Rp 15.96 billion, an Internal Rate of Return (IRR) of 14.68%—well above the cost of capital—and a favorable Payback Period of 7.78 years. The study concludes that the Cikamunding MHPP is a highly feasible and financially attractive investment, aligning with strategic energy goals.*

Keywords**—***Feasibility study, NPV, IRR, PBP*

I. BACKGROUND

Indonesia holds significant potential in renewable energy, particularly hydropower, supported by over 4,400 rivers across its territory. However, national electricity generation continues to rely heavily on fossil fuels, which account for more than 80% of the energy mix, while hydropower contributes only 14%. This reliance on non-renewable sources contradicts national sustainability goals and intensifies environmental concerns, particularly greenhouse gas emissions.

To address these challenges, the government has enacted several policy frameworks to accelerate the adoption of renewable energy. Presidential Regulation No. 5 of 2006 set early renewable energy targets, followed by Presidential Regulation No. 112 of 2022, which mandates PT PLN to prioritize renewable energy procurement, especially in regions with low electrification. Complementing this, Banten Province introduced Regional Regulation No. 7 of 2022 through its Regional Energy General Plan (RUED) 2022–2050, aiming to increase energy access and integrate local renewable resources [7] [10].

Mini hydroelectric power plants (MHPPs) are identified as a feasible solution due to their run-of-river schemes, which operate with minimal ecological disruption and are well-suited for Indonesia's mountainous and high-rainfall areas. In particular, Cikamunding Village in South Banten—where electricity access remains below the national average—has been designated for MHPP development. With a planned capacity of 6.17 MW, the Cikamunding MHPP is projected to supply power via PLN's 20 kV distribution system and contribute to the region's goal of achieving 100% electrification by 2026.

II. THEORETICAL REVIEW

A feasibility study is a structured investigation used to assess the viability of a proposed business or project by examining whether it can yield more benefits than costs. It serves as a crucial step in investment decision-making, minimizing risks while enhancing planning and control processes. The study typically examines several key aspects: market, technical, and financial feasibility.

A. Feasibility Study Framework

The feasibility framework typically includes three core components: market feasibility, technical feasibility, and financial feasibility. Market feasibility examines whether there is sufficient demand for the proposed product or service [4]. In the case of a Mini Hydroelectric Power Plant (MHPP), demand is assessed through projected electricity consumption in the region, which in turn is influenced by electrification rates and population growth. The target market in this study is PT PLN, which operates in the South Banten region, an area with a relatively low electrification ratio. Accurately forecasting future demand is therefore critical for ensuring optimal capacity planning [1].

B. Key Aspects of Feasibility

The feasibility framework typically includes three core components: market feasibility, technical feasibility, and financial feasibility [11]. Market feasibility examines whether there is sufficient demand for the proposed product or service. In the case of a Mini Hydroelectric Power Plant (MHPP), demand is assessed through projected electricity consumption in the region, which in turn is influenced by electrification rates and population growth. The target market in this study is PT PLN, which operates in the South Banten region, an area with a relatively low electrification ratio. Accurately forecasting future demand is therefore critical for ensuring optimal capacity planning [18].

Technical feasibility involves assessing the physical, technological, and environmental suitability of the project site. For MHPPs, this means examining hydrological conditions such as river discharge and head, terrain characteristics, turbine efficiency, and compatibility with the existing grid infrastructure [23]. The run-of-river system, which minimizes environmental disruption and capital costs, is particularly well-suited for rural, high-rainfall areas like South Banten. This approach allows for sustainable energy generation without the need for large-scale dam construction, making it an ideal model for decentralized electricity provision.

Financial feasibility focuses on evaluating whether the project is economically sustainable and capable of generating adequate returns over time [6]. Key financial indicators include Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP) [19] [20]. These metrics help investors assess the profitability of the project relative to its capital investment and operational costs. A positive NPV indicates value creation, while an IRR exceeding the project's discount rate suggests strong financial attractiveness. The payback period, on the other hand, reflects the time required to recoup the initial investment and is often used to gauge risk exposure [12] [21].

C. Feasibility Analysis Matrix

Financial feasibility is a critical component in evaluating the overall viability of infrastructure projects, particularly in capital-intensive sectors such as renewable energy. Three key financial indicators are commonly used to assess project performance: Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP). The NPV represents the difference between the present value of future cash inflows and outflows, discounted at a predetermined rate [22]. A positive NPV signifies that the project is expected to generate net economic benefits over its lifetime, thereby justifying the investment. The IRR, on the other hand, is the discount rate at which the NPV becomes zero. It serves as a comparative benchmark, where a project is deemed attractive if the IRR exceeds the cost of capital or the minimum acceptable rate of return. The Payback Period measures the duration required to recover the initial capital investment, offering insight into the project's liquidity and risk exposure. A shorter payback period is generally preferred, as it implies a quicker return on investment and reduced vulnerability to long-term uncertainties.

D. Sensitivity Analysis

To enhance the robustness and reliability of financial forecasts, a sensitivity analysis is conducted as part of the feasibility study [13] [29]. This analytical approach evaluates how variations in key input parameters—such as capital expenditure, operating costs, energy tariffs, and projected revenues—affect the project's financial outcomes. Sensitivity testing helps identify critical risk factors and quantify their potential impact on indicators like NPV, IRR, and PP [9] [24]. Advanced techniques such as Monte Carlo simulation and decision tree modeling are often employed to simulate a range of possible scenarios under uncertainty. These methods provide probabilistic insights and facilitate informed decision-making, especially in projects exposed to environmental, regulatory, or market volatility [29] [30]. In the context of the Cikamunding Mini Hydroelectric Power Plant, sensitivity analysis is essential for anticipating deviations in hydrological patterns, construction costs, and tariff adjustments, ensuring that the project remains feasible under dynamic conditions.

III. METHODS

A. Conceptual Framework

This study's conceptual model integrates three primary dimensions of feasibility: market demand, technical viability, and financial performance. The market aspect focuses on understanding electricity demand in Lebak Regency and the capacity of PT PLN to absorb renewable energy output. The technical component evaluates design elements such as turbine efficiency, river flow potential, and site infrastructure [5]. Financial viability is assessed using investment metrics like Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP). These dimensions are interlinked and collectively determine the project's feasibility. If the financial metrics yield NPV > 0, IRR > MARR, and PP within a desirable timeframe, the project is considered feasible.

B. Design Systematics

The Design Systematics section of this study outlines a structured methodological framework used to conduct the feasibility analysis of the Mini Hydroelectric Power Plant (MHPP) development in Cikamunding. The methodology consists of five critical stages: preliminary research, data collection, data processing, data analysis, and conclusion and recommendation formulation.

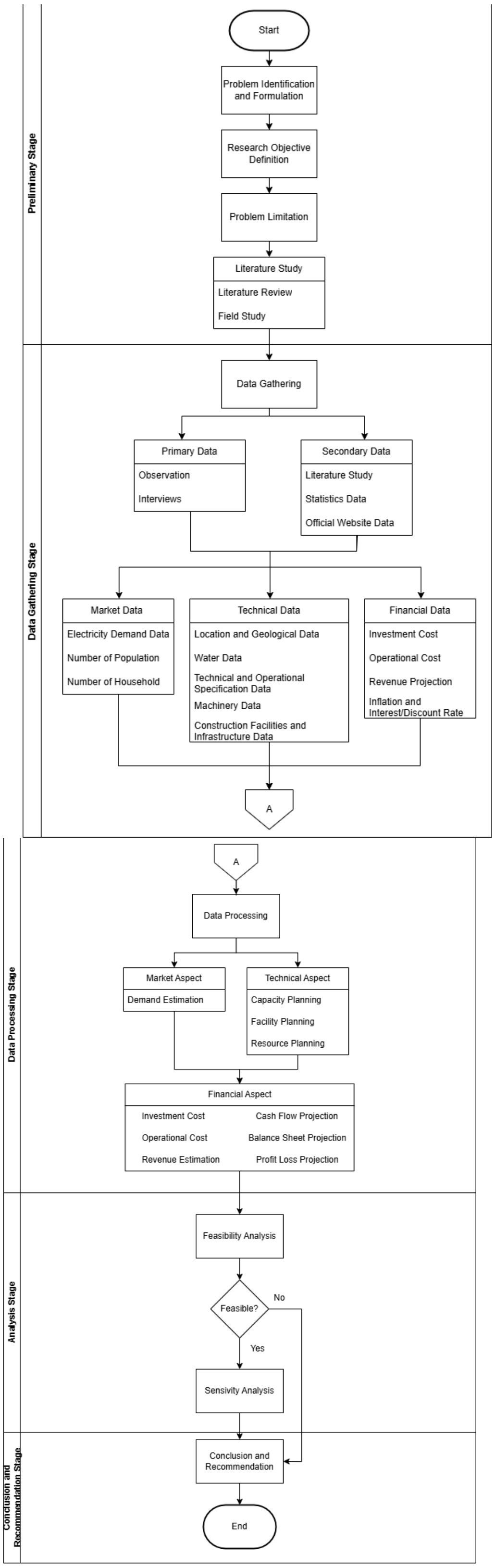

FIGURE 1
(Design Systematics)

C. Integrated System Identification

The success of the Cikamunding Mini Hydroelectric Power Plant (MHPP) relies on the effective integration of key subsystems, viewed holistically through a systems approach. These components include **Man**, **Material**, **Machine**, **Method**, and **Information**.

The **Man** component refers to skilled human resources essential for installation, operation, and maintenance. Adequate training is vital to ensure efficiency and reduce operational errors [17]. **Material** involves the use of natural water flow from the Cibareno River as the primary input, requiring consistent monitoring to sustain energy production [27] [28]. **Machine** encompasses turbines, generators, and supporting equipment, all of which must meet performance standards and be maintained regularly to ensure system reliability [15] [16].

The **Method** component includes the technical procedures and regulatory guidelines that govern plant operation, emphasizing adherence to national standards and safety protocols. Lastly, **Information** covers real-time monitoring and data analysis for performance tracking and informed decision-making.

IV. RESULT AND DISCUSSION

A. Data Collection

The data collection process in this study was conducted comprehensively across three domains—market, technical, and financial—to support the feasibility analysis of the Cikamunding Mini Hydroelectric Power Plant (MHPP). Data were acquired from both primary and secondary sources. Primary data were collected through consultations with project stakeholders and engineering teams involved in the pre-construction phase of the MHPP. Secondary data were sourced from regulatory publications, government databases, hydrological reports, and energy policy documents.

Market data were extracted from the *Regional Energy General Plan (RUED) of Banten Province* as outlined in *Regional Regulation No. 7 of 2022*, along with supporting data from *PT PLN's Electricity Supply Business Plan (RUPTL)*. The critical market indicator was the number of unelectrified households in Lebak Regency, which amounted to 23,266. These data were instrumental in projecting household electricity demand and justifying the need for distributed renewable energy infrastructure. Furthermore, the average electricity consumption per household in the region was determined to be approximately 4.915 kWh/day. These values provided the foundational assumptions for revenue modeling based on offtake agreements.

Technical data included hydrological records of the Cibareno River, which is the proposed water source for the MHPP. Parameters such as river discharge rates, rainfall patterns, topographical gradients, sediment characteristics, and the geotechnical suitability of the construction site were compiled from hydrological surveys and field observations. Turbine specifications, generator capacity, and overall system efficiency figures were also acquired, with particular focus on the use of Francis turbines, known for their compatibility with medium-head hydro schemes. Information on infrastructure accessibility and interconnection to the 20 kV grid operated by PT PLN was documented to assess logistical and operational feasibility.

Financial data were collected through engagement with engineering consultants, budget documents, and official cost standards. Capital expenditure (CAPEX) estimates were derived from project plans and engineering procurement quotes. Operational expenditure (OPEX) inputs included estimates for labor, maintenance, and system overhauls, aligned with industry benchmarks. Regulatory instruments such as *Presidential Regulation No. 112 of 2022* were used to identify the applicable feed-in tariff for hydropower and determine price-setting mechanisms for renewable energy [8].

B. Data Processing

Following the data collection phase, the next step was to systematically process these inputs into quantitative outputs necessary for feasibility evaluation. This stage covered demand projections, technical simulations, cost modeling, and financial forecasting, all carried out using spreadsheet-based models and standard hydropower planning formulas [14].

Market data were processed to estimate the potential electricity demand from unelectrified households in Lebak Regency. Using the known per-household consumption rate of 4.915 kWh/day and the total number of target households, the annual energy demand was computed. Since the MHPP has a planned generation capacity of 6.17 MW and is expected to produce 35.20 GWh per year (based on a plant factor of 0.65), the generated output was aligned with projected local demand. This validated the assumption that 100% of the electricity would be absorbed by the market via a **Power Purchase Agreement (PPA)** with PT PLN, ensuring consistent revenue for the project.

Technical data were processed using standard hydropower equations. The formula used for capacity estimation was:

$$P=\eta \cdot \rho \cdot g \cdot Q \cdot HP$$

Substituting these values yielded a projected capacity of approximately 6.16–6.17 MW. This estimate was cross-verified with flow duration curves and adjusted for seasonal discharge variations. The planning phase also involved optimizing the location of intake structures, headpond, and penstock alignment to maximize efficiency while minimizing civil works.

Resource and facility planning simulations were executed to determine material volumes, machinery needs, and workforce scheduling. Environmental design incorporated sediment flushing mechanisms and flood diversion capacity to ensure long-term system reliability. Equipment selection was tailored to the site's hydraulic profile, and grid interconnection design included safety, metering, and communication modules in line with PLN's technical standards.

Financial data were processed to produce a full project pro forma. Revenue streams were computed based on regulated tariffs—USD 9.09 cents/kWh—adjusted with a regional multiplier. Operating costs were broken down annually, including periodic major maintenance every five years. Capital costs were distributed across a two-year construction phase, with interest during construction (IDC) capitalized into total project costs.

Three major financial indicators were calculated; **Net Present Value (NPV)** = Rp 15.96 billion, **Internal Rate of Return (IRR)** = 14.68%, and **Payback Period (PP)** = 7.73 years. These metrics confirmed that the investment was viable and profitable under base case conditions [31].

To enhance decision robustness, a **sensitivity analysis** was also conducted. Revenue and operational costs were stressed by ±6-7% to simulate adverse scenarios. It was found that a revenue drop of more than 6.52% would lead to a negative NPV. In contrast, operational expenditure tolerances were higher; the project remained viable up to a 6.67% increase in OPEX. Capital expenditure was resilient up to a 7.15% increase before IRR dropped below the cost of capital.

C. Verification and Validation

Verification and validation were conducted to ensure the reliability and accuracy of the technical and financial models used in the feasibility study of the Cikamunding Mini Hydroelectric Power Plant (MHPP). Verification involved a systematic review of input data, including hydrological discharge, net head measurements, and cost parameters, to confirm internal consistency and computational accuracy within the modeling framework [25] [26]. These inputs were processed using standard engineering and economic equations, with results cross-checked for logical coherence and adherence to hydropower planning methodologies [3]. Validation was carried out by benchmarking key assumptions and outcomes against real-world standards and regulatory requirements. This included alignment with the national energy policy outlined in *Presidential Regulation No. 112/2022*, tariff structures set by PT PLN, and electrification targets stated in *Banten Provincial Regulation No. 7/2022*.

The results of the verification and validation confirmed that the annual energy production forecast of 35.17 GWh was consistent with site-specific flow rate data and turbine efficiency assumptions. Financial indicators such as a Net Present Value (NPV) of Rp 15.96 billion and an Internal Rate of Return (IRR) of 14.68% were found to be within acceptable thresholds defined by the Directorate General of Electricity, exceeding the minimum required IRR of 8.31%. Furthermore, the use of a Francis turbine, a plant factor of 0.65, and the applied grid interconnection design were validated as technically appropriate for the run-of-river scheme proposed. These results substantiate the conclusion that the project design is both technically sound and financially viable, with all core assumptions and projected outcomes grounded in verifiable and validated data sources.

D. Analysis

The market analysis confirms that the Cikamunding MHPP benefits from a highly secure demand environment. Under a Power Purchase Agreement (PPA) with PT PLN, Indonesia's state-owned electricity company, the plant's entire energy output is guaranteed to be absorbed. This is particularly significant in light of Presidential Regulation No. 112 of 2022, which mandates the prioritization of renewable energy procurement, and Banten Province's Regional Energy Plan (RUED), which sets targets for increased electrification and the expansion of clean energy generation. With 23,266 households in the Lebak Regency still lacking access to electricity, the project directly supports the national electrification agenda. Assuming stable operation and a projected annual generation of 35.17 GWh, the MHPP is expected to yield consistent revenues of approximately Rp 52.43 billion per year at a tariff of USD 0.0909 per kWh, providing a predictable and long-term income stream.

From a technical standpoint, the project is engineered for resilience and efficiency. The run-of-river design leverages the natural 54.13-meter net head of the Cibareno River, eliminating the need for large-scale dam infrastructure and thereby minimizing environmental disruption. The selection of horizontal-shaft Francis turbines—known for their high efficiency under medium-head conditions—supports consistent generation even with seasonal fluctuations in river flow. The dual-turbine setup also ensures redundancy and operational flexibility. Energy generated will be delivered via an 18.5-kilometer express feeder to the Bayah Substation. Load flow simulations confirm that this configuration allows for optimal grid absorption with 94.77% efficiency, maximizing energy delivery while minimizing losses. The hydrological characteristics, sedimentation risks, and plant factor of 65.18% have been validated against GIS and topographical data, reinforcing the technical robustness of the design.

The financial feasibility of the MHPP was determined through a comprehensive projection of revenue, expenditure, and capital investment. The total capital expenditure (CAPEX) is estimated at Rp 295.95 billion, allocated over a two-year construction period (2025–2026). This includes civil works, electromechanical equipment, land acquisition, and capitalized interest. The funding structure comprises 30% equity and 70% debt, with the latter secured at an 8.05% interest rate. Operational expenditures (OPEX) are forecast at Rp 4.98 billion per year, covering staffing, maintenance, insurance, and system overheads. Financial models account for 6% annual inflation and include major overhaul costs every five years to maintain system integrity.

The profitability analysis reveals strong financial performance. The Net Present Value (NPV) of the project is calculated at Rp 15.96 billion over a 10-year horizon (2025–2034), indicating that the MHPP generates more value than its total cost of capital. The Internal Rate of Return (IRR) is 14.68%, significantly above the Weighted Average Cost of Capital (WACC) of 8.31%, reflecting a substantial profitability margin. Furthermore, the Payback Period (PP) is estimated at 7.73 years, suggesting that the project will recover its initial investment in less than eight years, well within the expected 20+ year operating lifespan of a hydropower facility. These results affirm the financial sustainability of the MHPP and its potential to deliver long-term shareholder value.

To evaluate the project's resilience to risk, a sensitivity analysis was conducted on three key variables: revenue, CAPEX, and OPEX. The results demonstrate that the project is most sensitive to changes in revenue. A decrease of more than 6.52% in annual income would render the project financially unfeasible, with the NPV turning negative. However, even with a 6% drop in revenue, the project retains a positive NPV of approximately Rp 1.26 billion. Similarly, the project can tolerate a cost overrun in CAPEX of up to 7.155% before breaching financial viability. A 7% increase in CAPEX still maintains a positive NPV of around Rp 345 million, while an 8% increase would result in an NPV of approximately -Rp 1.88 billion. In terms of OPEX, the project shows a slightly higher tolerance, withstanding up to a 6.677% increase in operational costs before turning unviable. A 6% rise still yields an NPV of Rp 1.61 billion, whereas a 7% increase results in a loss of approximately Rp 771 million.

V. CONCLUSION

The Cikamunding Mini Hydroelectric Power Plant (MHPP) project is demonstrated to be a highly feasible investment across market, technical, and financial dimensions. A long-term Power Purchase Agreement (PPA) with PT PLN ensures market security and stable revenues, aligned with national goals for increasing rural electrification and renewable energy adoption. Technically, the site's natural head and river flow support a run-of-river design capable of producing 35.17 GWh annually, with minimal ecological disruption. The use of reliable Francis turbines, proper sediment control, and grid compatibility further reinforce technical viability.

Financial analysis confirms the project's profitability, with a positive Net Present Value (Rp 15.96 billion), a strong Internal Rate of Return (14.68%), and a Payback Period of 7.73 years, outperforming the assumed cost of capital. However, sensitivity analysis reveals the project's vulnerability to revenue fluctuations and cost overruns.

To enhance resilience, several key strategies are recommended: (1) implement robust preventive maintenance and real-time monitoring systems to ensure operational efficiency; (2) apply strict cost control measures during construction, including fixed-price EPC contracts; (3) establish long-term service agreements and train local operators for OPEX stability; (4) update hydrological assessments to address climate risks; and (5) engage stakeholders early to secure social acceptance and regulatory compliance.

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