Matching the Energy Demand of Surrounding Villages with Hydropower Potential of the Un-Gauged Myombwe River

Hamis A. Mrope
Department of Sustainable Energy Science and Engineering, Nelson Mandela Institution of Science and Technology, P.O. Box 447 Arusha, Tanzania

Joseph Kihedu
Department of Mechanical and Industrial Engineering, CoET, University of Dar es salaam, P.O.Box 35131, Dar es salaam, Tanzania

Abstract
Energy demand of twelve villages surrounding Magunguli waterfalls along un-gauged Myombwe River was assessed and matched with energy hydropower potential available. Estimation of the energy demand for the villages around was done by using diversity factor analysis covering common factors for grouped potential users. A questionnaire was used to find the number of potential electricity users in these twelve villages. Then diversified unit load and group diversity factors for classified loads were used to actual power demand. The study area has 3,747 households, while dispensaries are 8. In addition to that, there are 17 primary schools and 4 secondary schools. The current power demand of twelve villages is 1,569.24 kW. Energy demand forecast shows that, the demand will grow to 7,846.2 kW after four years will be 33,924.16 kW after 25 years. It was also noted that the average consumption for a household is 129.4 W. For education sector, the total demand is 122 kW at an average of 5,851 W per school. Commercial uses have the total demand of 790.34 kW while for public services total demand is 171.82 kW. With the gross head of 636 m and 1.98 m^3/s discharge, hydropower potential of Myombwe River was realized to be 9,388.68 kW. Therefore, this power generation can suffice optimum energy demand of the twelve villages for 4 years. Thereafter, additional source of power may be required.
Keywords: Hydropower potential, energy demand, un-gauged river.

1. Introduction

Mini-hydropower can be applied to sites ranging from a tiny scheme to electrify a single home, to a few hundred kilowatts for selling into the National Grid. Small-scale hydropower is one of the most commercial and trustworthy energy technologies to be well thought-out for providing dirt free power production. Mini-hydropower is in most cases “run-of-river”; in other words any dam or barrage is quite small, usually just a weir, and little or no water is stored. By using mini grids, mini hydropower plants are utilized for rural electrification. However, to ascertain the adequacy of the estimated hydropower, the estimated power demand of the expected beneficiaries should be known. The decisions of households and businesses regarding the use of energy have very important implications for long-run as well as short-run changes in economic activities (Khan and Ahmad, 2008).

There are several methods of determining energy demand of a certain area; by assessing inventory of the appliances, empirical models (De Vita *et al.*, 2006) and by using diversity factors (Mwangomo, 2010). With a significant potential for energy demand growth in the developing world, but there is unequally great uncertainty over the time and magnitude of this growth, providing information that may decrease this uncertainty should prove valuable to policy makers (De Vita *et al.*, 2006).

Tanzania is gifted with diverse energy sources most of which are untapped, these include biomass, hydro, uranium, natural gas, coal, geothermal, solar and wind. The primary energy supply includes biomass (90%); petroleum products (8%); electricity (1.5%), and the remaining (0.5%) is contributed by coal. Others including renewable energy sources such as solar, wind, geothermal, hydropower and biogas account for about 1% of the total energy consumed in Tanzania (TANESCO, 2008). More than 80% of energy delivered from biomass is consumed in rural areas; heavy dependence on biomass as the main energy source contributes to deforestation, while the importation of oil costs about 25% to 35% of the nation’s foreign currency earnings (Luhanga *et al.*, 1993). In Tanzania, only 14% of the country is electrified, urban areas contributing about 12% and the remaining 2% covers rural areas (Luhanga *et al.*, 1993). The development of rural Tanzania is very important since 80% of population in Tanzania is living in rural areas (Guide, 2004). This implies there is still an urgent need to encourage and promote the supply of affordable energy sources in rural areas where the majority of the population live. Extending the grid to many parts of Tanzania is not economically viable (TANESCO, 2008).

There are many regions of Tanzania where the grid is not yet operational, but they have sufficient hydro resources to meet the basic domestic and cottage industry needs of the local populations (Mtalo, 2005). Growing energy demand and concern for carbon emission is making hydropower development more favorable (Kumar *et* *al.*, 2011). Key barriers to the development of Small Hydropower Plants (SHP) in Tanzania are lack of local capacity both design and supplier units, lack of information about potential sites including hydrological data, un-gauged properties sites and policies (Klunne and Michael, 2010). Myombwe River, in Tanzania, has Magunguli water falls in Mufindi district. The water falls is surrounded by Magunguli, Kiyowela, Isaula, Idete, Nyigo, Ihawaga, Ikimilinzowo, Udumka, Ihomasa, Kilolo, Kitandalilo, Nyamande, Mahongole villages, all of which are not connected to the national grid. On an average, families spend about USD 20 per month. The energy sources are firewood, candles, dry-cell batteries and a few petrol generators. The main economic activity of the population is agriculture.

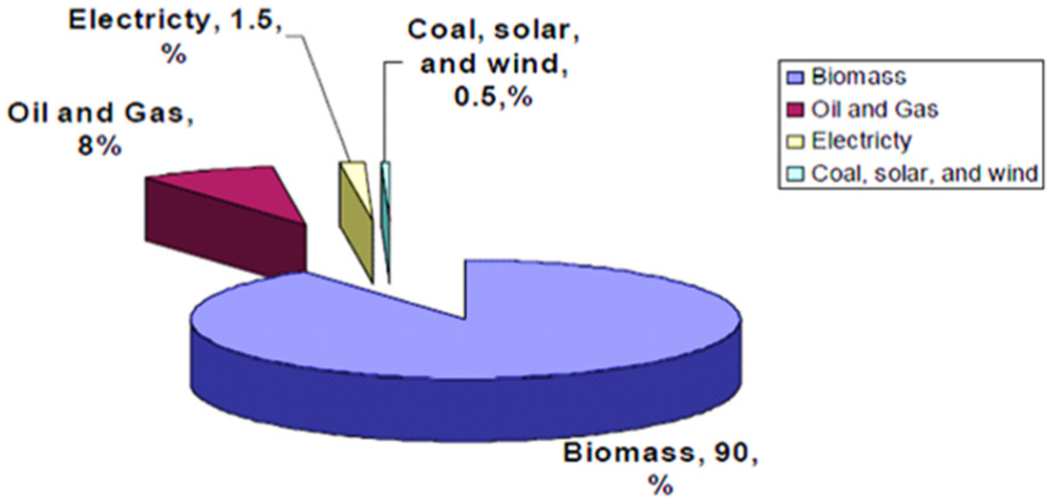

Figure 1: Status of Energy Consumption in Tanzania (MEM, 2003).

The proposed Myombwe Hydro Project is located on the Myombwe river fall in Mufindi District of the Iringa region, Tanzania. The district as a whole is blessed with magnificent mountains, beautiful valley, lush vegetation, several waterfalls and plentiful rainfall, all of which have made it possible to develop electricity generation plants. According to the 2012 Tanzania National Census, the population of Mufindi District is 321,714 with majority living in rural areas off the national electricity grid (TNBS, 2012). The present gridline point is at about 5 km distance form Mufindi Paper Mills Limited. There are no concrete plans for the expansion of the grid to nearby villages. If this will happen the power plant can also be connected to the grid at about 5 km from the proposed power house location. The project can also connect primary schools, secondary schools, dispensaries and several other institutions such as churches, mosques, government offices and private institutions. The number of establishments that were judged as ready for possible connections due to the quality of building (iron roofs, brick walls etc.) was approximately 3742.

2.0 Methodology

2.1 Electricity Power Demand for twelve Villages

A survey was conducted to determine the electrical load demand of the twelve villages that surround Magunguli waterfalls. The data was acquired through focus group discussion and structured interview. A total number of twelve villages were surveyed. The study focused on four key demand groups; which are residential customers, light commercial, light industries and other social services, as shown in Table 1. From the diversified unit load and group diversity factors for classified loads in Tables 1 and Table 2 were used to calculate load demand of each village. Individual diversified maximum power in each village was obtained by using Equation 1, and then total demand of all twelve villages was obtained.

$$MD = N_C * D_U * Dg \text{ (kW)} \quad (1)$$

where MD is Market demand, N_C number of consumers, D_U is diversified unit load and D_g is group diversity factor.

The estimation of demand forecast for 4 and 25 years of these twelve villages were done by using Equation 2.

$$TD = D(kW) * (1+\gamma) * n \quad (2)$$

where TD is Total load after n years, D is Load in kW, γ is Annual load growth rate (which is 0.25 for the first four years)and n is Number of years.

Table 1: Deversified Unit Load Diversity Factors for Classified Loads (TANESCO, 2008)

Classification load	Consumer	Diversified unit	Group Diversity
Residential	Small load house	0.2	0.6
	Medium load house	0.8	0.6
	Large load house	2	0.6
Light commercial	Small restaurant	0.2	0.6
	Hotel/camp	2	0.6
	Bar	2	0.6
	Guest house	2	0.8
	Small shop	0.2	0.6
	Shop	1	0.8
	Court	0.2	1
	Garage	1.5	1
	Small workshop	2	1
	Godown	0.5	1
	Ward/division h/q	2	1
	Custody	0.2	1
	Police station	1	1
	Office	2.5	1
	Petrol station	1	1
	Youth/Women centre	2	1
	Community centre	2	1
	Hospital /health centre	50	1
	Dispensary	0.5	1
	Bank	2.5	1
	Post office	0.5	1
	College	20	1
	Primary school	2	0.8
	Secondary school	20	0.8
	Tailoring	2	0.8
	Mission	50	1
	Market	1	1
Light industry	Grain mills	15	1
	Water pump	25	1
	Church	0.5	0.8
	Mosque	0.2	0.8
	Street lights	0.5	1
	Grain mills	15	1
Heavy industry	Plant		0.75

2.2 The Power Potential Available

The power generated from hydraulic turbines is a function of the effective head, the flow rate, and the efficiency of the turbine. The power potential at Myombwe stream was estimated by using the equation 1. Design data were collected from the site; which are potential head, design flow and turbine efficiency (Hamis Ally Mrope, 2014). The collected and adopted data are potential head 636 m, design flow 1.98 m^3s^{-1} and turbine efficiency 0.8.

$$P = \rho * Q * g * H * \eta \quad (3)$$

where P is the potential of the Myombwe River, ρ is the water density, g is the accelation due to gravity, H is the head of the river and η is the efficiency of the system.

3.0 Results and Discussion

3.1 Electricity Power Demand

The number of potential customers in the twelve surveyed villages is shown in Table 2. This table shows that the total number of household is 3,742, while dispensaries are 8. In these villages, there are 17 primary schools and 4 secondary schools. The study area has two water pumps located at Ikiliminzolo and Mtambula villages.

Table 2: Number of Potential consumers observed during survey

	Isaula	Ikiyowela	Idete	Magunguli	Ikiliminzolo	Ipilimo	Kilolo	Udumka	Mtambula	Nyigo	Ihagawa	Ihomasa	Total
Household	199	146	492	306	404	309	204	210	588	203	293	388	3742
Garage						1			1				2
Small Restaurant					3	9	4	7	11	1	2	6	43
Bar	3	3	6	3	4	12	5	18	10	3	3	5	75
Shops	3	6	19	11	6	8	13	13	32	3	3	26	143
Office	1	1	1	1		1	1	2	6	1	1	1	17
Dispensary	1		1	1	1	1	1		1		1		8
Small Workshop	1	1	1	1	1	2			3	1	1		12
Primary School		1	4		2	1	1	1	2	1	1	1	17
Secondary School	1				1				2				4
Tailoring	6	6	8	10	12	8	3	5	16	3	3	4	84
Carpentry	**2**	**2**	**2**	**4**	**3**	**2**	**2**	**9**	**7**	**2**	**2**	**5**	42
Grain Mills	2	2	2	3	2	3	3	3	2	2	2	4	30
Go down				2		1		2					5
Water Pump					1			1					2
Churches	2	3	5	2	2	4	5	4	7	2	1	4	41
Mosque	2	1	2	2	2	4	2	2	4	1	2	2	26

The results obtained on power demand of the study area are summarized in Table 3 which shows that the total power demand of twelve villages is 1,569.24 kW. From this table, the power demand after four years will grow to 7,846.2 kW and after 25 years the power demand will be 33,924.16 kW.

Table 3: Load Demand Forecast for all twelve Villages

Year	Residential Customers (kW)	Light Commercial	Other social servicers	Light industrial (kW)	Total (kW)	Energy (kWh)
2014	**605.25**	**640.9**	**27.9**	**687.5**	**1961.55**	**17,183,178.00**
2015	807	854.53	37.2	916.67	2615.4	22,910,904.00
2016	1210.8	1281.8	55.8	1375	3923.4	34,368,984.00
2017	**2421**	**2563.6**	**111.6**	**2750**	**7846.2**	**68732712**
…….						
2038	**10574.93**	**11090.13**	**478.0944**	**11781**	**33924.1544**	**297175592.5**

While the detailed annual load and energy demand are shown in Table 3, Table 4 shows number of years and values of annual load growth rate used in forecasting the future total load.

Table 4: Forecast Power Demand of all twelve Villages

Years	Classified Load	n	γ	Load (kW)	(1+γ)	Total Load (kW)
	Residential customers	4	0.25	484.2	1.25	2421
	Light commercial	4	0.25	512.72	1.25	2563.6
1 – 4	Other social services	4	0.25	22.32	1.25	111.6
	Light industrial	4	0.25	550	1.25	2750
	Total load after 4 years					7846.2
For γ = 0.04, 0.03 and 0.02						
	Residential customers	21	0.04	484.2	1.04	10574.93
	Light commercial	21	0.03	512.72	1.03	11,090.13
5 - 25	Other social services	21	0.02	22.32	1.02	478.0944
	Light industry	21	0.02	550	1.02	11,781
	Total load after 25 Years					33,924.16

In Table 5, it can be noted that the average consumption for household is 129.4 W and 484 kW in total. For education sector, the total demand is 122 kW at an average of 5,851 W per school. Commercial uses have the total demand of 790.34 kW with average of 1834 W while for public services total demand is 171.82 kW. The power demand of all twelve villages is 1,569.24 kW. It can be seen that commercial sector can have highest energy consumption than sectors.

Table 5: Average Power for Different Classification of Load.

Classification of Load	Category	Load (kW)	Consumer	Average (Kw) Per User
Household		484.20	3742	0.13
	Total	484.20		
	P/School	26.88	17	1.58
Education	S/School	96	4	24
	Total	122.88	21	5.85
	Tailoring	121.6	84	1.45
	Carpentry	84	42	2
	Grain Mills	450	30	15
	Garage	4.50	2	2.25
	S/Restaurant	5.16	43	0.12
	Bar	85.20	75	1.14
	Shops	22.88	143	0.16
	S/Workshop	17	12	1.42
Commercial	Total	790.34	431	1.83
	Mosque	4.32	25	0.17
	Churches	18	42	0.43
	W/Pump	100	3	33.33
	Go down	1.50	3	0.5
	Office	45	17	2.65
	Dispensary	3	8	0.38
Public Service	Total	171.82	98	1.75

3.2 Hydropower Potential of Magunguli Water falls

The measured parameters were Gross head (H) 636 m, discharge (Q) = 1.98 m^3/s. The net head loss should be not more than 5% (Pandey, 2004) whereby an assumption was made that head loss was 5% of the measured head, therefore the head loss (h) is 31.8 m. Net head (H_n) was determined as;

$$H_n = H - h = 636 - 31.8 = 604.2 \text{ m}$$

The selected turbine was Pelton type with an efficiency of 0.8, Gravitational constant (g) estimated to be 9.81 m/s^2 and density of water Density of the water (ρ) =1000 kg/m^3, Therefore, power potential (P) available at the site is given using equation 2 above;

$$P = 9.81 * 1000 * 604.2 * 0.8 * 1.98 m^3/s = 9388.69 \text{ kW}$$

The power potential available =9,388.69 kW

CONCLUSION AND RECOMMENDATION

Conclusion

This paper presents the results for matching energy demands and hydropower potential. The study area has 3,742 households, while dispensaries are 8. In addition to that, there are 17 primary schools and 4 secondary schools. The study area has two water pumps located at Ikiliminzolo and Mtambula villages. Total power demand of twelve villages is 1,569.24 kW. The power demand after four years will grow to 7,846.2 kW and after 25 years the power demand will be 33,924.16 kW. It was also noted that the average consumption for a household is 129.4 W. For education sector, the total demand is 122 kW at an average of 5,851 W per school. Commercial uses have the total demand of 790.34 kW while for public services total demand is 171.82 kW. With the gross head of 636 m and 1.98 m^3/s discharge, hydropower potential of Myombwe River was realized to be 9,388.68 kW. Therefore, this power generation can suffice optimum energy demand of the twelve villages for 4 years. Thereafter, additional source of power may be required.

Recommendation

Basing on the conclusions made from the findings the following recommendations are made:

i.) Relevant organizations in Mufindi District and Iringa region at large need to be sensitized to investment on hydropower plant for the 12 villages.

ii.) Professional help in establishing mini hydropower plants is vital for effective and efficient installation processes.

iii.) There is a need to develop a well-planned strategy for use of hydropower potential of Myombwe River for sustainable development.

iv.) The hydropower potential can supply power in 12 villages only for 4 years, therefore after 4 years there is a need of looking for other source of power.

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