FEASIBILITY STUDY OF UN-TAPPED SMALL HYDROPOWER POTENTIAL SITES IN TANZANIA

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Abstract
Small hydropower resources can play a very important role in providing electricity and power to the remote and rural areas of Tanzania where there is no feasible future for the grid extension. These types of small schemes can generate electricity up to a range of 1 MW. Tanzania has substantial number of small hydropower potential sites for electricity generation and to date it is estimated to be around 315 MW, however, only about 25MW (8%) of this potential have been developed so far, which means several number of potential sites, have not been studied and documented or have not been developed. This research presents the results of the feasibility study of six (6) un-tapped and un-studied small hydropower potential sites in Tanzania. The methodology used in this research was based on site visits, data measurements and collection (hydrological and Energy demand), information gathering, interviews and consultation, data analysis, designs and cost estimation.
The results showed that all the six (6) small hydropower sites studied are feasible and can potentially been developed to produce and supply cost effective electricity to the local off-grid areas as small hydropower plants.

Keywords: *Feasibility, Micro hydropower, Energy, Power, kW, REA, TZS, Tanzania.*

I. INTRODUCTION
1.1 General overview of the study
The majority of rural Tanzanians has no access to modern energy services and relies on traditional type of energy sources which are harmful to their health and the environment [1]. The government maintains that rural Tanzania cannot be transformed into a modern economy and that rural Tanzanian's livelihoods cannot be improved significantly without a dramatic improvement in their access to modern energy services [2].
Tanzania National Energy Policy 2015 sets national energy objectives to ensure availability of reliable and affordable energy supplies, promote efficient energy supplies, and also promote efficient energy use in order to support national development goals [3]. The Policy recognizes that the main thrust has to be based on private initiatives and investments for exploitation of local energy sources. The Policy sets an entirely new approach to modern energy in rural areas of Tanzania and the government has committed itself to develop and implement the new strategy to address modern energy needs of over 85% of Tanzanians living in rural areas [4].
An improved energy supply in the rural areas of Tanzania through public and private sector participation, will contribute significantly in improvement of the livelihoods of the rural population and attainment of sustainable economic growth [5]. In realizing this, the Rural energy Agency (REA) and other organs were established and entrusted to promote and facilitate rural energy development by working in partnership and collaboration with the private sector, Non-Governmental Organizations, Community-Based Organizations and Government Agencies [6].
With these reasons and the support from the Rural Energy Agency (REA) and Arusha Technical College, the research team managed to conduct feasibility studies of six (6) un-tapped potential small hydropower sites in Tanzania in order to update the current small hydropower potential studies.

1.2 Objectives of the study

- Conducting detailed feasibility study of six (6) potential small hydropower potential sites: Mtombozi, Likwela, Nungu, Mambwe, Kasansa and Ludende as shown on Figure 1.
- Determining, design and provide estimates of the structures required to construct Micro and Mini Hydropower systems at each of the potential site
- Conducting financial analysis on each of the six (6) small hydropower sites

II. MATERIALS

The six (6) proposed hydropower development schemes are located in the following Tanzania mainland districts of Kasansa – Mpanda, Mambwe - Rungwe, Nungu – Makete, Likwela – Mbinga, Mtombozi – Rural Morogoro and Ludende – Ludewa as shown on Figure 1.

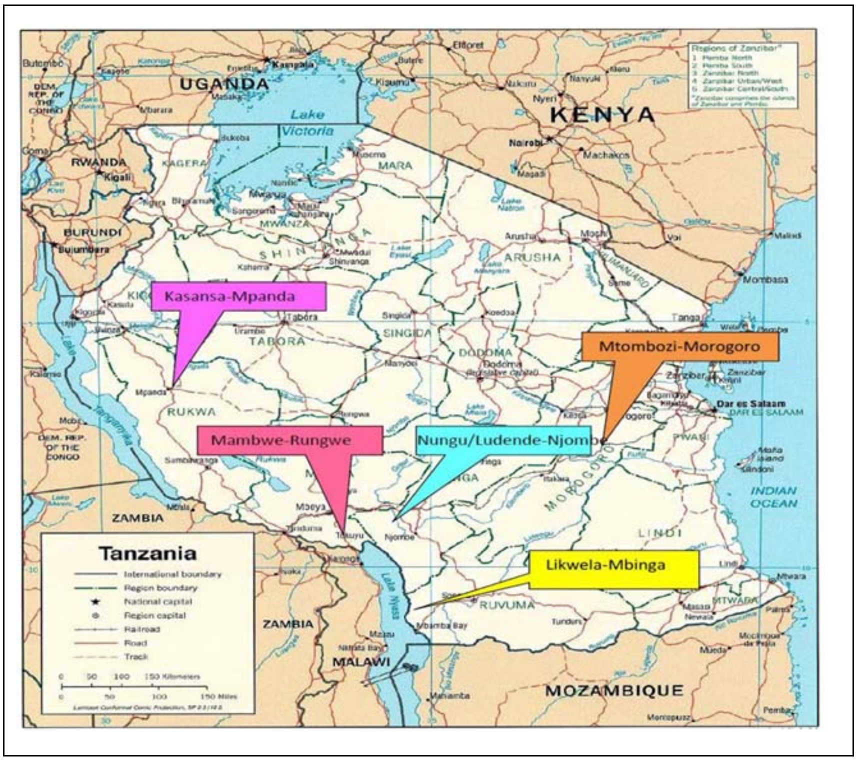

Figure 1: Six (6) schemes location of the small hydropower potential sites

2.1 Mtombozi Scheme:

This scheme will have the installed capacity of 100 kW with design discharge of 580 l/s and gross head of 25 m. The nearest road head for this scheme is Morogoro – Matombo - Lugeni Village and the site is about several meters from Lugeni village. The project area is located in Lugeni Village, Mtombozi Ward, Matombo Division, Morogoro Rural District, in Morogoro Region. Matombo lies to the south in the area of Uluguru Mountains. Specifically, the project site is located along Mtombozi river on the eastern side of Uluguru Mountains at Lat/Long: -6.82, 37.67. Mtombozi is accessible by road from Morogoro town which is 36 Km away and it is accessible by road from Dar es Salaam which is 169 Km away. Main load power center will be in ward no. 1 of Lugeni village. Lighting is the primary use and as a secondary use, small businesses, shops and agro-processing mills and social centers are proposed. 450mm dia. mild steel pipe, 4mm thick has been proposed in the penstock. The total length of the penstock is 400m. There will be three (3) expansion joints and ten (10) anchor blocks. There will be fifteen (15) support piers. The discharge from the penstock will be passed through 135 kW shaft power, Cross flow or Francis turbine and generator system will be used for the scheme which will have is 150 kVA, 3-Phase, synchronous, brushless generators. The total project cost of the Mtombozi scheme is TZS. 1,081,860,679 (Including VAT and Contingency). The cost of Mechanical works, electrical works, civil works and other expenses are TZS. 325,865,250, TZS. 36,508,000, TZS. 416,808,000 and TZS. 236,657,024 respectively. Cost per kW of the project is TZS. 10,818,606.8. Tariff for business use has been fixed to TZS.150 per unit (kWh). Tariff rate at 500 Watt per household is fixed for lighting purpose after conducting financial analysis. The proposed sources of finance to develop Mtombozi small hydropower project is summarized on Table 2.1.

Financial Features:

Total Investment Cost of Scheme	: **TZS. 1,081,860,679** (Including VAT and Contingency)
Investment Cost per kW	: **TZS. 10,818,606.8**
IRR	: **18.5%**
NPV	: **TZS. 413,576,842**
B/C Ratio	: **1.33**
Payback Period	: **7.5 Years**
Annuity Payment	: **TZS. 21,638,167**

Table 2.1: Proposed Sources of Finance

S/N	Source	Amount (TZS)	Share (%)	Remarks
1	World bank Grant or other	540,930,339.5	50	
2	REA Grant/Subsidy	270,465,169.5	25	
3	Local government support	54,093,033.95	5	
4	Local Labour & Materials	21,637,213.58	2	Item 4, 5 and 6
5	Community cash contribution	32,455,820.37	3	should be collected
6	Bank Loan by Community	162,279,101.9	15	by community
Total		**1,081,860,679**	**100**	

2.2 Likwela Scheme:

The scheme will have the installed capacity of 150 kW with design discharge of 1,220 l/s and gross head of 20 m. The nearest road head for this scheme is Songea – Mbinga - Likwela Village and the site is about few meters from Likwela village. Likwela proposed small hydropower scheme is in Likwela village, Mbinga district, Ruvuma region. It is about 25 km (through gravel road) from Mbinga town. The site is located at an average elevation of about 1475m above mean sea level. The site is located along Lumeme river. The river floor has a gentle slope along the river valley and fairly steep across the river-valley. Main load power center will be in ward no. 1 of Likwela village. Lighting is the primary use and as a secondary use, small businesses, shops and agro-processing mills and social centers are proposed. A 500mm diameter mild steel pipe, 4mm thick has been proposed in the penstock. The total length of the penstock is 350m. There will be three (3) expansion joints and twelve (12) anchor blocks. There will be eighteen (18) support piers. The discharge from the penstock will be passed through 175 kW shaft power, Cross flow or Francis turbine and generator system will be used for the scheme which will have 200 kVA, 3-Phase, synchronous, brushless generators. The length of Transmission is 1,525m. Transmission network is designed for both single phase and three phase connections. The total project cost of the Likwela scheme is TZS. 1,043,856,155 (Including VAT and Contingency). The cost of Mechanical works, electrical works, civil works and other expenses are TZS. 387,027,250, TZS. 61,108,250, TZS. 520,597,000 and TZS. 292,279,724 respectively. Cost per kW of the project is TZS. 8,907,572. Tariff for business use has been fixed to TZS.150 per unit (kWh). Tariff rate of 500 Watt per household is fixed for lighting purpose after conducting financial analysis. The proposed sources of finance to develop Likwela small hydropower project is summarized on Table 2.2.

Financial Features:

Total Investment Cost of Scheme	: **TZS. 1,336,135,879** (Including VAT and Contingency)
Investment Cost per kW	: **TZS. 8,907,572.5**
IRR	: **21.5%**
NPV	: **TZS. 945,514,753.7**
B/C Ratio	: **1.62**
Payback Period	: **7.5 Years**
Annuity Payment	: **TZS. 26,721,847**

Table 2.2: Proposed Sources of Finance

S/N	Source	Amount (TZS)	Share (%)	Remarks
1	World bank Grant or other	521,928,077.5	50	
2	REA Grant/Subsidy	260,964,038.8	25	
3	Local government support	52,192,807.75	5	
4	Local Labour & Materials	20,877,123.1	2	Item 4, 5 and 6 should be collected by community
5	Community cash contribution	31,315,684.65	3	
6	Bank Loan by Community	156,578,423.3	15	
	Total	**1,043,856,155**	**100**	

2.3 Nungu Scheme:

This scheme will have the installed capacity of 125 kW with design discharge of 700 l/s and gross head of 25 m. The nearest road head for this scheme is Makete – Matamba – Nungu Village and the site is about several meters from Nungu village. It is about 20 km (through earth road) from Chimala neighborhood. The site is located at an average elevation of about 1,925 m above mean sea level. The site is located along Misi river. The river has a fairly steep slope across the river-valley and a small fall along the valley just near the site. Main load power center will be in ward no. 1 of Nungu village. Lighting is the primary use and as a secondary use, small businesses and agro-processing mills and social centers are proposed. 450mm diameter mild steel pipe, 4mm thick has been proposed in the penstock. The total length of the penstock is 200m. There will be three (3) expansion joints and ten anchor blocks. There will be fifteen (15) support piers. The discharge from the penstock will be passed through 140 kW shaft power, Cross flow or Francis turbine and generator used for the scheme is 150 kVA, 3-Phase, synchronous, brushless generators. The length of Transmission is 2,508m. Transmission network is designed for both single phase and three phase connections. The total project cost of the Nungu scheme is TZS. 1,143,740,999 (Including VAT and Contingency). The cost of Mechanical works, electrical works, civil works and other expenses are TZS. 324,187,250, TZS. 55,708,000, TZS. 447,630,000 and TZS. 250,193,344 respectively. Cost per kW of the project is TZS. 9,149,928. Tariff for business use has been fixed to TZS. 150 per unit (kWh). Tariff rate at 500 Watt per household is fixed for lighting purpose after conducting financial analysis. The proposed sources of finance to develop Nungu small hydropower project is summarized on Table 2.3.

Financial Features:

Total Investment Cost of Scheme	: **TZS. 1,143,740,999** (Including VAT and Contingency)
Investment Cost per kW	: **TZS. 9,179,928**
IRR	: **21%**
NPV	: **TZS. 753,539,011.7**
B/C Ratio	: **1.57**
Payback Period	: **7.7 Years**
Annuity Payment	: **TZS. 22,874,820**

Table 2.3: Proposed Sources of Finance

S/N	Source	Amount (TZS)	Share (%)	Remarks
1	World bank Grant or other	571,870,499.5	50	
2	REA Grant/Subsidy	285,935,249.8	25	
3	Local government support	57,187,049.95	5	
4	Local Labour & Materials	22,874,819.98	2	Item 4, 5 and 6 should be collected by community
5	Community cash contribution	34,312,229.97	3	
6	Bank Loan by Community	176,061,149.9	15	
	Total	**1,143,740,999**	**100**	

2.4 Mambwe Scheme:

The scheme will have the installed capacity of 100 kW with design discharge of 160 l/s and gross head of 78 m. The nearest road head for this scheme is Tukuyu - Ruangwa-Mambwe and the site is about several meters from Mambwe village. Mambwe proposed small hydropower scheme is in Lupatu village, Rungwe district, Mbeya region. It is about 25 km (through gravel road) from Tukuyu town. The site is located along Kapiyu river at an average elevation of about 1,250 m above mean sea level. This river has a gentle slope across the stream-valley, and a small fall along the stream just near the site. Main load power center will be in ward no. 1 of Mambwe village. Lighting is the primary use and as a secondary use, small businesses and agro-processing mills and social centers are proposed. 400mm diameter mild steel pipe, 4mm thick has been proposed in the penstock. The total length of the penstock is 700m. There will be four (4) expansion joints and twenty (20) anchor blocks. There will be thirty (30) support piers. The discharge from the penstock will be passed through 2 x 65 kW shaft power, Pelton turbine and generator used for the scheme is 2 x 60 kVA, 3-Phase, synchronous, brushless generators. The length of Transmission is 760 m. Transmission network is designed for both single phase and three phase connections. The total project cost of the Mambwe scheme is TZS. 950,647,879 (Including VAT and Contingency). The cost of mechanical works, electrical works, civil works and other expenses are TZS. 276,132,250, TZS. 38,108,000, TZS. 346,572,000 and TZS. 207,954,224 respectively. Cost per kW of the project is TZS. 9,506,478.8. Tariff for business use has been fixed to TZS.150 per unit (kWh). Tariff rate of 500 watt per household is fixed for lighting purpose after conducting financial analysis. The proposed sources of finance to develop Mambwe small hydropower project is summarized on Table 2.4.

Financial Features:

Total Investment Cost of Scheme	: **TZS. 950,647,879** (Including VAT and Contingency)
Investment Cost per kW	: **TZS. 9,506,478.8**
IRR	: **20%**
NPV	: **TZS. 496,793,107.1**
B/C Ratio	: **1.45**
Payback Period	: **7.5 Years**
Annuity Payment	: **TZS. 19,012,957**

Table 2.4: Proposed Sources of Finance

S/N	Source	Amount (TZS)	Share (%)	Remarks
1	World bank Grant or other	475,323,939.5	50	
2	REA Grant/Subsidy	237,661,969.8	25	
3	Local government support	47,532,393.95	5	
4	Local Labour & Materials	19,012,957.58	2	Item 4, 5 and 6 should be collected by community
5	Community cash contribution	28,519,436.37	3	
6	Bank Loan by Community	142,597,181.9	15	
	Total	**950,647,879**	**100**	

2.5 Kasansa Scheme:

This scheme will have the installed capacity of 9 kW with design discharge of 35 l/s and gross head of 35m. The nearest road head for this scheme is Mpanda – Majimoto – Kasansa and the site is about few meters from Kasansa village. Proposed Kasansa micro hydropower scheme is in Kasansa village, Mlele district, Katavi region. It is about 150 km (earth road) from Mpanda town. The site is located at an average elevation of about 925 m above mean sea level. The scheme stream has a fairly steep slope, both along and across the stream valley. The site is near the ending of the Kasansa small river, where it opens to the Rukwa rift valley. Main load power center will be in ward no. 1 of Kasansa village. Lighting is the primary use and as a secondary use small businesses and hospital vaccination and sterilization are proposed. 200mm diameter mild steel pipe, 3.5mm thick has been proposed in the penstock. The total length of the penstock is 185 m. There will be two (2) expansion joints and ten (10) anchor blocks. There will be fifteen (15) support piers. The discharge from the penstock will be passed through 12 kW shaft power, Pelton turbine and generator used for the scheme is 15 kVA, 3-Phase, synchronous, brushless generator. The total project cost of the Kasansa scheme is TZS. 194,754,505 (Including VAT and Contingency). The cost of mechanical works, electrical works, civil works and other expenses are TZS. 45,313,250, TZS. 37,658,000, TZS. 62,400,000 and TZS. 49,316,472 respectively. Cost per kW of the project is TZS. 12,797,181.49. Tariff rate at 200 Watt per household is fixed for lighting purpose after conducting financial analysis. The proposed sources of finance to develop Kasansa Micro hydropower project is summarized on Table 2.5.

Financial Features:

Total Investment Cost of Scheme : **TZS. 194,687,722** (Including Contingency and VAT)

Investment Cost per kW : **TZS. 12,797,181.49**

IRR **: 14%**

NPV : **TZS. 21,992,951.27**

B/C Ratio : **1.12**

Payback Period : **6 Years**

Annuity Payments : **TZS. 3,235,090**

Table 2.5: Proposed Sources of Finance

S/N	Source	Amount (TZS)	Share (%)	Remarks
1	REA Grant/Subsidy	146,015,791.5	75	
2	Local government support	9,734,386.1	5	
3	Local Labour & Materials	3,893,754.4	2	Item 4, 5 and 6
4	Community Cash Contribution	5,840,631.7	3	should be collected
5	Bank Loan by Community	29,203,158.3	15	by community
	Total	**194,687,722**	**100**	

2.6 Ludende Scheme:

The scheme will have the installed capacity of 100 kW with design discharge of 164 l/s and gross head of 60 m. The nearest road head for this scheme is through Njombe - Mlangali to Ludende and the site is about one Kilometer from Ludende village and few additional Kilometers to the other three (3) villages of Madindo, Mlulu and Mhorong'wa. It is about 130 km (through gravel road) from Njombe township. The site is located along Vombwi small river at an average elevation of about 1,650 m above mean sea level. The main load power center will be in village no.1 of Ludende. Lighting is the primary use and as of secondary use, small businesses and agro-processing mills and social centers are proposed. For the design, 400mm diameter mild steel pipe, 4mm thick has been proposed for the penstock. The total length of the penstock is 200 m. There will be three (3) expansion joints and twenty (20) anchor blocks. Also, there will be twenty-five (25) support piers. The discharge from the penstock will be passed through 120 kW shaft power, Pelton turbine and generator used for the scheme is 120 kVA, 3-Phase, synchronous, brushless generators. The length of Transmission to the main load center (Ludende village) is about 1.5 Km. The transmission network to the other three (3) villages load power centers from the main load center is designed for both single phase and three phase connections. The total project cost of the Ludende scheme is TZS. 949,482.772 (Including VAT and Contingency). The cost of mechanical works, electrical works, civil works and other expenses are TZS. 223,632.250, TZS. 121,278,000, TZS. 302,432,000 and TZS. 217,986,030 respectively. Investment cost per kW of the project is TZS. 7,314,967. Tariff for business use has been fixed to TZS.150 per unit (kWh). Tariff rate of 500 watt per household is fixed for lighting purpose after conducting financial analysis. The proposed sources of finance to develop Ludende small hydropower project is summarized on Table 2.6.

Financial Features

Total Investment Cost of Scheme	: **TZS. 949,482,772** (Including VAT and Contingency)
Investment Cost per kW	: **TZS. 7,314,967**
IRR	: **12 %**
NPV	: **TZS. 129,096,425.09**
B/C Ratio	: **1.12**
Loan Payback Period	: **8 Years**
Loan Annuity Payment	: **TZS. 12,352,025.60**

Table 2.6: Proposed Sources of Finance

S/N	Source	Amount (TZS)	Share (%)	Remarks
1	Donors/World Bank/European Union Grant	474,741,386	50	
2	REA Grant/Subsidy	284,844,837.6	30	
3	Local government support	47,474,138.6	5	
4	Local Labour & Materials	18,989,655.44	2	Item 4, 5 and 6
5	Community cash contribution	28,484,483.16	3	should be collected
6	Bank Loan by Community	94,948,277.2	10	by community
	Total		**100**	

III. METHODOLODY

3.1 Procedures

Several procedures have been conducted prior and during the feasibility study in order to facilitate the collection of site information and conducting field work. Some of the procedures include:

(i) Consultations with stakeholders: Local government leaders were consulted

- To assess the leader's extent of support to the projects
- To seek for official introduction to the members of the communities located at or near the project sites
- To collect information on major events like recent droughts or floods that have occurred at project sites

(ii) Detailed Assessment of Social and Environmental setting in relation to the proposed projects including

- Community energy needs
- Community willingness to volunteer labour
- Existing land systems and uses at the sites
- Land ownership regimes at the sites
- Ecology of natural resources at the sites
- Positive and negative influences of projects to society and environment

(ii) Collection of resource and social – development documents associated with the proposed sites

- District environmental profiles
- District economic profiles
- Administrative site reports

(iv) Estimation and Economic Analysis

The methodology used to make estimations and economic analysis of the projects was as follows:

- Costing was done by collecting quotation of electrical, electronics, mechanical equipment, and the line materials needed for the project from various manufacturers and suppliers
- Preparation of detailed estimates of the project construction costs and annual operation and management cost based on approved designs and updated norms
- Calculation of tariff rates for the electricity uses, including all recommended end uses, so that the tariff is based on an affordable range for all the users and the fund generated. The fund generated from the tariffs is calculated such that it becomes sufficient for the annual operation and maintenance costs and replacement costs of the project components
- Preparation of economic analysis showing economic parameters like IRR, NPV and Payback Period on the basis of cash flows on each scheme

3.2 Energy potentials and uses

The main sources of energy in most of these site locations are fuel wood, kerosene, dry cell and charcoal. Household's uses firewood and charcoal for cooking, water heating and local brew making. Similarly, almost all houses use kerosene lamp and lantern for lighting. There is a possibility of promoting hydropower technology in and around the project area due to the availability of the flowing water from the nearby rivers.

Activities like cooking human food, animal food and making local brew are mostly carried out with firewood and charcoal. Lighting is another important activity performed in the household. Lighting hours per day in the settlements are about 6 -7 hours. However, the lighting hours in these project areas has been provisioned to 6.5 hours as per the suggestion and demand from the community members.

The proposed hydropower potential sites would supply electricity to some of the nearby villages. Average power demand per household has been taken as 150 Watts on average although a maximum of 500 Watts have been set. Moreover, the communities are interested to run mills for maize milling and establish different energy end uses after the introduction of hydropower plants.

3.3 Socio-economic condition and affordability

The projects areas is mostly inhabited by people whose livelihood is based on crop production particularly bananas, maize, rice, sugar, bananas, potatoes, cassava, tobacco and yams. They also generate income by selling various types of fruits and spices like cloves and ginger.

Income from agriculture is limited because land is scarce due to overpopulation and scarcity of land in these areas. The population increase is up to 6.5% [7]. Deforestation and other resource degradation contribute to scarcity of land in the site areas.

Some population from the project areas migrate to towns and cities where they work and do business. But they maintain homes and families back in these project areas. Therefore, they are able to pay for electricity if it is installed in these areas.

3.4 Status of community mobilization process

Members of the community and politicians in the site areas have shown interests to contribute on the development of hydropower plants in the villages. Members of the community in the villages discuss the need to establish hydropower scheme in the site areas and they are willing to contribute the efforts to establish these schemes. They are also willing to pay for electricity when these schemes are installed. However, there are no organization which are assigned to follow the establishment of these hydropower schemes in the sites areas.

3.5 Scheme layout, plant size and power requirements

These rivers are the sources of discharge for the potential sites. The discharge of these rivers was measured by the survey team during the site visit and data collection. All these rivers carry sufficient discharge even in dry season. Design discharge used in the calculations has been taken after making provision for evaporation, flushing, seepage for downstream release and environmental flow.

The estimated mechanical and electrical output power of each scheme has been calculated based on the following formula [8] and calculated values are shown on **Table 3.1** below.

Mechanical Power in kW: (Turbine Power)
Turbine Power (Pt) = Q x Hg x g x η_t [kW], where: Q = discharge in m^3/s, Hg = gross head in m, g = acceleration due to gravity = 9.81 m/s^2, η_t = turbine efficiency

Electrical Power in kW: (Generator Power)
Electrical Power (Pg) = Q x Hg x g x η_s [kW], where: η_s = system efficiency (η_t x η_g)
or
Electrical Power (Pg) = Turbine Power (Pt) x η_g [kW], where, η_g = generator efficiency

Table 3.1: Summary of the energy potential for the six (6) hydropower sites

Name of the project Scheme	River/ Stream	Est. design flow rate (m^3/s)	Est. design Head (m)	Est. Mechanical Power (kW)	Est. Electrical Power (kW)	System Efficiency (%)	Penstock dia. (mm)	Turbine Selection
Kasansa	Kasansa	0.035	35	12	9	75	200	Pelton
Mambwe	Kapiyu	0.16	78	124	96	77.4	400	Pelton
Nungu	Misi	0.7	25	174	125	71.8	450	Crossflow/ Francis
Likwela	Lumeme	1.1	20	200	150	75	500	Crossflow/ Francis
Mtombozi	Mtombozi	0.58	25	140	100	71.4	450	Crossflow/ Francis
Ludende	Vombwi	0.164	60	120	100	80.6	350	Pelton

Note: Values for design flow, Q and head, H have been obtained from the actual site measurements and also historical data.

3.6 Cost Estimates

Hydropower is one of the least expensive sources of power since the cost of hydropower is dominated by the initial capital cost of building the facilities while the ongoing operating and maintenance (variable) costs are low. Moreover, since hydropower generation does not require burning fuels, operations costs are not vulnerable to fuel price fluctuations. Existing hydropower facilities are very cheap to operate and they can operate for more than 25 years [9] without major replacement. The cost of hydropower plants are highly site-specific and depends on different factors, including hydrologic characteristics, site accessibility and distances for the transmission.

All the rates of the scheme have been worked out taking into consideration availability of local construction materials and labor. In addition, the rates for skilled and unskilled manpower are based on the local practice in the community. The rate of electro-mechanical equipment's are taken from the current price quotation of the manufacturer/installer. The costs are only indicative and close approximation, hence, should be used only for budgetary purposes. The cost of electro-mechanical equipment's may vary according to change in the market price in the given time. All costs of the material are included VAT.

3.7 Financial and Economic Aspects

The financial and economic analysis of the scheme indicates the validity of these project in terms of its capital cost. It focuses on the sources of funding for the project, annual income, annual expenditure and financial indicators of the project such as Net Present Value (NPV), Benefit Cost Ratio (B/C Ratio) and Internal Rate of Return on the Investment (IRR). The financial and economic analysis of the scheme indicates that the proposed scheme is viable both financially and economically.

3.8 Energy potential end use

Members of community in the project areas need electricity. Electricity from hydropower is an important alternative source of energy because the existing energy sources in the areas are unreliable and readily available. The people use mainly fuel wood and charcoal as their major source of energy. End uses include lighting for households and shops. Other uses involve electricity for saloons, phone charging, maize mills and small fruit or juice processing factories etc. The annual energy consumption for Matombo - Lugeni village is estimated to be 327.6 GWh as shown on **Table 3.2**.

Table 3.2: Typical list of end use energy demand (Matombo - Lugeni Village)

S/N	Energy use	Qty	Rated capacity (kW)	Operating hours per day	Operating days per month	Operating months per year	Total Energy Consumption per year (kWh/year)	Tariff TZS per kWh	Total Income per year (TZS)
A: Domestic use									
A.1	Household – Lighting and Power	50	0.5	24	30	12	216,000	100	21,600,000
Sub-Total A							**216,000**		**21,600,000**
B: Productive use									
B.1	Maize Mill	1	5	5	25	12	7,500	150	1,125,000
B.2	Men Saloon	1	2	8	25	12	4,800	150	720,000
B.3	Women Saloon	1	2	8	25	12	4,800	150	720,000
B.4	Shops	4	2	12	30	12	34,560	150	5,184,000
Sub-Total B							**51,660**		**7,749,000**
C: Social Infrastructure									
C.1	Social Center	1	4	8	25	12	9,600	150	1,440,000
C.2	Health centers	2	5	8	30	12	28,800	150	4,320,000
C.3	Schools	3	4	6	25	12	21,600	150	3,240,000
Sub-Total C							**60,000**		**9,000,000**
TOTAL (A + B + C)							**327,600**		**38,349,000**

3.9 Expected annual revenues

Based on the energy consumption per year in the area, the expected annual revenue for the Matombo small hydropower project is Thirty Eight Million, Three Hundred and Forty Nine Thousands (**TZS 38, 349,000**) as shown on **Table 3.2**.

In all the potential sites, domestic use tariff is fixed in terms of watts usage per month for lighting and power. However, for other uses, tariff is being designed on unit basis as shown on Table 3.3. The tariffs are calculated by considering aspects as follows:

- Demand for the services
- Purchasing capacity of the consumer
- Tariff from local regulatory authority - EWURA
- Income from end uses
- Total project cost
- Operating cost of the scheme

Table 3.3: Proposed tariff

Service	Tariff
Lighting	TZS. 100 per kWh per month
End use	TZS.150 per kWh

Tariffs are to be reviewed and revised periodically as the price levels change based on the economy of the area.

3.10 Estimated Annual Expenses

The total annual expenses of the typical 100kW hydropower plant like Mtombozi Hydropower Scheme is **TZS. 7,676,018** as shown on **Table 3.4** below.

Table 3.4: Total annual expenses (Typical 100 kW Plant)

S/N	Component	Qty	Monthly salary/Expenses [TZS]	Month	Total monthly expenses [TZS]	Remarks
1	Plant operator	1	100,000	12	1,200,000	
2	Plant Manager/Accountant	1	150,000	12	1,800,000	
3	Repair & Maintenance	LS			4,226,018	0.5% of the Project Cost
4	Office Expenses	LS	25,000	12	300,000	
5	Miscellaneous	LS	12,500	12	150,000	
TOTAL EXPENSES					**7,676,018**	

3.11 Financial Analysis

The financial analysis includes the financial status of the scheme. It focuses on the source of funding for the projects, annual income, annual loss and financial indicator of the project such as Net Present Value, Benefit Cost Ratio and Internal Rate of Return.

Material section shows the summary of the financial analysis of the schemes. The analysis includes VAT. The analysis shows that the proposed scheme is financially viable and economically affordable from Grants and Loans for the local people of the project areas.

3.11.1 Net Present Value (NPV), Benefit Cost Ratio (B/C ratio) and Internal Rate of Return (IRR)
Based on the estimated income and expenditure and considering standard discount rate of 12% and economic life of the plant to be 20 years, the NPV, IRR and B/C of the schemes are presented on section 2. The financial analysis has been done considering total project cost excluding the amount from subsidy.

3.11.2 Investment Cost
The total investment cost has been calculated after deducting all the applicable VAT and taxes from the total project cost. Investment cost has been calculated as follows:

Investment cost = Total project cost – VAT and Taxes

3.11.3 Operation and Maintenance Cost
The cost of system administration, management, operation and maintenance of the scheme have been considered as **0.5%.**

3.12 Economic Benefits
The economic benefits are those benefits which the scheme will bring to the society. The assessment of economic benefits covers quantifiable and non-quantifiable, direct as well as indirect benefits. Calculations in this case involve Economic Rate of Return on quantifiable non-incremental benefits.
Benefits have been assessed based on the avoided cost of diesel generation in the case of supply to productive end uses and the avoided cost of on kerosene use for lighting purposes in households. Members of community also avoid cost of dry cell use.

3.12.1 Benefits from Kerosene Replacement
The average use of kerosene in the project areas is 10 litres per household per month. After generation of the electricity it is assumed that a household would require only 2 litres of kerosene per household per month. Therefore, the hydropower schemes will replace 8 litres of kerosene per month in turn TZS 201,600 will be saved annually in each household. The calculation is based on the cost of kerosene at TZS 2,100 per litre.

3.12.2 Benefits from Diesel Replacement
It is envisioned that one maize mill will save three litre of diesel per operating hour on average. So, annually 4,500 liters diesel equivalent to TZS 9,450,000 will be saved based on unit cost of TZS 2,100 per liters of diesel.

3.12.3 Benefits from Dry Cell Battery Replacement
It has been revealed that the beneficiary households use about two and half pairs of dry cell batteries per month on average. The proposed hydropower scheme will save one and half pair of dry cell batteries per household per month, which will make 1,440 pairs of dry cell batteries, will be replaced per year. Therefore, TZS 2,160,000 will be saved per year by replacing dry cell batteries based on the cost of the dry cell at TZS 1,500

3.12.4 Incremental benefits
The benefits, which are not included in the analysis but could be mentioned, are the incremental benefits. The incremental benefits are the benefits that come from the increase in modernity from the electricity uses due to low prices of the available electricity. The benefits include the direct improvement in the quality of education as a result of availability of electricity. Indirect educational benefits due to availability of electricity include extended reading hours and better-quality lighting facility. Members of community will use electricity for media like TV, Radio and computer operations. Members of community will get opportunity to engage in income generating activities, especially during evening hours and at dawn. Reduction of air pollution will bring about health benefits.

IV. CONCLUSION
From the preceding analyses and discussions, it is found out that the studied hydropower potential schemes are technically and financially feasible. The implementation of theses project will provide high quality lighting for household purpose as well as reliable, affordable and environmentally safe power for end-use applications. A proposed hydropower potential capacity of 9 kW for Kasansa, 96 kW for Mambwe, 125 kW for Nungu, 150 kW for Likwele, 100 kW for Mtombozi and

100 kW for Ludende can be developed as hydropower plants based on Pelton, Crossflow or Francis turbines technology operating at rated gross heads of 35m, 78m, 25m, 20m, 25, 60m and design flows of 35 l/s, 160 l/s, 700 l/s, 1,100 l/s, 580 l/s, 164 l/s respectively. Among the six (6) studied sites, Kasansa, Mambwe, Mtombozi and Ludende falls under the micro hydropower scale due to their potential power capacity which is below 100 kW [10].

The financial analysis also shows that the NPV ranges between TZS 21,992,951.27 for 9 kW scheme to TZS 945,514,753.7 for 150 kW scheme with, B/C ratio from 1.12 to 1.62 and IRR from 12% to 21.5%, based on the electricity price at TZS 100 for lighting and TZS 150 per unit for power based on the current energy prices. The above estimated cost is below the standardized investment costs for such kind of of small scale hydropower projects of similar type which ranges between TZS 500 Million for 25kW plant, TZS 900 Million for a 50kW plant and around TZS 1.5 Billion for a 100kW plant [11]. Thus due to their reasonable investment cost, both schemes should be considered beneficial from all aspects viz. financially, environmentally, socially and economically. So, local governments or energy companies should invest and develop these kinds of small scale hydropower projects in order to supply reliable electricity to rural and off-grid areas of Tanzania or even connect to the national grid [12]. This will impact poverty reduction through introduction of small businesses, agro-processing industries and improved living standard and services [13].

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We hope these valuable information will underline the need to do and support more studies at different places of Tanzania in order to properly document the existing small hydropower potential sites in the country.

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