MUST Journal of Research and Development (MJRD) Volume 7 Issue 1, March 2026
e ISSN 2683-6467 & p ISSN 2683-6475

Assessment of Water Potential in Irrigation Scheme Infrastructure for Integrating Micro-Hydropower: A Case Study of Idete Prisons Complex in Morogoro, Tanzania

David Sowani *, Joel Mbwiga and Petro D. Ndalila
Mbeya University of Science and Technology, P.O Box 131, Mbeya, Tanzania

DOI: https://doi.org/10.62277/mjrd2026v7i10006

ARTICLE INFORMATION

Article History

Received: 30th September 2025
Revised: 02nd February 2026
Accepted: 06th March 2026
Published: 31st March 20226

Keywords

Micro-hydropower
Irrigation scheme
Renewable energy
Energy resilience
Electricity cost reduction

ABSTRACT

Using the Idete Prisons Complex in Morogoro, Tanzania as a case study, this study evaluates the water potential in an existing irrigation scheme infrastructure for the integration of a micro-hydropower plant. The goal of the research is to investigate a sustainable and economical solution to the complex's ongoing problems, such as high electricity costs and frequent power outages from the national grid (TANESCO), which impede daily operations and jeopardize security and service delivery. By utilizing the available water flow within the irrigation system, the study explores the viability of producing clean and dependable electricity through micro-hydropower. In order to ascertain flow rates and head two crucial factors for hydropower potential hydrological data were gathered and examined. System design and performance were simulated and optimized using HOMER Pro. The location has enough hydropower potential, according to the final results, to provide output power ranging from 24.35 kW to 29.27 kW. This can greatly offset electricity expenditures and lessen reliance on the unstable grid supply. By offering a reproducible approach for incorporating renewable energy into institutional and rural settings using already-existing water infrastructure, this research advances the energy industry. Additionally, it draws attention to the unrealized potential of micro-hydropower as a decentralized energy solution for enhancing resilience and energy availability in Tanzanian public infrastructure.

---

*Corresponding author's e-mail address: davidsowani360@gmail.com (Sowani, D.)

1.0 Introduction

The foundation of hydropower system planning and design, especially for small- and micro-scale applications, is the evaluation of water resources. To ascertain a site's energy potential and guarantee sustainability over the long run, a trustworthy assessment of the flow and head that are accessible is necessary (Kaunda *et al*., 2012). The controlled water flow via canals, diversion weirs, and distribution networks in irrigation-based infrastructures makes micro-hydropower integration possible (Kusre *et al.,* 2010). Irrigation systems frequently offer a somewhat steady and predictable water supply, which may be used to produce energy while preserving agricultural functions, in contrast to natural river flows that show significant seasonal changes (Nautiyal *et al.,* 2021). Hydrological measures, including flow rate monitoring, rainfall-runoff analysis, and discharge estimates, as well as hydraulic assessments to measure available head and conveyance efficiency, are commonly used methods for evaluating water potential in such projects (Kaunda *et al.,* 2012). These evaluations shed information on operational factors such as water distribution priorities, seasonal irrigation demands, and system maintenance in addition to the technical viability of integrating hydropower (Kilama, 2013). Therefore, a balanced approach is needed to guarantee that hydropower generation enhances irrigation functions rather than replaces them. Irrigation systems in Sub-Saharan Africa still do not fully utilise their potential for energy cogeneration. Irrigation systems in Sub-Saharan Africa still do not fully utilise their potential for energy cogeneration. For instance, Tanzania has created several small-scale irrigation projects to boost agricultural output, but these systems seldom include energy-generating components (Parag & Ainspan, 2019). Schools, hospitals, and prisons are examples of institutions having on-site irrigation networks that provide exciting chances to showcase integrated water-energy systems. This study's objective is to assess the water potential of the Idete Prisons Complex's current irrigation system to include a micro-hydropower system. Creating a sustainable energy source that may lessen the strain of expensive electricity rates and frequent power outages that now affect the facility is the main driving force. Hydrological analysis, energy production estimation, and system optimisation utilising sophisticated simulation tools like HOMER Pro are among the technical and economic factors taken into account in the evaluation (Nath, 2015).

The study evaluates the integration of a micro-hydropower system into the Idete Prisons Complex in Tanzania, aiming to address energy challenges like high costs and frequent outages. By utilising irrigation water flow, the system can potentially generate between 24.35 kW and 29.27 kW of electricity, addressing essential energy needs for lighting, water pumping, administration, and security. The research employs modelling tools, including HOMER Pro, to assess the feasibility and financial implications of this renewable energy solution. The initiative aligns with national objectives for rural electrification and aims to provide a sustainable and resilient energy source for public institutions, particularly in rural areas.

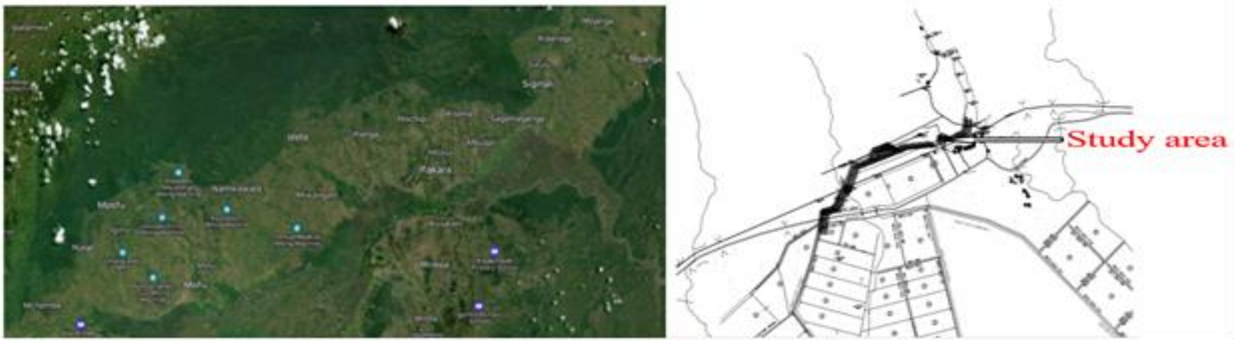
2.0 Material and Methods

2.1 Back Ground of the Study Area

The research was centred Background on the Idete Prisons Complex hamlet, which was founded in 1973 and has 61 houses, and was carried out in Idete Ward, Ifakala District, Morogoro Region, Tanzania (Latitude 8°11′59″ S, Longitude 36°34′59″ E). The region has a tropical savanna environment and is reachable by important transportation lines, such as the Tanzania–Zambia railway and the Morogoro–Iringa road. The 7,940-acre property is used for grazing (1,100 acres), forest (3,000 acres), residential/institutional (690 acres), and agricultural production (3,150 acres). One kilometre away from the farm, the Idete River offers a year-round supply of water, facilitating the construction of irrigation systems and providing opportunities for renewable energy applications, especially small-scale hydropower.

Figure 1

Project Location



Overall, the study area combines agricultural, forestry, and water resources with energy demand, creating an ideal setting for investigating renewable energy solutions in a rural context (URT-prison corporation sole, 2023, n.d.).

2.2 Methodology

This study's approach was designed to evaluate the Idete Prisons Complex in Morogoro, Tanzania's irrigation scheme infrastructure's potential for integration with a micro-hydropower (MHP) system. Field-based observations, evaluations of hydrological and energy demand, system design considerations, and techno-economic simulations utilising HOMER Pro software were all incorporated into the process. The technical and financial feasibility of the suggested solution may be methodically assessed thanks to this integrated approach. (Kamran *et al.,* 2019)

2.2.1 Collection of Hydrological Data

Long-term meteorological data (2015–2024), including temperature, streamflow (discharge), and rainfall, were used to gather hydrological information. Current meters were used to monitor the flow rates at important irrigation canals and diversion locations. Estimates from rainfall-runoff correlations were also used. In order to account for differences between rainy and dry periods, seasonal variations were recorded (Jensen, 2009).

The following was used to get the average flow rate (Q):

$$Q = \frac{V}{t} \qquad (1)$$

Where: Q is flow rate (m^3/s), the volume of water flowing across a cross-section is denoted by V (m^3), Time is represented by t (s).

2.2.2 Evaluation of the Hydraulic Power Available

The basic hydropower equation was used to evaluate the theoretical hydropower potential:

$$Pt = \rho\, g\, Q\, Hg, \qquad (2)$$

Where: Pt is defined theoretically power available (W), the density of water is denoted by ρ 1000 kg/m^3, g is acceleration due to gravity ($9.81 m/s^2$), Q is the rate of flow and the effective head (m) is denoted by H.

2.2.3 Turbine Power

The true power available at the turbine output once head losses are taken into consideration may be found using Equation (3).

$$P = \rho\, g\, Q\, H\, \eta \quad (W) \qquad (3)$$

Where: H is net head (2m), System efficiency is represented by η (85%), The system's real electric power output is 24.348 kW.

Where η takes into consideration transmission, generator, and turbine losses.(Abeykoon & Hantsch, 2017).

2.2.4 Head Measurement

The measurement of heads within the irrigation scheme was conducted to assess the vertical height difference between the water intake and potential turbine location, which is essential for estimating the energy conversion capacity of a micro-hydropower system. Field measurements used handheld GPS devices and were verified with errors. The gross head was established by comparing the elevations of the highest water diversion point and the discharge location, with potential hydraulic losses noted for net head adjustments. This methodology ensured accurate head data, providing reliable input for assessing hydropower potential (Otuagoma *et al.,* 2015).

2.2.5 Profiling of Energy Demand

The electrical consumption profile was created across seven end-use sectors, including homes, schools, churches, health centres, offices and prisoner housing, community halls, and small-scale industrial units, for the purpose of assessing the hydropower system's viability for the prison complex. (Tsuanyo *et al.,* 2023) Each appliance's energy use was calculated using:

$$E = P.t \qquad (4)$$

Where E is equal to the energy used (Wh), P is the appliances rated power (W), and t is hours of operation (h). The total energy usage by sector was calculated as follows:

$$E_{sector} = \sum_{i=1}^{n} P_i \cdot t_i \qquad (5)$$

And the complex's overall load requirement was determined by:

$$E_{total} = \sum_{j=1}^{n} E_{sector,j} \qquad (6)$$

Where m is the total number of sectors and n is the number of appliances per sector.

2.2.6 Choosing the Type and Efficiency of the Turbine

For micro-hydropower systems, choosing the right turbine is crucial since it affects both viability and energy efficiency. Based on site-specific head and flow, reaction turbines (Francis, Kaplan, and propeller) work best in low-head, high-flow situations, whereas impulse turbines (Pelton and Turgo) are preferred in high-head, low-flow situations. (Erinle *et al.,* 2020). To choose a turbine, this study examined the Idete irrigation system's net head and canal flow rates. Realistic power output requires derating factors since efficiency ranges from 70% to 90%. The necessity of matching turbines with local hydrological conditions for optimal generation is highlighted by this method, which adheres to hydropower design principles (Abeykoon & Hantsch, 2017).

The evaluation of hydropower potential, which considers hydrological and climatic factors, indicates that the chosen location can reliably provide electricity all year long, despite its relatively low elevation of 2 meters. The evaluation of hydropower potential, which considers hydrological and climatic factors, indicates that the chosen location can reliably provide electricity all year long, despite its relatively low elevation of 2 meters. Using the usual hydropower generation formula, the power output was estimated based on a rigorous monthly examination of rainfall, flow rate, and temperature trends.

The rainfall data displays a bimodal pattern that is characteristic of East Africa, with brief rains (October–December) and substantial precipitation during the lengthy rainy season (March–May). Rainfall averages during these times range from 160 to 220 mm, which causes rivers to release more water, raising flow rates to 3.35 m^3/s in April. As a result, peak power outputs of up to 29.27 kW are supported during certain months, above the minimum requirement. Rainfall is reduced by 60 to 90 mm during the dry season (June to August), and flow rates drop to about 1.1 to 1.4 m^3/s. Given that efficient turbine operation (assumed at 85% efficiency) compensates for tiny flow variations, the system may still generate at or slightly above the minimum needed output of 24.35 kW even during these months with somewhat lower water availability. With monthly maximums between 27°C and 32°C and minimums between 15°C and 20°C, temperature data indirectly affect evaporation losses and may impact open canal systems, but the impact on closed-pipe turbine systems is minimal. However, consistently warm temperatures allow for maintenance-free operation without the risk of freezing or a drop in flow due to temperature. The location sustains flow rates adequate to allow energy production year-round, with natural surpluses during the wet seasons, according to the data, which indicate that stream flow stability is the most significant variable in hydrology. These findings imply that the microhydrometers' and microhydro systems' capacity and design are in good harmony with the physical features of the location, rendering it a viable and sustainable option for supplying local energy.

3.1 Modelling and Simulation

A steady and sufficient flow rate is required all year round for dependable hydropower at a low head (2 meters). The location receives moderate to heavy rainfall throughout the rainy seasons (March–May and October–December), according to the meteorological data displayed in Table 3. This greatly increases the stream flow rates, allowing for peak outputs of up to 29.27 kW in months like April and November. The dry season months of June through August, on the other hand, have less rainfall and lower flow rates, but they are still adequate to fulfil the microhydro's baseline requirement for maintaining a minimum power output of 24.33 kW. Temperatures between 27°C and 32°C (max) and 15°C and 20°C (min) have no discernible effects on hydropower production, but they are important for system efficiency as a whole (evaporation losses, pipeline friction, etc.). The crucial variable in this low-head design, the flow rate, is continuously kept above 1.1 m^3/s throughout the year, which is adequate for hydropower generation.

3.2 Average Load Profile of Idete Prison Complex

The Idete Prisons Complex exhibits a diversified electricity demand profile driven by multiple end-use classes: households, schools, churches, health centres, offices, prisoner accommodation, community halls, and small-scale industrial activities whose operating hours create distinct diurnal peaks. From Table 2, the connected (diversified) load totals 24.33 kW, while the tallied daily energy is 184.901 kWh. Taken over 24 hours, that energy corresponds to an average power of 24.33 kW (184.901 kWh / 24 hours), indicating long periods of low demand punctuated by shorter high-use windows. The 24-hour load, table 2, is therefore expected to show morning and early-evening peaks linked to household routines; school and office start-up; lighting; water pumping; cooking; and community uses (church/community hall), with a shoulder or midday rise where small-scale industrial processes and the health centre’s equipment operate. Overnight, a base load persists for security lighting, refrigeration/medical cold chain, network/ICT, and essential accommodation services, keeping demand above zero even in off-peak hours. Aggregating these daily patterns over a month.

3.2.1 Household Purpose

In the prisons complex, the home section exhibits the highest diversity of appliances, including ceiling fans, TVs, radios, DVD players, and refrigerators, with a total energy demand of 13.44 kW and daily consumption of 101.91 kWh. Lighting and security illumination are the primary contributors, alongside refrigeration, which is crucial for preserving food. The findings highlight the home sector as the largest energy consumer, underscoring the need for targeted energy efficiency measures to reduce consumption effectively.

3.2.2 School

Despite its small power needs, the school's daily electricity consumption of 3.006 kWh is crucial for operations. The primary demand stems from equipment like printers, computers, and lamps, which, despite low individual usage, create a constant energy requirement during school hours. Also, security lights that stay on for up to 12 hours add to this baseline use. This underscores the significance of consistent, albeit minor, energy demands in ensuring facility security and smooth functioning.

3.2.3 Church

When compared to other functional units, the church segment of the complex demonstrates low energy consumption, primarily due to its modest lighting needs, with security and illumination lights consuming only 0.047 kW and daily consumption of 0.015 kWh. The main energy load comes from the music system, which uses 0.23 kW and 1.334 kWh per day, particularly during church services or gatherings. The church's daily energy requirement is merely 1.349 kWh, reflecting its total load of 0.277 kW. Its infrequent, event-driven operation distinguishes it from other buildings, such as lodging and offices, which usually exhibit continuous energy demand, reinforcing its minor role in the overall energy consumption profile of the complex.

3.2.4 Health Center

Compared to other functional units, the church in the complex has low energy consumption due to modest lighting needs, with security and illumination lights using only 0.075 kW and daily consumption of 0.90 kWh. The main energy load is from television, computers, printers, laboratory equipment, and refrigerators at 0.61 kW and 7.02 kWh per day, used mainly during services. The church's daily energy requirement is 7.92 kWh, reflecting a total load of 0.685 kW, and its infrequent operation highlights its minor contribution to the complex's overall energy consumption compared to continuously occupied buildings like lodging and offices.

3.2.5 Office and Prisoner Accommodation Rooms

Security lighting contributes significantly to the area's power usage, with a demand of 1.41 kW and daily consumption of 13.68 kWh. When combined with additional loads from televisions, general lighting, computers, and office devices, the result is 2.251 kW and daily usage of 18.586 kWh. This highlights the dual nature of energy demand driven by security and administrative activities, underscoring the importance of effective energy planning and potential energy-saving measures.

3.2.6 Community Hall

Security lighting accounts for significant energy use, demanding 0.249 kW with a daily consumption of 1.98 kWh. When combined with additional loads from televisions, general lighting, and office devices, the total demand for the office and hotel reaches 1.599 kW and a daily usage of 14.28 kWh. This emphasizes the need for effective energy planning and potential energy-saving measures due to the dual nature of energy demand from security and administrative activities.

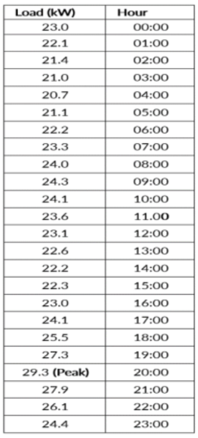
Table 1

Summary of Daily Energy Demand According to Load Classification at Idete Prisons Complex

Load classification	Daily energy demand (kWh)	Daily energy demand (kW)
House hold purpose	101.91	13.44
School	3.006	0.413
Church	1.349	0.277
Health center	7.92	0.685
Office and prisoner accommodation room	18.586	2.251
Community hall	14.28	1.599
Small-scale industrial	37.86	5.66
Total	**184.901**	**24.325**

Table 2

Daily Load Demand Table (24-Hour)



Load (kW)	Hour
23.0	00:00
22.1	01:00
21.4	02:00
21.0	03:00
20.7	04:00
21.1	05:00
22.2	06:00
23.3	07:00
24.0	08:00
24.3	09:00
24.1	10:00
23.6	11.00
23.1	12:00
22.6	13:00
22.2	14:00
22.3	15:00
23.0	16:00
24.1	17:00
25.5	18:00
27.3	19:00
29.3 (Peak)	20:00
27.9	21:00
26.1	22:00
24.4	23:00

3.2.7 Small-Scale Industrial Activities

Industrial usage is a significant consumer of energy at the Idete Prison Complex, with devices like water pumps, motors, and grinding machines operating efficiently. A carpentry factory's motors alone consume 37.86 kWh daily and 5.66 kW. The complex's total daily energy consumption is 184.901 kWh, with a load of 24.325 kW, primarily driven by domestic use and small-scale industrial operations, alongside contributions from a church and school.

This disparity emphasises how crucial it is to differentiate between the average demand figures given in various time periods. Although the annual average of 24.325 kW is shown in Table 1, the equivalent daily energy consumption of 184.901 kWh/day in Figure 7 shows that this demand does not remain constant over 24 hours. The 24.325 kW should instead be interpreted as an average load during times of active operation, when institutional functions like school sessions, community gatherings, or farming and processing operations account for the majority of power consumption. Demand drastically decreases during off-peak or nighttime hours, reducing the total daily energy use down to the recorded 184.901 kWh/day. As a result, rather than representing a full-day mean, the 24.325 kW number more correctly represents an operational or peak-period average demand, highlighting the necessity of contextualising load data in energy planning and system sizing.

3.3 Assessment of Hydropower Resources

Data on the hydro-potential of micro-hydropower systems (MHPS) was obtained by a field evaluation at the suggested location. The focus of the hydro-energy evaluation is the Ifakara tributary in Idete Village, Kilombero District, Morogoro Region, Tanzania. Using conventional techniques, direct measurements were made in this tributary to estimate head characteristics and gather basic irrigation canal data. Additionally, the National Aeronautics and Space Administration (NASA) databank and the Tanzania Meteorological Authority (TMA) via the Iringa Meteorological Station (IMS) provided the possibility for meteorological data (table 3). Various meteorological data are crucial for comprehending how variations in rainfall and temperature impact MHPS performance and power production.

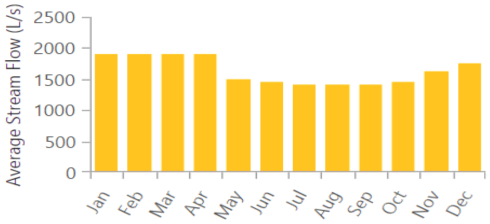
Table 3

Collected Data for Meteorological Information (2015 to 2024)

Month	Avg. Rainfall (mm)	Flow Rate (m³/s)	Max Temp (°C)	Min Temp (°C)
January	95	1.52	31	20
February	85	1.48	32	20
March	180	1.61	30	19
April	220	1.60	29	18
May	160	1.47	28	17
June	90	1.43	27	16
July	60	1.34	27	15
August	65	1.34	28	16
September	75	1.33	29	17
October	160	1.34	30	19
November	210	1.46	31	20
December	180	1.51	31	20

Figure 3

Hydropower Resources Assessment of the Study Area

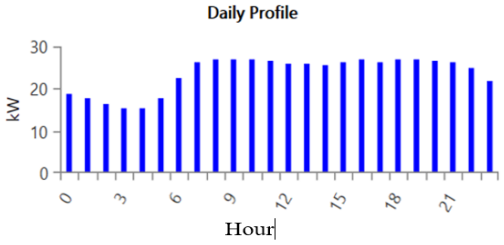


3.4 HOMER Pro Optimization

The load simulation results from HOMER Pro indicate significant insights into energy demand patterns at daily, seasonal, and yearly levels. The daily profile reveals lower consumption during late night and early morning hours (21–23 kW), moderate demand during the day (22–24 kW), and a peak around 20:00 at approximately 29.27 kW, typical of residential and small commercial usage patterns. Seasonally, monthly averages range from 22.3 kW to 2.3 kW, with fluctuations linked to factors like weather, social activities, and agricultural cycles, leading to higher demands during longer nights or increased motor activity in busy agricultural periods, as seen in figure 4.

Figure 4

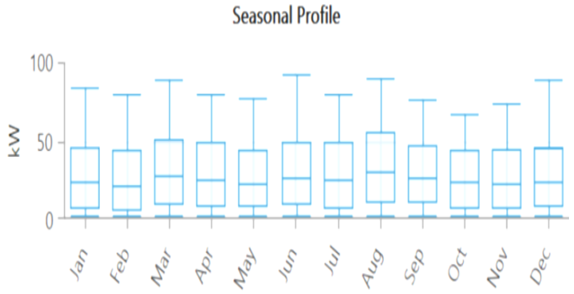
Profile of Daily Load



Lastly, the system maintains an overall average demand of 24.325 kW, with an annual high of 29.27 kW, according to the yearly load profile shown in Figure 6. For long-term planning and system stability, this very small difference between average and peak demand points to a steady consumption pattern with only slight seasonal variations. This stability improves the project's economic sustainability by lowering the risk of oversizing or underusing generating assets. The existence of distinct peaks, however, emphasises the need for careful system design that takes into consideration not just the average yearly requirements but also the ability to handle short-term oscillations and maximum demand occurrences. This factor is especially important when combining micro-hydropower with hybrid components like energy storage systems or solar photovoltaic arrays, which need to be set up to fill supply shortages and guarantee continuous operation. In the end, the results emphasise the need for a well-rounded design strategy that maximises resource use, ensures dependability, and promotes sustainable operation under various seasonal and temporal circumstances.

Figure 5

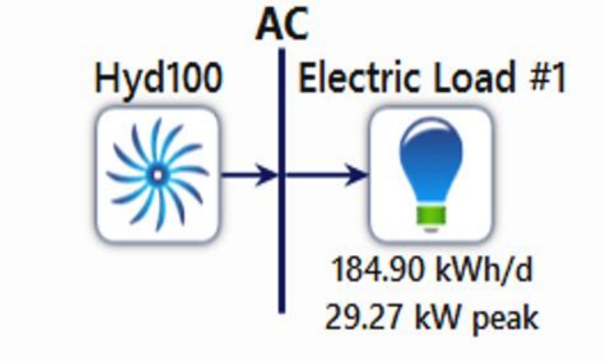
Seasonal Scaled Load Profile



A comprehensive evaluation of a grid-connected micro-hydropower system's techno-economic viability has been conducted using HOMER (Hybrid Optimisation Model for Electric Renewables), a sophisticated tool developed by the National Renewable Energy Laboratory (NREL). HOMER models a variety of energy resources, including wind, solar, micro-hydropower, biomass, fuel cells, battery storage, conventional generators, and grid connections. It allows for the assessment of these resources in isolation or in hybrid configurations under varying demand and resource scenarios, facilitating the identification of optimal technical and economic solutions. The tool provides decision-makers with the capability to model long-term system performance and conduct sensitivity studies on factors like fuel costs and resource availability. Its application has underscored its significance in sustainable energy planning, effectively balancing grid resilience, cost reduction, and renewable energy integration.

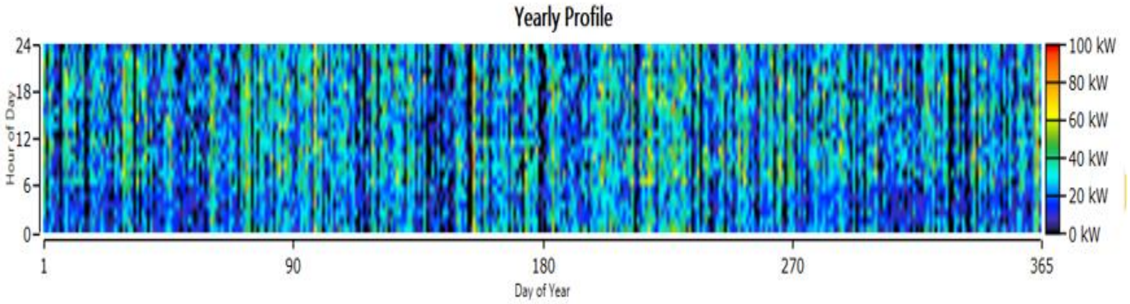
Figure 7

Proposed Micro Hydro Schematic (Homer)



HOMER requires a comprehensive set of input parameters encompassing both technical and contextual elements to produce optimal system configurations. Key technical parameters include the performance characteristics of components like solar modules, hydro turbines, and batteries. Meteorological data, such as solar radiation and hydropower parameters, are essential for accurate resource availability calculations. The load profile, which details demand fluctuations, is critical for modelling consumption behaviour. Financial viability inputs, like capital investment and operational costs, are necessary, along with a defined search space for optimisation. Finally, accurate performance modelling necessitates equipment parameters like efficiency curves and derating factors, as well as specific operational conditions and constraints that may affect performance outcomes. Through the integration of these datasets, HOMER performs systematic simulations and comparisons of a broad range of possible system topologies, finally determining which ones strike the best balance between economic viability and technical dependability. (Bahramara *et al.,* 2016) have thoroughly examined HOMER's operation. Figure 7 shows the schematic diagram of the proposed grid-connected micro-hydropower system that satisfies the load demand.

Figure 6
Yearly Load Profile



3.4.1 Hydropower Characteristics from HOMER Pro

Table 4. Results of the HOMER optimisation for the suggested micro-hydropower system are summarised. According to the research, the system achieves an efficiency of 85% under a 2 m head and 1.46 m^3/s flow, with a capital cost of USD 32,845, annual O&M expenditures of USD 1,642, and a 25-year lifespan. By combining capital, replacement, and operational costs with grid sales and salvage value, HOMER ensures cost-effectiveness and dependability while minimising the Net Present Cost (NPC) and Levelized Cost of Energy (LCOE).

Table 4
Hydropower Characteristics (From HOMER Pro)

Hydro economics		Turbine properties		Features of the generator	
The cost of capital ($)	32,845.00	Head available (m)	2	Power output (kW)	24.33
The cost of replacement ($)	26,923.00	Rate of design flow (m^3/s)	1.46	The voltage (V)	415
Cost of O & M ($/yr)	1,642.00	Minimum rate of flow (%)	80	The frequency (Hz)	50
Life span (years)	25	Minimum rate of flow (%)	80	Cost ($)	211,180
		Effectiveness (%)	85	Phase	
		Nominal capacity (kW)	29.27	Maximum power (kW)	100
		Maximum power (kW)	100		

3.5 Head Measurement Outcomes

By measuring the elevation difference between the water levels in the upstream forebay and the downstream tailrace, the gross head of the proposed site was determined. According to field measurements, the gross head was around 2.0 m. The net head was calculated to be around 1.8 m after taking into consideration frictional and small hydraulic losses in the penstock system. According to these findings, the location is technically appropriate for reaction turbines like Kaplan types, which are designed for dependable operation in low-head and moderate-flow scenarios. This is because the site is classified as low-head hydropower.

3.6 Turbine Selection and Power Output

Site-specific elements such as required output capacity, design flow rate, and available head influence the turbine selection. According to the HOMER optimisation results, a nominal capacity of 29.27 kW at 85% efficiency may be produced has a design flow rate of 1.46 m^3/s and a low head of 2 m. Kaplan turbine is best suited given these specifications since these turbines are made specially to function well in low-head (less than 10 m) and low-to-medium flow circumstances. This guarantees long-term economic performance, compliance with the system's operating limits, and dependable energy conversion. Eq. (7) may be used to determine the real power available at the turbine output after accounting for head losses.

$$P = p.g.Q.H.\eta \qquad (7)$$

Using the HOMER results (gross head H = 2m, efficiency η = 0.85 and Q = 1.46 m^3/s) and the reported design flow, the calculation is:

$$P = 1000 \times 9.81 \times 1.46 \times 2 \times 0.85 = 24.348\ kW$$

A low-head reaction turbine (such as a gross flow turbine) is recommended for effective operation under the site's gross head and gross flow circumstances since the calculated power (about 24.348 kW) and the HOMER-reported output (~24.348 kW) match.

4.0 Conclusion

A low-head (2 m) micro-hydropower system that can generate at least 24.348 kW and a maximum output of 29.27 kW is shown to be technically feasible throughout the year by the feasibility study. According to the hydrological data, seasonal rainfall patterns produce sufficient stream flow volumes, and even during the dry season, flow rates are sufficient to supply the baseline energy demand. For distant or off-grid applications, this system can be a dependable independent or hybrid energy option, particularly in areas like rural Tanzania where steady grid power is erratic or nonexistent. With further suggestions for incorporating solar PV or battery storage to improve supply dependability during seasonal drops in flow rate, the research encourages investment in such hydroelectric facilities. In conclusion, the location offers a low-impact, high-community, sustainable, and efficient energy option.

5.0 Recommendation

The suggested low head micro-hydropower system should be put into place as a sustainable energy source for Tanzania's rural areas in light of the findings. Integration with solar PV and battery storage should be taken into consideration to improve reliability, particularly during seasonal fluctuations in flow rates. With little effect on the environment, this hybrid strategy will provide a steady supply of energy, lessen reliance on erratic grid electricity, and promote community development.

6.0 Funding Statement

The study was privately financed.

7.0 Acknowledgement

Sincere thanks are extended to Mbeya University of Science and Technology (MUST) for its academic support and direction during this research. We would especially want to thank Idete Prisons Complex's management and employees for their cooperation during the data collection process. The authors also thank their mentors and colleagues for their crucial support and insights during the research process.

8.0 Declaration of Conflicting Interests

The authors disclose no conflicts of interest.

9.0 References

Abeykoon, C., & Hantsch, T. (2017). Design and analysis of a Kaplan turbine runner wheel. *Proceedings of the World Congress on Mechanical, Chemical, and Material Engineering*, *June*. https://doi.org/10.11159/htff17.151

Bahramara, S., Moghaddam, M. P., & Haghifam, M. R. (2016). Optimal planning of hybrid renewable energy systems using HOMER : A review. *Renewable and Sustainable Energy Reviews*, *62*, 609-620. https://doi.org/10.1016/j.rser.2016.05.039

Erinle, T. J., Ejiko, S. O., & Oladebeye, D. H. (2020). Design of Micro Hydro Turbine for Domestic Energy Generation. *Iarjset*, *7*(4), 85-93. https://doi.org/10.17148/iarjset.2020.7414

Jensen, H. D. (2009). Final report on CCQM-K36.1. *Metrologia*, *46*(1A), 08004–08004. https://doi.org/10.1088/0026-1394/46/1a/08004

Kamran, M., Asghar, R., Mudassar, M., & Abid, M. I. (2019). Designing and economic aspects of run-of-canal based micro-hydro system on Balloki-Sulaimanki Link Canal-I for remote villages in Punjab, Pakistan. *Renewable Energy*, *141*, 76-87. https://doi.org/10.1016/j.renene.2019.03.126

Kaunda, C. S., Kimambo, C. Z., & Nielsen, T. K. (2012). *Hydropower in the Context of Sustainable Energy Supply : A Review of*

Technologies and Challenges. *2012*. https://doi.org/10.5402/2012/730631

Kilama, D. (2013). *Review of small hydropower technology*. *26*, 515–520.

Kusre, B. C., Baruah, D. C., Bordoloi, P. K., & Patra, S. C. (2010). Assessment of hydropower potential using GIS and hydrological modeling technique in Kopili River basin in Assam (India). *Applied Energy*, *87*(1), 298-309. https://doi.org/10.1016/j.apenergy.2009.07.019

Nautiyal, H., Singal, S. K., & Sharma, A. (2021). Small hydropower for sustainable energy development in India. *Renewable and Sustainable Energy Reviews*, *15*(4), 2021–2027. https://doi.org/10.1016/j.rser.2011.01.006

Otuagoma, S., Ogujor, E., & Kuale, P. (2015). Determination of Head for Small Hydropower Development: a Case Study of River Ethiope At Umutu. *Nigerian Journal of Technology*, *35*(1), 190. https://doi.org/10.4314/njt.v35i1.26

Parag, Y., & Ainspan, M. (2019). Energy for Sustainable Development Sustainable microgrids : Economic , environmental and social costs and benefits of microgrid deployment. *Energy for Sustainable Development*, *52*, 72-81. https://doi.org/10.1016/j.esd.2019.07.003

Ranjan Nath, D. (2015). Small Hydro Power and its Potentiality in Assam. *International Journal of Engineering Trends and Technology*, *23*(8), 391-395. https://doi.org/10.14445/22315381/ijett-v23p274

Tsuanyo, D., Amougou, B., Aziz, A., Nka Nnomo, B., Fioriti, D., & Kenfack, J. (2023). Design models for small run-of-river hydropower plants: a review. *Sustainable Energy Research*, *10*(1), 1-23. https://doi.org/10.1186/s40807-023-00072-1

URT- Prison Corporation Sole (2023).