Pre-Feasibility Studies for Mini- Grid and Energy Centres in Mohale's Hoek District

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1. Summary

The following table provides an overview on the features and feasibility of mini-grids, energy centres in selected villages in Mohale's Hoek. Please note that the electricity demand listed here for the years 2019 and 2030 is only the electricity apt to be supplied by the mini-grid, energy centre respectively. We assume, that energy centres will not supply affluent households as these households usually already feature an own power supply.

Table 1: Overview selected features of energisation solutions in Mohale's Hoek

Village	Ribaneng	Ketane	Phamong	Koebunyane	Mpharane	
Solution	**Mini-grid**	**Mini-grid**	**Energy centre**	**Energy centre**	**Mini-grid**	**Energy centre**
Number of Households	250	180	350	150	180	
Anchor customer	1 health centre, 5 schools, 5 government institutions incl. community council, ten retail facilities, 2 crafts	1 large clinic, 4 schools, 5 government institutions incl. post office, police station, 10 retail facilities incl. shops & guest house, 4 grain mills	1 health centre, three schools, 5 government institutions, 13 retail facilities	1 health centre, one primary school, one church, and four commercial retail facilities	1 health centre, two schools, 6 government institutions, 10 commercial retail facilities	
Present annual demand kWh	29,300	42,150	54,800	12,900	43,000	
2019 annual demand kWh	119,220	111,440	10,860	4,480	111,840	5,800
2030 annual demand kWh	495,700	418,500	-	-	413,700	-
Size PV plant kW 2019 / 2030	120/307	131/302	15.3	6.44	114/309	8.15
Size storage kWh 2019 / 2030	431/873	397/762	50	20	403/724	28
Additional future power source	Hydro	Hydro	-	-	Hydro	-
Length power lines km 2019 / 2030	15.94/17.78	7.23/8.06	-	-	5.52/6.16	-
Size of energy centre	-	-	Large	Small	-	Medium
Initial investment Maloti 2019 / 2030	5,057,826/ 17,613,919	4,578,844/ 15,216,163	2,048,184	791,747	4,047,027/ 14,965,657	1,155,684
Internal Rate of Return (with national tariff) 2019 / 2030	-14%/-10%	-15%/-11%	-	-	-15%/-11%	-
Required tariff Maloti/kWh 2019 / 2030	6.74/5.06	6.55/5.21	-	-	8.49/6.90	-

2. Mohale's Hoek District

The Mohale's Hoek district comprises an area of 3,530 km^2 which accounts for about 12% of the total area of Lesotho. The district population is 174,000. Mohale's Hoek is the 5th largest district in Lesotho, accounting for 8.2% of the country's total population (Census 2016 estimates). Number of households in the district is around 43,500. According to the 2016 census estimates, approximately 56% of the total households are female headed.

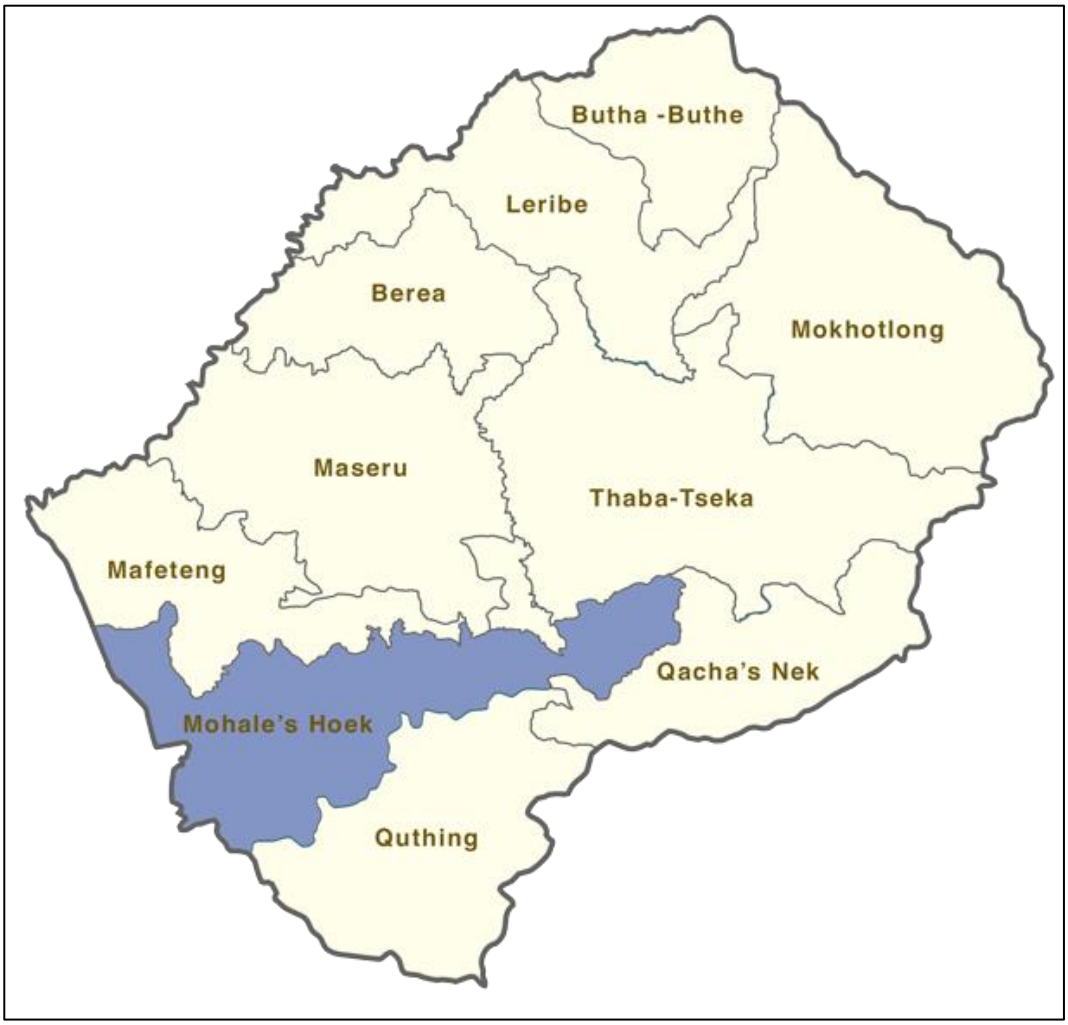
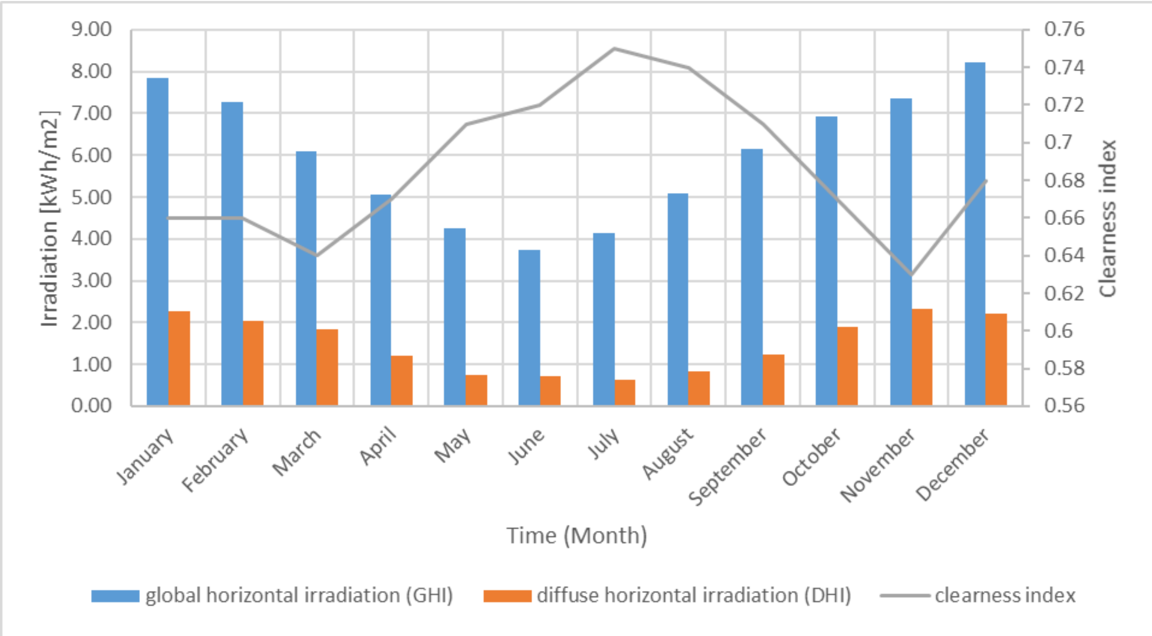


Figure 1: Location of Mohale's Hoek in Lesotho

2.1 Renewable energy potential

Mohale's Hoek **(**-30.16 (30°09'36"S), +27.48 (27°28'48"E)) is located in the southern part of Lesotho. Average insolation of Mohale's Hoek as given by the NASA climatologic database ranges from a minimum of 3.20 kWh/m^2/day in June to a maximum of 7.03 kWh/m^2/day in December with an annual average of 5.13 kWh/m^2/day and an average clearness index of 0.59. The clearness index is a measure of the clearness of the atmosphere which is the fraction of the solar radiation that is transmitted through the atmosphere to strike the surface of the earth. The shiniest days of the year are in the months of November-January (6.59, 7.03 and 6.86 kWh/m^2/day, respectively). Mohale's

Hoek is ideally suited for large solar installation as it has very high solar radiation levels and clearness index (Figure 2, Table 2).



Source: Photovoltaic Geographical Information System (PVGIS), European Commission

Figure 2: Average solar irradiation in Mohale's Hoek over the year (source: Photovoltaic Geographical Information System (PVGIS), European Commission)

Table 2: Daily global horizontal irradiation data in Mohale's Hoek (source: Photovoltaic Geographical Information System (PVGIS), European Commission)

Month	Clearness index	Daily GHI (kWh/m^2/day)
January	0.66	7.8
February	0.66	7.3
March	0.64	6.1
April	0.67	5.1
May	0.71	4.1
June	0.72	3.7
July	0.75	4.2
August	0.74	5.1
September	0.71	6.2
October	0.67	6.9
November	0.63	7.3
December	0.68	8.2
Average	0.69	6.0

Wind: In Mohale's Hoek, the average annual wind speed is approximately 4.74 m/s, which is greater than the 4 m/s rule of thumb to consider the technology viable.

Hydro: Mini-hydropower is a very promising technology in Mohale's Hoek, being a home to one of the major sub-basin river systems in Lesotho, Makhaleng River with a catchment area of 2 911 km^2. A number of small rivers such as Ketane River and Ribaneng River also run through Mohale's Hoek district in the vicinity of pre-selected project areas.

2.2 Households characteristics

For household data analysis, we extracted the results of the BOS Household Study 2017 for the Mohale's Hoek district. In the Mohale's Hoek district, the average household consists of four persons. More than 55% have four members and more while more than a quarter has 6 members and more. The age distribution of the residents in the households surveyed in Mohale's Hoek is slightly weighted toward the older age classes. Approximately 52% of the residents were under 25, while 15 % were between 40 to 59 years of age. Only about 10% of the residents were over 60 years of age. Based on the age distribution, with more than half of the population under the age of 40 it is highly likely that a stable consumer base will be maintained over the next twenty years.

The majority of Mohale's Hoek' inhabitants own at least one housing unit. Almost one-third of the total households have two units and about 10% have three or four housing units. The number of housing units per household may serve as an indicator for the wealth of a particular household. The same applies to the total housing area per household. The BOS National Energy Survey 2017 indicates that almost half of households are live in an area of less than 30 m^2 (Figure 3).

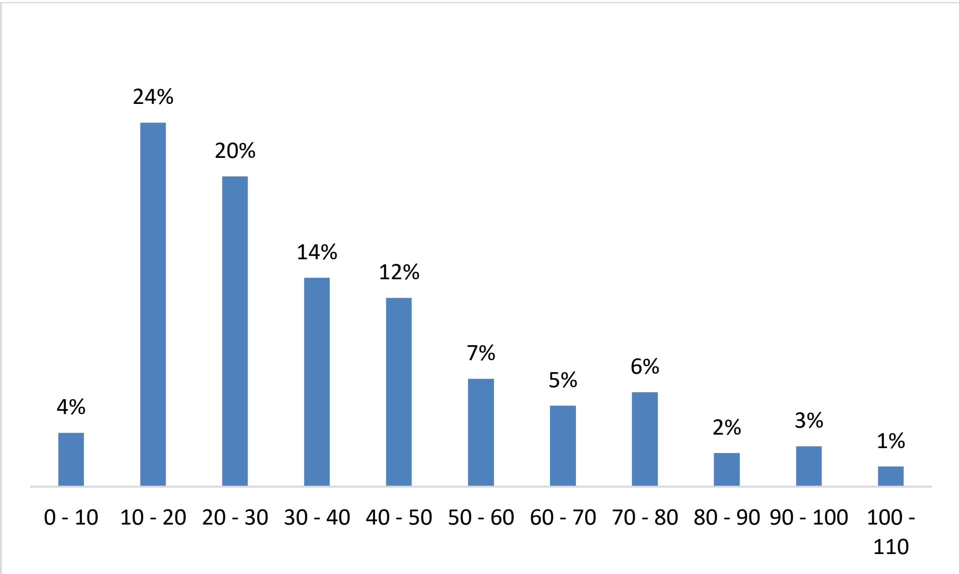


Figure 3: Distribution of household's usable area size in Mohale's Hoek. Source: BOS National Energy Survey 2017.

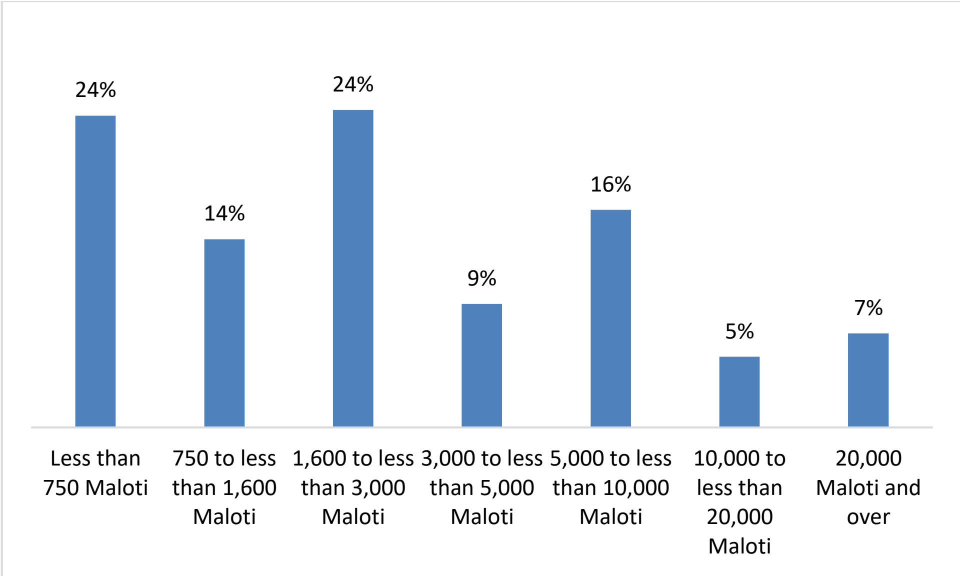


Figure 4: Distribution of household income in Mohale's Hoek. Source: BOS National Energy Survey 2017.

The BOS National Energy Survey of 2017 show that 62% of household in the district earn less than 3,000 Maloti, only 37% have more than 3,000 Maloti and almost a quarter less than 750 Maloti per month, (Figure 4). This suggests that the majority of the households relies on direct barter and self-sustained farming. In addition, the significant share of households relies on additional transfer payments as about 30% of Mohale's Hoek population receive remittances (money transfers from workers working abroad). Their value varies usually between 500 and 5,000 Maloti. In general, income levels are low in Mohale's Hoek thereby limiting the purchasing power of households for energy.

The households in the Mohale's Hoek district rely on three main sources of energy: wood and wood wastes, animal dung as well as straw/shrubs/grass (BOS National Energy Survey 2017). Energy consumption in summer is about 50-70% lower than in winter, indicating that heating is a major energy service in the Mohale's Hoek district. The majority (38%) of the households in Mohale's Hoek districts travel more than two hours to acquire biomass energy supplies. Almost a quarter of the households travel between half an hour while 19% of the households travel between one and two hours. However, biomass collection is a usually a non-commercial activity, and there are not necessarily paid opportunities to use the freed time so individual household budgets – as indicated earlier - might be too restricted to allow for a commercial purchase of energy. Thus, present biomass collection might be not substituted even in the presence of a modern energy supply.

In Mohale's Hoek, access to electricity is very limited: slightly more than 20% of the households are supplied with electricity in their homes, (BOS Energy Survey 2017). Another 14% of households own a PV solar panel.

Cooking is one of the most energy-intensive activities of households. The main energy sources for cooking in Lesotho are biogas (22%), paraffin/kerosene (19%), LPG (17%), animal dung (17%).

Domestic space heating is another energy-intensive thermal application. In non-electrified households, wood and wood-waste are the main energy source for space heating. In general, about 60% of inhabitants of Mohale's Hoek use energy for heating during cold months.

The main sources for lighting in Lesotho are paraffin and candles. Most of the non-electrified households in Lesotho rely on candles as a main energy source for lighting, with paraffin accounting for the predominant source for this purpose for most of remaining households.

3. Ribaneng Mini-Grid

Ribaneng (29°50'39.3"S 27°39'54.2"E) is located North-East of Mohale's Hoek and is approximately 125 km from Mohale's Hoek town and is off the main roads. Its elevation is 1,737 m. It had population of 7,509 in 2006. Makheleng River passes nearby this village.

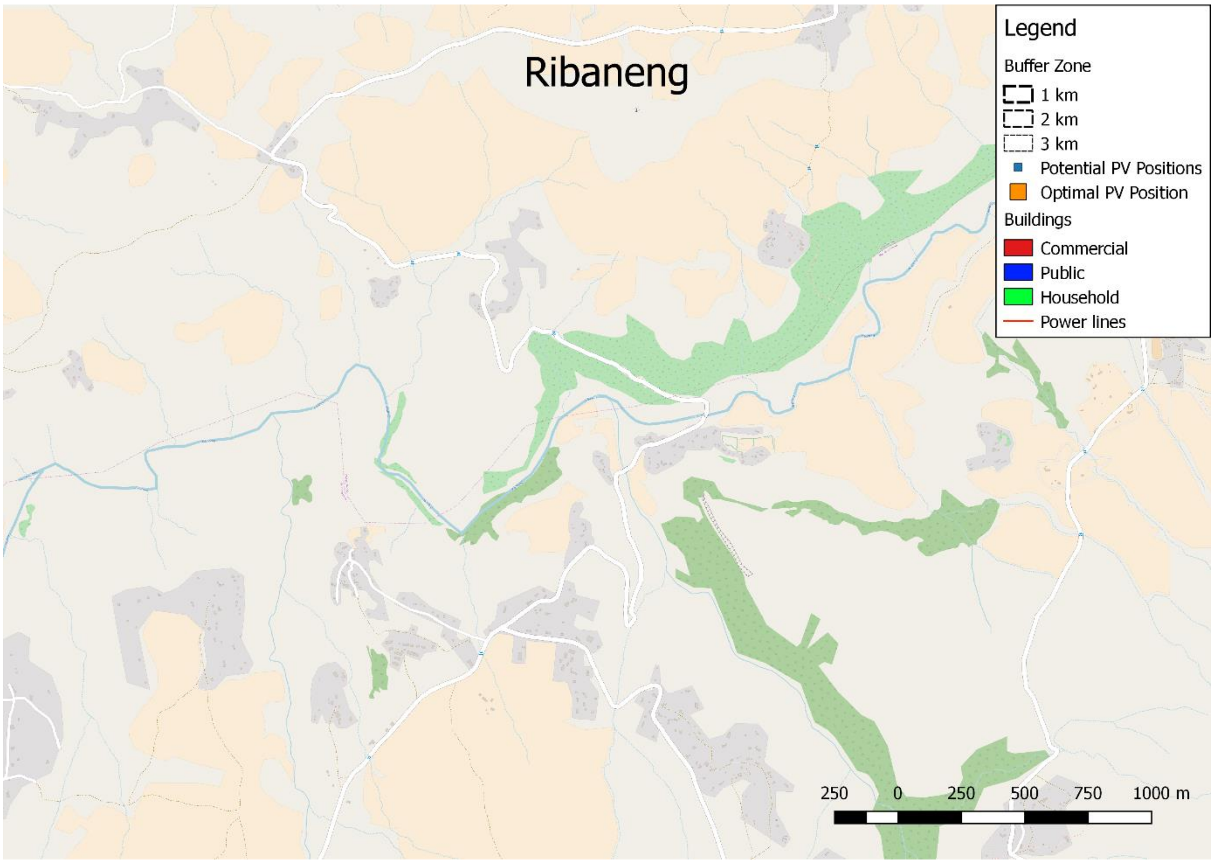


Figure 5: Map of Ribaneng

We have designed the solar systems in such a way that they generate excess power in summer, mist will not impede sufficient supply of power. In the winter months, it is cold and dry with temperatures below zero and frost and snow are a common occurrence. There are high daily and seasonal variations of weather.

Figure 6: Ribaneng valley

3.1 Customer Base

Ribaneng accommodates more than 250 households, consisting of about 1,500 individuals. According to the UNDP Project Document, Ribaneng has six medium size shops, a clinic, two primary schools, the Independent Electoral Commission, a sizeable number of mines and RSA workers, a community council; street lighting, a hammer mill. Three main income sources in Ribaneng are domestic employment, mining and farming. The distance to the service centre is 6 km that can be covered in an hour.

3.1.1 Households

Socio-demographic characteristics

In Ribaneng we interviewed ten households (HH). They tend to have quite many members: the average number of HH members was six, HH have from three to ten members (Q B1[1]). Large households are more reliable energy purchasers, due to their strong attachment to the place of residence as well as high and stable energy demand.

[1] In brackets reference to the corresponding question in the questionnaire. For questionnaire refer to the Annex.

All surveyed households have only one housing unit at their disposal (Q C1). Nine households live in a house of polata type which is the most common housing type in the district of Mohale's Hoek. One household lives in an optaka house, which is also popular on this territory. On average there are slightly more than two rooms in one house, in a room live 3-4 persons on average. The usable area ranges from 38 and 96 sqm and accounts for 57 sqm on average (about 11 sqm per HH member) (Q C2). The interviewed households are characterized by very low or non-existent money earnings. Six households do not have any income in monies. Two households earn about M150 per month, other two HH about M1,500 (Q C3). Only one HH, from among those with no income, receives remittances amounting to M400 per year, say M33 in a month (Q C4). No household has plans to move away from the village in the next five years (Q I1).

Energy supply

Nine interviewed households in Ribaneng use fuel wood, and one uses wood waste as the only one biomass source. All these wood masses were obtained by collection. Households used 150 to 835 kg of fuel wood per year equivalent 700 to 4,100 kWh per year (Q D1). All households have an area where they can collect fuel wood in their community (Q D2). In all cases it is a communal forest (Q D3). The majority of households need to travel to the edge of the main collecting area and back between half an hour and an hour, for two it is between 60 minutes and 1.5 hours (Q D4). Fuel wood collection time ranges from 30 minutes to more than 2 hours, five households spend between 60 minutes and 1.5 hours, two 1.5-2 hours, one more than 2 hours, two from 30 minutes to 1 hour (Q D5). In sum, travelling and collection time accounts for 1.5 to 4.5 hours. Six households that answered to the question D6 about number of times for wood collection indicated six, five or four times per month. In total, households usually use 100 to 140 hrs. a year for fuel wood collection. With an hourly wage of 8 Maloti this converts into annual costs of approx. 1,000 Maloti.

In all the interviewed households, women assume the responsibility of collecting fuel wood. No men are involved in this activity. In one case two children help a woman to collect wood (Q D7). It is clear from this distribution that fuel wood and wood waste collection is purely female and children's activity. No household has an improved fuel-wood stove (Q D8). None of the households interviewed spend any money on biomass (Q D9).

Nine households use wood as a main energy source for cooking, one uses LPG. As an alternative energy source for these purposes, animal dung is used by eight HH, paraffin by two HH, LPG and coal by one (Q F1). No household has a wonder box (Q F4). Amounts of different energy sources for cooking (Q F2), energy consumption of every HH per year and expenses are shown in the Table 3.

Table 3: Household use of energy sources in Ribaneng

HH No.	Cooking			Space and water heating			Lighting			HH income, M/a
	Use of energy sources	Annual energy consumption, kWh/a	Annual expenses, M/a	Use of energy sources	Annual energy consumption, kWh/a	Annual expenses, M/a	Annual use of energy sources	Annual energy consumption, kWh/a	Annual expenses, M/a	
1	5.3 kg of LPG per month, 4 kg coal per day	13,516	3,858	100 kg wood per month	5,880	0	30 litres of paraffin	311	390	18,000
2	5.3 kg of LPG per month, 1 litre paraffin per day	4,592	6,048	50 kg wood per week	12,740	0	25 litres of paraffin, 12 candles	261	361	0
3	5 kg fuel wood per day	8,943	0	50 kg wood per month	2,940	0	20 litres of paraffin, 12 candles	209	296	18,000
4	1 litre paraffin per day, 3 kg fuel wood per day	9,143	4,745	20 litres of paraffin per year, 45 kg wood per month	2,853	260	20 litres of paraffin, 12 candles	209	296	0
5	2.5 kg animal dung per day	4,230	1,800	820 kg wood per year	4,018	0	20 litres of paraffin, 6 candles	208	278	0
6	2 kg fuel wood per day	3,577	0	40 kg wood per month	2,352	0	25 litres of paraffin, 12 candles	261	361	1,800
7	2 kg fuel wood per day	3,577	0	50 kg wood per month	2,940	0	20 litres of paraffin, 12 candles	209	296	0
8	2 kg fuel wood per day	3,577	0	70 kg wood per month	4,116	0	30 litres of paraffin, 12 candles	312	426	0
9	2 kg fuel wood per day	3,577	0	50 kg wood per month	2,940	0	20 litres of paraffin	207	260	0
10	2 kg fuel wood per day	3,577	0	1.5 kg wood per month	88	0	20 litres of paraffin, 12 candles	209	296	1,800
	Average	**5,831**	**1,645**	**-**	**4,087**	**26**	**-**	**240**	**326**	**-**

Two households of ten heated their house in the last year (Q G1). One used for it a paraffin heater, the other a paola (Q G2). As an energy source for space heating paraffin, wood, and animal dung were used (Q G3). These two households have a heating area of 38 and 22 sqm (Q G6). For water heating all households use wood (Q G7).

All households in Ribaneng interviewed in the survey use paraffin for lighting purposes as a main energy source (Q H1). As an alternative source most additionally use candles (Table 3). Please note that the energy consumption calculated here on the basis of the energy content of the fuels used cannot be directly translated into demand for electrical power because conversion of power into light is much more efficient than conversion of fuels resulting in either a better energy service with the same energy input in terms of kWh or to a lower power demand in kWh terms with the same quality of energy service. One litre of paraffin costs M13, one candle M3. In average, the households spent M326/a, so the equivalent budget would be at least available for purchasing power for lighting purposes.

None of the households interviewed in Ribaneng uses any electric appliances in the house (Q E1). It is expectable that all of them want to have electricity in their houses (Q E7). Regarding future uses of electricity, all ten households want to use it for radio, and lighting, nine HH for phone charging, six for cooking, two for TV, ironing, and water heating (Q E8).

All households are willing to pay for electricity and indicate mostly not relevant amounts of M50 to M1,000 per month, when only small part of interviewed households have any money income (Q E9). Nine HH want to pay for electricity with Mpesa, and one would prefer EcoCash (Q E10).

Table 4: Households desired future uses of electricity in Ribaneng, ranked starting from the most popular ones

Electricity uses	**HH 1**	**HH 2**	**HH 3**	**HH 4**	**HH 5**	**HH 6**	**HH 7**	**HH 8**	**HH 9**	**HH 10**	**Total**
Lighting	X	X	X	X	X	X	X	X	X	X	10
Radio	X	X	X	X	X	X	X	X	X	X	10
Phone charging	X	X	X	X	X		X	X	X	X	9
Water heating		X		X							8
Cooking/ re-heating	X	X	X			X			X	X	6
TV		X							X		2
Ironing		X							X		2
Refrigeration											0
Charging (other than phone)											0
Laundry											0
Dishwashing											0
Space heating											0
Air-conditioning											0
Computer											0
Water pumping											0
Workshop											0
Sewing											0
Total	7	7	6	5	7	4	6	7	6	8	-

All households are ready to pay for electricity for lighting, though in some cases it does not seem realistic, considering their earnings (Q H4, Table 5). In a first step, we asked for the general willingness to pay for power (answers in 3rd column). In a second step we refined the question on the willingness to individual purposes (columns 4 – 6), where the sum of individual specific willingness to pay do not necessarily sum up to the same amount as the general willingness to pay. Also, the willingness to pay deviates substantially from the actual expenses for e.g. lighting. In summary, it seems appropriate to assume some demand for power for lighting but not for heating or cooking. Further, it seems reasonable to assume some demand for power for additional applications like phone charging, radio, television and refrigerators confirming what are described in the General Part. This is also reflected in the average willingness to pay for electricity in general of monthly 575 Maloti.

Table 5: Ability and willingness to pay for electricity in general and for different applications of households in Ribaneng

HH #	Earnings per month (ability to pay)	Willingness to pay for electricity per month (Maloti and % of earnings)				Plans to buy electric appliances
		In general	For cooking	For space heating	For lighting	
1	M1,500	M500 (33%)	M230 (15%)	M150 (10%)	M100 (7%)	Refrigerator, hair dryer, television (flat screen), electric kettle/element
2	0	M500 (-)	M250 (-)	M100(-)	M100 (-)	Refrigerator, television (flat screen)
3	M1,500	M500 (33%)	M100 (7%)	M100 (7%)	M100 (7%)	Television (flat screen), iron
4	0	M500 (-)	M150 (-)	M100 (-)	M50 (-)	Television (flat screen), iron, phone charger
5	0	M800 (-)	M200 (-)	M200 (-)	M100 (-)	
6	M150	M1,000 (666%)	M200 (133%)	M150 (100%)	M100 (67%)	Television (flat screen), electric kettle/element
7	0	M600 (-)	M200 (-)	M250 (-)	M150 (-)	Television (flat screen), iron, electric kettle/element
8	0	M1,000 (-)	M250 (-)	M200 (-)	M100 (-)	
9	0	M300 (-)	M100 (-)	M100 (-)	M100 (-)	Television (CRT), iron, electric kettle/element, electrical hair clipper, phone charger
10	M150	M50 (33%)	M250 (167%)	M300 (200%)	M50 (33%)	Television (LCD), electric kettle/element, phone charger
	Average	M575	M193	M165	M95	

Regarding plans to buy electrical sources in the near future, two households are planning to purchase solar PV, whereas generators and car batteries are not relevant for anybody (Q I4).

Energy demand forecast

All surveyed households in Ribaneng belong to the basic type, with low income and no electrical appliances. As the sample is not representative and was rather picked out situational, we rely on our general load forecast, described in the General Part. Based on 250 households presently living in Ribaneng and 1% growth rate of the number of households per year, the energy demand forecast for 2019 and 2030 is presented in the Table 6.

Table 6: Future power demand by households in Ribaneng

Household type	No. of HH in Ribaneng			Total power demand, kWh/year		
	Present	2019	2030	Present	2019	2030
Basic	163	164	183	0	4,920	109,800
Medium	62	64	71	3,100	32,000	191,700
Affluent	25	25	28	7,500	45,000	81,200
Total	**250**	**253**	**282**	**10,600**	**81,920**	**382,700**

3.1.2 Anchor customers

Main characteristics

Ribaneng has a health clinic, health staff houses, primary schools, council offices, grocery shops, and a church, the chief stated in the interview. Clinic and clinic staff houses use solar PV as an energy source. Other institutions do not have any energy sources.

We interviewed seven anchor customers: four public (community council, primary school, health centre, church), and three commercial (food retailers: two cafes and one shop) (Q B1). Public institutions are in cooperative ownership, commercial in individual ownership (Q B2). All facilities are small with the church, cafes, and the shop all having only one worker. The school employs eight workers, seven of them are female, and the health centre has seven employees, with six of them women (Q B3). Regarding earnings, three commercial companies generate some income, where both cafes earn between M1,000 and M2,000 per month, and a shop has a little bit more with M2,000 to M5,000 (Q B4). The school receives subsidies from the state accounting for M5,000 to M10,000 last year, which is slightly more than M600 per month (Q B6).

Most anchor customers work seven days a week, except primary school and community council opened five days a week and church working only one day in a week (Q D1). Commercial facilities have longer working hours per day: from 8 to 12. Council works 8.5 hours a day, health centre 8 hours, school 6, and church 4 (Q D2). All companies and institutions operate all over the year, except school with 8 months of operation (Q D3).

Five customers cover one building, primary school has five buildings, and health centre four buildings at its disposal (Q D4). Buildings of school, health centre and church were constructed in the period between 1976 and 1985, buildings of one café and council later in 1996-2005. Total area of the disposed buildings ranges from 558 m^2 by the health centre and 394 m^2 by the school to between 57 and 105 m^2 by all commercial facilities, council and church. Heated area was cited only by the community council and amounts for 48 m^2 of the 97 available. Only buildings of the community council and health centre are insulated in some way (Q D5).

Energy supply

Charcoal and biomass energy sources, namely wood, were used only by public facilities (school, community council, health centre). The prices amounted to M2 per kg wood and M5 per kg charcoal (Q C1). Charcoal was used for space heating, and wood for cooking. Energy sources were paid in cash (Q C2).

Table 7: Consumption of energy resources and electricity generation of selected anchor customers in Ribaneng

Anchor customer	Wood		Charcoal		LPG		Solar PV	
	Quantity, kg	End use	Quantity, kg	End use	Quantity, kg	End use	System size	End use
Lekhatje Primary school	1,600	Cooking						
Lehlakaneng Community council			30	Space heating	48	Heating		
Ribaneng Health centre			200	Space heating			25 panels	Lighting
Total quantity	**1,600**		**230**		**48**			
Unit costs	M2/kg		M5/kg		M22/kg			
Total costs	**M3,200**		**M1,150**		**M1,056**			

Only the health centre uses solar electricity. There, it is used for lighting on all days (Q C3).

All interviewed anchor customers in Ribaneng want to have electricity in its facilities (Q C4). They stress the importance for companies and institutions from their branch to have electricity (Q C5). At the same time, they are convinced that it is expensive (Q C6). No one has indicated their willingness to pay for electricity (Q C7). Regarding preferred way to pay for electricity, five anchor customers would like to pay via mobile phone, and two in cash (Q C8).

No anchor customer uses any central air-conditioning systems (Q D6), as well as independent heating/cooling systems (Q D8). As for the usage of central heating systems, only community council has a LPG system in operation. It operates four months a year, five days a week over eight months, in sum, 160 hours a year. 48 kg of LPG were used over the last year (Q D7). The price of LPG derived from statements of household customers is about M22/kg.

All anchor customers are ready to pay for electricity for heating/cooling purposes. Commercial enterprises (cafes and food retailer) have a willingness to pay between M300 and M600 (17-20% of the month income). It seems to be realistic. Ability to pay of public institutions is more difficult to define, since we are mostly not aware of the level of subsidies which they get from the state and/or district council. Primary school and health centre are ready to pay M5,000 each, but it is questionable if the state will accept these expenditures. Willingness to pay for electricity for heating/cooling purposes of the church (M500) and community council (M100) looks somehow feasible but the question of the expenditure approval by the competent authorities remains (Q D9, Table 9).

Table 8: Electric equipment of selected anchor customers in Ribaneng

Anchor customer	Small equipment	Refrigerating equipment	
	Type & number	Type & number	Capacity, l
Ribaneng Health centre	1 printer	2 laboratory fridges	20 & 10 l
Mokhoabong General Café		1 refrigerator, 1 freezer	40 l (freezer)
Thizas Shop		2 freezers	40 l
Mantolo General Café		1 freezer	40 l

No anchor customer uses any lights (Q D10), no one has light or motion sensor controls (Q D11, Q D12). Regarding willingness to pay for electricity for lighting, the highest willingness and accordingly the need for lighting comes from the health centre (M3,000), other public institutions do not see it as such important electricity application, probably because their operating hours mostly fall on sunshine day period. Commercial customers are ready to pay for electricity for lighting between M100 and M900 (7-26% of the month earnings) (Q D13, Table 9).

School and health centre have cooking facilities in their buildings (Q D15). School uses wood, and health institution LPG for cooking purposes (Q D16). School, health centre and church are ready to pay for electricity for cooking, above all school is willing to pay an exorbitant sum of M20,000 per month (Q D17).

Cafes, food retailer, and a health centre have refrigerating equipment for food or medical uses (Q D18). Commercial customers show high willingness to pay for electricity for refrigeration (between 20 and 33% of the month income). For school and health centre it is also important (Q D20).

Table 9: Ability and willingness to pay for electricity in general and for different applications of anchor customers in Ribaneng

Anchor customer	Earnings per month ability to pay	Willingness to pay for electricity per month (Maloti)					
		Heating Cooling	Lighting	Cooking	Fridge	Total	
						Maloti	% of earnings
Mokhoabong General Café	M1,500	M300	M150	M0	M500	M950	63%
Lekhatje Primary school	M625	M5,000	M500	M20,000	M10,000	M35,500	5,680%
Lehlakaneng Community Council	NA	M100	M50	M0	M0	M150	NA
Lekhatje LECSA Church	NA	M500	M100	M500	M0	M1,100	NA
Thizas Shop	M3,500	M600	M900	M0	M1,000	M2,500	71%
Ribaneng Health Center	NA	M5,000	M3,000	M2,000	M2,000	M12,000	NA
Mantolo General Café	M1,500	M300	M100	M0	M300	M700	47%
Total	M7,125	M12,000	M4,800	M22,500	M13,800	M52,900	

No anchor customer has plans to replace any units or install new energy consuming systems or technologies, switching new fuel, or change industrial processes (Q F1-F4). Neither they want to purchase any electrical sources like solar PV, generator or car battery or upgrade their buildings with some energy efficiency measures (Q F9-F10). The main reasons for it are lack of awareness about technologies and lack of device on local market (Q F11).

Energy demand forecast

Table 11 summarizes major characteristics of anchor customers in Ribaneng. Presently, they have a substantial higher power demand than the group of private households. Based on their willingness to pay and under consideration of the potential ability to pay, we expect that the power demand will increase substantially once the mini-grid is available (Table 10).

Table 10: Future power demand of anchor customers in Ribaneng

Type	Number of institutions	Power demand, kWh/year	
		2019	2030
Health	1	2,600	5,200
School	5	2,500	17,500
Government	5	6,500	13,000
Retail	10	25,600	76,800
Craft	2	100	500
Total		**37,300**	**113,000**

Table 11: Main characteristics of anchor customers in Ribaneng

#	Name	Type	Size	Operation hours	Electrical equipment	Annual power demand	Present power supply	Willigness to pay, Maloti/month
1	Ribaneng Health Centre	**Health**	7 employees; 4 buildings, area 558 m^2	8 h/day, 7 days/week, all year long	2 laboratory fridges, 1 printer	540 kWh	25 solar panels	12,000
2	Lekhatje Primary School	**School**	8 employees; 5 buildings, area 394 m^2	6 h/day, 5 days/week, 8 months/year	None	0	None	35,500
3	Lehlakaneng Community Council	**Government**	1 building, area 97 m^2	8,5 h/day, 5 days/week, all year long	None	0	None	150
4	Lekhatje LECSA Church	**Government**	1 employee; 1 building, area 105 m^2	4 h/day, 1 day/week, all year long	None	0	None	1,100
5	Mokhoabong General Café	**Retail**	1 employee; 1 building, area 78 m^2	8 h/day, 7 days/week, all year long	1 refrigerator, 1 freezer	1,400 kWh	None	950
6	Mantolo General Café	**Retail**	1 employee; 1 building, area 74 m^2	10 h/day, 7 days/week, all year long	1 freezer	530 kWh	None	900
7	Thizas Shop	**Retail**	1 employee; 1 building of 57 m^2	12 h/day, 7 days/week, all year long	2 freezers	1,050 kWh	None	2,500
					Total	3,520 kWh		52,900

The power demand distributes spatially as depicted in the Table 12.

Table 12: Development of power demand in Ribaneng by distance from power plant site

Customer	Annual Power Demand MWh											
	Present				2019				2030			
	1km	2km	3km	total	1km	2km	3km	total	1km	2km	3km	total
Households	5.8	4.0	1.7	11.5	44.5	30.2	13.3	87.9	185.6	126.0	55.6	367.2
Anchor customers	14.5	0.0	0.0	14.5	19.6	0.0	0.0	19.6	35.2	0.0	0.0	35.2
Total	20.3	4.0	1.7	**26.0**	64.0	30.2	13.3	**107.5**	220.8	126.0	55.6	**402.4**

3.2 Set-up for Mini-Grid

We designed the mini-grid by using HOMER Pro software. For sizing the generation plants we used the consumption pattern as derived in previous sections of this report.

To cover present electricity demand, the least-cost option is PV + storage (Table 13). Capacity of battery storage should exceed maximum hourly output of solar panels in about 3 times, but this ratio is highly dependent on relative costs of solar panels and battery. In this combination the unmet load accounts for about 2%, and excess electricity produced nearly 40% what provides incentives and considerable additional scope for electricity demand growth. Particularly, loads for additional refrigerators could be easily accommodated as the excess generation occurs during summer, when also power demand of refrigerators peaks.

Table 13: Elements of mini-grid setup in Ribaneng in present conditions

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	30.7 kW	519,005	0	5,987
Battery	104 kWh	405,600	1,622,400	13,520
System converter	9.64 kW	25,054	25,064	0
Power lines	15.78 km	331,380	0	6,628
Power meters	276 units	883,200	0	17,664
Total	-	**2,164,239**	**1,647,464**	**1,094,953**

Basing calculations on presently existing power demand i.e. no additional demand is assumed even when power is available through the mini-grid, is the most conservative approach for sizing the mini-grid. In practise, additional power demand will occur as we assumed in the scenario for the year 2019 (Table 14). The set-up remains rather the same only the sizes of all elements increases substantially, leading to a threefold higher investment need.

Table 14: Elements of mini-grid setup in Ribaneng in 2019

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	120 kW	2,028,000	0	23,400
Battery	431 kWh	1,680,900	6,723,600	56,030
System converter	47 kW	122,200	122,200	0
Power lines	15.94 km	334,694	0	6,694
Power meters	279 units	892,032	0	17,841
Total	-	**5,057,826**	**6,845,800**	**2,599,113**

For the Mini Grid three feasible sites were identified. Two of them, the sites which are marked blue on Figure 7, were chosen according to physical criterions like the direction to the sun, area size and availability of space. The yellow marked optimal site was determined according to the calculation algorithm of the geometrical mean of all buildings in the radius 1-3 km in the village. So, it is the location that has the minimum sum of distances to all existing potential residential, public and business customers. In the case of Ribaneng the theoretically chosen potential site for a mini-grid coincided with the site chosen as a result of field research. This particularly suitable site is presented on the following map as two squares, blue and yellow, inscribed in each other.

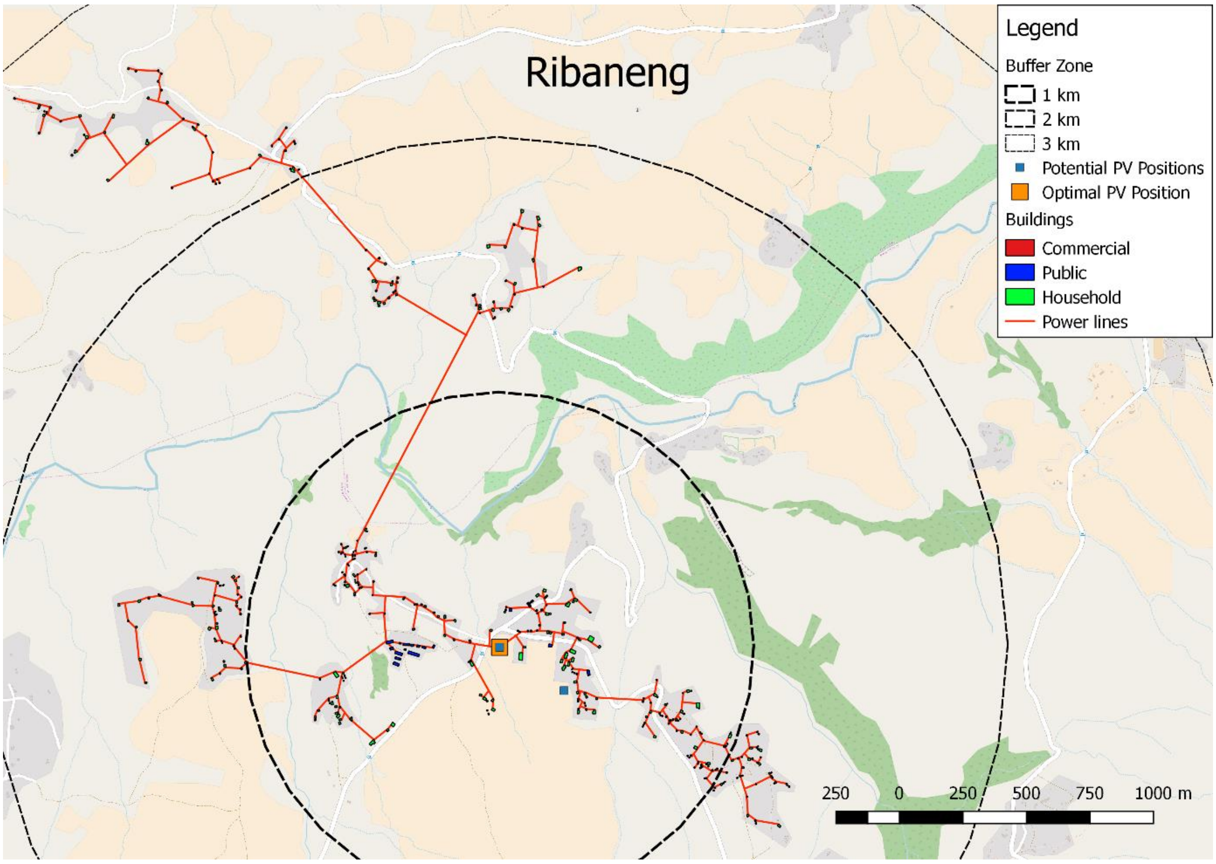


Figure 7: Map of the mini-grid set-up in Ribaneng in 2019

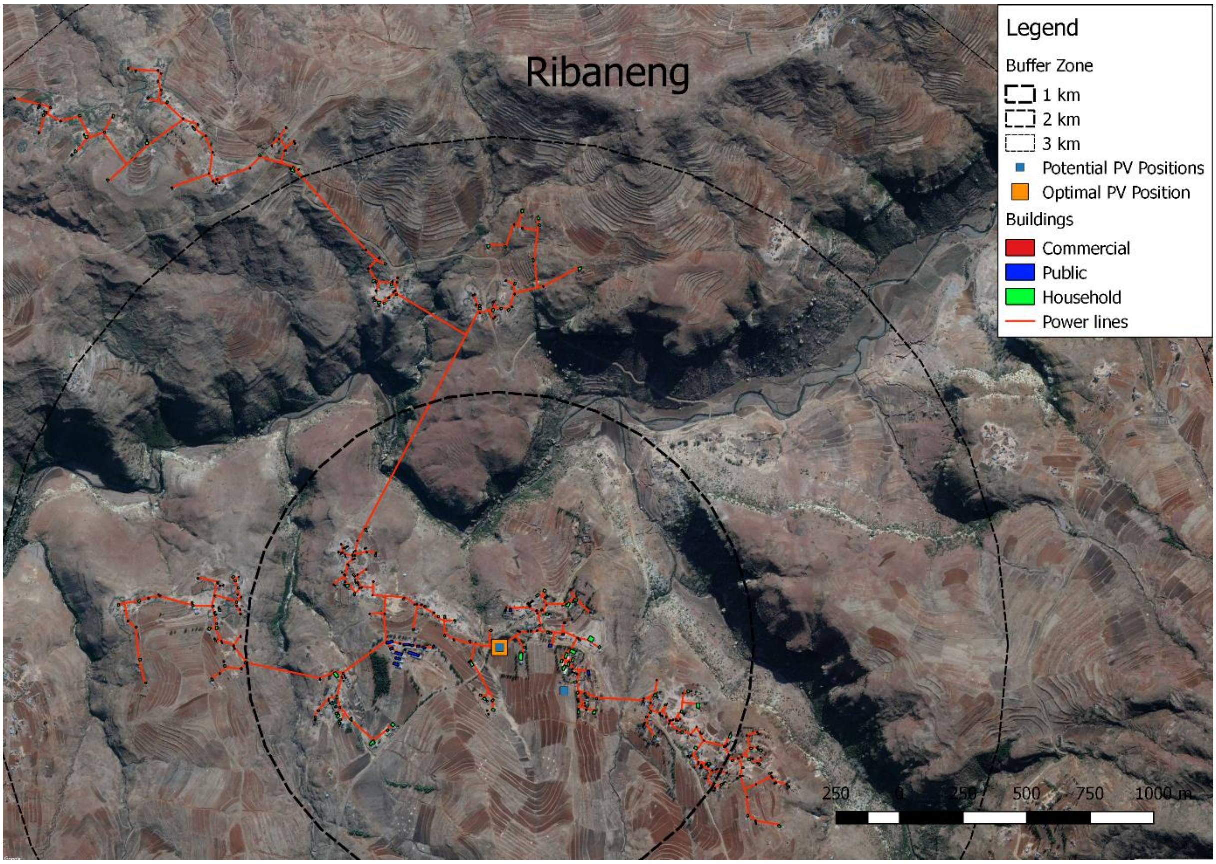


Figure 8: Satellite map of the mini-grid set-up in Ribaneng in 2019

The Figure 9 shows the distribution of initial investment costs in a mini-grid setup for 2019. One can see that almost a quarter of capital costs represent grid facilities (power lines and customer connections).

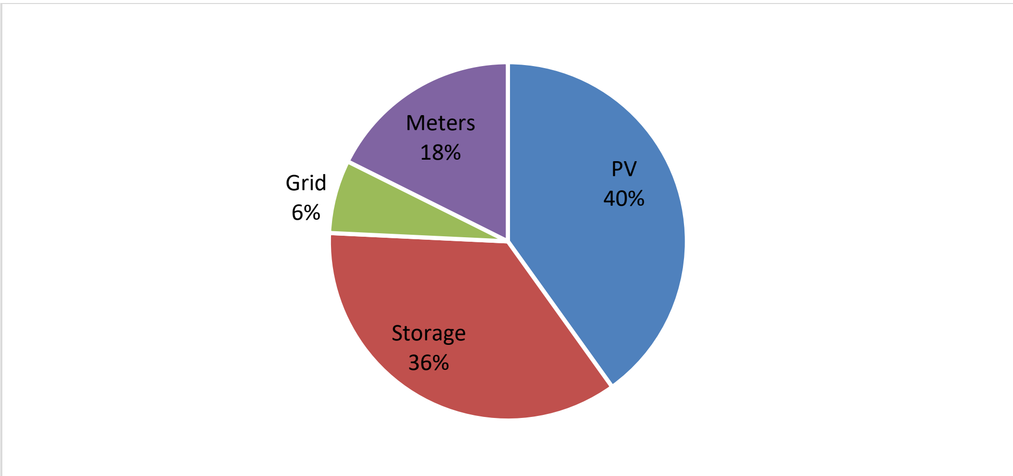


Figure 9: Distribution of capital costs of a mini-grid in Ribaneng in 2019

Assuming power demand increase in long-term till 2030, HOMER offers solution combining PV, storage and hydro power as an option with the lowest levelized cost of electricity (LCOE). Until then, it is due to carry out extensive research of river flow rates and conditions throughout the year to define hydro energy potential. Besides, in the long-term period of more than ten years further reductions of PV and battery costs are foreseen, whereas the hydropower costs would most probably remain the same, as the technology is already well-advanced, and the cost reduction potential is quite exhausted.

Table 15: Elements of mini-grid setup in Ribaneng in 2030

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	307 kW	6,253,000	0	72,150
Battery	873 kWh	3,404,700	13,618,800	113,490
Hydro Power Plant	100 kW	6,000,000	0	180,000
System converter	226 kW	587,600	587,600	0
Power lines	17.78 km	373,407	0	7,468
Power meters	311 units	995,212	0	19,904
Total	**-**	**17,613,919**	**14,206,400**	**9,825,310**

The expected growth of demand allows for lower generating costs in the future (Table 16). Thereby we have not considered that due to technology advancements some elements to be added in the future will have very likely lower specific CAPEX than presently. There is a high rate of excess power to allow for a generation entirely based on renewable energies. This waste of energy could be avoided in two ways: Either one would allow a minor share of fossil-based generation which would run during winter, when PV generation is low, leading also to lower overall generation costs. Or additional seasonal usage of the excess power is created, e.g. refrigeration and cooling which both would perfectly match the generation patterns of solar generation.

Table 16: Characteristics of mini-grid setup in Ribaneng in present and future

Time horizon	Unmet load, %	Excess electricity, %	LCOE, M/kWh
Present	2.02	39.2	10.242
2019	2.08	33.4	6.741
2030	2.29	66.7	5.060

3.3 Economic Viability

We calculated the internal rate of return (IRR) with revenues on the basis of the present national electricity tariffs. This calculation allows to assess the economic viability under the present framework conditions. Additionally, we calculated a uniform tariff for all customers allowing for an IRR of 8%, equivalent to levelized costs of electricity (LCOE). The difference between the LCOE tariff and the national tariff indicates the amount of public support needed to keep tariffs in the mini-grid at the level of LEC tariffs in the national grid. For the calculation, we assume two different scenarios. The first scenario assumes that the energy demand will remain stable on the level of 2019 over the entire project lifetime of 25 years. In that case, the IRR with revenues on the level of national tariffs will be negative, -14%. Under these conditions, the project is not economic viable without public support. The difference between revenue from national tariffs and annualized costs, consisting of capital costs including replacement, and operation and maintenance costs, accounted for M8,460,485 over 25 years, or M338,419 per year. Converted into electricity demand, the subvention need would be M2.84/kWh. Regarding allowance need in terms of customers, some M1,226 should be additionally paid per year for one customer.

The second scenario earmarks the increase of electricity demand between 2019 and 2030 according to the load forecast and stable demand after 2030. Under these circumstances, the difference between tariff revenue and total project expenditure amounts M22,018,536 over whole project lifetime, and M880,741 per year. Subvention need per kWh would be something lower than in the first scenario: M2.18/kWh. Due to significant annual increase of energy demand, allowance needs per customer would also increase, accounting for M2,857 per customer per year.

3.4 Summary

Ribaneng is a relatively large village in our sample, with many households and several important anchor loads. Current electricity demand is about 29,300 kWh per year (for 64% of demand anchor customers are responsible, for 36% households). In the future, growth in electricity demand is expected: in 2019, when mini-grid will be commissioned, we expect an annual consumption of 119,200 kWh (69% by households, 31% by commercial and public customers). Power demand shares will drastically grow, because when households receive grid electricity, they will purchase electric appliances, for example, switching from ineffective paraffin lamps and candles to LED lights and acquiring long desired refrigerators, irons, radios and hair clippers. The forecasted long-term demand for the year 2030 is 495,700 kWh in a year with an increased share of households in total energy consumption (77%).

In order to cover this constantly increasing power demand, a highly scalable modular energy system is required. The most optimal renewable energy technology for this is solar combined with storage. It can be commissioned and expanded in a short period of time. Besides, in that field further cost reductions in both PV solar panels and battery storage are expected. Closer to the end of considered period till 2030, it can be necessary to integrate other RES technologies, like hydro or wind power, but it will require detailed study of demand forecast and potential of these technologies in the region.

4. Ketane Mini-Grid

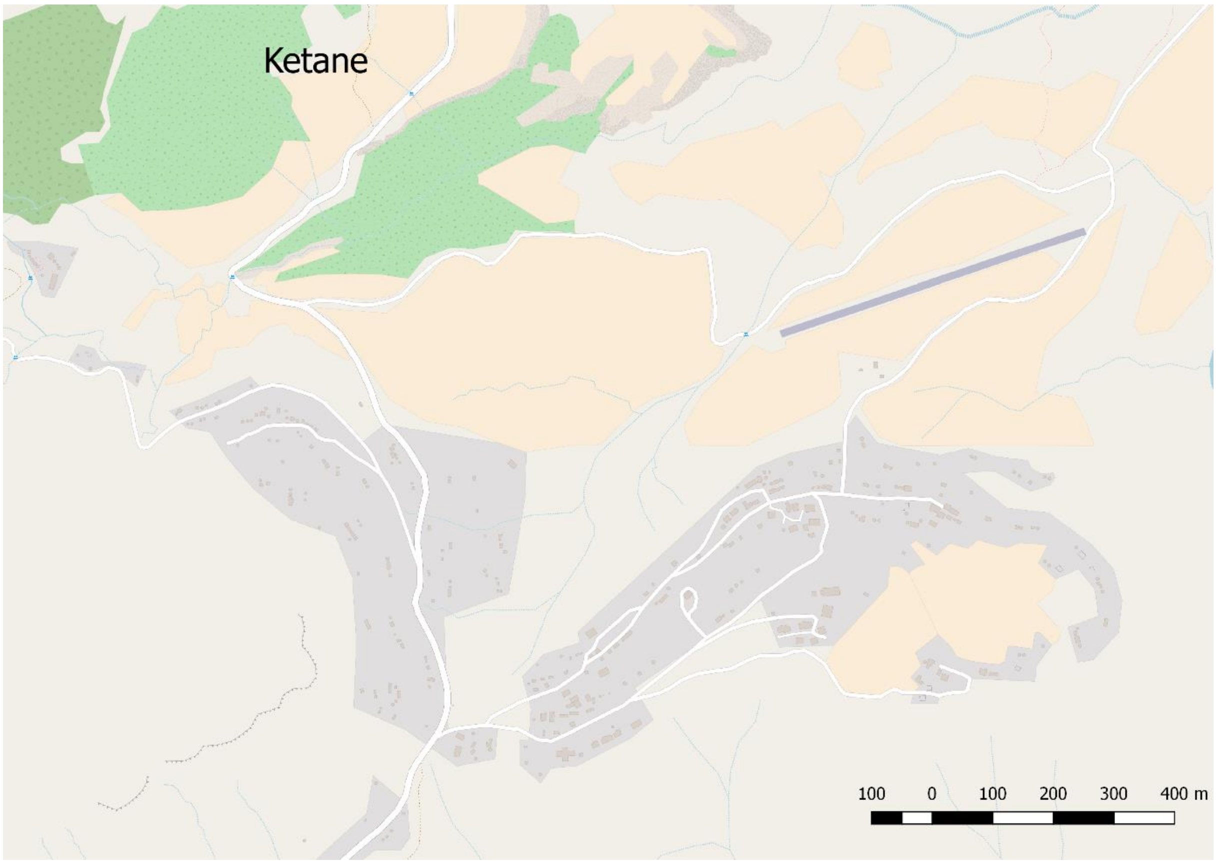


Figure 10: Map of Ketane

Ketane is located west of the rugged Mokhele mountain range at the end of poor gravel road that follows the Senqu and Ketane river valleys. It has health centre, mission, school, airstrip and postal agency. The main villages are Matebesi and Ha Maponyane.

Figure 11: Ketane landscapes

4.1 Customer Base

4.1.1 Households

Sociodemographic characteristics

According to UNDP data, number of households in Ketane is about 180. In the survey, ten households (HH) from the village were interviewed. The responses largely confirmed what the BOS household survey has found in 2017. Households questioned in the survey have between 1 and 7 members, with four households featuring 5 to 7 members (Q B1[2]). Households with more members tend to be more stable demanders for energy: Houses are more constantly occupied, children usually involved would require attention and the likelihood of long-term absence is lower, all these statements compared to single or two-person households. The average number of HH members is 5 persons. Households have between 1 and 4 housing units at its disposal and on average about 2 units (Q C1).

[2] In brackets reference to the corresponding question in the questionnaire. For questionnaire refer to the Annex.

Housing types in the district are diverse. The most popular types mentioned were Rontabole (6 HH), Polata (4 HH), Bungalow (4 HH), Optaka (2 HH) (Q C2). Households have from one to eight rooms totally at their disposal, where three households have 6 to 8 rooms.

The housing area ranges between 20 and 216 m^2, with households with one housing unit having area sizes ranging from 20 m^2 to 50 m^2 area size, households with two housing units have an area size of 53-96 m^2, and one household with three housing units having also the highest usable area size of 216 m^2 (Q C2). The means that the value of disposable area per household member in Ketane accounts for 21 m^2. The average area of houses owned by one HH is 78 m^2. Such large mean area is due to the presence of a household with big houses of an area of 216 m^2 in the sample. Without this HH, average area of houses would be 57 m^2. We consider this household as affluent with remittances of M5,000-M10,000. Seven of the ten interviewed households in Ketane had earnings per month ranging between M150 and M7500, with an average of M2,936 (Q C3). Remittances were received by four households with one household receiving M1,000-M2,000 while the other three households that did not have any earnings received remittances of M5,000 – M10,000 in the previous year (Q C3, Q C4).

One of the ten interviewed households is planning to move away from the village in the next five years for better economic conditions (Q I1).

Energy supply

Regarding used biomass resources, all households use fuel wood either through collection (7 HH), purchasing (2 HH) or as payment in kind (1 HH) (Q D3). Nine of ten households indicated that they have a place to collect fuel wood. They used four trees fuel wood or between 10 and 96 bundles last year, which is equivalent to 150-2,000 kWh per year. Also, five of ten HH used animal waste, obtained through self-production (1 HH), purchased (1 HH) or collected (3 HH). The quantities used were between 24 and 4,500 kg of animal waste, equivalent of 100-21,000 kWh in a year. In addition, one household used 24 bundles of aloe, equivalent to 300 kWh collected for free and purchased 24 bundles of shrubs, equivalent to 600 kWh (Q D1). Those who needed to source fuel wood outside travel a minimum of 30 minutes and up to over 120 minutes to the collection area (Q D4). These travel times are comparable to the average in the district, indicating that fuel wood is not an easily available resource. Households need 30 minutes to over two hours to collect wood. They collect wood one to eight times per month (Q D5-D6). In sum it results in average time spent for travelling and collecting wood per year between 30 and 288 hours. With an hourly wage of 8 Maloti this converts into annual costs between 240 and 2,300 Maloti. In fuel wood collection in the village mostly women are involved (10 from 8 HH), as well as three children from two HH, and two men from two HH (Q D7). In practise however, the majority of interviewed households do not spend any money for purchasing biomass sources except two households that spent between up to M200 per month (Q D9). For purchasing commercial fuels they all usually pay in cash (Q D10) and would prefer to continue to pay for it in that way or through Mpesa (Q D11).

In general, respondents found it hard to separate the energy consumption for cooking, space heating, and water heating, because often the same appliance with the same fuel is used for all three purposes at the same time. That is also why consumptions for individual purposes do not match the total consumption given by individual households. However, the answers may provide some guidance when it comes to energy consumption for individual purposes.

One household indicated to have a queen stove whereas we could not find any improved wood stoves (Q D8). No household has a wonder box (Q F4).

Households in Ketane use fuel wood (5 HH), LPG (4 HH) and paraffin (1 HH) as main energy sources for cooking (Q F1). Eight households interviewed rely on a second fuel type for cooking like paraffin (1 HH), wood (4 HH), LPG (2 HH) and animal dung (1 HH). Three of the households that use LPG for cooking use approximately 9 kg per month and expend on it M200 per month, the respondent in the fourth household was not able to give details because the owner of the household was not there. Two households also use 0.5 litres paraffin per day and 5 litres per month and pays for it M10 per litre.

One household additionally uses two stacks of fuel wood for cooking per week on which they expend M30 per week. Seven households additionally use between 2 pieces per day and one bundle of fuel wood for cooking purposes every three days and receive it for free by collecting (Q F2).

Households in Ketane are ready to pay between M10 and M500 for electricity for cooking per month, on average M89 (Q F3, Table 19). This number seems reasonable compared to the actual expenses for cooking fuels.

Eight households out of ten in Ketane heat their houses (Q G1). For space heating, they use coal stove (1 HH), paraffin heater (2 HH), paola (4 HH), open fire (1 HH) (Q G2). Wood (6 HH) and paraffin (2 HH) are used as main energy source of heating (Q G3). Only one household uses animal dung as an alternative energy source for space heating. The heating area of interviewed households was in the range of 7-50 m^2 (Q G6). As for willingness to pay, only two interviewed households in Ketane are ready to pay M50 and M300 for electricity for space heating per month, on average M175 (Q G5, Table 19).

For water heating the households use paraffin, wood or animal dung as main energy source. One household does not heat water, since water is heated while cooking. It confirms once again the interdependence between consumption of energy resources for cooking and heating. As alternative sources for water heating LPG, paraffin, wood or animal dung are used (Q G7). Two households use LPG for water heating and expend between M200 and M400 per year for that purpose. Two households use 48-96 litres of paraffin pays M576–M960 per year for it. Eight households use fuel wood for water heating purposes which ranges from one bundle to 24 bundles, as well as half a tree per year. In addition, three households use 50 kg – 3,800 kg animal dung for the same purpose obtained by collecting (Q C8).

Table 17: Household use of energy sources in Ketane

HH No.	Cooking			Space and water heating			Lighting			HH income, M/a
	Use of energy sources	Annual energy consumption, kWh/a	Annual expenses, M/a	Use of energy sources	Annual energy consumption, kWh/a	Annual expenses, M/a	Use of energy sources	Annual energy consumption, kWh/a	Annual expenses, M/a	
1	9 kg of LPG per month, 0.5 litres paraffin per day	3,271	4,201	18 litres of paraffin per month	2,236	2,160	1 candle per week, 2 litres of paraffin per day	7,563	6,864	42,000
2	9 kg of LPG per month, 5 kg wood per week	2,656	2,400	5 litres of paraffin per month, 5 kg wood per week	1,964	600	0.5 litres paraffin per day	1,889	1,680	91,620
3	9 kg of LPG per month, 5 kg wood per week	2,656	2,400	3 bundles wood per day	16,097	0	6 candles per year, 1 W rechargeable battery lamp	10	18	90,000
4	5 litres paraffin per month, 1 bundle wood per 3 days	2,410	600	1 bundle wood per 2 weeks, 3,800 kg animal dung per year	18,242	0	12 candles per year, 12 litres paraffin per year	126	180	4,800
5	1 bundle wood per 3 days	1,789	0	36 bundles wood per year	529	0	12 litres paraffin per year	124	144	9,000
6	11 kg wood per week	2,803	730	1 bundle wood per year, 50 kg animal dung	250	0	4 candles per year, 6 litres per year	63	84	9,000
7	9 kg of LPG per month	1,382	2,400	9 kg LPG, 3.5 trees per year	1,830	500	6 candles per year, 12 litres per year	125	162	7,500
8	1 bundle wood per 3 days	1,789	0	24 bundles wood, 120 kg animal dung per year	917	0	104 candles per year	16	312	1,800
9	1 bundle wood per 3 days	1,789	0	48 litres paraffin, 8 bundles wood, 600 kg animal dung per year	3,434	576	6 candles per year, 3 litres paraffin per year	32	54	7,500
10	2 pieces wood per day	3,577	0	18 kg LPG, 6 bundles wood per year	319	400	12 candles per year, 1 W rechargeable battery lamp	10	36	7,500
Average		**2,412**	**1,273**	-	**4,582**	**424**	-	**996**	**953**	-

For lighting households in Ketane use rechargeable battery lamps, candles and paraffin (Q H1). Candles and paraffin are used as alternative sources as well. Please note that the energy consumption we calculated is on the basis of the energy content of the fuels used. It cannot be directly translated into demand for electrical power because conversion of power into light is much more efficient than conversion of fuels resulting in either a better energy service with the same energy input in terms of kWh or to a lower power demand in kWh terms with the same quality of energy service. On average, the households spent M953 per year on fuels for lighting, so the equivalent budget would be at least available for purchasing power for lighting purposes.

Interviewed households in Ketane do not use any light bulbs (Q H3). At least six households are willing to pay M20 or more for lighting. The minimum willingness to pay for lighting ranges between M5 and M100 for electricity for lighting per month and is M27 on average (Q H4).

Two interviewed households in Ketane use electrical appliances at home (Q E1). They both generate their own electricity (Q E2) with solar panels (Q E3). One household received electricity for free, and the other purchased it in the last year (Q E4). The amount spent on electricity was not cited (Q E5). As for current electricity uses, one household uses it for radio and phone charging, other only for phone charging, having consumption of 23 and 6 kWh/year respectively (Q E6).

All households interviewed in Ketane want electricity in their houses (Q E7) and have multiple choices for using electricity in the future. All households want to use it lighting. Cooking/re-heating, TV, phone charging, radio, and refrigeration also rank high. Additionally, electricity for ironing, sewing air-conditioning, charging other than phone, space heating, dishwashing, computer, workshop are each desired by at least one household. As not relevant uses were chosen laundry and water pumping (Q E8).

Table 18: Households desired future uses of electricity in Ketane, ranked starting from the most popular ones

Electricity uses	HH 1	HH 2	HH 3	HH 4	HH 5	HH 6	HH 7	HH 8	HH 9	HH 10	Total
Lighting	X	X	X	X	X	X		X	X	X	9
Phone charging	X	X	X		X			X	X	X	7
Cooking/re-heating	X	X	X		X			X	X	X	7
TV	X	X	X		X				X	X	6
Radio	X	X	X		X				X		5
Refrigeration	X	X	X						X	X	5
Ironing	X		X							X	3
Water heating	X	X									2
Charging (other than phone)	X		X								2
Sewing	X	X									2
Space heating	X										1
Computer		X									1
Workshop				X							1
Dishwashing		X									1
Air-conditioning	X										1
Laundry											0
Water pumping											0
Total	12	10	8	2	5	1	0	3	6	6	-

One household is ready to pay M1,000 per month for electricity. For this household, this value seems rather unrealistic, since its monthly income amounts to M2,000 to M4,999, and the sum of M1,000 would represent a share of the income of between 20% and 50%. Some interviewed households have decent willingness to pay for electricity in general between M20 and M250, in average about M115 (Q E9, Table 19). As a first step, we asked for the general willingness to pay for power (answers in 3rd column). As a second step we refined the question on the willingness to individual purposes (columns 4 – 6), where the sum of individual specific willingness's to pay do not necessarily sum up to the same amount as the general willingness to pay. Also, the willingness to pay deviates substantially from the actual expenses for e.g. lighting. In summary, it seems appropriate to assume some demand for power for lighting but not for heating or cooking. Further, it seems reasonable to assume some demand for power for additional applications like phone charging, radio, television and refrigerators confirming what is described in the General Part. This is also reflected in the average willingness to pay for electricity in general of M213 monthly. As a preferred way to pay for electricity, respondents from Ketane chose cash and Mpesa (Q E10).

Table 19: Ability and willingness to pay for electricity in general and for different applications of households in Ketane

HH No.	Earnings per month (ability to pay)	Willingness to pay for electricity per month (Maloti and % of earnings)				Plans to buy electric appliances
		In general	For cooking	For space heating	For lighting	
1	M3,500	M1,000 (29%)	M500 (14%)	M300 (9%)	M100 (3%)	Refrigerator, electric stove, electric heater, tumble dryer, hair dryer, television (CRT), air conditioner, iron, electric kettle/element, bread maker, microwave, electrical pot, electrical hair clipper, phone charger, other
2	M7,635	M100 (1%)	M20 (0.3%)	0	M10 (0.1%)	Refrigerator, electrical geyser, chest/deep freezer, electric stove, washing machine, hair dryer, television (CRT), air conditioner, electric kettle/element, bread maker, toaster, microwave, electrical pot, phone charger, other
3	M7,500	M200 (3%)	M50 (0.6%)	0	M35 (0.5%)	Refrigerator, electric stove, flat screen television, iron, kettle, microwave
4	M400	M150 (38%)	M30 (8%)	0	M20 (5%)	Other (wood cutting machine)
5	M750	M50 (7%)	M30 (4%)	0	M20 (3%)	Most electrical appliances are there just waiting for electricity
6	M750	M20 (3%)	M10 (1%)	0	M5 (0.7%)	None (responded needs lighting only because she is old)
7	M625	-	-	-	-	-
8	M150	M50 (33%)	M20 (13%)	0	M25 (17%)	Electric stove
9	M625	M100 (16%)	M20 (3%)	0	M20 (3%)	Refrigerator, flat screen television, kettle, phone charger
10	M625	M250 (40%)	M100 (16%)	M50 (8%)	M20 (3%)	Refrigerator, electric stove, hoover, television (CRT), desktop computer, iron, toaster, microwave
	Average	M213	M87	M39	M28	

Considering plans to purchase electrical appliances in the next five years, households indicated that they plan to purchase electric stove, electrical pot, electric kettle/element, iron, refrigerator, bread maker, electric geyser, television (CRT), flat-screen television, microwave, electric heater, electric hair clipper, hair dryer, phone charger, desktop computer, washing machine and other electrical appliance such as an electric wood cutting machine. Of no interest to the households were dishwasher, laptop and LCD television (Q I3).

One household of the ten wants to purchase solar PV, gas generator and car battery in the next five years, the other HH does not have such plans (Q I4).

Energy demand forecast

Two interviewed households in Ketane are representatives of the medium type, having proper income, solar panels and already using electricity for phone charging. Remaining households belong to the basic or medium (households with high income of over M7,500 per month) type. Considering the number of households living in Ketane, 180, and an annual growth rate of 1%, we made projections for the future energy demand in 2019 and 2030.

Table 20: Present and future power demand by households in Ketane

Household type	No. of HH in Ketane			Total power demand, kWh/year		
	Present	2019	2030	Present	2019	2030
Basic	117	118	132	0	3,540	79,200
Medium	45	46	51	2,250	23,000	137,700
Affluent	18	18	20	5,400	32,400	58,000
Total	**180**	**182**	**203**	**7,650**	**58,940**	**274,900**

4.1.2 Anchor customers

According to UNDP data, Ketane has following anchor loads: post office, large clinic, police station, 3 schools, local council offices, 1 supermarket, 7 medium size shops, RCC mission, 4 grain mills, guest house, IEC office, agriculture offices, VCL/ETL communication tower, low voltage electricity network connected to diesel generators.

Energy demand forecast

Based on the assumptions made for present and future energy demand, we evaluated these characteristic values for potential public and commercial customers in Ketane.

Table 21: Present and future power demand of anchor customers in Ketane

Type	Number of institutions	Power demand, kWh/year		
		Present	2019	2030
Health	1	12,250	14,300	28,600
School	4	0	2,000	14,000
Government	5	4,250	8,000	16,000
Retail	10	18,000	28,000	84,000
Craft	4	0	200	1,000
Total		**34,500**	**52,500**	**143,600**

The power demand distributes spatially as depicted in the Table 22.

Table 22: Development of power demand in Ketane by distance from power plant site

Customer	Annual Power Demand MWh											
	Present				2019				2030			
	1km	2km	3km	total	1km	2km	3km	total	1km	2km	3km	total
Households	6.6	0.3	0.0	6.8	50.3	1.9	0.0	52.2	210.0	8.1	0.0	218.2
Anchor customers	26.2	0.5	0.0	26.7	37.1	1.1	0.0	38.1	77.0	6.1	0.0	83.1
Total	32.8	0.7	0.0	**33.5**	87.3	3.0	0.0	**90.3**	287.0	14.2	0.0	**301.2**

4.2 Set-up for Mini-Grid

Given the demand forecast for the years 2019 and 2030, the set-up of the mini-grid setup with the help of HOMER Pro software. For dimensioning the generation plants we used the consumption pattern as derived in previous sections of this report. For the present supply situation, solution with PV + storage is the most optimal. Battery capacity should exceed the PV maximum hourly output for about three times.

Table 23: Elements of mini-grid setup in Ketane in present conditions

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	49.8 kW	841,620	0	9,711
Battery	148 kWh	577,200	2,308,800	19,240
System converter	15.5 kW	40,300	40,300	0
Power lines	7.16 km	150,297	0	3,006
Power meters	172 units	550,400	0	11,008
Total	-	**2,159,817**	**2,349,100**	**1,074,125**

Basing calculations on presently existing power demand i.e. not additional demand is assumed even when power is available through the mini-grid, is the most conservative approach for sizing the mini-grid. In practise, additional power demand will occur as we assumed in the scenario for the year 2019 (Table 24). The set-up remains rather the same only the sizes of all elements increases substantially, leading to more than a twofold higher investment need.

Table 24: Elements of mini-grid setup in Ketane in 2019

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	131 kW	2,213,900	0	25,545
Battery	397 kWh	1,548,300	6,193,200	51,610
System converter	41.9 kW	108,940	108,940	0
Power lines	7.23 km	151,800	0	3,036
Power meters	174 units	555,904	0	11,118
Total	-	**4,578,844**	**6,302,140**	**2,282,725**

Figure 12 presents the distribution of capital costs between different components of a mini-grid. It shows that power grid components (lines and meters) amount 15% of the capital costs.

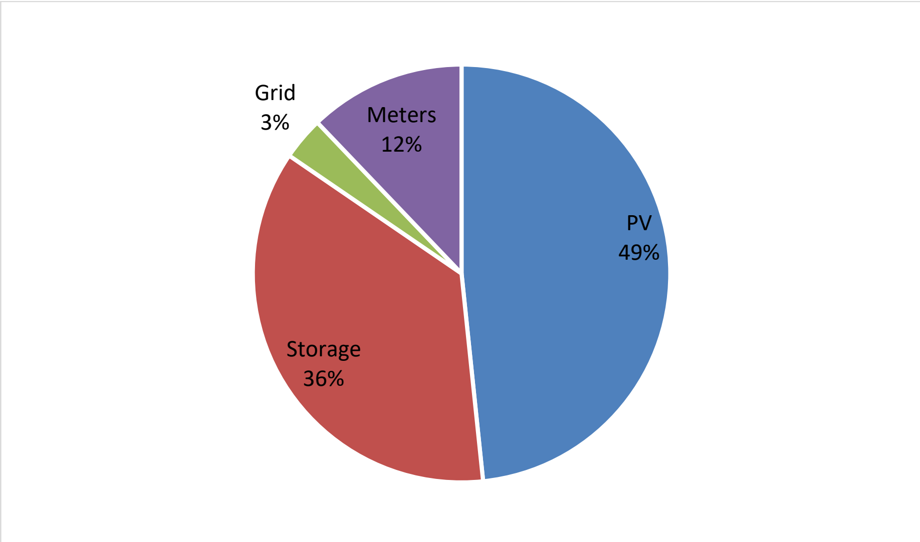


Figure 12: Distribution of capital costs of a mini-grid in Ketane in 2019

For the energy situation in 2030, characterized by considerably increased demand, a solution of PV + hydro + storage represents the least-cost alternative. In this case, LCOE will be reduced (M5.2/kWh instead of M6.6-7.6/kWh) and excess electricity will increase (from 44% to 69%) in comparison to solutions for present and 2019.

For the Mini Grid two feasible sites were identified. One of the sites, marked blue on the Figure 13, was chosen according to physical criteria like direction to the sun, area size and availability of space. The yellow marked optimal site was determined according to the calculation algorithm of the geometrical mean of all buildings in the radius 1-3 km in the village. So, it is the location that has the minimum sum of distances to all existing potential residential, public and business customers. In the case of Ketane the theoretically chosen potential site for a mini-grid coincided with the site chosen as a result of field research. This particularly suitable site is presented on the following map as two squares, blue and yellow, inscribed in each other.

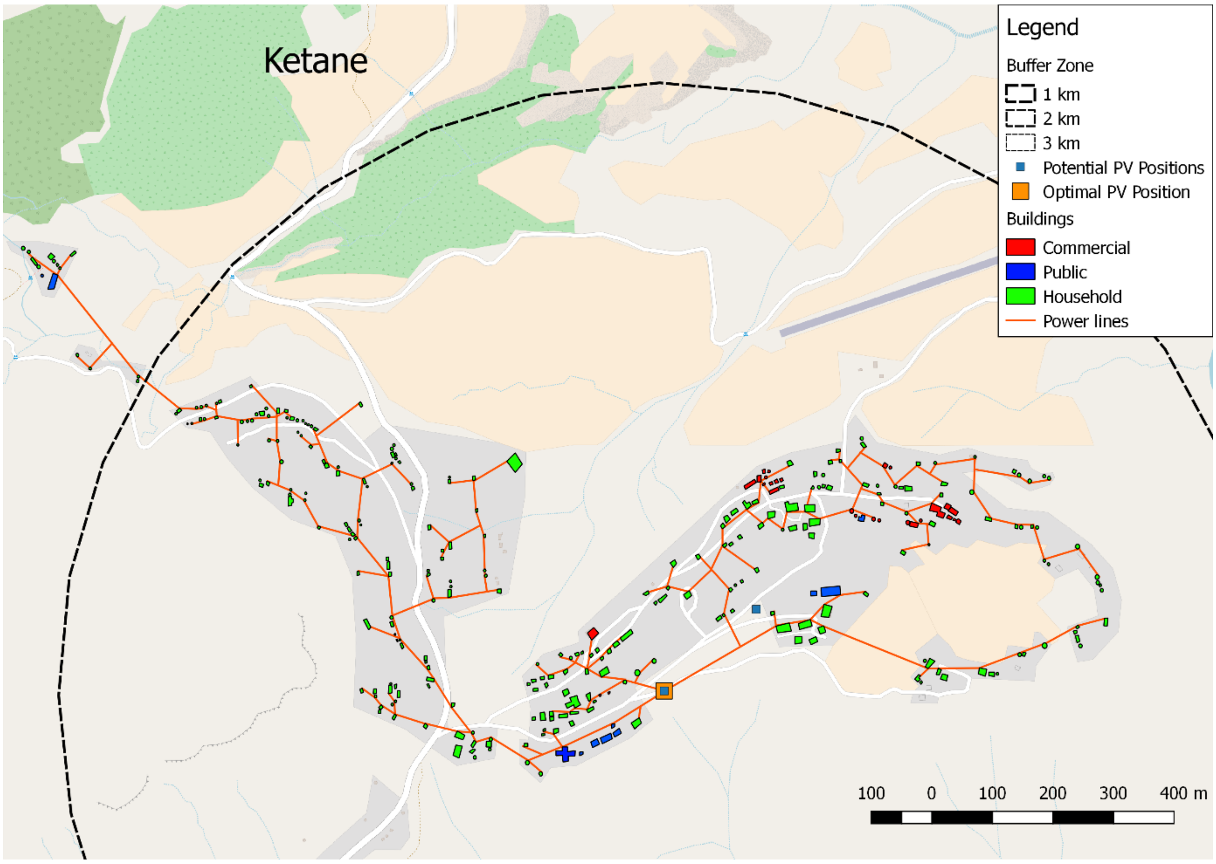


Figure 13: Map of the mini-grid set-up in Ketane in 2019

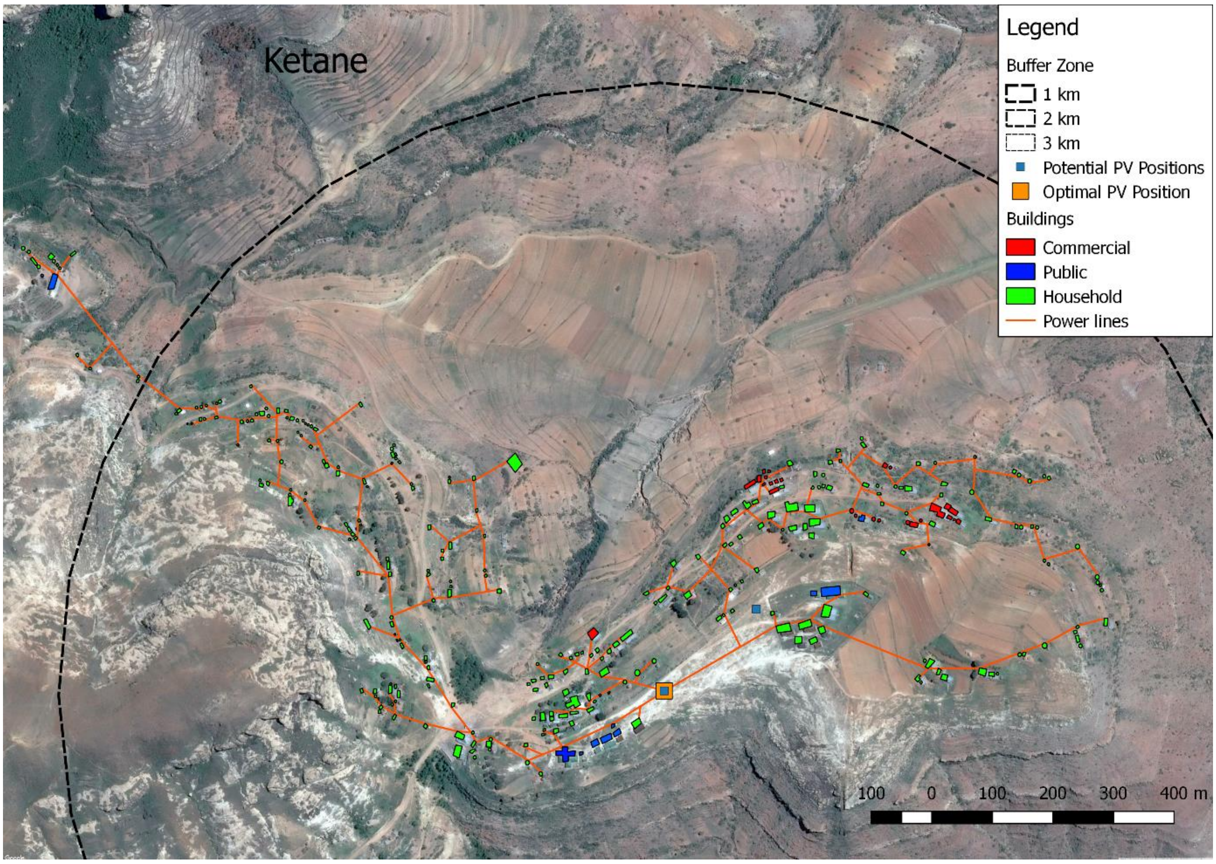


Figure 14: Satellite map of the mini-grid set-up in Ketane in 2019

Table 25: Elements of mini-grid setup in Ketane in 2030

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	302 kW	5,103,800	0	58,890
Battery	762 kWh	2,971,800	11,887,200	99,060
Hydro Power Plant	100 kW	6,000,000	0	180,000
System converter	135 kW	351,000	351,000	0
Power lines	8.06 km	169,358	0	3,387
Power meters	194 units	620,204	0	12,404
Total	**-**	**15,216,163**	**12,238,200**	**8,843,525**

The expected demand growth allows for lower generating costs in the future (Table 26). Thereby we have not considered, that due to technology advancements some elements to be added in the future will have very likely lower specific CAPEX (LCOE) than presently. There is a high rate of excess power to allow for a generation entirely based on renewable energies. This waste of energy could be avoided in two ways: Either one would allow a minor share of fossil based generation which would run during winter, when PV generation is low, leading also to lower overall generation costs. Or additional seasonal usage of the excess power is created, e.g. refrigeration and cooling which both would perfectly match the generation patterns of solar generation.

Table 26: Characteristics of mini-grid setup in Ketane in present and future

Time horizon	Unmet load, %	Excess electricity, %	LCOE, M/kWh
Present	2.14	44.2	7.581
2019	2.10	43.9	6.554
2030	2.24	69.0	5.214

4.3 Economic Viability

We calculated the internal rate of return (IRR) with revenues on the basis of the present national electricity tariffs. This calculation allows to assess the economic viability under the present framework conditions. Additionally, we calculated a uniform tariff for all customers allowing for an IRR of 8%, equivalent to levelized costs of electricity (LCOE). The difference between the LCOE tariff and the national tariff indicates the amount of public support needed to keep tariffs in the mini-grid at the level of LEC tariffs in the national grid. For the calculation, we assume two different scenarios. Two scenarios of electricity demand forecast are considered. The first scenario assumes a constant demand stays on the level of 2019 over the entire project lifetime of 25 years. In this case, IRR received from LEC tariffs will be negative on the level of -15%. Under these conditions, the project is not economic viable without public support. The difference between revenue and annualized costs, including both CAPEX and OPEX, accounts for M7,550,876 over 25 years, and M302,035 per year. Considering electricity supplied to the customers, the need for subvention is M2.71 per kWh. For a single final customer the support amounts to M1,468 per year.

For the second scenario the electricity demand increases in the period between 2019 and 2030 and remains the same from 2031 till 2043. In that case, difference between tariff revenue and total project costs will be M19,731,796 in sum, or M789,272 per year. Converted to electricity consumption, M2.29 per kWh must be paid in addition to compensate the revenue deficit. Translated into individual customers, M3,441 per year and customer accounts for allowance need.

4.4 Summary

Ketane is the middle-size village, with average number of households and relatively high number of anchor loads. Current electricity demand is 42,150 kWh per year with about 82% of share of anchor customers and 18% of households. In the year of the mini-grid commissioning a considerable demand growth is expected, at the range of 111,440 kWh, where residential loads take over the large part of it, more than 50%. In the long-term till 2030, annual demand forecast amounts 418,500 kWh, with shift of the large share in total energy consumption towards households (66% HH, 34% anchor customers).

Under given conditions, regarding demand of 2019, a PV + storage solution would be optimal. As time goes by and electricity demand grows, it could be easily expanded with some additional solar modules. In order to meet the demand of 2030 and to reduce unmet load, it would be reasonable to include hydro or wind power plant. The decision on the choice of specific RES technologies can be made on the basis of studies of RES potential.

5. Phamong Energy Centre

Phamong is located on the northern side of the Senqu River. It can be accessed either via Mt. Moorosi or via the poor quality road on the northern side of the river. Phamong is an important centre for the surrounding area. It is the seat of a principal chief, has a number of shops, a mission and a high school. It is also home to the Bethel Business and Community Development (BBCDC) which has played a pioneering role in the development of solar power technologies for cooking, lighting and heating. The villages include: Phamong Ha Letsie, Matsetseng, Putsoane, Ha Ntloane, Ha Lelimo, Masaballeng, Ramabula, and Ikarabelle.

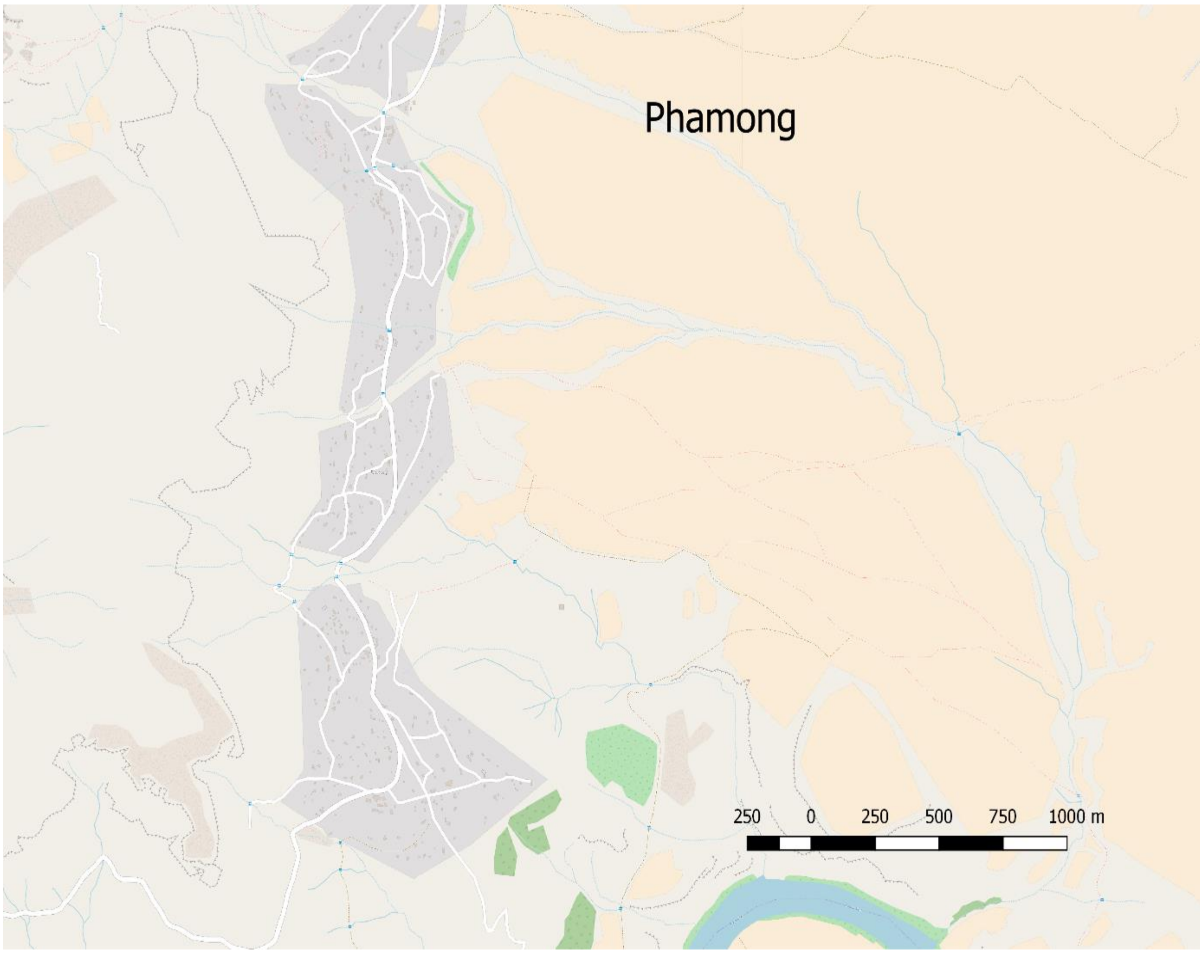


Figure 15: Map of Phamong

5.1 Customer Base

5.1.1 Households

Sociodemographic characteristics

In Phamong three households were interviewed. These HH have in average three members (Q B1) and one to two housing units (Q C1). The largest house of mansion type has an area of 40 m^2 and 6 rooms. Other houses are small with areas of 18 and 25 m^2 (Q C2). The household which owns the largest house has relatively high disposable income of M3,500 per month, other two HH have less than M1,000 at their disposal (Q C3). No HH receives remittances from workers abroad (Q C4).

Energy supply

For housing purposes two HH use fuel wood and shrubs, and one HH additionally obtains animal dung. All biomass sources were obtained by collection and costed nothing. The first household used significantly more biomass resources (fuel wood and shrubs) equivalent to 39,400 kWh in a year, compared to other HH with slightly less than 7,000 kWh/year (fuel wood, animal dung, shrubs) (Q D1). All households have an area to collect fuel wood in a communal forest (Q D2, Q D3).

All three households indicated very long travel times to the edge of the main collecting area and back between 1.5 and 2 hours and more than 2 hours (Q D4). Collection time was also quite long: 1-1.5 hour or even more than 2 hours (Q D5). Households need to go to collect wood three or eight times in a month (Q D6). In sum, travelling and collection time amounts three to six hours. In total, households use 200 to 300 hours a year for fuel wood collection. Considering an hourly wage of M8, annual costs for this activity amount approx. M2,000. In wood collection are involved men, women and children quite even (Q D7).

All households do not spend any money on biomass (Q D9). Households use cash for fuel payments and would prefer to use it or Mpesa (Q D10, Q D11).

Households in Phamong use wood and LPG as main source of energy for cooking, and as alternative straw, animal dung, and paraffin (Q F1). The specific quantities of energy sources for cooking are presented in the Table 27. Willingness to pay for electricity for cooking ranges from M50 to M200 (Q F3, Table 29).

All households heat their houses (Q G1). For heating were used paraffin heater, open fire and paola (Q G2). Main source of energy was wood in two cases and paraffin in one case. No alternative sources were available (Q G3). Considering the heating season of two months, energy consumption for space heating was calculated for every household (Q G4, Table 27). No expenses were indicated. Willingness to pay for electricity for space heating is between M25 and M100 (Q G5, Table 29). Households have a heating area of 16-30 m^2 (Q G6).

For water heating was used wood, paraffin, LPG, and animal dung (Q G7).

For lighting, households used paraffin and candles (Q H1). No light bulbs were used according to the households' answers (Q H3). Willingness to pay for electricity for lighting is decent and ranges from M25 to M50 (Q H4, Table 29). In average, the households spent M1,200/a, so the equivalent budget would be at least available for purchasing power for lighting purposes.

All HH have some electric appliances at their disposal (Q E1). Two households of three generate their own electricity with a solar panel (Q E3), two purchase it additionally (Q E4). One HH spent on electricity M1,200, other M150 in a last year (Q E5, Table 29). Households with solar panels used electricity for phone charging and radio resulting in energy demand of approx. 23 kWh/year, other household used it for charging, having demand of 6 kWh in a year (Q E6). All households want to have electricity in their houses (Q E7). Regarding future uses of electricity, all want to use it for cooking/re-heating, radio, phone charging, lighting, and charging other than phone. Two of three support TV, laundry, ironing, dishwashing, sewing, air-conditioning, computer, refrigeration, space and water heating, and workshop (Q E8). Interviewed households are ready to pay between 50 and 500 Maloti per month for electricity (Q E9, Table 29). They would prefer to pay for electricity in cash or Mpesa (Q E10).

No household wants to move away from the village in the next five years (Q I1). No one plans to purchase solar PV, generator or car battery (Q I4).

Table 27: Household use of energy sources in Phamong

HH No.	Cooking			Space and water heating			Lighting			HH income, M/a
	Use of energy sources	Annual energy consumption, kWh/a	Annual expenses, M/a	Use of energy sources	Annual energy consumption, kWh/a	Annual expenses, M/a	Use of energy sources	Annual energy consumption, kWh/a	Annual expenses, M/a	
1	9 kg LPG per month; 10 litres paraffin per month; 5 stacks wood per month; 1 stack straw per day	9,460	3,840	8 litres paraffin per week	4,306	4,160	2 packs of candles per month, 1 litre paraffin per day	3,800	2,184	42,000
2	7.5 stacks wood per month; 15 bags animal dung per month; 1 bundle straw per week	6,017	0	25 kg wood a week for space heating, 50 stacks wood per year for water heating	7,595	0	2 packs of candles per month, 4 litre paraffin per month	515	1,128	9,000
3	4 stacks wood per month; 30 bags animal dung per month; 0.28 stacks straw per day	6,753	0	35 kg wood a week for space heating, 3 stacks per year for water heating	8,992	0	8 candles per month	14	288	4,800
Average		**7,410**	**1,280**	**-**	**6,964**	**1,387**	**-**	**1,443**	**1,200**	**-**

Table 28: Households desired future uses of electricity in Phamong, ranked starting from the most popular ones

Electricity uses	HH 1	HH 2	HH 3	Total
Lighting	X	X	X	3
Phone charging	X	X	X	3
Charging (other than phone)	X	X	X	3
Cooking/re-heating	X	X	X	3
Radio	X	X	X	3
Water heating	X		X	2
Refrigeration	X		X	2
TV	X		X	2
Ironing	X		X	2
Space heating	X		X	2
Workshop	X		X	2
Laundry	X		X	2
Dishwashing	X		X	2
Sewing	X		X	2
Air-conditioning	X		X	2
Computer	X		X	2
Water pumping			X	1
Total	16	5	17	-

All households are ready to pay for electricity for lighting (Q H4, Table 29). In a first step, we asked for the general willingness to pay for power (answers in 3rd column). In a second step we refined the question on the willingness to individual purposes (columns 4 – 6), where the sum of individual specific willingness to pay do not necessarily sum up to the same amount as the general willingness to pay. Also, the willingness to pay deviates substantially from the actual expenses for e.g. lighting. In summary, it seems appropriate to assume some demand for power for lighting but not for heating or cooking. Further, it seems reasonable to assume some demand for power for additional applications like phone charging, radio, television and refrigerators confirming what are described in the General Part. This is also reflected in the average willingness to pay for electricity in general of monthly 230 Maloti, a very limited which likely reflects the limited overall budgets available.

Table 29: Ability and willingness to pay for electricity in general and for different applications of households in Phamong

HH #	Earnings per month (ability to pay)	Willingness to pay for electricity per month (Maloti and % of earnings)				Plans to buy electric appliances
		General	Cooking	Space heating	For lighting	
1	M3,500	M150 (4%)	M80 (2%)	M50 (1%)	M50 (1%)	Refrigerator, electrical geyser, chest/deep freezer, electric stove, electric heater, washing machine, dishwasher, tumble dryer, hoover, hair dryer, television (CRT), television)flat screen), Television LCD, desktop computer, laptop, air conditioner, iron, electric kettle/element, bread maker, toaster, microwave, electrical pot, electrical hair clipper, phone charger, other
2	M750	M50 (7%)	M50 (7%)	M25 (3%)	M25 (3%)	Electric heater, other
3	M400	M500 (125%)	M200 (50%)	M100 (25%)	M50 (13%)	Refrigerator, electrical geyser, chest/deep freezer, electric stove, electric heater, washing machine, hair dryer, laptop, air conditioner, electric kettle/element, bread maker, microwave, electrical pot, electrical hair clipper, phone charger, other
	Average	M233	M110	M58	M42	

Energy demand forecast

Interviewed households in Phamong according to the current energy demand belong to the medium type, though two households with the lower incomes can also be representatives of the basic category. Using the assumptions made, following evaluation of present and future electricity consumption was carried out. Power demand in 2019 reflects only the share of the total demand of households covered by the Energy Centre.

Table 30: Present and future power demand by households in Phamong

Household type	No. of HH in Phamong	Total power demand, kWh/year	
		Present	2019
Basic	228	0	2,960
Medium	88	4,400	6,400
Affluent	35	10,500	0[3]
Total	**350**	**14,900**	**9,360**

[3] Affluent households are energy self-sufficient and cover their energy needs by themselves.

5.1.2 Anchor customers

Energy demand forecast

The forecast for power demand of anchor customer is based on the results of the entire survey (Table 31). However, only schools will be supplied with energy by the energy centre whereas for the other types specific individual demand is too high to be covered by the energy centre. Moreover, the other customers types often already feature own generation facilities.

Table 31: Present and future power demand of anchor customers in Phamong

Type	Number of institutions	Power demand, kWh/year	
		Present	2019
Health	1	12,250	12,250
School	3	0	1,500
Government	5	4,250	4,250
Retail	13	23,400	23,400
	Total	**39,900**	**41,400**

The power demand distributes spatially as depicted in the Table 32. Here, also anchor customers other than schools and affluent households are included even though we do not expect them to be supplied by the energy centre.

Table 32: Development of power demand in Phamong by distance from energy centre

Customer	Annual Power Demand MWh											
	Present				2019				2030			
	1km	2km	3km	total	1km	2km	3km	total	1km	2km	3km	total
Households	7.3	2.7	0.0	10.1	9.4	3.5	0.1	13.0	233.1	86.7	1.4	321.1
Anchor customers	18.9	1.8	0.0	20.7	18.9	1.8	0.0	20.7	48.5	5.4	0.0	53.9
Total	26.2	4.5	0.0	**30.8**	28.3	5.3	0.1	**33.7**	281.6	92.1	1.4	**375.0**

5.2 Set-up for Energy Centre

For the Energy Centre three feasible sites were identified. Two of them, the sites which are marked blue on the Figure 16, were chosen according to physical criteria like direction to the sun, size of area, and availability of space. The yellow marked optimal site was determined according to the calculation algorithm of the geometrical mean of all buildings in the radius 1-3 km in the village. So, it is the location that has the minimum sum of distances to all existing potential residential, public and business customers. In the case of Phamong the theoretically chosen potential site for EC coincided with the site chosen as a result of field research. This particularly suitable site is presented on the following map as two squares, blue and yellow, inscribed in each other.

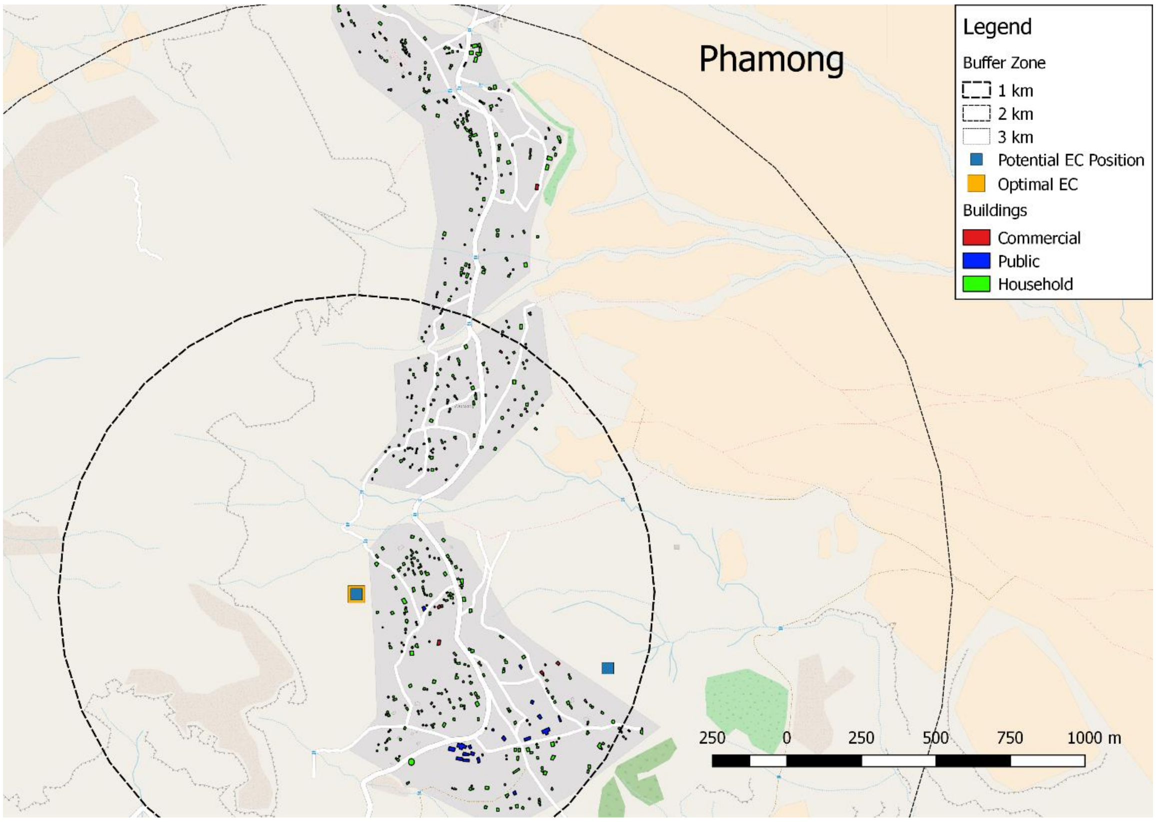


Figure 16: Spatial distribution of customers and positions of energy center in Phamong

5.3 Economic Viability

As Phamong belongs to the large villages with its 350 households, a large energy centre should be built in there. Main features, initial investment, annual expenditure, replacement costs due every five years as well as residual value after 10 years of operation are presented in the Table 33 below.

Table 33: Main features and financial parameters of an energy centre in Phamong

Features	
Number of households in the village	350
Building area, m2	100
Vehicle, #	1
Employees, #	4
Capacity PV	15.3
Capacity storage	50

Initial investment	
Building costs, M	200,000
Vehicle, M	200,000
PV+storage, M	469,310
Initial Stockage, M	796,510
Equipment, M	36,000
Staff Training, M	5,000
Contingencies	341,364
Total initial investment	**2,048,184**

Annual costs	
Salaries, M	100,000
Maintenance PV, M	9,386
Depreciation on hardware investment	57,200
Vehicle Maintenance and fuels	20,000
Contingencies	37,317
Total annual costs	**223,903**

Replacement costs	
Inverter+ storage	195,000
Vehicle	200,000

Annual revenue	
Charging lights, phones #/yr	36,500
Charging large batteries #/yr	7,500
Charging lights, phones, M	182,500
Charging large batteries, M	75,000
Equipment services	36,000
Profit on equipment sales	238,953
Total annual revenue	**532,453**

Residual Value	
Building costs, M	100,000
Vehicle, M	0
PV+storage, M	234,655
Initial Stockage, M	796,510
Equipment, M	0
Total residual value	**1,131,165**

To supply energy needs of potential customers in Phamong and to cover the electricity demand for the services provided through the centre, a PV power plant of 15.3 kW with storage facility of 50 kWh is needed. One may consider building up this plant in stepwise along the expected increase in power demand and power related services.

We calculated the cash flow over a period of ten years after establishing the energy centre (Figure 17). Even though most of the equipment as well as the building will be not worn out after ten years we expect that power provision through batteries will be replaced either by a mini-grid or a connection to the central grid after 2029. Besides the initial investment (we assumed 2018, i.e. the year before start of operation, for reasons of calculation) certain elements like vehicles or inverters needs to be replaced after five years. Annual revenues arise from provision of charging services (lights, phones, large batteries), equipment services (printing, calling, internet services, sales of drinks and snacks, etc.), as well as profit on equipment sales. With an internal rate of return of 8%, net present value of the project over ten years amounts to M79,400, i.e. the energy centre is economically feasible.

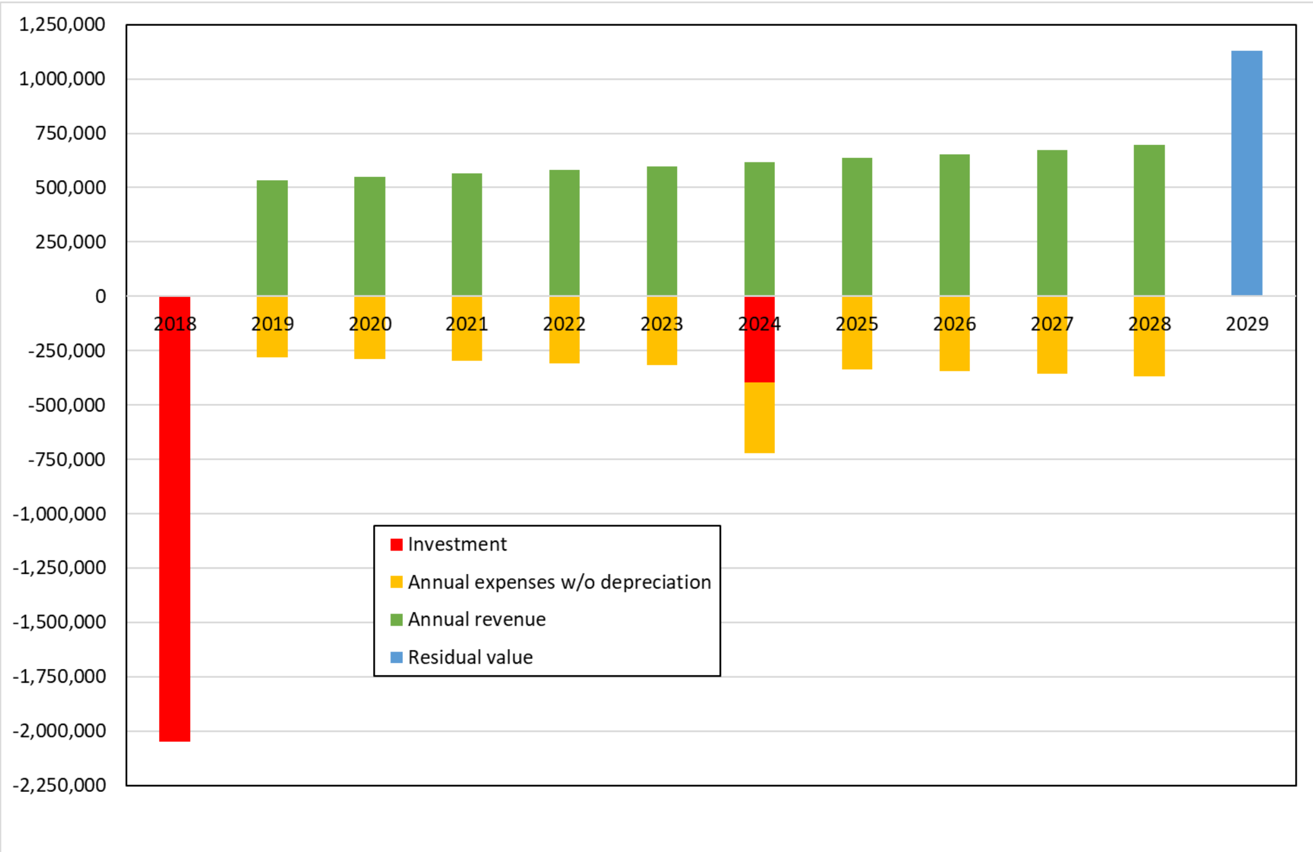


Figure 17: Cash flow of the energy centre in Phamong in 2018-2029

5.4 Summary

Since Phamong is one of the largest villages in our sample and has 350 households and three schools, it shows a relatively high demand for energy centre services. It is densely populated in the small radius of 1-2 km, that makes it an attractive location for an energy centre, which can be easily reached on foot by many potential customers. Energy centre should have an area of approx.

100 m², in order to accommodate extensive stockage of goods, its display and office premises. Four employees, two sales assistants and two maintenance agents, should be hired to serve customers in the energy centre and beyond with demonstrations, small repairs and replacements. A vehicle will be needed to deliver products and spare parts directly to the customer's doorstep. Combination of PV and battery storage will cover energy needs of customers and own energy consumption of the centre. With a noticeable growth of energy demand, this PV can be scaled up with relatively small effort. Provided that offered goods will find appropriate demand, and battery and phone charging in the centre will become popular, the establishment of such a facility is economically profitable with initial investment of M2,048,184 and provides a rate of return of 9% after ten years of operation.

6. Koebunyane Energy Centre

Koebunyane (29°52'43.4"S 28°21'26.3"E) is situated approximately 89.83 km East of Mohales Hoek town. It is also 40.55 km North West of Qachas Nek town. It's off the main roads.

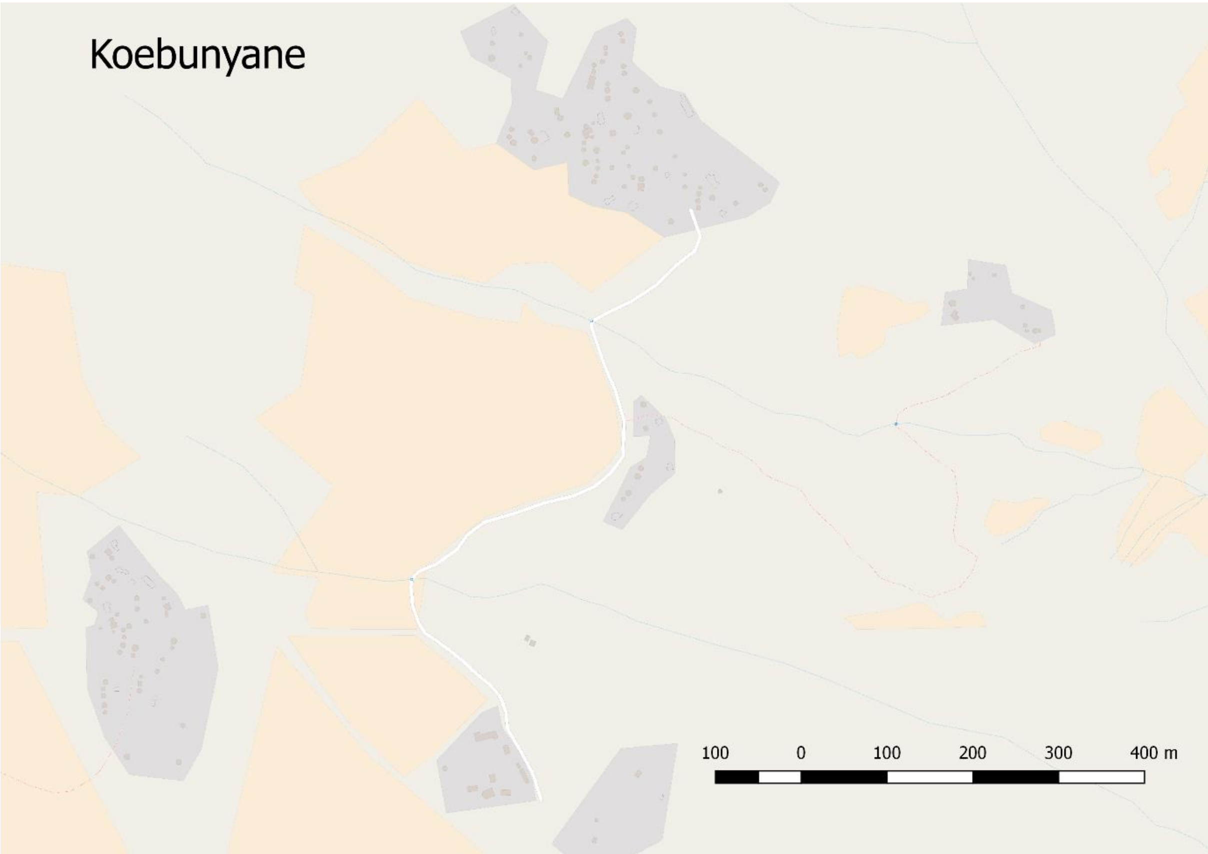


Figure 18: Map of Koebunyane

Figure 19: Anchor customers in Koebuyane (from left to right, top to bottom Koebuyane Health Centre, Thusanang General Café, RCC Church, RCC Primary School)

6.1 Customer Base

According to the chief of Koebunyane, three main income sources in the village are subsistence farming, wool and mohair, soil conservation called “fato-fato”.

6.1.1 Households

Energy demand forecast

The number of households in Koebunyane amounts approx. 150. Based on the assumptions on current and future energy demand, we calculated key parameters for the village. Power demand in 2019 reflects only the share of the total demand of households which will be covered by the Energy Centre. Therefore, affluent households were not considered in the calculation for 2019, since they already cover their own energy needs using solar home systems, solar lanterns and rechargeable batteries.

Table 34: Present and future power demand by households in Koebunyane

Household type	No. of HH in Koebuyane	Total power demand, kWh/year	
		Present	**2019**
Basic	98	0	1,270
Medium	37	1,850	2,700
Affluent	15	4,500	0
Total	**150**	**6,350**	**3,980**

6.1.2 Anchor customers

Main characteristics

In Koebunyane there are one health centre, one primary school, one church, and four commercial retail facilities. Five anchor customers were interviewed in the survey: a health centre, a school, a church, and two cafes (Q B1). Health centre and church are in a state ownership, cafes in individual, and school in private (Q B2). A health centre has the highest number of employees: 7 workers, school has 4 employees, and cafes one or two (Q B3). One café has a relatively high income between M10,000 and M50,000, other between 2 and 5k Maloti per month. Health centre and church receive approx. M250-300 per month. School does not earn anything (Q B4-B6).

Health centre works 8 hours a day, 5 days a week over 11 months of a year. School has operating hours of 8 per day, 5 days a week over 10 months of a year. Church is open only one day a week for two hours all year round. Both cafes operate 12 hours every day in a year (Q D1-D3).

Almost all anchor customers have one building at its disposal, except health centre which has two (Q D4). The largest area belongs health centre with 339 m^2. It is also the only building with insulation (Q D5).

Energy supply

Coal and biomass resources are used by both cafes and health centre.

Table 35: Consumption of energy resources and electricity generation of selected anchor customers in Koebunyane

Anchor customer	Wood		Charcoal		LPG		Solar PV	
	Quantity, kg	End use	Quantity, kg	End use	Quantity, kg	End use	System size	End use
Bataung General Shop	106	Space, water heating, cooking					51 W	Lighting, phone charging
Thusanang General Café	340	Water heating, cooking						
Koebunyane Health centre	100	Space heating	150	Space heating	2 units of 48 kg	Heating	200 W	Lighting
Total quantity	**546**		**150**		**96**		**251 W**	
Unit costs	M4/kg		M13/kg					
Total costs	**M2,000**		**M2,000**					

Health centre and Bataung General Shop use solar electricity of 200 and 51 Watts respectively. Health centre uses this electricity from 12 panels for lighting, café also for phone charging (Q C3). No anchor customer has a generator (Q E4).

All anchor customers want to have electricity in their facilities, think that it is important and expensive (Q C5-C7). They would prefer to pay for it via mobile phone or bank transfer (Q C8).

No one has central air-conditioning system (Q D6). Health centre has a heating system on the LPG basis, which operates 10 months a year and has two units of 48 kg (Q D7-D8). Willingness to pay for electricity for heating/cooling is presented in the Table 37.

Table 36: Electric equipment of selected anchor customers in Koebunyane

Anchor customer	Lighting		Small equipment	Refrigerating equipment	
	Type & number	Capacity, W	Type & number	Type & number	Capacity, l
Bataung General Shop	3 LED	15 W			
Koebunyane Health centre	22 LED	12 W	1 desktop, 1 monitor, 1 printer, 1 HH appliance	1 laboratory fridge	120

Both anchor customers, who have solar panels: health centre and one café, have LED lights (Q D10). No one has light or motion sensor controls (Q D11-D12). Willingness to pay for electricity for lighting is cited in the Table 37 (Q D13). Regarding small equipment, only health centre has some appliances like desktop, monitor, printer (Q D14).

In cafes and school there are cooking facilities (Q D15). For this, mainly wood and sometimes paraffin are used (Q D16). Willingness to pay for electricity for cooking is shown in the Table 37 (Q D17). Refrigeration equipment is used only by the health centre: it has a laboratory fridge of 120 litres (Q D18-D19). Willingness to pay is shown in Table 37 (Q D20).

Table 37: Ability and willingness to pay for electricity in general and for different applications of anchor customers in Koebunyane

Anchor customer	Earnings per month ability to pay	Willingness to pay for electricity per month (Maloti)					
		Heating/Cooling	Lighting	Cooking	Fridge	Total	
						Maloti	% of earnings
Koebunyane Health centre	M292	-	-	-	-	-	-
Koebunyane Primary School	NA	M200	M200	M350	-	M750	NA
Roman Catholic Church	M250	M60	-	-	-	M60	24%
Bataung General Shop	M30,000	M1,000	M1,000	M1,200	M600	M3,800	13%
Thusanang General Café	M3,500	M100	M100	M0	M100	M300	9%
Total	M34,042	M1,360	M1,300	M1,550	M700	M4,910	-

Regarding future plans of replacing units or installing new energy consuming systems or purchasing solar PV, generator or car battery, no anchor customer has any plans due to high purchasing costs and high installation and labour costs (Q F1-F11).

Energy demand forecast

Present power demand and supply of anchor customers in Koebunyane are summarized in the Table 38. Future power demand of all anchor customers in the village, including non-interviewed ones, is presented in the Table 39. We derived the forecast for power demand of anchor customer on the results of the entire survey (Table 39). However, only school will be supplied with energy by the energy centre whereas for the other types specific individual demand is too high to be covered by the energy centre. Moreover, the other customer types often already feature own generation facilities.

Table 38: Main characteristics of anchor customers in Koebunyane

#	Name	Type	Size	Operation hours	Electrical equipment	Annual power demand	Present power supply	Willingness to pay, Maloti/month
1	Koebunyane Health centre	**Health**	7 employees; 2 buildings, area 339 m^2	8 h/day, 5 days/week, 11 months/year	LED, 22 units of 12 W; desktop, monitor, printer, household appliance; 1 laboratory fridge	2,736 kWh	12 solar panels of 200 W	n.a.
2	Koebunyane Primary School	**School**	4 employees; 1 building, area 49 m^2	8 h/day, 5 days/week, 10 months/year	None	0	None	750
3	Roman Catholic Church	**Government**	1 building	2 h/day, 1 day/week, all year long	None	0	None	60
4	Bataung General Shop	**Retail**	2 employees; 1 building	12 h/day, 7 days/week, all year long	LED, 3 units of 15 W	200 kWh	1 solar panel of 51 W	3,800
5	Thusanang General Café	**Retail**	1 employee; 1 building, area 52 m^2	12 h/day, 7 days/week, all year long	None	0	None	300
					Total	2,936 kWh		4,910

Table 39: Present and future power demand of anchor customers in Koebunyane

Type	Number of institutions	Power demand, kWh/year	
		Present	2019
Health	1	2,736	2,736
School	1	0	500
Government	1	0	0
Retail	4	3,800	3,800
Total		**6,536**	**7,036**

The power demand distributes spatially as depicted in the Table 40. Here, also anchor customers and affluent households are included even though we do not expect them to be supplied by the energy centre.

Table 40: Development of power demand in Koebunyane by distance from energy centre

Customer	Annual Power Demand MWh											
	Present				2019				2030			
	1km	2km	3km	total	1km	2km	3km	total	1km	2km	3km	total
Households	3.1	0.0	0.0	3.1	4.0	0.0	0.0	4.0	98.9	0.0	0.0	98.9
Anchor customers	6.3	0.0	0.0	6.3	6.8	0.0	0.0	6.8	21.5	0.0	0.0	21.5
Total	9.4	0.0	0.0	**9.4**	10.8	0.0	0.0	**10.8**	120.4	0.0	0.0	**120.4**

6.2 Set-up for Energy Centre

For the Energy Centre two feasible sites were identified. One site, which is marked blue on the Figure 20, was chosen according to physical criteria like direction to the sun, area size and availability of space. The yellow marked optimal site was determined according to the calculation algorithm of the geometrical mean of all buildings in the radius 1-3 km in the village. So, it is the location that has the minimum sum of distances to all existing potential residential, public and business customers. In the case of Koebunyane the theoretically chosen potential site for EC coincided with the site chosen as a result of field research. This particularly suitable site is presented on the following map as two squares, blue and yellow, inscribed in each other.

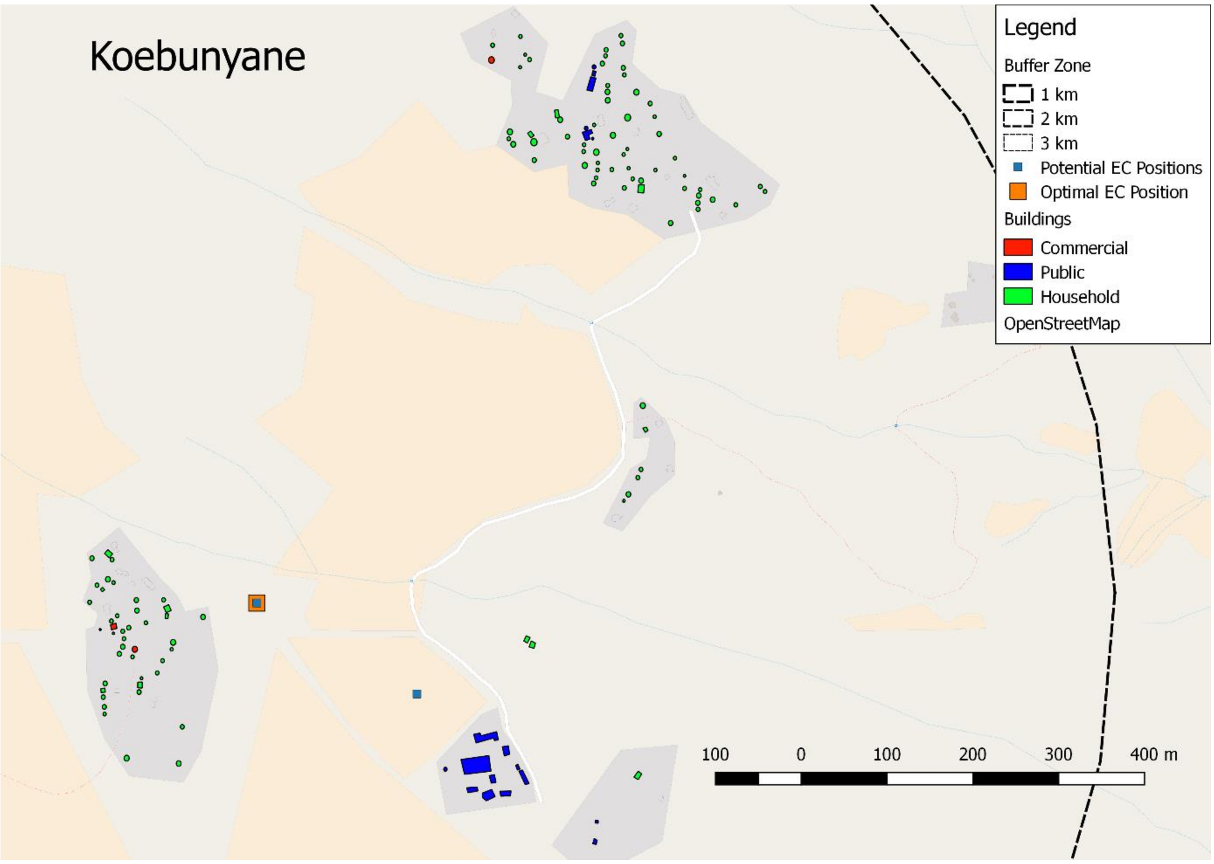


Figure 20: Spatial distribution of customers and positions of energy centre in Koebunyane

6.3 Economic Viability

Koebunyane is a rather small village with about 150 households and few anchor customers, a planned energy centre should be accordingly small. Main features, initial investment, annual expenditure, replacement costs due every five years as well as residual value after ten years of operation are presented in the Table 41 below.

A small solar power plant of 6.44 kW capacity combined with the storage of 20 kWh nominal capacities will be needed to supply energy needs of basic and medium household types in Koebunyane as well as demand of a school, not to forget about the electricity demand of the services provided through the energy centre. One may consider building up this plant in stepwise along the expected increase in power demand and power related services.

We calculated the cash flow over a period of ten years starting after establishing the energy centre (Figure 21). Even though most of the equipment as well as the building will be not worn out after ten years we expect that power provision through batteries will be replaced either by a mini-grid or a connection to the central grid after 2029. Besides the initial investment (we assumed 2018, i.e. the year before start of operation, for reasons of calculation) certain elements like vehicles or inverters needs to be replaced after five years. Annual revenues arise from provision of charging services (lights, phones, large batteries), equipment services (printing, calling, internet services, sales of drinks and snacks, etc.), as well as profit on equipment sales. With an internal rate of return of 8%, net present value of the project over ten years is equal to M32,639, i.e. the energy centre is economically feasible.

Table 41: Main features and financial parameters of an energy centre in Koebunyane

Features	
Number of households in the village	150
Building area, m2	50
Vehicle, #	0.5
Employees, #	2
Capacity PV	6.44
Capacity storage	20
Initial investment	
Building costs, M	100,000
Vehicle, M	100,000
PV+storage, M	192,440
Initial Stockage, M	236,550
Equipment, M	25,800
Staff Training, M	5,000
Contingencies	131,958
Total initial investment	**791,747**
Annual costs	
Salaries, M	50,000
Maintenance PV, M	3,849
Depreciation on hardware investment	30,160
Vehicle Maintenance and fuels	10,000
Contingencies	18,802
Total annual costs	**112,811**
Replacement costs	
Inverter+ storage	78,000
Vehicle	100,000
Annual revenue	
Charging lights, phones #/yr	12,167
Charging large batteries #/yr	2,850
Charging lights, phones, M	60,833
Charging large batteries, M	28,500
Equipment services	25,000
Profit on equipment sales	70,965
Total annual revenue	**185,298**
Residual value	
Building costs, M	50,000
Vehicle, M	0
PV+storage, M	96,220
Initial Stockage, M	236,550
Equipment, M	0
Total residual value	**382,770**

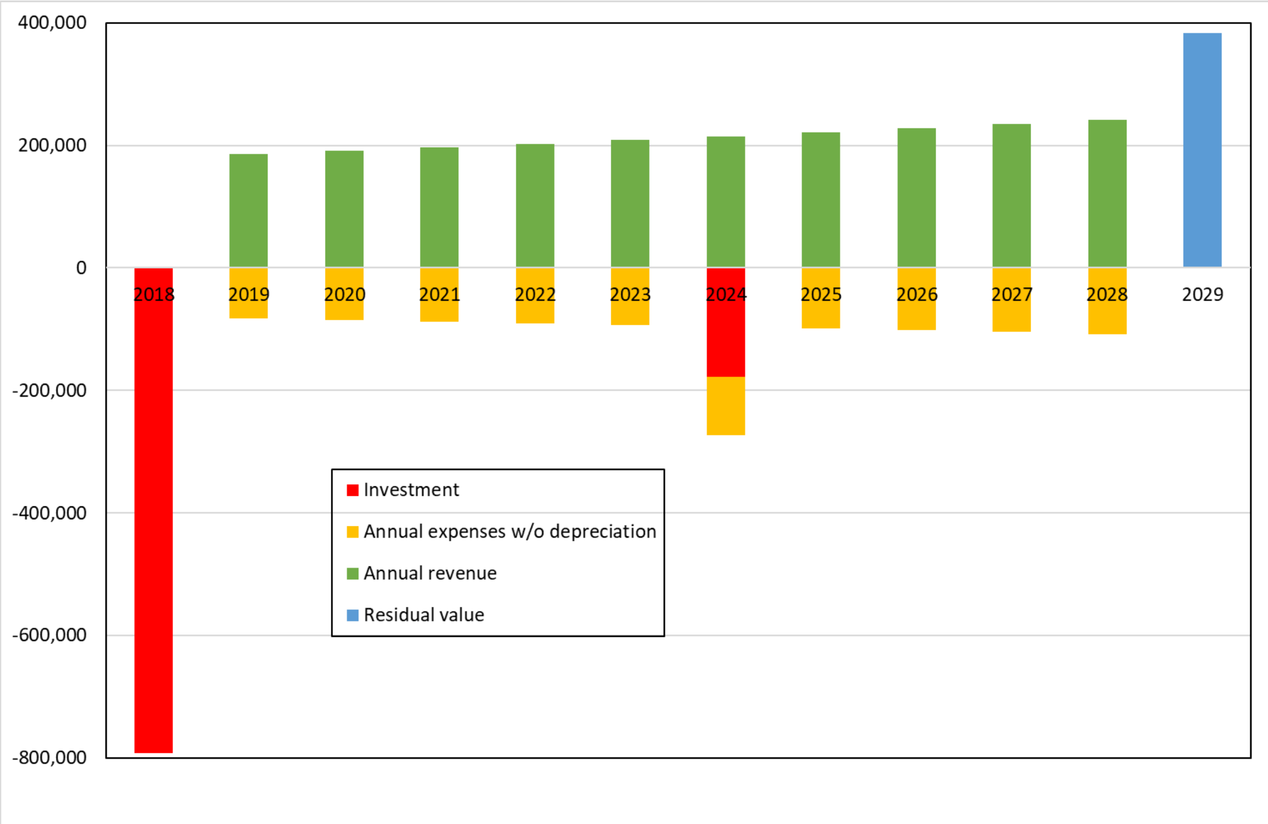


Figure 21: Cash flow of the energy centre in Koebunyane in 2018-2029

6.4 Summary

Koebunyane is a small settlement with 150 households and one school, therefore the dimension of an energy centre should be small. Energy centre should be placed close to households and public loads, so that potential customers will not need to overcome long distances to get their batteries and phones charged. The area of a building where energy centre will be located should be about 50 m^2 that is sufficient for relatively small stockage of products. Two employees, one sale's assistant and one maintenance agent, should maintain the functioning of an energy centre. Sales assistant will stay at the premises showing products to clients and explaining their features and usage patterns, whereas maintenance agent will be on the way to support customers on-site replacing broken devices and delivering spare parts. One vehicle can be shared with other energy centre in the neighbourhood. Combination of PV and battery storage will cover energy needs of potential customers and own energy consumption of the centre. If a significant increase of energy demand will be observed in the village, solar power plant can be easily scaled up. Given that offered goods will be actively purchased by households and anchor customers, and service of a battery and phone charging in the centre will be popular among the population, the establishment of energy centre is economically profitable with initial investment of M791,747 and provides a rate of return of almost 9% after ten years of operation.

7. Mpharane (new site) Mini-Grid or Energy Centre

Mpharane (29°52'53.3"S 29°03'36.0"E) is a village situated 116 km South East of Thaba-Tseka Town, about 5 km from Sehlabathebe National Park. It has Leqooa river as its main river which offers good head for mini-hydro development. There is no nearby main road.

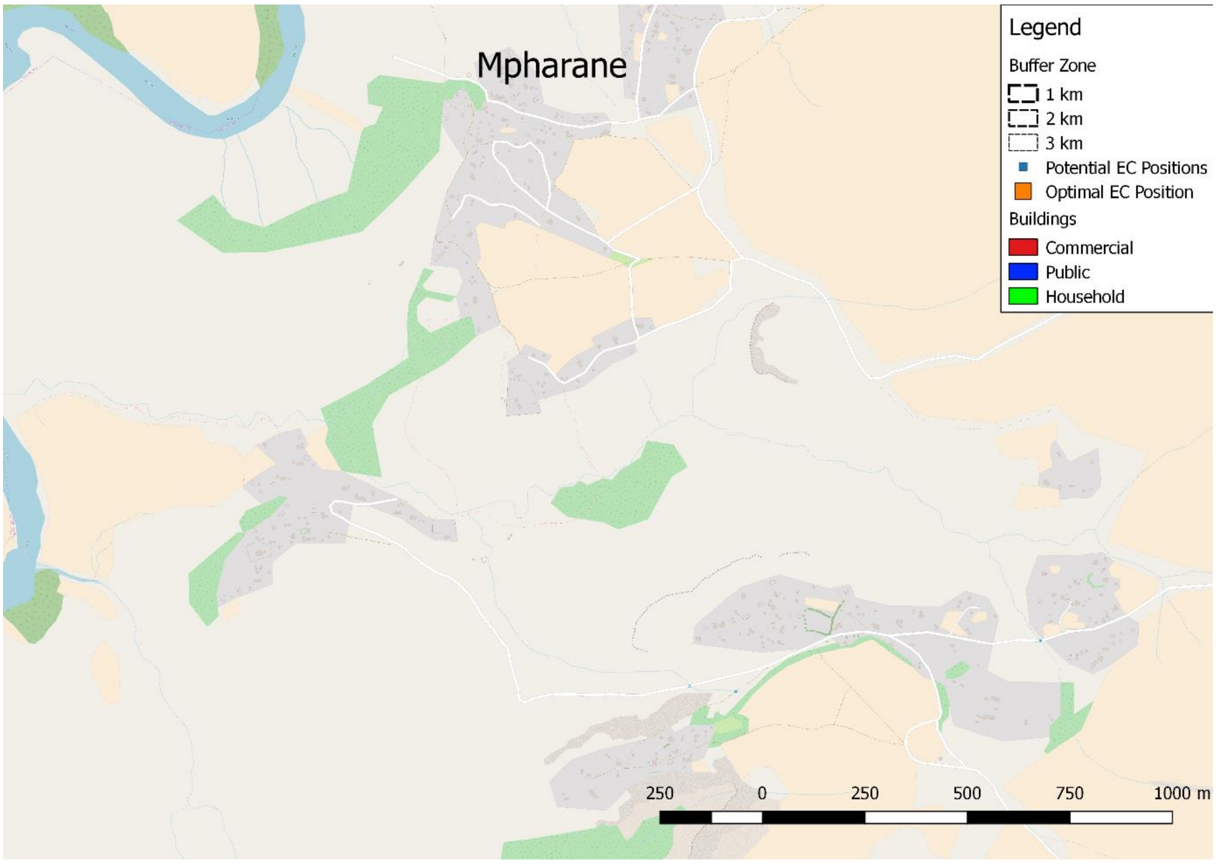


Figure 22: Map of Mpharane

7.1 Customer Base

7.1.1 Households

Energy demand forecast

The number of households in Mpharane amounts approx. 180. This is a new village in our sample, therefore no interviews were carried out with households. Based on the assumptions on current and future energy demand, we calculated key parameters for the village. It is not yet defined if here a mini-grid or an energy centre will be built, so we considered both demand projections.

Table 42: Present and future power demand by households in Mpharane

Household type	No. of HH in Mpharane			Total power demand in case of mini-grid, kWh/year			Total power demand in case of energy centre, kWh/year	
	Present	2019	2030	Present	2019	2030	Present	2019
Basic	117	118	132	0	3,540	79,200	0	1,521
Medium	45	46	51	2,250	23,000	137,700	2,250	3,285
Affluent	18	18	20	5,400	32,400	58,000	5,400	0
Total	**180**	**182**	**203**	**7,650**	**58,940**	**274,900**	**7,650**	**4,806**

7.1.2 Anchor customers

Energy demand forecast

Based on findings of our survey and coupled with spatial data we calculated the spatial distribution of present and projected future power demand in Mpharane for both mini-grid and energy centre. In the case of energy centre construction only schools' power needs will be covered by EC, other anchor customers will keep present level of power consumption as at present which they already cover with own generation.

Table 43: Present and future power demand of anchor customers in Mpharane

Type	Number of institutions	Power demand within mini-grid, kWh/year			Power demand supplied by energy centre, kWh/year	
		Present	2019	2030	Present	2019
Health	1	12,250	14,300	28,600	12,250	12,250
School	2	0	1,000	7,000	0	1,000
Government	6	5,100	9,600	19,200	5,100	5,100
Retail	10	18,000	28,000	84,000	18,000	18,000
	Total	**35,350**	**52,900**	**138,800**	**35,350**	**36,350**

Table 44: Development of power demand in Mpharane by distance from mini-grid generation site

Customer	Annual Power Demand MWh											
	Present				2019				2030			
	1km	2km	3km	total	1km	2km	3km	total	1km	2km	3km	Total
Households	3.4	0.7	0.0	4.1	26.0	5.5	0.0	31.5	108.4	23.0	0.0	131.4
Anchor customers	16.3	0.5	0.0	16.8	21.0	1.1	0.0	22.0	24.5	7.7	0.0	32.1
Total	19.7	1.2	0.0	**20.9**	46.9	6.6	0.0	**53.5**	132.9	30.7	0.0	**163.6**

The power demand in case of energy centre distributes spatially as depicted in the Table 45. Here, also anchor customers and affluent households are included even though we do not expect them to be supplied by the energy centre.

Table 45: Development of power demand in Mpharane by distance from energy centre

Customer	Annual Power Demand MWh											
	Present				2019				2030			
	1km	2km	3km	total	1km	2km	3km	total	1km	2km	3km	Total
Households	3.4	0.7	0.0	4.1	4.4	0.9	0.0	5.3	108.4	23.0	0.0	131.4
Anchor customers	6.3	0.0	0.0	6.3	6.8	0.0	0.0	6.8	21.5	0.0	0.0	21.5
Total	9.7	0.7	0.0	**10.5**	11.2	0.9	0.0	**12.1**	129.9	23.0	0.0	**152.9**

7.2 Set-up for Mini-Grid or Energy Centre

For the set-up of a mini-grid in Mpharane, three different energy consumption levels were considered: present patterns, 2019 and 2030, whereas the year 2019 stands for an immediate increase of consumption against present patterns fostered by the eased access to power. In the case of present energy demand the most optimal solution is solar and battery storage. Battery should have a capacity of about 3.5 times higher than PV to supply energy demand. Unmet load in this setup slightly exceeds 2%, excess electricity accounts for less than 40%.

Table 46: Elements of mini-grid setup in Mpharane in present conditions

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	44.3 kW	748,670	0	8,639
Battery	152 kWh	592,800	2,371,200	19,760
System converter	16.1 kW	41,860	41,860	0
Power lines	5.47 km	114,807	0	2,296
Power meters	101 units	323,200	0	6,464
Total	**-**	**1,821,337**	**2,413,060**	**928,975**

In the case of a demand increase in 2019 HOMER choses the same solution as for present conditions, scaled up to a PV and battery storage with about five times larger capacity, which leads to more than twofold higher investments.

Table 47: Elements of mini-grid setup in Mpharane in 2019

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	114 kW	1,926,600	0	22,230
Battery	403 kWh	1,571,700	6,286,800	52,390
System converter	40.9 kW	106,340	106,340	0
Power lines	5.52 km	115,955	0	2,319
Power meters	102 units	326,432	0	6,529
Total	**-**	**4,047,027**	**6,393,140**	**2,086,700**

Figure 23 presents the distribution of capital costs between different components of a mini-grid. It shows that power grid components (lines and meters) amount 11% of the capital costs.

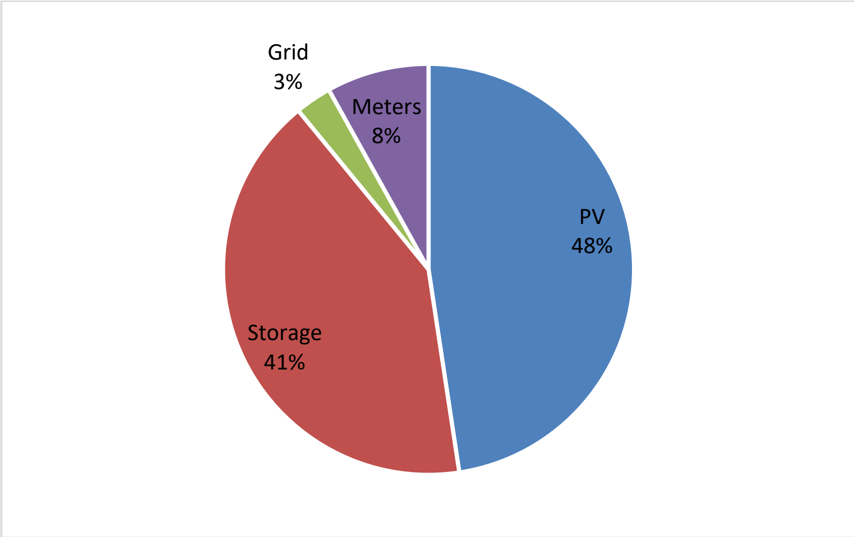


Figure 23: Distribution of capital costs of a mini-grid in Mpharane in 2019

For the Mini Grid two possible positions were identified. One of them, the potential positions which are marked blue on Figure 24, were chosen according to physical criterions like the terrain and availability of free space. The yellow marked optimal site was determined according to the calculation algorithm of the geometrical mean of all buildings in the radius 1-3 km in the village. So, it is the location that has the minimum sum of distances to all existing potential residential, public and business customers. In the case of Mpharane the theoretically chosen potential site for EC coincided with the site chosen as a result of field research. This particularly suitable site is presented on the following map as two squares, blue and yellow, inscribed in each other.

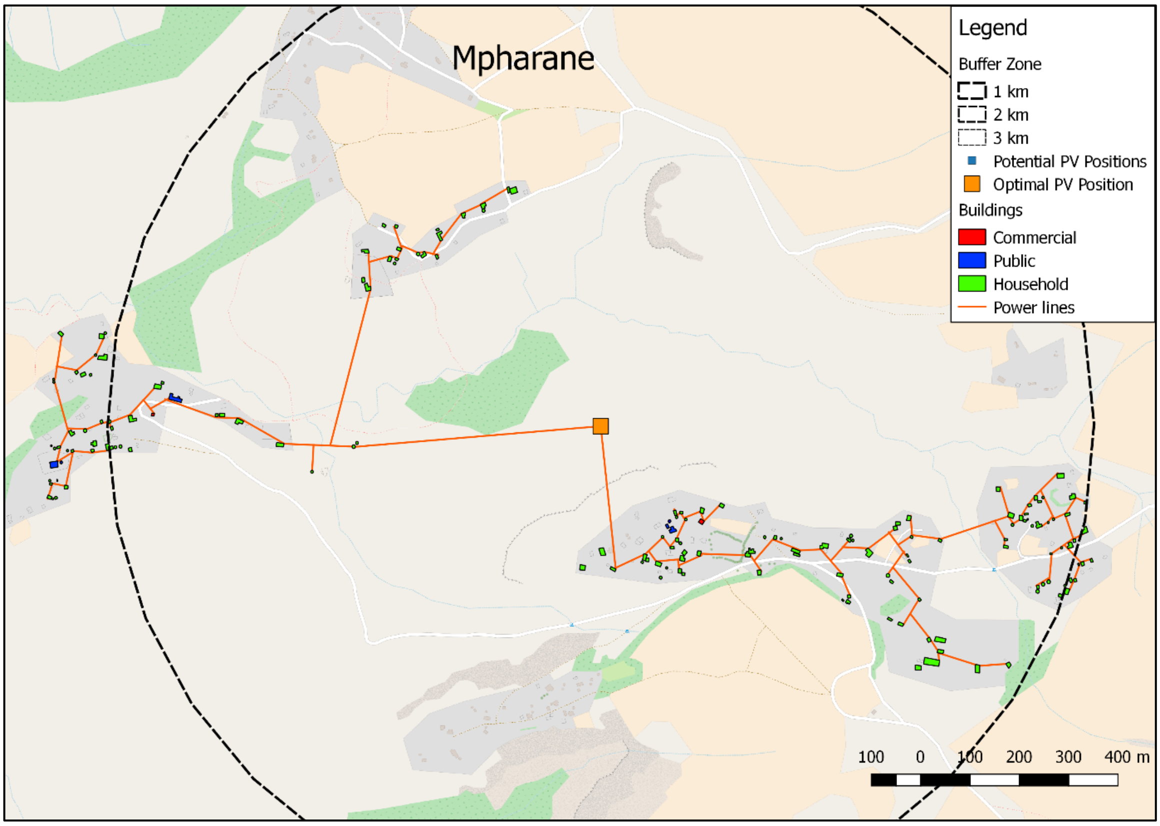


Figure 24: Map of the mini-grid set-up in Mpharane in 2019

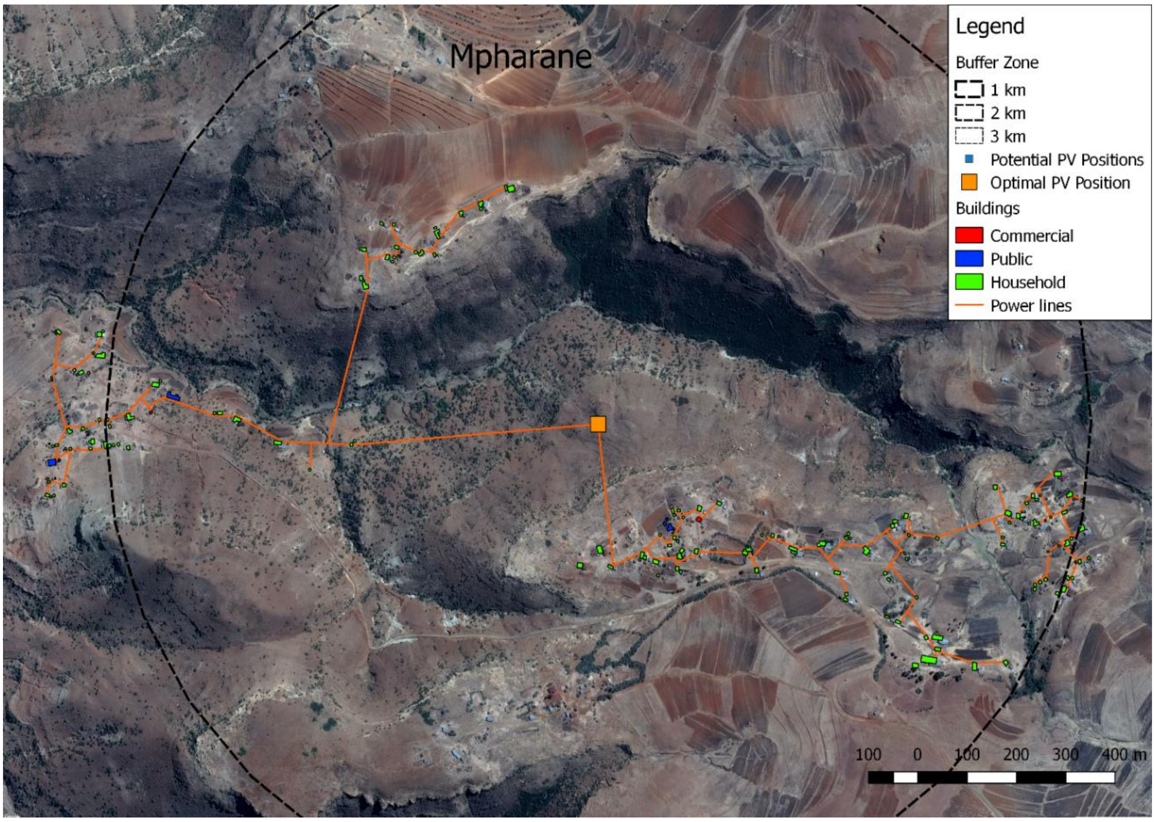


Figure 25: Satellite Map of the mini-grid set-up in Mpharane in 2019

In the long-term with constantly increasing demand additional energy source should be added to solar power plant. HOMER proposes hydro power plant of 100 kW. In this case, LCOE will be reduced (M6.9/kWh instead of M8.5-9.1/kWh), but still remains high in comparison to other villages and excess electricity will increase (from 37-39% to 70%) in comparison to solutions for present and 2019. Feasibility of this choice involving hydropower also needs to be verified in detailed studies of hydropower potential in the village.

Table 48: Elements of mini-grid setup in Mpharane in 2030

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	309 kW	5,222,100	0	60,255
Battery	724 kWh	2,823,600	11,294,400	94,120
Hydro Power Plant	100 kW	6,000,000	0	180,000
System converter	164 kW	426,400	426,400	0
Power lines	6.16 km	129,367	0	2,587
Power meters	114 units	364,190	0	7,284
Total	**-**	**14,965,657**	**11,720,800**	**8,606,150**

The expected demand growth allows for lower generating costs in the future (Table 49). Thereby we have not considered that due to technology advancements some elements to be added in the future will have very likely lower specific CAPEX (LCOE) than presently. There is a high rate of excess power to allow for a generation entirely based on renewable energies. This waste of energy could be avoided in two ways: Either one would allow a minor share of fossil-based generation which would run during winter, when PV generation is low, leading also to lower overall generation costs. Or additional seasonal usage of the excess power is created, e.g. refrigeration and cooling which both would perfectly match the generation patterns of solar generation.

Table 49: Characteristics of mini-grid setup in Mpharane in present and future

Time horizon	Unmet load, %	Excess electricity, %	LCOE, M/kWh
Present	2.02	38.4	9.109
2019	2.06	37.5	8.490
2030	2.28	70.1	6.901

For the Energy Centre one feasible site was identified. The yellow marked optimal site on the Figure 26 was determined according to the calculation algorithm of the geometrical mean of all buildings in the radius 1-3 km in the village. So, it is the location that has the minimum sum of distances to all existing potential residential, public and business customers.

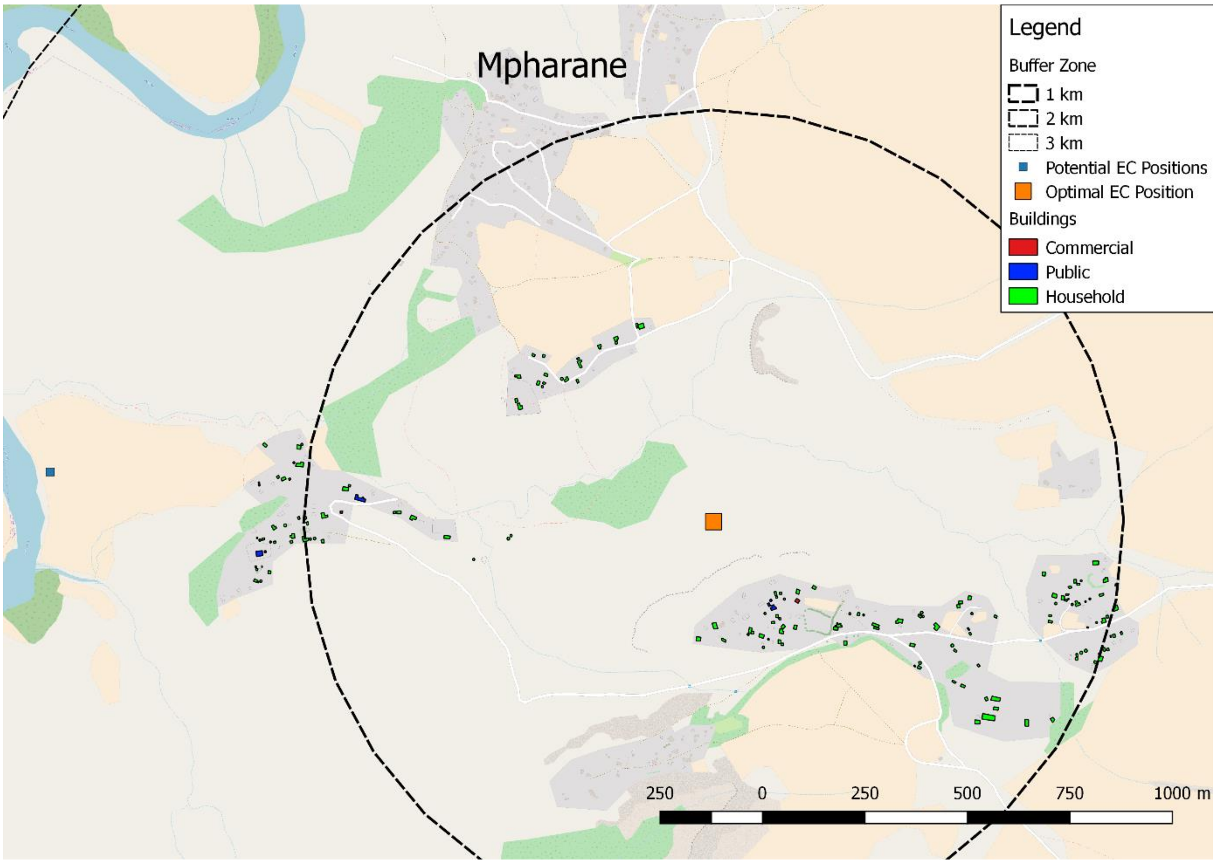


Figure 26: Spatial distribution of customers and positions of energy center in Mpharane

7.3 Economic Viability

Given commission of a mini-grid, we calculated the internal rate of return (IRR) with revenues on the basis of the present national electricity tariffs. This calculation allows to assess the economic viability under the present framework conditions. Additionally, we calculated a uniform tariff for all customers allowing for an IRR of 8%, equivalent to levelized costs of electricity (LCOE). The difference between the LCOE tariff and the national tariff indicates the amount of public support needed to keep tariffs in the mini-grid at the level of LEC tariffs in the national grid. For the calculation, two scenarios of electricity demand forecast are considered. The first scenario assumes a constant demand remaining on the level of 2019 over the entire project lifetime of 25 years. In this case, IRR received from LEC tariffs will be negative on the level of -15%. Under these conditions, the project is not economic viable without public support. The difference between revenue and annualized costs, including both CAPEX and OPEX, accounts for M6,932,802 over 25 years, and M277,312 per year. Considering electricity supplied to the customers, the need for subvention is M2.48 per kWh. For a single final customer the support amounts to M1,381 per year.

For the second scenario the electricity demand increases in the period between 2019 and 2030 and remains the same from 2031 till 2043. In that case, difference between tariff revenue and total project costs will be M18,997,119 in sum, or M759,885 per year. Converted to electricity consumption, M2.23 per kWh must be paid in addition to compensate the revenue deficit. Translated into individual customers, about M3,387 per year and customer accounts for allowance need.

In case of energy centre, a medium-sized facility should be commissioned. Main features, initial investment, annual expenditure, replacement costs due every five years as well as residual value after 10 years of operation are presented in the Table 50. A PV power plant of 8.15 kW capacity with a battery storage of 28 kWh nominal capacity will cover energy needs of households and anchor customers in Mpharane, as well as provide electricity for energy centre' services. One may consider building up this plant in stepwise along the expected increase in power demand and power related services.

We calculated the cash flow over ten years after establishing the energy centre (Figure 27). Even though most of the equipment as well as the building will be not worn out after ten years we expect that power provision through batteries will be replaced either by a mini-grid or a connection to the central grid after 2029. Besides the initial investment (we assumed 2018, i.e. the year before start of operation, for reasons of calculation) certain elements like vehicles or inverters needs to be replaced after five years. Annual revenues arise from provision of charging services (lights, phones, large batteries), equipment services (printing, calling, internet services, sales of drinks and snacks, etc.), as well as profit on equipment sales. With an internal rate of return of 8%, net present value of the project over ten years is equal to M532,522, i.e. the energy centre is economically feasible. Calculated IRR is very high exceeding 16%. It seems that the medium-sized energy centre setup is the most profitable one for appropriate villages compared to small and large-sized, given well-chosen stockage, building size and workforce.

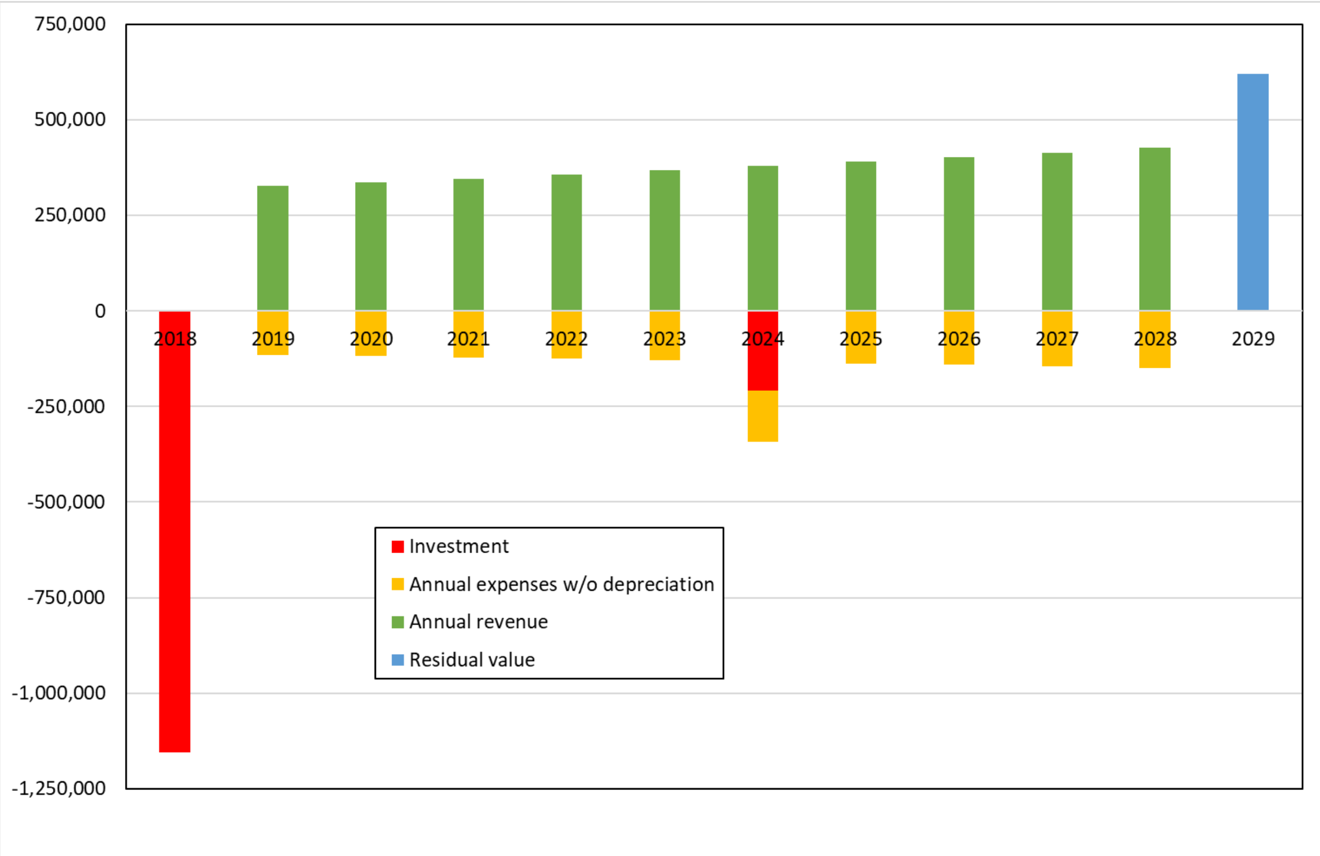


Figure 27: Cash flow of the energy centre in Mpharane in 2018-2029

Table 50: Main features and financial parameters of an energy centre in Mpharane

Features	
Number of households in the village	180
Building area, m2	80
Vehicle, #	0.5
Employees, #	3
Capacity PV, kW	8.15
Capacity storage, kWh	28
Initial investment	
Building costs, M	160,000
Vehicle, M	100,000
PV+storage, M	254,825
Initial Stockage, M	412,545
Equipment, M	30,700
Staff Training, M	5,000
Contingencies	192,614
Total initial investment	**1,155,684**
Annual costs	
Salaries, M	75,000
Maintenance PV, M	5,097
Depreciation on hardware investment	34,140
Vehicle Maintenance and fuels	10,000
Contingencies	24,847
Total annual costs	**149,084**
Replacement costs	
Inverter+ storage	109,200
Vehicle	100,000
Annual revenue	
Charging lights, phones #/yr	24,333
Charging large batteries #/yr	5,100
Charging lights, phones, M	121,667
Charging large batteries, M	51,000
Equipment services	30,000
Profit on equipment sales	123,764
Total annual revenue	**326,430**
Residual value	
Building costs, M	80,000
Vehicle, M	0
PV+storage, M	127,413
Initial Stockage, M	412,545
Equipment, M	0
Total residual value	**619,958**

7.4 Summary

Mpharane is medium-sized village with several anchor loads. Current electricity demand is about 43,000 kWh per year (for 82% of demand anchor customers are responsible, for 18% households). In the future, growth in electricity demand is expected: in 2019, if the decision of investors will fall on mini-grid commissioning, we expect an annual consumption of 111,840 kWh (relatively evenly distributed: 53% by households, 47% by commercial and public customers). The forecasted long-term demand for the year 2030 is 413,700 kWh in a year with an increased gap of shares between households (66%) and anchor customers (34%).

In order to cover this constantly increasing power demand, a highly scalable modular energy system is required. The most optimal renewable energy technology for this is solar combined with storage. It can be commissioned and expanded in a short period of time. Besides, in that field further cost reductions in both PV solar panels and battery storage are expected. Closer to the end of considered period till 2030, it can be necessary to integrate other RES technologies, like hydro or wind power, but it will require detailed study of demand forecast and potential of these technologies in the region.

Considering an establishment of energy centre, which also represents a viable option for the village, a medium-sized one should be built. The ideal place to set it will be in close proximity to the main potential customers (households and some anchor customers). An energy centre should have an area of approx. 80 m^2 for stocking and displaying products and office rooms. Two sales assistants in the shop and one maintenance agent will support customers with tips by choosing the right product, repairs and delivering goods and spare parts. One vehicle should be shared with another energy centre or some business or public facility in the vicinity of the energy centre site.

Solar power plant with storage will be construed to perfectly match power demand of potential customers and can be easily scaled up by the increased consumption and observable need of an energy centre extension. Provided that offered goods will be actively purchased by households and anchor customers, and services of a battery and phone charging in the centre will become popular among the population, the establishment of energy centre is economically profitable with initial investment of M1,155,684 and provides a rate of return of more than 16% after 12 years of operation.

8. References

Bureau of Statistics Lesotho, National Energy Survey 2017

HOMER Pro Software Tool

Photovoltaic Geographical Information System (PVGIS), European Commission