Pre-Feasibility Studies for Mini- Grid and Energy Centres in Qacha's Nek District

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Content

1. Summary

The following table provides an overview on the features and feasibility of mini-grids and energy centres respectively, in selected villages in the province of Qacha's Nek. 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 their own power supply.

Table 1: Overview selected features of energisation solutions in Qacha's Nek

Village	Sehlabathebe	Lebakeng	Matebeng	Melikane
Solution	**Mini-grid**	**Mini-grid**	**Energy centre**	**Energy centre**
Number of Households	180	300	250	100
Anchor customers	One health centre, two schools, five government institutions, 12 retailers	One clinic, two primary schools, community council, five medium-sized shops, one craft	One health centre, one school, five government institutions, six retail facilities	One health centre, one school, community council, three commercial enterprises
Present annual demand kWh	39,000	62,300	55,400	23,280
2019 annual demand kWh	109,110	156,310	7,150	3,170
2030 annual demand kWh	411,500	592,450	-	-
Size PV plant kW 2019 / 2030	164/313	196/453	12	5.63
Size storage kWh 2019 / 2030	388/734	562/1,027	33	15
Additional future power source	Hydro	Hydro	-	-
Length power lines km 2019 / 2030	6.66/7.43	5.24/5.85	-	-
Size of energy centre	-	-	Medium	Small
Initial investment Maloti 2019 / 2030	4,928,613/ 15,093,090	6,287,648/ 19,182,001	1,258,581	750,130
Internal Rate of Return (with national tariff) 2019 / 2030	-17%/-11%	-16%/-9%	-	-
Required tariff 2019 / 2030	9.48/6.99	8.93/6.30	-	-

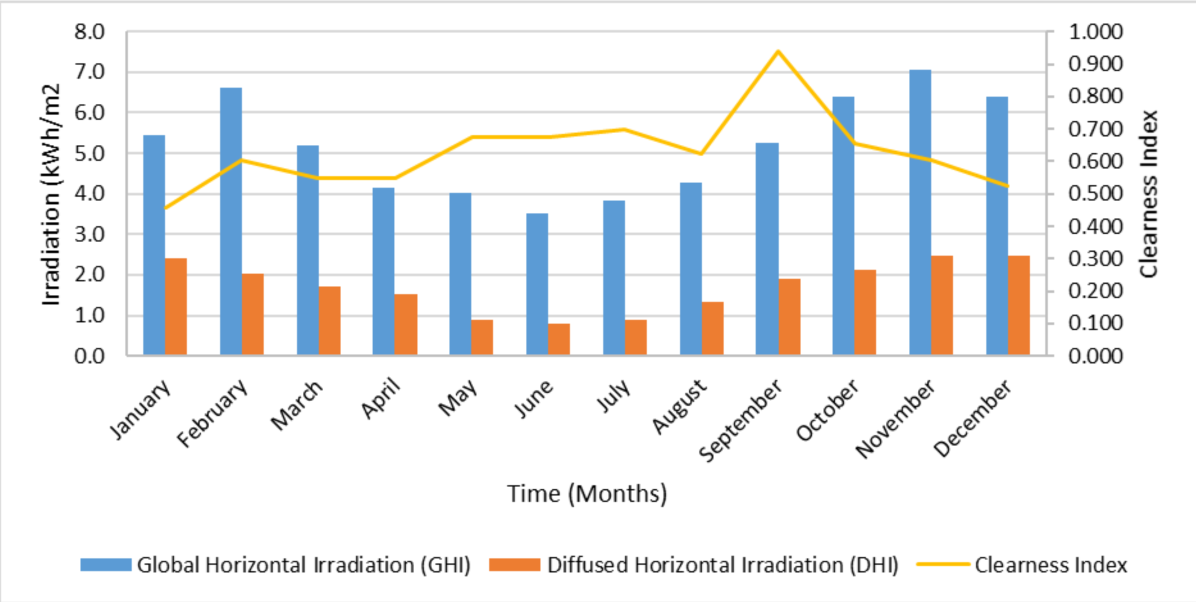
2. Qacha's Nek district

Qacha's Nek district borders on the Eastern Cape province of South Africa. The total population of the district is about 80,000 inhabitants, the area spans over approximately 2,000 km². The only town in the district is the capital Qacha's Nek.

Figure 1: Location of Qacha's Nek in Lesotho

2.1 Renewable energy potential

Qacha's Nek (-30.12 (30°07'12"S), +28.69 (28°41'24"E)) is located in the south-eastern part of Lesotho. Average insolation of Qacha's Nek as given by the NASA climatologic database ranges from a minimum of 3.22 kWh/m²/day in June to a maximum of 6.07 kWh/m²/day in December with an annual average of 4.75 kWh/m²/day and an average clearness index of 0.55. 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 (5.80, 6.07 and 6.00 kWh/m²/day, respectively) (Figure 2, Table 2).



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

Figure 2: Average solar irradiation in Qacha's Nek over the year

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

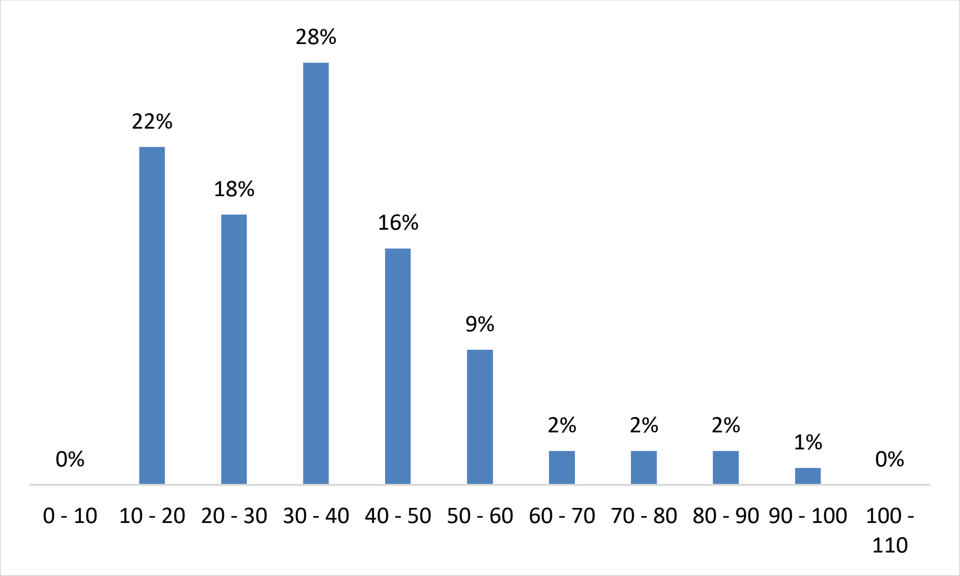
Month	Clearness index	Daily GHI (kWh/m^2/day)
January	0.457	5.5
February	0.603	6.6
March	0.548	5.2
April	0.549	4.2
May	0.673	4.0
June	0.673	3.5
July	0.697	3.8
August	0.625	4.3
September	0.940	5.2
October	0.653	6.4
November	0.605	7.0
December	0.526	6.4
Average	0.6	5.2

Wind: Average annual wind speed is approximately 4.71 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 Qacha's Nek. Qacha's Nek is a home to a number of larger rivers such as Tsoelike River (where a 400 kW mini-hydro power plant was constructed – currently mothballed), Leqooa/Tsoelikane River at Sehlabathebe. Senqu River also runs through the district.

2.2 Household characteristics

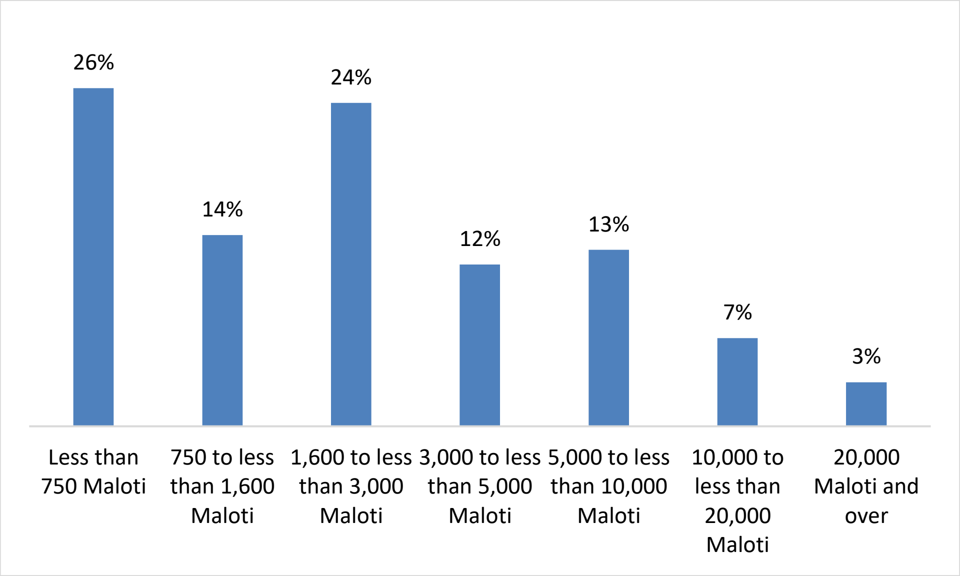
For the data analysis, we extracted the results of the BOS Household Study 2017 for the Qacha's Nek district. In the Qacha's Nek district the average household consists of five persons. 60% of households have four members and more. The majority of Qacha's Nek's inhabitants interviewed within the BOS survey have two housing units at their disposal (47%). Another 39% have one housing unit each while 14% have 3 or 4 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 16% of households features 50 m^2 and more in Qacha's Nek (Figure 3). Taken those as the more affluent, the share of this group matches well with the share of households with three and four housing units in our sample.



Source: BOS National Energy Survey 2017.

Figure 3: Distribution of household's usable area size in Qacha's Nek

When it comes to the disposable income almost two third of households in the district earn less than M3,000 per month, and only 23% more than M5,000 (Figure 4). A substantial share of households relies on additional transfer payments: 41% of Qacha's Nek population receive remittances (money transfers from workers working abroad). Their value varies between M500 and M1,000. In general, income levels are low in rural areas, limiting the budgets available for power purchase.



Source: BOS National Energy Survey 2017.

Figure 4: Distribution of household income in Qacha's Nek

In the district, energy supply of households relies on three main energy sources which are all biomass: wood and wood wastes, animal dung and straw/shrubs/grass (BOS National Energy Survey 2017). Energy consumption in summer is about 30-100% lower than in winter, indicating that heating is a major energy service. Households put substantial efforts into acquiring the biomass for energy supply. In almost half of the cases in Qacha's Nek, forests for biomass collections are situated two hours or more away from the household. The collection itself accounts typically for another 0.5 to 2 hrs. This means people would benefit substantially through reduced labour time from an eased access to energy. 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 Qacha's Nek, access to electricity is limited: Only 28% of households are supplied with electricity from the central grid (BOS Energy Survey 2017). Another 7% of households own a solar PV.

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 sources for space heating. In general, about 84% of inhabitants of Qacha's Nek use energy for heating during cold months.

The main energy sources used 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. Sehlabathebe Mini-Grid

Sehlabasthebe is located 100 km North East of the Qacha's Nek Town, and is the home to the only national park in Lesotho. Ranging in elevation from 2,200 m to 2,600 m, it falls entirely within the Themeda-Festuca alpine grassland. Water in the form of streams, rivers and pools is abundant. Mean annual rainfall is 769 mm, with most rains in November-March. Mean annual maximum and minimum temperatures are 19.6 ºC and 2.2 ºC. Mist is a common phenomenon during summer. As we have designed the solar systems in 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. The main river Leqooa runs throughout the year and offers good head for mini-hydro development.

Figure 5: Anchor customers in Sehlabathebe (from top left clockwise: Koung Clinic, Ha Paulosi police office, local court Koung, Mabotle Lodge hotel)

3.1 Customer Base

Sehlabathebe accommodates more than 180 households. There exist a police post, a supermarket, more than 10 medium size shops, a large clinic, administration office for the national park, a post office, the office of the community council, the office of the Independent Electoral Commission, a primary school, and a secondary school. These entities are all potential anchor loads. According to the local councillor, the three main income sources in the village are livestock, crops, and self-employment through small scale enterprises.

3.1.1 Households

Socio-demographic characteristics

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 3 and 8 members, with three households featuring 7-8 members (Q B1[1]). The average number of HH members is slightly more than 5 persons. Households have between 1 and 3 housing units at its disposal and on average about 2 (Q C1).

Housing types in the district are diverse. The most popular types mentioned were rontabole (4 HH), bungalow (3 HH), mok'huk'hu (two housing units) (Q C2). Households have from one to 10 rooms totally at their disposal, where four households have 4 to 6 rooms, and household with the highest number of housing units – 3 - can boast of 10 rooms.

The housing area ranges between 13 and 217 m^2, with households with one housing unit having area sizes ranging from 13m^2 to 64 m^2 area size, households with two housing units have an area size of 41-71 m^2, and household with three housing units having also the highest usable area size of 217 m^2 (Q C2). The means that the value of disposable area per household member in Sehlabathebe accounts for 35 m^2. The average area of houses owned by one HH is 67 m^2. Such large mean area is due to the presence of a household with big houses of an area of 217 m^2 in the sample. Without this HH, average area of houses would be 46 m^2. We consider this household as affluent however income data given did not confirm.

We found earnings per month between M150 and M7,500, with an average of M3,080 (Q C3). Remittances are received by two households, with one household receiving between M300 and M500 and the other receiving between M2,000 and M5,000 per year (Q C4).

None of the households interviewed planned to move away from the village in the next five years (Q I1).

Energy supply

Regarding used biomass resources, all households, except three, use fuel wood either through self-production (4 HH), collection (2 HH) or received for free (1 HH). This means they are sourcing the fuel wood from their own yard, collecting wood or get wood donated (Q D3). They used between one to 10 trees fuel wood or 600 kg to 2,500 kg last year, which is equivalent to 2,900-12,250 kWh per year. Also, seven of ten HH used animal waste, obtained through self-production (5 HH) or collected (2 HH). The quantities used were between 550 kg and 9,000 kg of animal waste, equivalent of 2,600-42,000 kWh in a year. In our household sample, no other biomass resources were used (Q D1). Four HH sourced the fuel wood in the household yard (Q D3). Those who needed to source fuel wood outside travel a minimum of 30 minutes and up to 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 one hour to collect wood. They collect wood one to two times per month (Q D5-D6). In sum it results in average time spent for travelling and collecting wood per year between 6 and 12 hours. With an hourly wage of 8 Maloti this converts into annual costs between 50 and 100 Maloti. In fuel wood collection

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

in the village mostly children are involved (11 from 5 HH), as well as eight males from six HH, and three women from two HH (Q D7). In practise however, interviewed households do not spend any money for purchasing biomass sources (Q D9). For purchasing commercial fuels, they all usually pay in cash (Q D10) and would prefer to pay for it in that way or with eco-cash (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.

Households indicated to have paola, queen stove and fireplaces whereas we could not find any improved wood stove (Q D8). No household has a wonder box (Q F4). Households in Sehlabathebe use animal dung (8 HH) and LPG (2 HH) as main energy sources for cooking (Q F1). All households interviewed rely on a second fuel type for cooking like paraffin (5 HH), wood (4 HH), and LPG (1 HH). Households in Sehlabathebe are ready to pay between M50 and M300 for electricity for cooking per month, on average M135 (Q F3, Table 5). This number seems reasonable compared to the actual expenses for cooking fuels.

Six households out of ten in Sehlabathebe heat their houses (Q G1). For space heating, they use paraffin heater (2 HH), fireplace (2 HH) or paola (2 HH) (Q G2). Animal dung, paraffin and wood are used as main energy source (Q G3). Wood and animal dung are alternative energy sources for space heating used. The heating area of interviewed households was in the range of 7-40 m^2 (Q G6). As for willingness to pay, interviewed households in Sehlabathebe are ready to pay between M20 and M300 for electricity for space heating per month, on average M71 (Q G5, Table 5). For water heating the households use animal dung or paraffin as main energy source. As alternative source wood, LPG, paraffin, or straw/shrubs are used (Q G7).

In Sehlabathebe households use paraffin, candles and solar lanterns for lighting, often in combination (Q H1). 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 M495/a on fuels for lighting, so the equivalent budget would be at least available for purchasing power for lighting purposes.

Table 3: Household use of energy sources in Sehlabathebe

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	19 kg LPG per month, 5 litres paraffin per 3 days	3,477	5,459	2,500 kg wood for space heating, 19 kg LPG and 20 litres paraffin per year for water heating	12,700	5,030	20 litres paraffin, 24 candles per year	211	290	94,800
2	Wood, 25 kg animal dung per year	240	0	Animal dung (5 kg per day for space heating, 50 kg per year for water heating), one stack of straw	8,837	0	144 candles per year	22	360	9,000
3	19 kg LPG per 2 months, 10 litres paraffin per week	6,841	4,136	1 tree wood, 184 litres paraffin, 325 kg animal dung	3,921	1,656	2 litres paraffin per year, 6 fluorescent bulbs 11 W	166	23	42,000
4	96 litres paraffin per year	994	1,252	10 litres paraffin, 150 kg animal dung	809	115	5 litres paraffin, 24 candles per year	55	118	1,800
5	19 kg LPG per 6 months, 25 kg animal dung	604	810	2.5 trees, 575 kg animal dung	3,928	0	48 litres paraffin, 144 candles per year	518	984	42,000
6	0.11 kg LPG per day	514	949	182.5 litres paraffin per year	1,889	2,008	53 litres paraffin, 3 compact fluorescent bulbs 11 W for 120 mins each day	573	610	42,000
7	438 kg wood per year, 1,215 kg animal dung per year	7,857	0	248.2 kg wood, 438 kg animal dung per year	3,275	0	12 candles, 52 litres paraffin	540	628	42,000
8	402 kg wood per year, 767 kg animal dung per year	5,575	0	197.1 kg wood, 511 kg animal dung per year	3,367	0	20 candles, 52 litres paraffin	541	648	42,000
9	401 kg wood per year, 1,387 kg animal dung per year	8,484	0	160.6 kg wood, 730 kg animal dung per year	4,218	0	18 candles, 52 litres paraffin	541	643	18,000
10	0.1 kg per LPG per day, 0.01 litre paraffin per day	505	942	182.5 litres paraffin	1,889	2,008	20 candles, 52 litres paraffin	541	648	132,000
	Average	**3,509**	**1,355**	**-**	**4,483**	**1,082**	**-**	**371**	**495**	**-**

Two households use light bulbs: household #3 uses 6 fluorescents with capacity of 11 W, with bulbs lit all night long, while household #6 uses 3 fluorescents with capacity of 11 W with bulbs lit for two hours each night (Q H3). Households are willing to pay between M20 and M200 for electricity for lighting per month, on average M63 (Q H4, Table 5). This slightly exceeds their current expenses for lighting.

Interviewed households in Sehlabathebe do not use any electric appliances at the moment (Q E1). However, they all desired to be supplied with electricity in their houses (Q E7, Table 4). Considering plans to purchase electrical appliances in the next five years, most households indicated that they plan to purchase electric stove, electric kettle/element, iron, refrigerator, television LCD. Some households plan to purchase microwave, electric heater, electric hair clipper, television flat-screen, phone charger, desktop computer, washing machine. Of no interest to the households were dishwasher, tumble dryer, laptop, air conditioner, bread maker, toaster, and electric pot (Q I3).

Table 4: Households desired future uses of electricity in Sehlabathebe, 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
Cooking/ re-heating	X	X	X	X		X	X	X	X	X	9
TV	X		X	X	X	X	X	X		X	8
Refrigeration			X		X	X	X	X	X	X	7
Water heating			X		X	X	X			X	5
Space heating			X			X	X	X	X		5
Radio	X		X	X	X						4
Ironing	X		X	X	X						4
Phone charging		X	X		X						3
Computer						X	X			X	3
Charging (other than phone)			X								1
Laundry											0
Dishwashing											0
Sewing											0
Air-conditioning											0
Water pumping											0
Workshop											0
Total	5	3	10	5	7	7	7	5	4	6	-

Interviewed households have decent willingness to pay for electricity in general between M50 and M800, in average about M100 (Q E9, 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'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 monthly M375. As a preferred way to pay for electricity respondents from Sehlabathebe chose Ecocash and Mpesa (Q E10).

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

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	M7,900	M200 (3%)	M80 (1%)	M60 (1%)	M200 (3%)	Refrigerator, electric stove, TV flat screen, electric kettle, microwave, hair clipper
2	M750	M60 (8%)	M50 (7%)	M50 (7%)	M20 (3%)	Electric stove, TV LCD, iron, electric kettle
3	M3,500	-	M150 (4%)	M300 (9%)	M60 (2%)	Refrigerator, electric stove, electric heater, washing machine, desktop computer, iron, electric kettle, microwave, hair clipper, phone charger
4	M150	M50 (33%)	M70 (47%)	M30 (20%)	M20 (13%)	Electric stove, electric heater, TV LCD, iron, electric kettle
5	M3,500	M200 (6%)	M50 (1%)	M20 (1%)	M30 (1%)	Refrigerator, TV LCD, iron
6	M3,500	M800 (23%)	M250 (7%)	M50 (1%)	M70 (2%)	Refrigerator, geyser, deep freezer, electric stove, electric heater, washing machine, desktop computer, laptop, hoover, hair dryer, TV, electric kettle, microwave, phone charger, breadmaker, toaster, hair clipper
7	M3,500	M500 (14%)	M200 (6%)	M50 (1%)	M50 (1%)	Refrigerator, geyser, deep freezer, electric stove, electric heater, hoover, dryer, TV, desktop computer, laptop, iron, air conditioner, electric kettle, breadmaker, microwave, electrical pot, hair clipper, phone charger
8	M3,500	M400 (11%)	M150 (4%)	-	M50 (1%)	Refrigerator, deep freezer, electric stove, electric heater, hoover, dryer, TV, laptop, iron, electric kettle, toaster microwave, hair clipper, phone charger
9	M1,500	M500 (33%)	M50 (3%)	M50 (3%)	M80 (5%)	Refrigerator, deep freezer, electric stove, electric heater, dryer, TV, iron, electric kettle, microwave, hair clipper, phone charger
10	M11,000	M700 (6%)	M300 (3%)	M100 (1%)	M50 (<1%)	Refrigerator, geyser, deep freezer, electric stove, hoover, dryer, TV, desktop computer, laptop, iron, electric kettle, breadmaker, toaster, microwave, electrical pot, hair clipper, phone charger
	Average	M379	M135	M71	M63	-

None of the households interviewed planned to buy a solar PV set, a generator running on gas, or a car battery in the next five years (Q I4).

Energy demand forecast

Based on income and endowment with appliance, we rate some of the interviewed households as medium type, but most others are of a basic type. For the entire village, we assume a distribution of household types as described in the General Part. For forecasting, we assume that the number of households equally over all household types increase by 1% per year. Further the specific demand of all household types is expected to increase once electricity is available due to more electrical appliances. The answers given on planned purchases of appliances confirms this trend. However, experiences in other countries showed that household demand for power remained stable even five years after power supply arrived (Blog World Bank 2017). In any case, it gets clear that returns from power supply rely mainly on the medium and affluent households (Table 6). From the commercial point of view, the less endowed households are less interesting, however they are those who would most benefit from enhancing their living conditions through the supply of power.

Table 6: Present and future power demand by households in Sehlabathebe

Household type	No. of HH in Sehlabathebe			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**

3.1.2 Anchor customers

Main characteristics

The village features one health centre, two schools, five government institutions, and 12 retailers. In Sehlabathebe, we interviewed nine anchor customers: health centre, two schools, three government institutions (police post, community council, local court) and three commercial users (two restaurants, one hotel) (Q B1). Commercial facilities are individually owned while government institutions are owned by the state (Q B2). Interviewed anchor customers have between 2 and 12 employees. The police post has the most employees (12), followed by the health centre (10), and the local court (6). Schools and restaurants did not report the number of employees (Q B3). Government institutions, health centre, schools do not have any earnings while restaurants and hotels earn between M3,500 and M7,500 per month. No anchor customer indicated to have any remittances (Q B5-B6).

Interviewed anchor customers consists of between one to 10 buildings and on average 4 buildings. The police has the most buildings (10), followed by the health centre (8), the schools (5 and 4) and the local court (5). Commercial customers have only one building each. (Q D4). The total building area ranges from 90 m^2 to 1,113 m^2, which is on average 416 m^2. The health centre has the biggest area at its disposal, followed by the police post and both schools. Among commercial facilities the average total area is 144 m^2. Almost all interviewed customers heat their buildings, and more than half of the buildings are insulated (Q D5).

Most anchor customers work seven days a week, except the health centre, the community council and the local court (5 days/week). Schools did not specify their operating hours (Q D1). In other villages, schools are usually operated for five days a week. All commercial users operate between 13 and 24 hours per day over the entire year. The police post is open around the clock, other government institutions 8 hours per working day. All anchor customers operate throughout the year (Q D2, Q D3).

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

Anchor customer	Charcoal		Wood		LPG		Pellet		Petrol		Solar PV		Generator	
	kg	Purpose	kg	Purpose	kg	Purpose	kg	Purpose	l	Purpose	Size	Purpose	Size	Purpose
Paolosi Police Post	750	Space heating	500	Space heating	144 kg	Heating	2,000 kg (40 units of 50 kg)	Heating	-	-				
Lehloenya Public Bar	600	Space heating			-	-	-	-	1,800	Heating	80 W	Lighting	650 W	Lighting, other uses
Sehlabathebe Health Centre	5,000	Space heating	2,500		240 kg (5 units of 48 kg) + LPG heater 21 kW	Heating	-	-	-	-	40 panels	Lighting, water heating, entertainment		
Khomophatsoa Community Council	500	Space heating	500	Space heating	192 kg (4 units of 48 kg) + LPG heater 4.2 kW	Heating	-	-	-	-				
Sehlabathebe Local Court	500	Water heating	6,250	Space & water heating	-	-	-	-	-	-				
Mabotle Lodge	-	-	300	Space heating	114 kg (6 units of 19 kg)	Heating	-	-	-	-			5.5 kW	Lighting, other uses
Green-House Tarven	-	-	100	Space heating			-	-	-	-	80 or 115 W	Lighting	5.5 kW	Lighting, other uses
Total quantity	**7,350**	**-**	**10,150**	**-**	**690 kg**	**-**	**2,000 kg**		**1,800**					
Unit costs	M0.9/kg (Bar)	-	M2/kg		M22/kg	-								
Total costs		**-**			**M15,180**	**-**								

Energy supply

Most interviewed anchor customers consumed wood and charcoal over the last year. Based on five answers anchor customers consumed between 500 and 5,000 kg charcoal last year (equivalent to 4,000-40,500 kWh). Charcoal was used for space and water heating. 250-2,500 kg wood (1,225-12,250 kWh) were consumed for the same purposes over the last year. A non-specified amount of animal dung was used as well (Q C1). The health centre and one restaurant use solar electricity. Solar energy is used for lighting, water heating, and entertainment (Q C2).

None of the interviewed anchor customers used air conditioning systems (Q D6). Almost all customers have some heating system: four entities from different branches (health centre, police post, community council, hotel) have LPG system (3-6 units, unit capacity of 48 or 19 kg, total capacity between 114 and 240 kg), which operates 6-12 months a year, on all days a week, 4-8 hours per day. The local court, the hotel, and the restaurant have a heating system running on wood, which operates 4-8 hours per day, 2-7 days in a week over 2-12 months. The local court uses a heating system with 120 units of 50 kg, 6,000 kg totally. The hotel and the restaurant use one tree each. Police post uses pellets, 40 units of 50 kg, 2,000 kg in sum. One restaurant uses a heating system fuelled by petrol, operating 9 hours/day 7 days/week, with one unit of 5 litres, 1,800 litres are used per year (Q D7). The police post, the health centre, and the community council uses LPG heaters. They operate intensively for 6 or 8 months in a year, 5 or 7 days a week, 4 or 16 hours per day. The number of units of capacity 4.2 kW was between 1 and 5, so the total capacity of the units is 4.2 to 21 kW (Q D8). Since interviewed anchor customers are already relatively well equipped with heating systems, only three of them (all commercial enterprises) showed any willingness to pay for electricity for heating/cooling between M80 and M500, what corresponds to 1-14% of their monthly total budget (Q D9, Table 9).

Table 8: Electric equipment of selected anchor customers in Sehlabtahebe

Anchor customer	Lighting		Small equipment	Refrigerating equipment	
	Type & number	Capacity, W	Type & number	Type & number	Capacity, l
Lehloenya Public Bar	2 incandescent	40	1 monitor		
Sehlabathebe Health Centre	76 fluorescent	16	1 desktop	1 drug fridge	338
Khomophatsoa Community Council	22 fluorescent	15			
Mabotle Lodge	15 fluorescent	15			
Green-House Tarven	2 incandescent	60			

Some companies use light bulbs. Three companies use fluorescent bulbs (between 15 and 76 units, capacity 15-16 W), two use incandescent bulbs (2 units each, capacity 40-60 W), also energy saver bulbs are used by one respondent. Light bulbs are in operation by all commercial users, health centre and community council (Q D10). Health centre has light sensor controls for operating the lighting in the service area (Q D11-D12). Any willingness to pay for electricity for lighting is observed only by commercial users and lies between M30 and M100 (only a fraction 0-3% of the income per month) (Q D13, Table 9). As for small equipment, one monitor and one desktop were in operation by one restaurant and a health centre in Sehlabathebe (Q D14).

Three institutions in Sehlabathebe have some cooking facilities: police post, health centre and hotel (Q D15). As an energy source LPG is in use (Q D16). Only two respondents (restaurant and hotel) are ready to pay for electricity for cooking. Willingness to pay lies between M50 and M200, 1-6% of the month earnings (Q D17, Table 9).

Only health centre has refrigerating equipment at its facilities: drug fridge of 338 litres (Q D18-D19). No anchor customer is willing to pay for electricity for refrigeration (Q D20, Table 9). According to the councillor of Sehlabathebe, the health centre, the health staff houses, the council offices, and some grocery as well as beer shops use electricity generated with solar PV. Teacher houses and bakery are supplied with LPG, and community centre with a generator.

Three anchor customers generate electricity with solar panels (both restaurants, health centre) (Q E1). The restaurants feature each one panel of 80W, 115 W respectively. The health centre is equipped with 40 panels, and use electricity for lighting (all), water heating and entertainment (health centre). Three anchor customers (all commercial facilities) use a generator to generate electricity and/or heat (capacity 5.5 kW or 650 W), fuelled by diesel 500 ppm or unleaded petrol. The power is used for lighting and other purposes. The generators are operated on average for 6 hours per day throughout the year (Q E4).

Regarding common methods to pay for energy resources, two customers indicated cash while others indicated that the government, magistrate, or District Health Management Team usually pays.

All respondents, with the exception of both schools, desire to have electricity in their facilities. They think that it is important for companies and institutions from their branches to have (Q C4, Q C5). At the same time, most of these users do not perceive electricity to be expensive (Q C6). Respondents stated that their company/institutions (only commercial facilities) were ready to pay for electricity between M200 and M1,000 per month, which is 3-29% of their month income (Q C7, Table 9). Preferred methods to pay for electricity of commercial customers were via mobile phone (Q C8).

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

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
Paolosi Police Post	M0	-	-	-	-	-	-
Lehloenya Public Bar	M7,500	M80	M30	M50	-	M160	2%
Sehlabathebe Health Centre	M0	-	-	-	-	-	-
Mavuka Secondary School	M0	-	-	-	-	-	-
Mavuka Primary School	M0	-	-	-	-	-	-
Khomophatsoa Community Council	M0	-	-	-	-	-	-
Sehlabathebe Local Court	M250	-	-	-	-	-	-
Mabotle Lodge	M3,500	M500	M100	M200	-	M800	23%
Green-House Tarven	M3,500	M300	M30	-	-	M330	9%
Total	M14,750	M880	M160	M250	-	M1,290	

Two anchor customers (both restaurants) are planning to replace fuel by electricity in the next five years (Q F1-F2). They suggest this action will reduce their energy consumption (Q F3). Three interviewed customers (restaurants, local court) want to install new energy consuming systems or technologies: computers or computer systems, laptops, printers (Q F4, Q F5). One restaurant plans to buy a generator in the next five years (Q F9).

There are plans to upgrade buildings by some anchor customers: two want to insulate walls and replace windows, one replaces light bulbs with CFL or LED, install SWH or fit a ceiling (Q F10).

Energy demand forecast

Present power demand and supply of anchor customers in Sehlabathebe are summarized in the Table 11. Future power demand of all anchor customers in the village, including non-interviewed ones, is presented in the Table 10.

Table 10: Future power demand of anchor customers in Sehlabathebe

Type	Number of institutions	Power demand, kWh/year	
		2019	2030
Health	1	8,960	17,900
School	2	1,000	7,000
Government	5	8,870	17,700
Retail	12	31,340	94,000
Total		**50,170**	**136,600**

Table 11: Main characteristics of anchor customers in Sehlabathebe

#	Name	Type	Size	Operation hours	Electrical equipment	Annual power demand	Present power supply	Willingness to pay[2], Maloti/month
1	Sehlabathebe Health Centre	**Health**	10 employees; 8 buildings, area 1,113 m^2	8 h/day, 5 days/week, all year long	Fluorescent light bulbs, 76 units of 16 W; 1 desktop; 1 drug fridge	6,909 kWh	40 solar panels	0
2	Mavuka Secondary School	**School**	5 buildings, area 568 m^2	n.a.		0	None	0
3	Mavuka Primary School	**School**	4 buildings, area 416 m^2	n.a.		0	None	0
4	Paolosi Police Post	**Government**	12 employees; 10 buildings, area 876 m^2	24 h/day, 7 days/week, all year over		0	None	0
5	Khomophatsoa Community Council	**Government**	3 employees; 1 building, area 118 m^2	8 h/day, 5 days/week, all year long	Fluorescent light bulbs, 22 units of 15 W, energy saver	3,416 kWh	None	0
6	Sehlabathebe Local Court	**Government**	6 employees; 5 buildings, area 225 m^2	8 h/day, 5 days/week, all year long		0	None	0
7	Lehloenya Public Bar	**Retail**	1 building, area 105 m^2	13 h/day, 7 days/week, all year long	Incandescent light bulbs, 2 units of 40 W; 1 monitor	467 kWh	1 solar panel of 80 W; 1 generator of 650 W	160
8	Mabotle Lodge	**Retail**	2 employees; 1 building, area 236 m^2	24 h/day, 7 days/week, all year long	Fluorescent light bulbs, 15 units of 15 W	1,971 kWh	1 generator of 5.5 kW	800
9	Green-House Tarven	**Retail**	1 building, area 90 m^2	16 h/day, 7 days/week, all year long	Incandescent light bulbs, 2 units of 60 W	701 kWh	1 solar panel of 115 W; 1 generator of 5.5 kW	330
					Total	13,464 kWh		1,290

[2] Sum of willingness to pay for electricity for heating/cooling, lighting, cooking, and refrigeration (Table above).

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

Table 12: Development of power demand in Sehlabathebe 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	4.4	0.3	0.0	4.7	33.7	1.9	0.0	35.7	140.9	8.1	0.0	149.1
Anchor customers	19.0	2.3	0.0	21.3	27.3	3.9	0.0	31.1	75.6	16.8	0.0	92.4
Total	23.4	2.5	0.0	**25.9**	61.0	5.8	0.0	**66.8**	216.5	24.9	0.0	**241.5**

3.2 Set-up for Mini-Grid

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

HOMER analysis shows that for the electricity supply under conditions in present, the combination of PV power plant and storage is the most optimal and least-cost solution. Capacity of battery storage should exceed maximum hourly output of solar panels in about 2 times, but this ratio depends to a large extent on relative costs of solar panels and battery. In this combination the unmet load accounts for about 2%, and excess electricity produced 53.5% which makes possible to connect further loads but represents also a large value compared to other villages under present conditions. It is advisable to consider other mini-grid setup to eliminate such extensive electricity production.

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

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	59.3 kW	1,002,170	0	11,564
Battery	136 kWh	530,400	2,121,600	17,680
System converter	13.1 kW	34,060	34,060	0
Power lines	6.60 km	138,516	0	2,770
Power meters	121 units	387,200	0	7,744
Total	**-**	**2,092,346**	**2,155,660**	**993,950**

Regarding the expected demand increase, the modular characteristics of pv allow for an easy stepwise adaptation of generation. In this regard, developers may further install lines able to accommodate higher loads than the expected near future loads. For expected demand increase in 2019 after commissioning of a mini-grid, the most optimal option remains a combination of solar power plant and storage. Significant enlargement of PV and battery size leads to an almost threefold higher investment needs.

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

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	164 kW	2,771,600	0	31,980
Battery	388 kWh	1,513,200	6,052,800	50,440
System converter	43.4 kW	112,840	112,840	0
Power lines	6.66 km	139,901	0	2,798
Power meters	122 units	391,072	0	7,821
Total	**-**	**4,928,613**	**6,165,640**	**2,325,975**

Figure 6 presents the distribution of capital costs between different components of a mini-grid. It shows that power grid components (lines and meters) amount more than 10% of the capital costs.

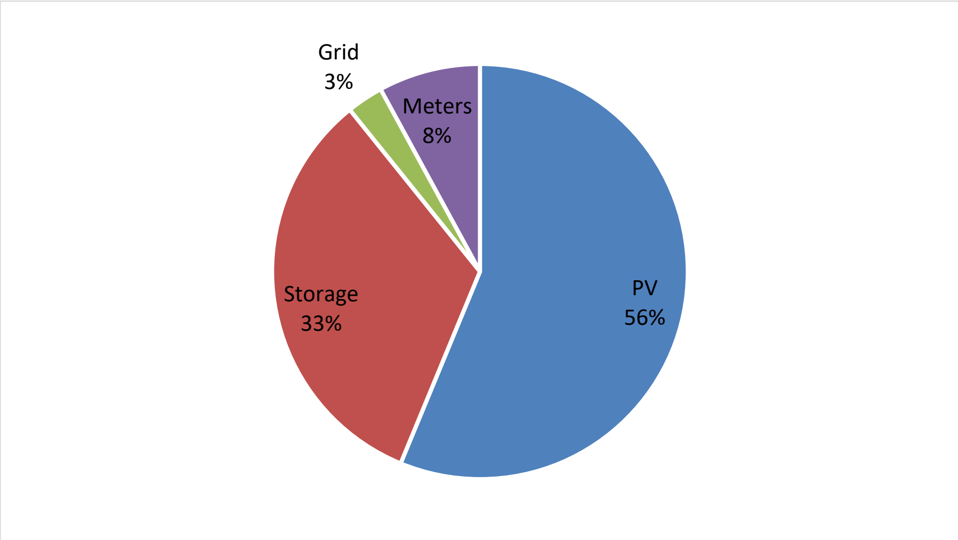


Figure 6: Distribution of capital costs of a mini-grid in Sehlabathebe in 2019

For the Mini Grid two feasible sites were identified. One site, marked blue on the Figure 7, 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 Sehlabathebe 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.

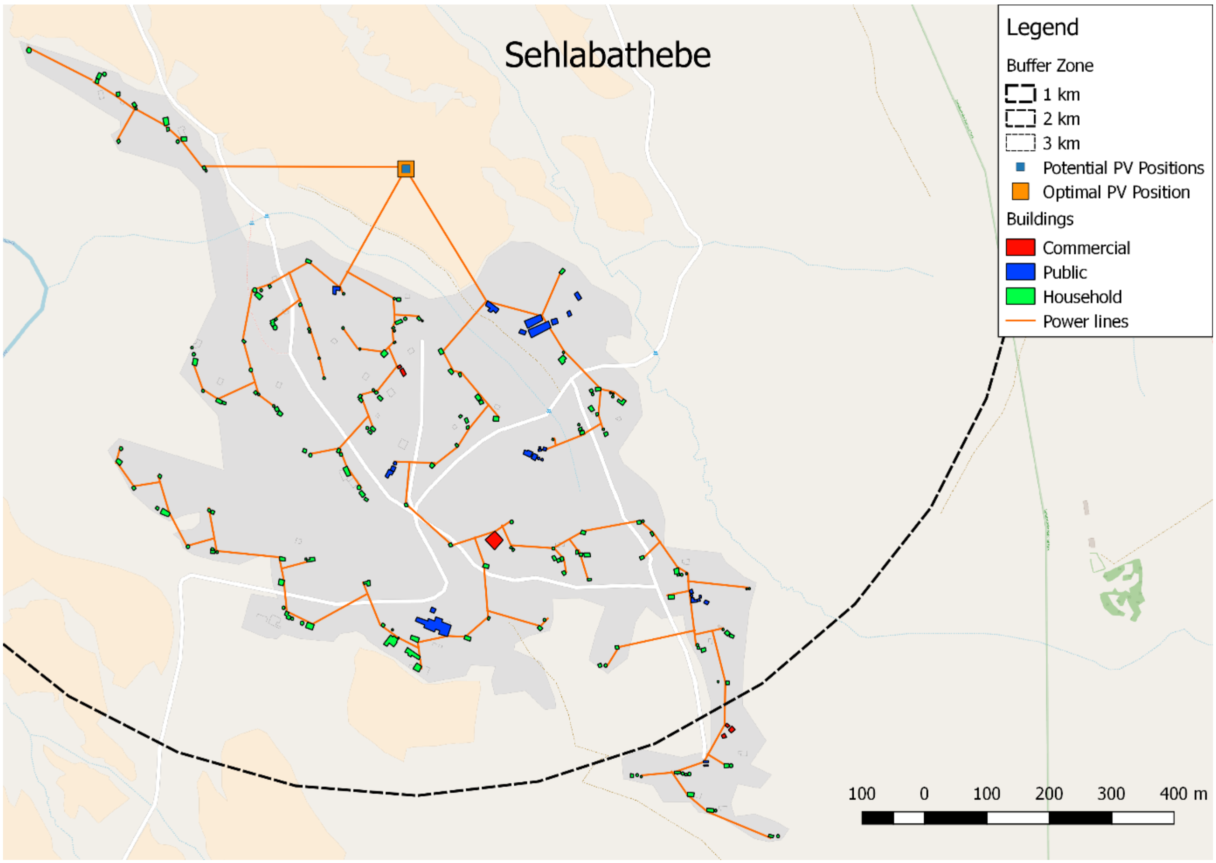


Figure 7: Map of the mini-grid set-up in Sehlabathebe

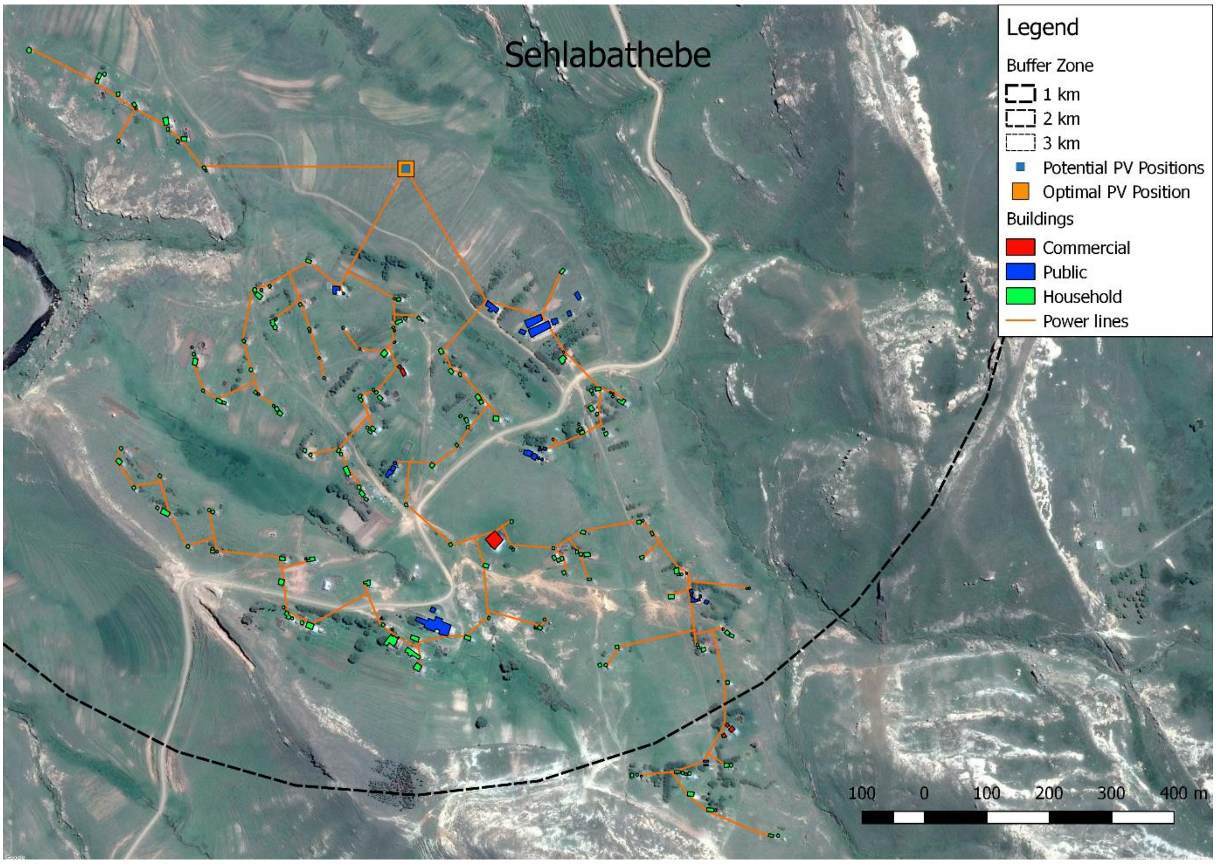


Figure 8: Satellite map of the mini-grid set-up in Sehlabathebe

For the long-term period till 2030, additional to the solar power plant generation sites like hydro power plant can be considered. The option with PV, storage and hydro is cited as a least-cost by HOMER software. 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 Sehlabathebe in 2030

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	313 kW	5,289,700	0	61,035
Battery	734 kWh	2,862,600	11,450,400	95,420
Hydro Power Plant	100 kW	6,000,000	0	180,000
System converter	134 kW	348,400	348,400	0
Power lines	7.43 km	156,083	0	3,122
Power meters	136 units	436,307	0	8,726
Total	-	**15,093,090**	**11,798,800**	**8,707,575**

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 Sehlabathebe in present and future

Time horizon	Unmet load, %	Excess electricity, %	LCOE, M/kWh
Present	2.18	53.5	10.351
2019	2.17	52.9	9.481
2030	2.26	69.1	6.994

3.3 Economic Viability

For the assessment of economic viability of a mini-grid setup, 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, -17%.

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 M8,055,914 over 25 years, or M322,237 per year. Converted into electricity demand, the subvention need would be M2.95/kWh. Regarding allowance need in terms of customers, some M1,597 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 M19,435,758 over whole project lifetime, and M777,430 per year. Subvention need per kWh would be somewhat lower than in the first scenario: M2.29/kWh. Due to significant annual increase of energy demand, allowance needs per customer would also increase, accounting for M3,449 per customer per year.

3.4 Summary

Sehlabathebe is a middle-sized village with 180 households and some anchor loads. Current electricity demand is on the level of 39,000 kWh per year, where about 80% is consumed by anchor customers, and 20% by households. This uneven distribution of shares in total energy consumption is a rather typical situation for settlements which at the moment do not have electrification. Since the commission of a mini-grid this relation will change fundamentally. Residential customers will consume 54% of electricity delivered and public and commercial customers about 46%. Annual electricity demand will grow from 109,100 kWh in 2019 to approx. 411,500 kWh in 2030.

In order to cover this demand, first PV power plant and storage solutions would be sufficient. It should be noticed that excess electricity values for demand in present and near future are quite high and lead to boosted investment costs. Therefore, it is recommendable to consider other mini-grid setup or solution for this village. In the long-term, additional energy resources should be attracted. It can be hydro power plant, or wind mill. The decision should be made upon study of a potential of these RE technologies in the region and further development of relative costs of the technologies.

4. Lebakeng Mini-Grid

Lebakeng (29°53'25.7"S 28°38'36.4"E) is a village in Lesotho located approximately 79.7 km north of Qacha's Nek Town. It has two main rivers: Orange River and Lebakeng River. In this village, there is an airport called Lebakeng airport. It is also off the main roads.

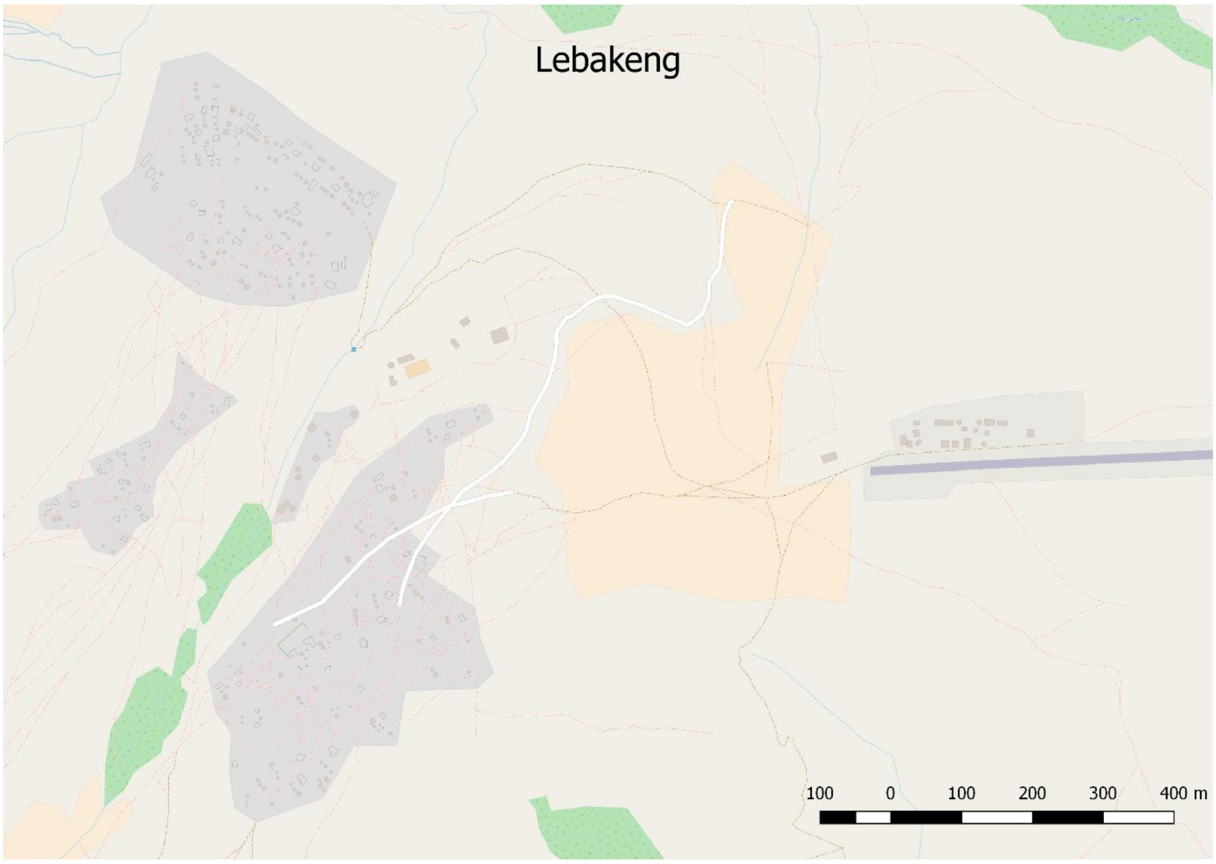


Figure 9: Map of Lebakeng

4.1 Customer Base

Lebakeng accomodates more than 300 households. To the potential anchor loads belong a clinic, two primary schools, five medium-sized shops, the office of the community council, and a hammer mill. Three main income sources in the village are wool and mohair, local beer, and hawking, the chief told in the interview.

4.1.1 Households

Socio-demographic characteristics

In the survey we interviewed ten households (HH) from the village.

Households questioned in the survey have between 2 and 11 members (Q B1). The average number of household members is 6-7 persons. The interviewed households in Lebakeng exhibit quite high number of members in the regional comparison.

Households have between one and four housing units at their disposal, on average three. It is a relatively high value in the village comparison and can be attributed to the high number of household members (Q C1).

Housing types in the district are diverse. The most distributed type among HH in Lebakeng is rontabole: at least one house of such type belongs to every HH. Polata and heisi are also quite popular. Households have one to five rooms in total, on average three rooms. The total housing area per household ranges between 13 and 112 m^2, on average 50 m^2. The mean value of disposable area per household member in Lebakeng accounts for 8 m^2 (Q C2).

Seven households of ten receive some earnings, between M750 and M3,500 per month, on average M1,375 (Q C3). Those households, which have no income, receive remittances, between M125 and M1,667 per month (Q C4).

No households are going to move away from the village in the next five years (Q I1).

Energy supply

As for biomass resources, all households in Lebakeng without exceptions use fuel wood obtained by collection in the amount of 900 to 3,600 kg per year, on average 2,000 kg, which is equivalent to 4,400-17,600 kWh, on average 9,800 kWh in a year. Additionally, one household used 960 kg animal dung, obtained by self-production (4,500 kWh).

All households have an area for wood collection (Q D2). They source the fuel wood in the communal forest (Q D3).

Respondents from Lebakeng indicated that they have to travel 1 to 2 hours to reach the area of a wood collection (Q D4). To collect wood, they need up to one hour (Q D5). In sum it results in average time spent for travelling and collecting wood per month between 1.5 and 2.5 hours. One household needs to go to collect wood 20 times per month. Time spent for it accounts for 50 hours per month. Total travelling and collection time per year for most households accounts for 18-30 hours, with an average time of 25 hours. Regarding an hourly wage of 8 Maloti this converts into annual costs of approx. 202 Maloti.

In almost all households only women are involved in the fuel wood collection, on average two women per HH. Only in two HH two men in each case are responsible for this work (Q D7).

No household has improved fuel wood stove at its disposal (Q D8).

Interviewed households do not spend money for purchasing biomass (Q D9). They usually pay in cash when purchasing commercial fuels (Q D10) and would prefer to pay for it in that way further (Q D11).

Most households in Lebakeng use wood as main energy source for cooking. Also, LPG and paraffin are used by one HH respectively (Q F1). As alternative sources are used wood, paraffin and animal dung.

Table 17: Household use of energy sources in Lebakeng

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	4.5 kg wood per day	8,048	0	182.5 kg wood per year	894	0	48 litres paraffin per year, candles	500	318	18,000
2	4.5 kg wood per day	8,048	0	182.5 kg wood per year	894	0	48 litres paraffin per year, 1 packet candles per year	500	330	18,000
3	3.95 kg wood, 0.33 litres paraffin per day	8,311	2,190	30 litres paraffin per year	311	600	48 litres paraffin per year	497	864	18,000
4	1,560 kg wood per year	7,644	0	540 kg wood per year	2,646	0	24 litres paraffin per year, 1 packet candles per year	250	462	20,004
5	0.43 kg LPG per day	2,009	4,084	600 kg wood per year	2,940	0	24 litres paraffin per year, 1 packet candles per year	250	474	42,000
6	1,440 kg wood per year	7,056	0	480 kg wood per year	2,352	0	48 litres paraffin per year, 1 packet candles per year	500	906	3,504
7	8 kg wood per day	14,308	0	160 kg wood per year, 60 litres paraffin	1,405	1,200	1 kW solar home system, 24 litres paraffin per year	248	480	42,000
8	1,200 kg wood per year	5,880	0	600 kg wood per year	2,940	0	48 litres paraffin per year, 2 packets candles per year	500	1,044	9,000
9	3.95 kg wood per day, 0.5 litres paraffin per day	8,953	3,285	25 litres paraffin per year	259	216	1 kW solar home system, 48 litres paraffin per year	497	864	18,000
10	2.7 kg wood per day, 2.19 kg charcoal per day	11,304	1,099	100 kg wood per year	490	0	24 litres paraffin per year	248	480	1,500
Average		**8,156**	**1,066**	**-**	**1,513**	**202**	**-**	**399**	**622**	**-**

Households in Lebakeng are ready to pay between M50 and M200 for electricity for cooking per month, on average M94. (Q F3, Table 19). No household has a wonder box (Q F4).

Three households of ten in Lebakeng heat their houses (Q G1). For space heating, two HH use paola fuelled by wood, one household uses a paraffin heater (Q G2-G3).

As for willingness to pay, only four households in Lebakeng are ready to pay for electricity for space heating, between M20 and M100 per month (Q G5, Table 19). The heating area of interviewed households lies between 7 and 20 m^2 (Q G6). For water heating the majority of households use wood as main energy source. Some use paraffin (Q G7).

For lighting almost all households in Lebakeng use paraffin, one HH uses solar home system (Q H1). As an alternative, HH use candles, paraffin, and solar home system. In average, the households spent M622/a on energy sources for lighting, so the equivalent budget would be at least available for purchasing power for lighting purposes. 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.

Thanks to the installed solar home systems, household # 7 uses fluorescent light bulb, and household # 9 uses LED. Both light bulbs have capacity of 5 W and are used for three hours a day (Q H3).

Households are ready to pay between M15 and M50 for electricity for lighting per month. Realistic values are 1-3% of the month income (Q H4, Table 19).

Only two interviewed households in Lebakeng use any electrical appliances at home (Q E1). These HH generate electricity at home with solar panel (Q E2-E3). They both spent some money on electricity, expenses vary largely between M50 or M2,000 (Q E4-E5). Both households used electricity for lighting and phone charging, and one HH additionally for radio (Q E6). All households want electricity in their houses (Q E7).

Table 18: Households desired future uses of electricity in Lebakeng, 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
Cooking/ re-heating	X	X	X	X	X	X	X	X	X	X	10
TV	X	X	X	X	X	X	X	X	X	X	10
Phone charging	X	X	X	X	X	X	X	X	X	X	10
Refrigeration	X	X	X	X	X	X	X	X	X	X	10
Water heating	X	X	X	X	X	X	X	X	X	X	10
Radio	X	X	X	X	X	X	X	X	X		9
Ironing	X	X	X	X	X	X	X	X		X	9
Workshop				X		X	X				3
Charging (other than phone)			X				X				2
Computer							X		X		2
Space heating							X				1
Laundry				X							1
Sewing		X									1
Air-conditioning					X						1
Water pumping											0
Dishwashing											0
Total	8	9	9	10	9	9	12	8	8	7	

As for future uses of electricity, all households pointed out lighting, phone charging, cooking/re-heating, TV, refrigeration, water heating. For many households radio and ironing are also possible applications, for some HH workshop, computer, charging (other than phone), sewing, air-conditioning, space heating, laundry as well (Q E8). Interviewed households show willingness to pay for electricity in general between M150 and M500, on average M260, 9-240% of their month income (Q E9, Table 19).

As a preferred way to pay for electricity respondents from Lebakeng chose Mpesa or cash (Q E10).

Considering plans to purchase electrical appliances in the next five years, all households want to obtain phone charger, electric kettle/element, microwave, refrigerator, iron. Most respondents plan to purchase electric stove, electric hair clipper, television flatscreen, electric pot, chest/deep freezer, and hair dryer. Some HH plan to obtain television LCD or CRT, laptop, electric heater, washing machine (Q I3). No household considers to buy any own power generation in the next five years (Q I4). When we compared disposable income with the plans for buying appliances, we found the plans unrealistic as they seem to exceed the financial capabilities of the individual household.

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

HH #	Earnings per month (ability to pay)	Willingness to pay for electricity (Maloti and % of earnings)				Plans to buy electric appliances
		In general	For cooking	For space heating	For lighting	
1	M1,500	M250 (17%)	M100 (7%)	M0	M50 (3%)	Refrigerator, chest/deep freezer, electric stove, hair dryer, TV flatscreen, iron, electric kettle, microwave, hair clipper, phone charger
2	M1,500	M300 (20%)	M100 (7%)	M0	M50 (3%)	Refrigerator, electric stove, hair dryer, TV CRT, iron, electric kettle, microwave, electric pot, hair clipper, phone charger
3	M1,500	M150 (10%)	M80 (5%)	M0	M30 (2%)	Refrigerator, chest/deep freezer, electric stove, TV flatscreen, iron, electric kettle, microwave, phone charger
4	M1,667	M200 (12%)	M100 (6%)	M20 (1%)	M30 (2%)	Refrigerator, chest/deep freezer, electric stove, washing machine, hair dryer, TV flatscreen, iron, electric kettle, microwave, electric pot, hair clipper, phone charger
5	M3,500	M300 (9%)	M100 (3%)	M50 (1%)	M50 (1%)	Refrigerator, chest/deep freezer, electric stove, electric heater, hair dryer, TV flatscreen, iron, electric kettle, microwave, electric pot, hair clipper, phone charger
6	M292	M150 (51%)	M60 (21%)	M0	M30 (10%)	Refrigerator, chest/deep freezer, electric stove, hair dryer, TV flatscreen, iron, electric kettle, microwave, electric pot, hair clipper, phone charger
7	M3,500	M500 (14%)	M200 (6%)	M100 (3%)	M50 (1%)	Refrigerator, chest/deep freezer, electric stove, hair dryer, TV flatscreen, laptop, iron, electric kettle, microwave, electric pot, hair clipper, phone charger
8	M750	M150 (20%)	M50 (7%)	M0	M15 (2%)	Refrigerator, chest/deep freezer, TV LCD, iron, electric kettle, microwave, hair clipper, phone charger
9	M1,500	M300 (20%)	M100 (7%)	M50 (3%)	M50 (3%)	Refrigerator, electric stove, electric heater, TV LCD, laptop, iron, electric kettle, microwave, electric pot, hair clipper, phone charger
10	M125	M300 (240%)	M50 (40%)	M0	M20 (16%)	Refrigerator, electric stove, TV flatscreen, iron, electric kettle, microwave, phone charger
	Average	M260	M94	M22	M38	

Energy demand forecast

Households interviewed in Lebakeng belong partly to medium type, having solar home systems, light bulbs and relatively proper income. Other households are representatives of a basic type due to absence of electric appliances and low income. Considering 300 households living in the village and 1% growth rate of the HH number per year, we estimated present and future energy demand.

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

Household type	No. of HH in Lebakeng			Total power demand, kWh/year		
	Present	2019	2030	Present	2019	2030
Basic	195	197	220	0	5,910	132,000
Medium	75	76	85	3,750	38,000	229,500
Affluent	30	30	34	9,000	54,000	98,600
Total	**300**	**303**	**338**	**12,750**	**97,910**	**460,100**

4.1.2 Anchor customers

Main characteristics

In Lebakeng we interviewed five anchor customers: health centre, community council, two commercial users (food retail, café) and craft (wool and mohair) (Q B1). Health centre and council are state institutions; other companies are in individual ownership (Q B2). Health centre has most employees – 29, including 6 permanent and 23 temporary. Other facilities have 1 to 4 employees, where community council and workshop have 4 employees each, and food retailers one each (Q B3).

Only food retail shop and café cited any earnings, they were M750 and M3,500. No anchor customer received any remittances (Q B5, Q B6).

Most anchor customers work seven days a week, excepting community council (5 days/week) (Q D1). Commercial users operate 8-9 hours per day over the whole year, health centre round the clock, council 8.5 hours per working day (Q D2, Q D3).

The majority of customers cover one whole building, only health centre has 17 buildings at its disposal (Q D4). Most buildings were constructed in the period of 1996-2015. The total building area ranges from 24 m^2 to 30 m^2 among commercial facilities, 980 m^2 for health centre, 66 m^2 for community council. Some buildings are insulated (Q D5).

Energy supply

Table 21: Consumption of energy resources and electricity generation of selected anchor customers in Lebakeng

Anchor customer	Hard coal		Wood		LPG		Solar PV		Generator	
	kg	Purpose	kg	Purpose	kg	Purpose	System size	Purpose	Size	Purpose
Lebakeng Health Centre	500	Space heating	20	Space heating	Heat pump		12 panels of 130 W	Lighting, charging	NA	Lighting, other uses
Thaba Khubelu					2 heat pumps 36 kcal	Heating				
Center Café							1 panel of 80 W	Lighting		
Total quantity	**500**		**20**				**1,640 W**			

From the interviewed anchor customers only health centre indicated to have consumed any hard coal and biomass energy sources over the last year: it was 500 kg hard coal and 20 kg wood for space heating (Q C1-C2).

Two customers, among them health centre and café, used solar electricity last year. Health centre has a panel of 130 W which is used on 70% of days, café's panel is 80 W and operates on 60% of days. Solar energy was used for lighting (Q C3).

Most respondents want to have electricity in their facilities and think that it is important for companies and institutions from their branches to have it (Q C4, Q C5). At the same time, users do not perceive electricity as expensive (Q C6).

Respondents stated that their company/institution is ready to pay for electricity in general between M250 and M1,000 per month (Q C7).

Preferred methods to pay for electricity were via mobile phone and cash (Q C8).

The health centre and the community council use heat pumps fuelled by LPG as air conditioning systems (Q D6). The council operates two heat pumps of 36 kcal capacity, which are used five months in a year on working days. Both anchor respondents use a heating system running on LPG, which operates 5 or 8.5 hours seven days a week 5 or 9 month in a year (Q D7). No independent heating or cooling systems were used (Q D8).

Only two anchor customers, community council and café, are willing to pay for electricity for heating/cooling M100 per month (Q D9, Table 22).

Health centre as the only interviewed anchor customer in Lebakeng use light bulbs: 65 fluorescent bulbs and 15 LED bulbs of 5 W. A café also uses some unspecified lighting sources (Q D10). There are no light or motion sensor controls for operating the lighting in service area (Q D11-D12). Three anchor customers (commercial users and community council) are ready to pay for electricity for lighting between M50 and M100 (Q D13, Table 22).

Small equipment like monitors, laptops, servers, printers was in operation by health centre (Q D14, specific devices listed in the Table 24).

The only institution with some cooking facilities among anchor customers in Lebakeng was a health centre (Q D15). As an energy source LPG is in use (Q D16). Only health centre is ready to pay for electricity for cooking M300 per month (Q D17, Table 22).

Health centre also has refrigerating equipment at its facilities (Q D18). Among this equipment are 6 refrigerators, 1 freezer, 1 laboratory fridge, 1 blood plasma freezer (Q D19).

One anchor customer, food retail shop, is willing to pay for electricity for refrigeration, at the rate of M100 per month (Q D20, Table 22).

According to the chief of Lebakeng, health centre, health staff houses, and community offices use solar electricity from PV panels.

Two anchor customers generate electricity with solar panels (Q E1). Health centre has 12 panels of 130 W and uses electricity for lighting and charging. Panels operate 15 hours/day. Café has one panel of 80 W and uses electricity for lighting, this panel operates 2 hours/day over 10 months/year (Q E2). Health centre additionally uses a generator to generate electricity and/or heat, fuelled by diesel 50 ppm and used for lighting and other purposes (Q E4).

Table 22: Ability and willingness to pay for electricity in general and for different applications of anchor customers in Lebakeng

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
Sekiring	0	-	-	-	-	-	-
Centre General Dealer	M750	-	M50	-	M100	M150	20%
Lebakeng Health Centre	0	-	-	M300	-	M300	-
Thaba Khubelu	0	M100	M50	-	-	M150	-
Center Café	M3,500	M100	M100	-	-	M200	6%
Total	M4,250	M200	M200	M300	M100	M800	

No anchor customers are planning to replace some existing equipment in the next five years (Q F1). Health centre and café want to install new energy consuming systems or technologies, which were not specified (Q F4). Retailer and café also want to buy solar PV in the next five years (Q F9).

Two anchor customers plan to fit a ceiling, one to replace light bulbs with CFL (Q F10).

Energy demand forecast

Present power demand and supply of anchor customers in Lebakeng are summarized in the Table 24. 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. Future power demand of all anchor customers in the village, including non-interviewed ones, is presented in the Table 23.

Table 23: Future power demand of anchor customers in Lebakeng

Type	Number of institutions	Power demand, kWh/year	
		2019	2030
Health	1	46,200	92,400
School	2	1,000	7,000
Government	1	750	1,500
Retail	5	10,400	31,200
Craft	1	50	250
Total		**58,400**	**132,350**

Table 24: Main characteristics of anchor customers in Lebakeng

#	Name	Type	Size	Operation hours	Electrical equipment	Annual power demand	Present power supply	Willingness to pay[3], Maloti/month
1	Lebakeng Health Centre	**Health**	29 employees; 17 buildings, area 980 m^2	24 h/day, 7 days/week, all year round	65 fluorescent bulbs; 15 LED of 5 W; 6 monitors, 5 laptops, 1 server, 1 printer; 6 refrigerators, 1 freezer, 1 laboratory fridge, 1 blood plasma freezer	44,150 kWh	12 solar panels of 130 W; 1 generator	300
2	Thaba Khubelu	**Government**	4 employees; 1 building, area 66 m^2	8.5 h/day, 5 days/week, all year round	None	0	None	150
3	Centre General Dealer	**Retail**	1 employee; 1 building, area 30 m^2	8 h/day, 7 days/week, all year round	None	0	None	150
4	Center Café	**Retail**	1 employee; 1 building, area 24 m^2	9 h/day, 7 days/week, all year round	Light bulbs (not specified)	0	1 solar panel of 80 W	200
5	Sekiring	**Craft**	4 employees	n.a.	None	0	None	-
					Total	44,150 kWh		800

[3] Sum of willingness to pay for electricity for heating/cooling, lighting, cooking, and refrigeration (Table above).

The power demand distributes spatially as depicted in the Table 25.

Table 25: Development of power demand in Lebakeng 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	6.4	0.0	0.0	6.4	48.7	0.0	0.0	48.7	203.3	0.0	0.0	203.3
Anchor customers	20.4	0.5	0.0	20.8	27.6	1.1	0.0	28.7	47.7	7.0	0.0	54.7
Total	26.7	0.5	0.0	**27.2**	76.3	1.1	0.0	**77.3**	250.9	7.0	0.0	**258.0**

4.2 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.

In the case of low current demand, the solution made of solar power plant and battery storage seems to be the best. The values of unmet load and excess electricity are within the respectable realms (about 2% and 47% respectively). 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. With the demand growth in the long-term perspective till 2030 it will be necessary to consider further energy sources like hydro power plants.

Table 26: Elements of mini-grid setup in Lebakeng in present conditions

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	79.2 kW	1,338,480	0	15,444
Battery	218 kWh	850,200	3,400,800	28,340
System converter	23.7 kW	61,620	61,620	0
Power lines	5.19 km	109,053	0	2,181
Power meters	157 units	502,400	0	10,048
Total	**-**	**2,861,753**	**3,462,420**	**1,400,325**

Assuming the increased energy demand in 2019, the most optimal and least-cost solution still remains PV in combination with battery storage. The set-up remains rather the same only the sizes of all elements increases substantially, leading to more than twofold higher investment need.

Table 27: Elements of mini-grid setup in Lebakeng in 2019

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	196 kW	3,312,400	0	38,220
Battery	562 kWh	2,191,800	8,767,200	73,060
System converter	63.8 kW	165,880	165,880	0
Power lines	5.24 km	110,144	0	2,203
Power meters	159 units	507,424	0	10,148
Total	**-**	**6,287,648**	**8,933,080**	**3,090,775**

Figure 10 shows the distribution of capital costs between different components of a mini-grid. It can be noticed that power grid components (lines and meters) amount a significant share of about 10% of the capital costs.

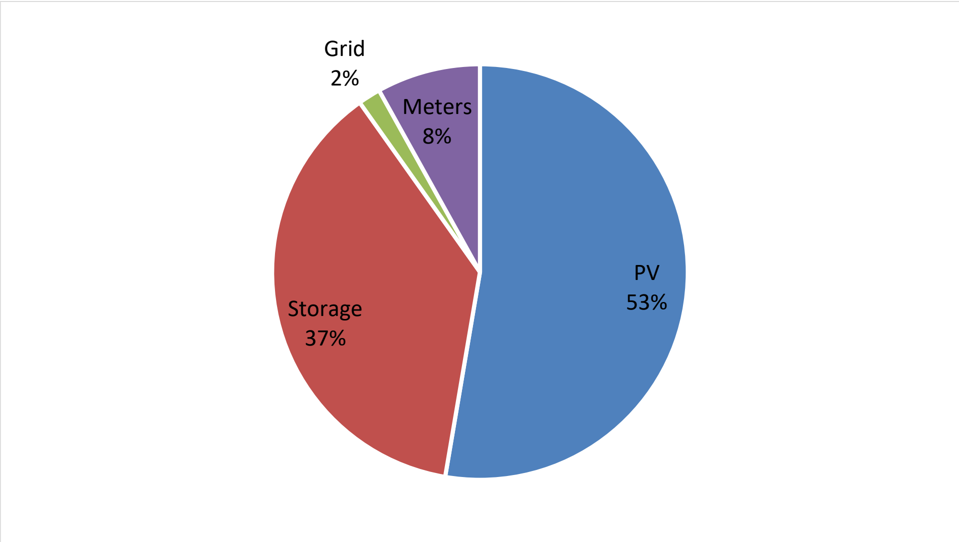


Figure 10: Distribution of capital costs of a mini-grid in Lebakeng in 2019

For the Mini Grid two feasible sites were identified. One site which is marked blue on Figure 11, 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 Lebakeng 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.

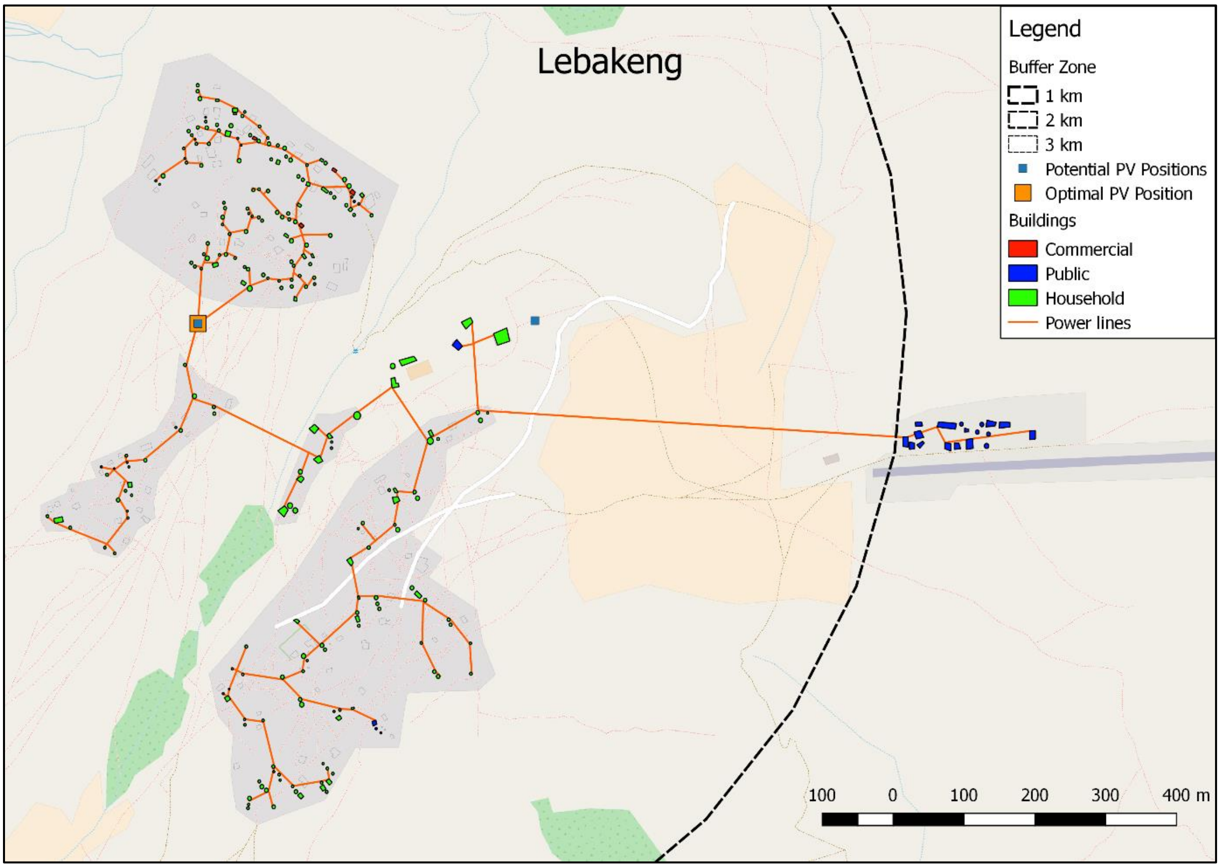


Figure 11: Map of the mini-grid set-up in Lebakeng

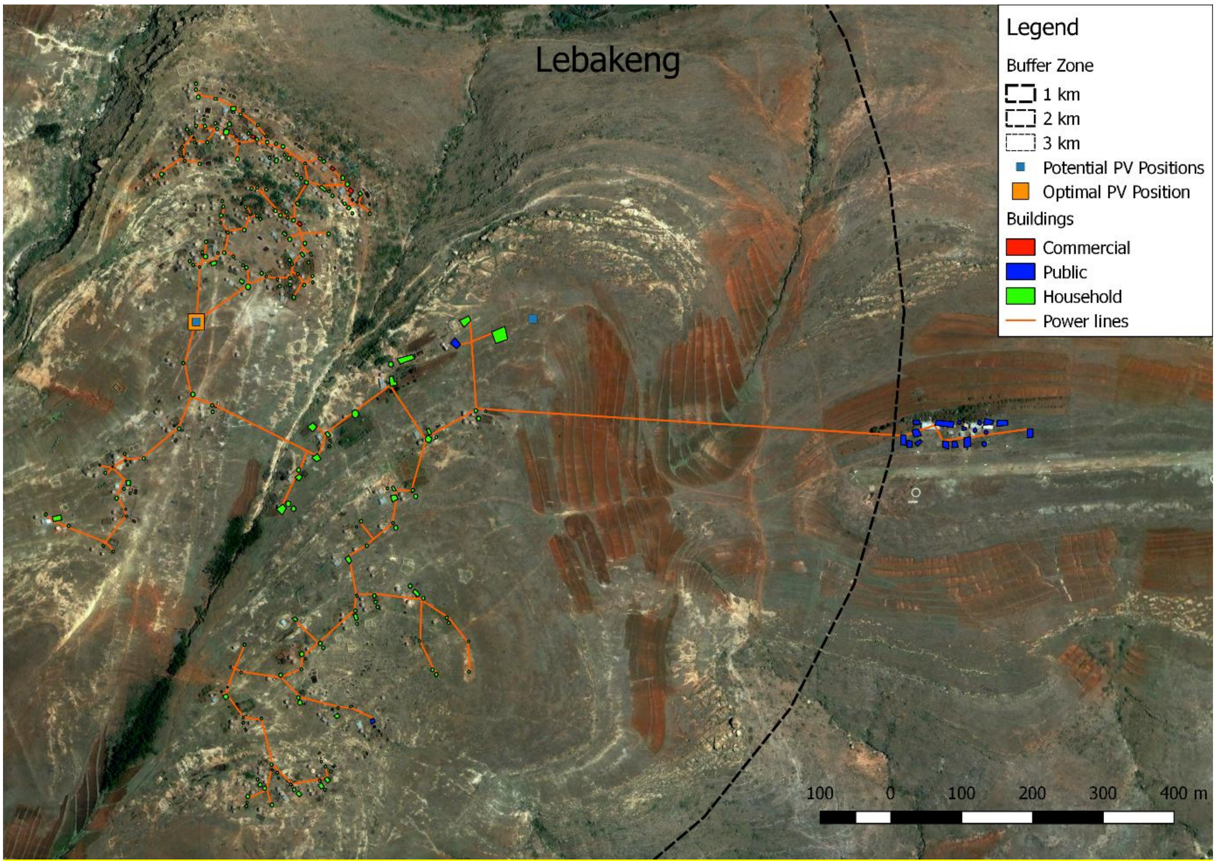


Figure 12: Satellite map of the mini-grid set-up in Lebakeng

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 28: Elements of mini-grid setup in Lebakeng in 2030

Element	Size	CAPEX (Maloti)	Replacement costs (Maloti)	OPEX (Maloti/year)
PV Power Plant	453 kW	7,655,700	0	88,335
Battery	1,027 kWh	4,005,300	16,021,200	133,510
Hydro Power Plant	100 kW	6,000,000	0	180,000
System converter	320 kW	832,000	832,000	0
Power lines	5.85 km	122,884	0	2,458
Power meters	177 units	566,117	0	11,322
Total	**-**	**19,182,001**	**16,853,200**	**10,390,625**

The expected growth of demand allows for lower generating costs in the future (Table 29). 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 29: Characteristics of mini-grid setup in Lebakeng in present and future

Time horizon	Unmet load, %	Excess electricity, %	LCOE, M/kWh
Present	2.15	47.1	9.485
2019	2.14	46.1	8.931
2030	2.30	62.5	6.295

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. To assess economic viability, we used two scenarios of electricity demand changes. 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, -16%. 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 M10,653,667 over 25 years, or M426,147 per year. Converted into electricity demand, the subvention need would be M2.72/kWh. Regarding allowance need in terms of customers, some M1,361 should be additionally paid per year for one customer.

The second scenario foresees the constant 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 M22,713,610 over whole project lifetime, and M908,544 per year. Subvention need per kWh would be a little bit lower than in the first scenario: M1.87/kWh. Due to significant annual increase of energy demand, allowance needs per customer would also increase, accounting for M2,579 per customer per year.

4.4 Summary

Lebakeng belongs to the largest villages in our sample with big number of households and some anchor loads. In present, households, public and business customers about 62,300 kWh annually, with 20% of energy consumed by households and 80% by anchor customers. This relation will shift more to residential customers in the course of the time. For 2019, if mini-gird will be commissioned, a growth in demand up to 156,300 kWh is expected, where 63% of demand will come from households, whereas 37% will be consumed by anchor customers. For 2030, the demand is forecasted to be about 592,450 kWh per year (for 78% of that demand households are responsible, for 15% anchor customers).

As already observed in other villages in Lesotho, for the next few years the solution of PV + storage will be optimal for reliable energy supply. With the development of demand, further technologies as hydro should be considered in order to reduce unmet load and support economic sustainability.

5. Matebeng Energy Centre

Matebeng (29°47'28.3"S 28°48'12.5"E) is a town in southeast Lesotho, situated close to the Senqu River. It lies at the western approach to the Matebeng Pass, which links it with the town of Mavuka. It is found 112 km north of Qachas Nek. This village is the main roads.

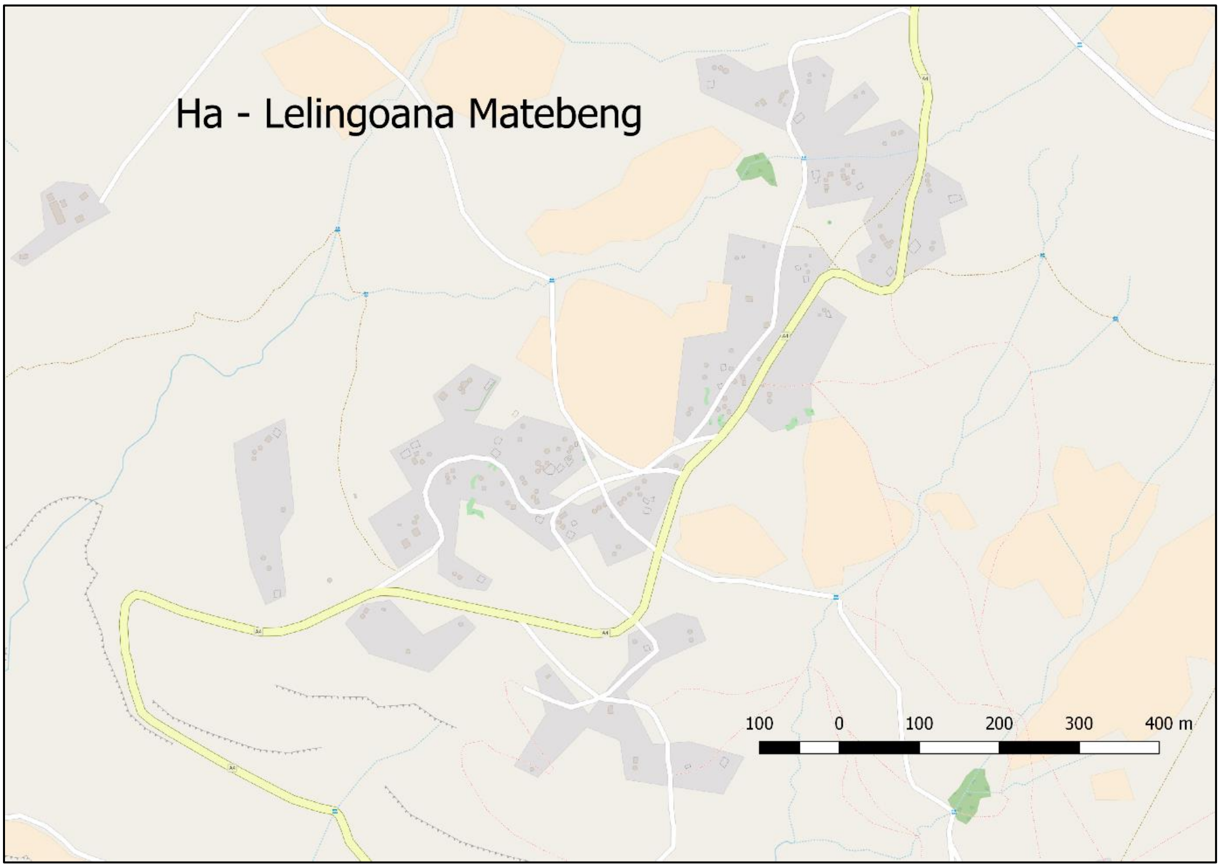


Figure 13: Map of Matebeng

5.1 Customer Base

According to the chief of the village, three main income sources are wool and mohair, livestock and crops. The administrative centre is a city Qacha's Nek.

5.1.1 Households

Energy demand forecast

In Matebeng live approximately 250 households. We calculated an energy demand forecast according to the assumptions made. 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 30: Present and future power demand by households in Matebeng

Household type	No. of HH in Matebeng	Total power demand, kWh/year	
		Present	2019
Basic	163	0	2,120
Medium	62	3,150	4,530
Affluent	25	7,500	0
Total	**250**	**10,650**	**6,650**

5.1.2 Anchor customers

Main characteristics

In Matebeng we interviewed five anchor customers: health centre, school, and three commercial facilities (hotel, restaurant, food retail shop) (Q B1). All commercial facilities are in individual ownership, school and clinic are state institutions (Q B2). Health centre has 10 employees, school 5, commercial facilities between 1 and 3 (Q B3).

Unfortunately, only food retailer provided earnings per month (M7,500), health centre and school did not indicate any income (Q B5, Q B6).

Most anchor customers work seven days a week, excepting school (5 days/week) (Q D1). All commercial users operate between 12 (food retail, restaurant) and 24 (hotel) hours per day over the whole year, health centre 24 hours a day all days, and school 7 hours over 8 months in a year (Q D2, Q D3).

Customers cover between one and three whole buildings: health centre has two buildings, hotel and food retailer three each, other customers have one building each (Q D4). The total building area ranges from 38 m^2 to 650 m^2, whereby health centre has a largest area of 650 m^2. Commercial facilities have between 38 and 66 m^2. Almost all buildings are insulated (Q D5).

Energy supply

Table 31: Consumption of energy resources and electricity generation of selected anchor customers in Matebeng

Anchor customer	**Hard coal**		**Wood**		**LPG**		**Solar PV**		**Generator**	
	kg	Purpose	kg	Purpose	kg	Purpose	System size	Purpose	Size	Purpose
Malimo Tarven							3 panels of 80 W	Lighting	5.5 kW	Other uses
Khutlang General Dealer							2 panels of 80 W	Lighting		
Qudu Primary School			6,525	Cooking						
Matebeng Health Centre	4,000	Space heating			4		43 panels of 130 W	Lighting	5.5 kW	Other uses
Total quantity	**4,000**		**6,525**		**4**		**5,990 W**		**11 kW**	

Health centre and school indicated to use any coal and biomass energy sources over the last year: health centre used 4,000 kg hard coal for space heating (34,800 kWh), school consumed 6,525 kg wood for cooking (32,000 kWh) (Q C1). Most anchor customers pay for fuel in cash (Q C2).

Three customers, among them health centre, restaurant, and food retail shop, used solar electricity last year. The capacity of solar panels was 130 W by health centre, and 80 W by commercial users. Solar energy was used on 70-100 % of days for lighting (Q C2).

All respondents want to have electricity in their facilities and think that it is important for companies and institutions from their branches to have (Q C4, Q C5). At the same time, they do not perceive electricity as expensive (Q C6).

Respondents stated that their company/institution is ready to pay for electricity between M250 and M1,000 per month. It cannot be proven as realistic or not, since we do not know the income level of most interviewed customers (Q C7).

Preferred method to pay for electricity was via mobile phone (Q C8).

No air conditioning systems were in use by the interviewed anchor customers (Q D6). Health centre has a heating system running on LPG (13 units), which operates 4 hours 7 days a week over the whole year (Q D7). No independent heating or cooling systems were used (Q D8).

Anchor customers are willing to pay for electricity for heating/cooling between M50 and M200, on average M90 (Q D9, Table 33).

Light bulbs were used by three anchor customers: health centre, restaurant and food retail shop. All three use LED lights, 3-19 units of 5 W. Health centre additionally uses fluorescent light bulbs, 53 units (Q D10). Health centre has a light sensor controls for operating the lighting in service area (Q D11). Anchor customers are ready to pay for electricity for lighting between M50 and M100, on average M60 (Q D13, Table 33).

As for usage of small equipment, like desktops, monitors, laptops, servers, printers, or household appliances, health centre uses 5 monitors and one household appliance, and restaurant uses one printer (Q D14).

All interviewed anchor customers have some cooking facilities in their buildings (Q D15). Most of them use LPG as an energy source, school uses wood (Q D16). Respondents are ready to pay for electricity for cooking between M50 and M300 per month, on average M120 (Q D17, Table 33).

Three customers have refrigerating equipment at their facilities: health centre, restaurant and food retail shop (Q D18). Among this equipment can be found 2 refrigerators, one freezer, and vaccine freezer by health centre, and 2 freezers by commercial facilities each (Q D19).

Table 32: Electric equipment of selected anchor customers in Matebeng

Anchor customer	Lighting		Small equipment	Refrigerating equipment	
	Type & number	Capacity, W	Type & number	Type & number	Capacity, l
Malimo Tarven	4 LED	5 W	1 printer	2 freezers	111
Khutlang General Dealer	3 LED			2 freezers	111
Matebeng Health Centre	53 fluorescent, 19 LED	LED: 5 W	5 monitors, 1 HH appliance	2 refrigerators, 1 freezer, 1 vaccine freezer	Refrigerator: 160, freezers: 111

Only food retail and the restaurant are willing to pay for electricity for refrigeration, at the rate of M50 or M200 per month (Q D20, Table 33).

According to the chief of the village, health centre, health staff houses, council offices, some grocery shops and beer shops were equipped with solar panels to generate electricity.

Three anchor customers generate electricity with solar panels (Q E1), with 2 to 43 solar panels of 80 or 130 W, and use electricity for lighting. Health centre have 43 panels of 130 W, restaurant and food retail shop have two or three PV panels of 80 W. Panels operate for 3 or 24 hours per day for 9 months or all year long: health centre uses self-generated solar electricity over 24 hours all year round, restaurant uses it round the clock over 9 months per year, and food retailer uses it over three hours every day in the year (Q E2). Two anchor customers (health centre and restaurant) use a generator to generate electricity and/or heat (capacity 5.5 kW), fuelled by unleaded petrol. Generators are in use for 5 hours per day all days in a month over three months in a year (restaurant) or 1 hour a day over 1 month per year (health centre) (Q E4).

All commercial facilities want to replace some units by other units in the next five years (Q F1). The school and commercial users also want to install new energy consuming systems or technologies (Q F4). These anchor customers plan to buy a solar PV as well (Q F9). Three respondents plan to replace light bulbs with CFL, the restaurant and the hotel plan to insulate walls. The hotel plans to install a solar water heater and the food retail shop plans to replace windows (Q F10). The school explains the absence of building upgrade plans with the lack of appropriate equipment on the local market (Q F11).

Table 33: Ability and willingness to pay for electricity in general and for different applications of anchor customers in Matebeng

Anchor customer	Earnings per month ability to pay	Willingness to pay for electricity per month (Maloti)					
		Heating/ Cooling	Lightin g	Cooking	Fridge	Total	
						Maloti	% of earnings
Malimo Tarven	n.a.	M50	M50	M100	M50	M250	-
Malimo Guest House	n.a.	M150	M80	M150	-	M380	-
Khutlang General Dealer	M7,500	M200	M100	M300	M200	M800	11%
Qudu Primary School	0	M50	M50	M50	-	M150	-
Matebeng Health Centre	0	-	-	-	-	-	-
Total	**M7,500**	**M450**	**M280**	**M500**	**M250**	**M1,580**	

Energy demand forecast

Present power demand and supply of anchor customers in Matebeng are summarized in the Table 35. Future power demand of all anchor customers in the village, including non-interviewed ones, is presented in the Table 34.

We derived the forecast for power demand of anchor customer on the results of the entire survey. 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 have own generation facilities.

Table 34: Present and future power demand of anchor customers in Matebeng

Type	Number of institutions	Power demand, kWh/year	
		Present	2019
Health	1	31,434	31,434
School	1	0	500
Government	5	4,250	4,250
Retail	6	9,090	9,090
Total		**44,774**	**45,274**

Table 35: Main characteristics of anchor customers in Matebeng

#	Name	Type	Size	Operation hours	Electrical equipment	Annual power demand	Present power supply	Willingness to pay[4], Maloti/month
1	Matebeng Health Centre	**Health**	10 employees; 2 buildings, area 650 m^2	24 h/day, 7 days/week, all year round	Fluorescent bulbs, 53 units; LED lights, 19 units of 5 W; 5 monitors, 1 HH appliance; 2 refrigerators, 1 freezer, 1 vaccine freezer	31,434 kWh	43 solar panels of 130 W; 1 generator of 5.5 kW	0
2	Qudu Primary School	**School**	5 employees; 1 building, area 84 m^2	7 h/day, 5 days/week, 8 months/year	None	0	None	150
3	Malimo Tarven	**Retail**	2 employees; 1 building, area 42 m^2	12 h/day, 7 days/week, the whole year	LED lights, 4 units of 5 W; one printer; 2 freezers	1,847 kWh	3 solar panels of 80 W; 1 generator of 5.5 kW	250
4	Malimo Guest House	**Retail**	1 employee; 3 buildings, area 38 m^2	24 h/day, 7 days/week, the whole year	None	0	None	380
5	Khutlang General Dealer	**Retail**	3 employees; 3 buildings, area 66 m^2	12 h/day, 7 days/week, the whole year	LED lights, 3 units; 2 freezers	1,844 kWh	2 solar panels of 80 W	800
					Total	35,125 kWh		1,580

[4] Sum of willingness to pay for electricity for heating/cooling, lighting, cooking, and refrigeration (Table above).

The power demand distributes spatially as depicted in the Table 36. Here, also anchor customers and affluent households are included even though we do not expect them to be supplied by the energy centre.

Table 36: Development of power demand in Matebeng 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	2.8	0.0	0.0	2.8	3.7	0.0	0.0	3.7	90.8	0.0	0.0	90.8
Anchor customers	37.7	0.0	0.0	37.7	38.2	0.0	0.0	38.2	84.3	0.0	0.0	84.3
Total	40.5	0.0	0.0	**40.5**	41.8	0.0	0.0	**41.8**	175.1	0.0	0.0	**175.1**

5.2 Set-up for Energy Center

For the Energy Centre, one feasible site was identified in Matebeng. The yellow marked optimal site on the Figure 14 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.

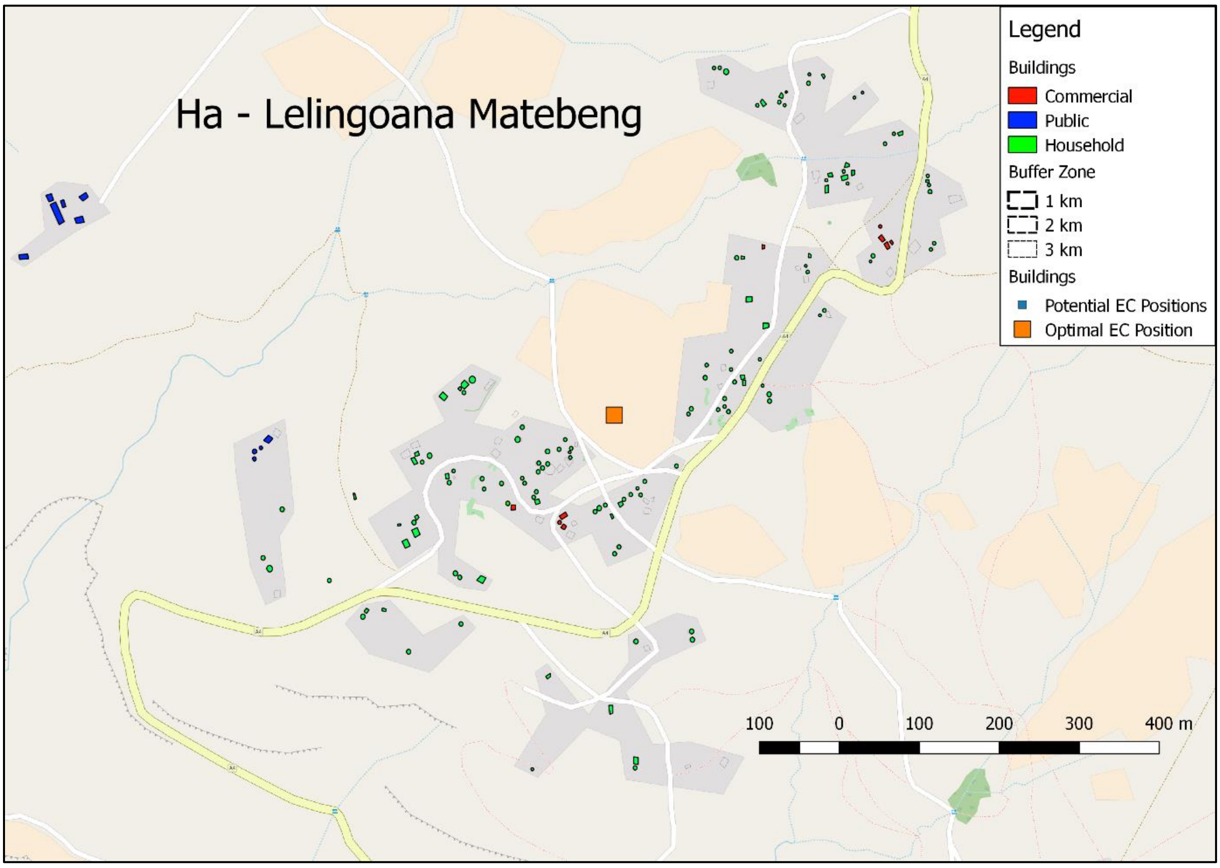


Figure 14: Spatial distribution of customers and positions of energy center in Matebeng

5.3 Economic Viability

Matebeng with its 250 households and few anchor customers belongs to middle-sized villages, so the energy centre to be constructed here should be of medium size. In the Table 37 main characteristics and financials of the energy centre in Matebeng like initial investment, annual expenditure, replacement costs due every five years as well as residual value after 10 years of operation are cited.

In order to supply energy needs of households, business and public customers in Matebeng as well as to cover the electricity demand for the services provided through the centre, a solar power plant of 12 kW with battery storage facility of 33 kWh is needed. It can be taken into consideration to build up this plant in stepwise mode along the expected increase in power demand and power-related services.

We calculated the cash flow over a period of ten years after commissioning the energy centre (Figure 15). 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 M428,508, that makes this energy centre setup economically feasible and very profitable compared to other setups (small and large).

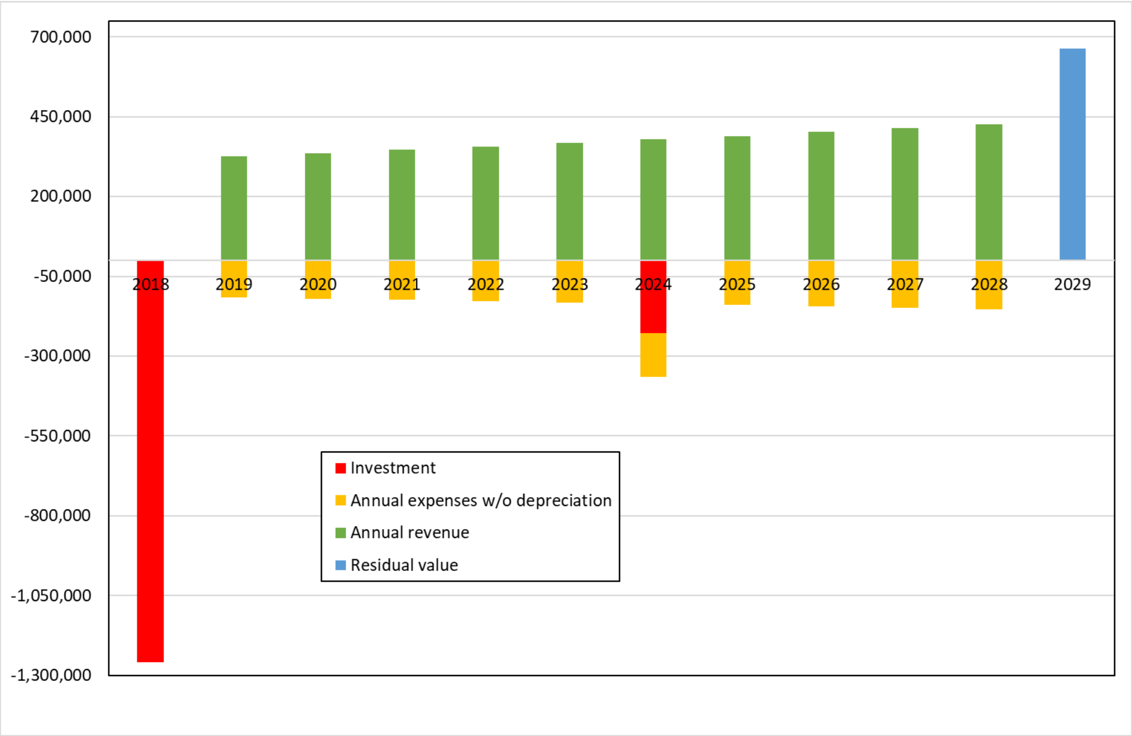


Figure 15: Cash flow of the energy centre in Matebeng in 2018-2029

Table 37: Main features and financial parameters of an energy centre in Matebeng

Features	
Number of households in the village	250
Building area, m2	80
Vehicle, #	0.5
Employees, #	3
Capacity PV, kW	12
Capacity storage, kWh	33
Initial investment	
Building costs, M	160,000
Vehicle, M	100,000
PV+storage, M	340,573
Initial Stockage, M	412,545
Equipment, M	30,700
Staff Training, M	5,000
Contingencies	209,764
Total initial investment	**1,258,581**
Annual costs	
Salaries, M	75,000
Maintenance PV, M	6,811
Depreciation on hardware investment	34,140
Vehicle Maintenance and fuels	10,000
Contingencies	25,190
Total annual costs	**151,142**
Replacement costs	
Inverter+ storage	128,700
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	170,286
Initial Stockage, M	412,545
Equipment, M	0
Total residual value	**662,831**

5.4 Summary

Matebeng, with 250 households living in the village, is on the upper limit of the interval of middle-sized villages. This implies that the energy centre will be medium. The settlement is densely populated in the small radius, that makes it an attractive location for an energy centre to be easily reached on foot by potential customers. Energy centre should have a building area of about 80 m^2 to accommodate stock, display and office rooms. It should have three employees, two sales assistants and one maintenance agent who will support customers by choosing a right energy product, explain advantages and profits of using energy efficient products and technologies, handle small repairs and deliver products and spare parts. A vehicle will be needed for trips around the village and neighborhoods which for cost-saving purposes can be shared with another energy centre or some business located in the close proximity. Combination of PV and battery storage will cover energy needs of customers and own energy consumption of the centre. If a noticeable growth of energy demand will be observed, this PV system can be scaled up with relatively small effort. Given that stocked goods will find demand, and services of the centre like battery and phone charging will become popular, the establishment of such a facility is economically profitable with initial investment of M1,258,581 and provides a rate of return of more than 14% as a result of ten years of operation.

6. Melikane Energy Centre

Figure 16: Anchor customers in Melikane (clockwise from top left: café, shop, Melikane Clinic, Melikane Combined School)

Melikane (29°58'00.2"S 28°44'29.1"E) 54.3 km north of Qachas Nek town and is about 3km from Orange River. There is no nearby main road.

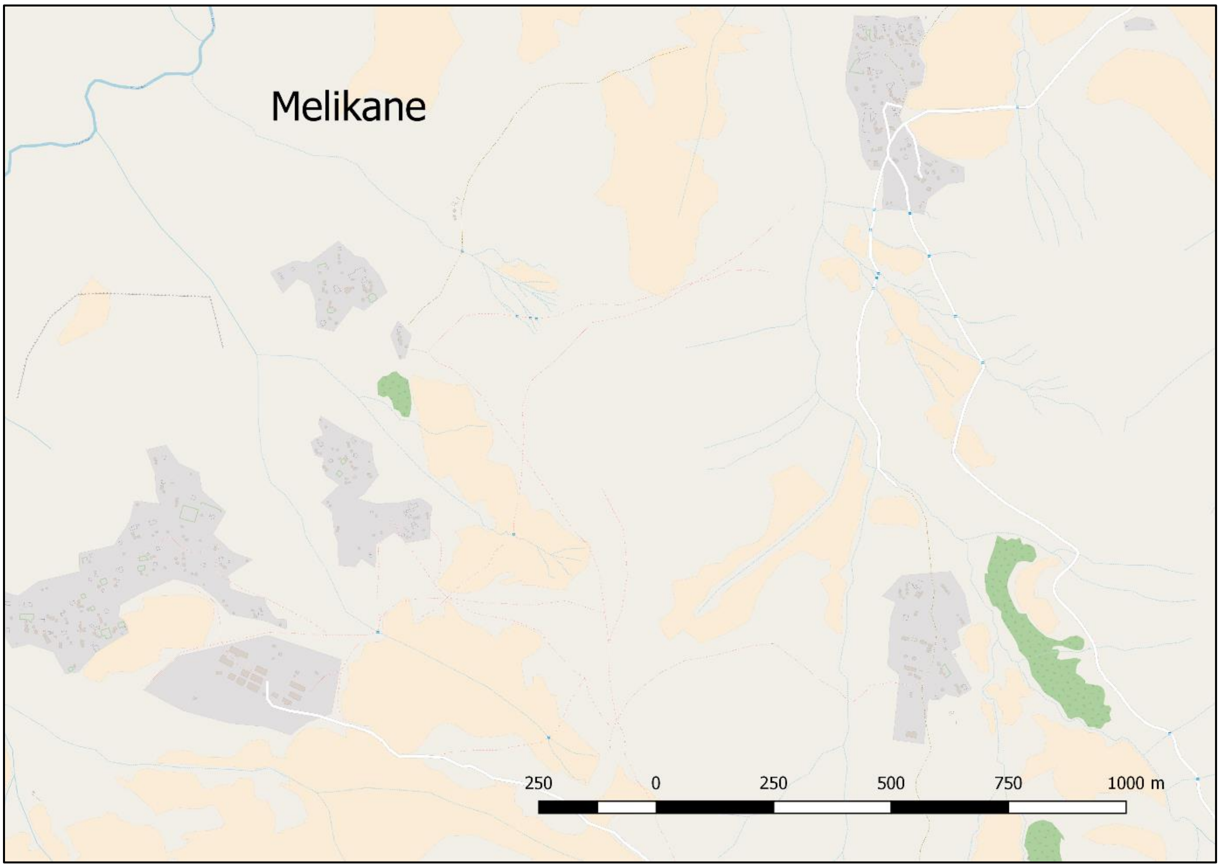


Figure 17: Map of Melikane

6.1 Customer Base

Three main income sources in the village are crops, livestock and local beer, according to the messenger of local council.

6.1.1 Households

Energy demand forecast

Melikane approximately has 100 households. 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 38: Present and future power demand by households in Melikane

Household type	No. of HH in Melikane	Total power demand, kWh/year	
		Present	2019
Basic	65	0	845
Medium	25	1,250	1,825
Affluent	10	3,000	0
Total	**100**	**4,250**	**2,670**

6.1.2 Anchor customers

Main characteristics

In Melikane six anchor customers were interviewed: the health centre, school, community council and three commercial enterprises (restaurants) (Q B1). All commercial facilities are in individual ownership, health centre, school and council are within the state institutions (Q B2). The health centre has the highest number of employees (9) followed by the community council with 5 workers while the commercial facilities have only one employee each (Q B3).

The earnings per month of commercial customers are quite high: M7,500-M30,000. Government institutions do not receive any money. No anchor customer receives any subsidies/money transfers (Q B5, Q B6).

Commercial customers work seven days a week while the health centre and the community council work 5 days/week (Q D1). Commercial users operate between 7 and 21 hours per day over the whole year while the health centre and the community council operate 8 hours a day throughout the year (Q D2, Q D3).

Commercial customers cover one or two whole buildings, the health centre has 8 buildings, the school 4 and community council 2 buildings at its disposal (Q D4). The total building area ranges from 66 m^2 to 938 m^2, on average 456 m^2, which is a very big size for Lesotho relationships. School has the total area of 938 m^2, health centre 843 m^2, one of the restaurants 630 m^2, community council 115 m^2. Almost all customers heat some parts of their buildings. Some buildings are insulated (Q D5).

Table 39: Consumption of energy resources and electricity generation of selected anchor customers in Melikane

Anchor customer	Charcoal		Wood		Paraffin		LPG		Solar PV		Generator	
	kg	Purpose	kg	Purpose	l	Purpose	kg	Purpose	System size	Purpose	Size	Purpose
Thaba-Litsoene Council	150	Space heating	150	Space heating			1 unit of 48 kg; 1 unit of 4.2 kW	Heating				
Thueleng Store					60	Space heating	12 units of 23 kg (276 kg)	Heating	50 or 80 W	Charging	2,200 kW	Heating, other uses
Thabong General Dealer			3 trees, 15 stacks	Space heating					2 panels of 80 and 48 W (128 W)	Lighting, charging, entertainment	50 Hz	Lighting
Atamelang General Dealer											850 kW	Lighting, other uses
Melikane Health centre	1,000	Space heating	1,250	Space heating			20 units of 48 kg (960 kg); 5 units of 4.2 kW (21 kW)	Heating	4 panels of 80 W & 6 panels of 130 W	Lighting, water heating		
Total quantity	**1,150**		**1,775**		**60**		**1,284 kg; 25.2 kW**		**1,308 W**		**3,050 kW**	
Unit costs					M11.5/l							
Total costs			**M500 (Dealer)**		**M690**							

Energy supply

Regarding biomass and coal resources, two anchor customers (community council and health centre) used charcoal (150 kg and 1,000 kg, equivalent of 1,215 or 8,100 kWh) for space heating; three respondents (council, health centre, restaurant) consumed wood (150 kg, 1,250 kg, 3 trees, equivalent to 735, 6,125, or 14,700 kWh) also for space heating; one restaurant used 60 litres paraffin for the same purpose (Q C1). All commercial facilities paid for energy resources in cash (Q C2).

Three customers, health centre and two restaurants, used solar electricity last year. All have solar panels of the capacity between 48 and 130 W, operating every day. Solar electricity was used for lighting, charging, water heating, entertainment (Q C2).

All respondents want to have electricity in their facilities and perceive that it is important for companies and institutions from their branches to have electricity (Q C4, Q C5). At the same time, most users do not perceive electricity as expensive (Q C6).

Three respondents (commercial users) stated that their company/institution is ready to pay for electricity between M500 and M3,000 per month, which is a share of their month income of 2-13% (Q C7).

Preferred methods to pay for electricity were via mobile phone or cash (Q C8).

No air conditioning systems were in use by the interviewed anchor customers (Q D6). Three anchor customers (community council, health centre, restaurant) have a heating system running on LPG, 1 to 20 units, capacity of 23 or 48 kg, total capacity 48 kg to 960 kg. These heating systems were used 24 hours/day throughout the year. Also, health centre and restaurant use heating systems on wood. Health centre has 50 units of 25 kg, totally 1,250 kg. Restaurant consumed 15 stacks of wood for heating. The system operates 4 hours/day over 6 months a year (Q D7). Also community council and health centre use LPG heaters, 1 and 5 units respectively of 4.2 kW. The total capacity amounts 4.2 kW for council and 21 kW for health centre. LPG heaters are used for 2 or 6 h/day over 3 or 6 months a year (Q D8).

Only two anchor customers (two restaurants) are willing to pay for electricity for heating/cooling M200 or M800, what corresponds to 1-3% share of the month income, so it is quite a realistic perception (Q D9, Table 41).

Table 40: Electric equipment of selected anchor customers in Melikane

Anchor customer	Lighting		Small equipment	Refrigerating equipment	
	Type & number	Capacity, W	Type & number	Type & number	Capacity, l
Thaba-Litsoene Council	20 fluorescent	15 W	2 desktops, 2 printers		
Thueleng Store	1 incandescent	40 W		1 refrigerator	350w-50hz-220v
Thabong General Dealer	4 fluorescent	15 W		1 freezer	320 W
Atamelang General Dealer	3 incandescent	60 W		1 freezer	320 W
Melikane Health centre	54 incandescent	36 W	1 monitor	Vaccine fridges	

Almost all anchor customers in Melikane use any type of light bulbs: three use incandescent and two use fluorescent lights. The health centre has the largest number of light bulbs: 54 units of incandescent with capacity of 36 W. Community council uses 20 fluorescent lights of 15 W. Restaurants have 1-4 incandescent or fluorescent bulbs (Q D10). Health centre has light sensor controls for operating the lighting in service area (Q D11). Only the commercial users are ready to pay for electricity for lighting between M20 and M200 (up to 1% of their income per month) (Q D13, Table 41).

Community council and health centre have any small equipment like desktops, monitors, laptops, servers, printers, or household appliances in operation: the first has 2 desktops and 2 printers, the second 1 monitor (Q D14).

Two restaurants have cooking facilities and they use LPG for it (Q D15-D16). Commercial respondents are ready to pay for electricity for cooking M70-M800 per month (0-3% of their monthly earnings) (Q D17, Table 41).

Most customers have refrigerating equipment at their facilities: all restaurants and health centre (Q D18). Among this equipment there were one refrigerator and two freezers by the restaurants, and vaccine fridges by the health centre (Q D19).

As usual in this sample, only commercial customers are willing to pay for electricity for refrigeration, at the rate of M30 or M500 per month (0-2% of their month income) (Q D20, Table 41).

Three anchor customers generate electricity with solar panels (health centre, two restaurants) (Q E1), with 1-10 panels, and use electricity for lighting, charging and water heating. Health centre has 10 panels, restaurants have 1-2 panels at their disposal. Panels operate for 6 or 12 hours per day all year long (Q E2). Also, three commercial users have a generator to generate electricity and/or heat (capacity between 850 and 2,200 W), fuelled by unleaded petrol or diesel 500 ppm and used for lighting, heating and other purposes. Generators operate between 4 and 7 hours per day every day all over the year (Q E4).

Regarding future plans, one restaurant wants to install new energy consuming systems in the next five years: computer, till machine (Q F4). School plans to buy solar PV (Q F9). Two interviewed customers plan to fit a ceiling, one to replace windows, one to insulate walls, one to replace light bulbs with CFL (Q F10). As reasons of not doing such activities, absence of knowledge about the technologies and high purchasing costs were cited (Q F11).

Table 41: Ability and willingness to pay for electricity in general and for different applications of anchor customers in Melikane

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
Thaba-Litsoene Council	0	-	-	-	-	-	-
Thueleng Store	M30,000	M200	M20	M70	M30	M320	1%
Thabong General Dealer	M7,500	-	M50	M150	M30	M230	3%
Atamelang General Dealer	M30,000	M800	M200	M800	M500	M2,300	8%
Melikane Health centre	0	-	-	-	-	-	-
Melikane Combined School	0	-	-	-	-	-	-
Total	M67,500	M1,000	M270	M1,020	M560	M2,850	

Energy demand forecast

Present power demand and supply of anchor customers in Melikane are summarized in Table 43. Future power demand of all anchor customers in the village, including non-interviewed ones, is presented in the Table 42. We derived the forecast for power demand of anchor customer on the results of the entire survey. 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 42: Present and future power demand of anchor customers in Melikane

Type	Number of institutions	Power demand, kWh/year	
		Present	2019
Health	1	7,604	7,604
School	1	0	500
Government	1	1,061	1,061
Retail	3	10,367	10,367
Total		**19,032**	**19,532**

Table 43: Main characteristics of anchor customers in Melikane

#	Name	Type	Size	Operation hours	Electrical equipment	Annual power demand	Present power supply	Willingness to pay[5], Maloti/month
1	Melikane Health centre	**Health**	9 employees; 8 buildings, area 843 m^2	8 h/day, 5 days/week, all year long	54 incandescent light bulbs of 36 W; 1 monitor; vaccine fridges	7,604 kWh	6 solar panels of 130 W, 4 solar panels of 80 W	0
2	Melikane Combined School	**School**	4 buildings, area 938 m^2	n.a.	None	0	None	0
3	Thaba-Litsoene Counsil	**Government**	5 employees; 1 building, area 115 m^2	8 h/day, 5 days/week, all year long	20 fluorescent light bulbs of 15 W; 2 desktops, 2 printers	1,061 kWh	None	0
4	Thueleng Store	**Retail**	1 building, area 66 m^2	11 h/day, 7 days/week, the whole year	1 incandescent light bulb of 40 W; 1 refrigerator	3,227 kWh	1 solar panel of 50 W; 1 generator of 2,200 W	320
5	Thabong General Dealer	**Retail**	1 employee; 1 building, area 144 m^2	7 h/day, 7 days/week, the whole year	4 fluorescent light bulbs of 15 W; 1 freezer	2,957 kWh	1 solar panel of 80 W, 1 solar panel of 48 W; 1 generator	230
6	Atamelang General Dealer	**Retail**	1 employee; 2 buildings, area 570 m^2	21 h/day, 7 days/week, the whole year	3 incandescent light bulbs of 60 W; 1 freezer	4,183 kWh	1 generator of 850 W	2,300
					Total	19,030 kWh		2,850

[5] Sum of willingness to pay for electricity for heating/cooling, lighting, cooking, and refrigeration (Table above).

The power demand distributes spatially as depicted in the Table 44. Here, also anchor customers and affluent households are included even though we do not expect them to be supplied by the energy centre.

Table 44: Development of power demand in Melikane 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	1.7	3.9	0.0	5.6	2.2	5.0	0.0	7.2	54.2	124.7	0.0	178.9
Anchor customers	9.3	3.5	0.0	12.8	9.3	3.5	0.0	12.8	25.6	10.4	0.0	36.0
Total	11.0	7.4	0.0	**18.4**	11.5	8.5	0.0	**20.0**	79.8	135.0	0.0	**214.8**

6.2 Set-up for Energy Center

For the Energy Centre three feasible sites were identified. Two of them, the sites which are marked blue on the Figure 18, were 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 of 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 Melikane 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.

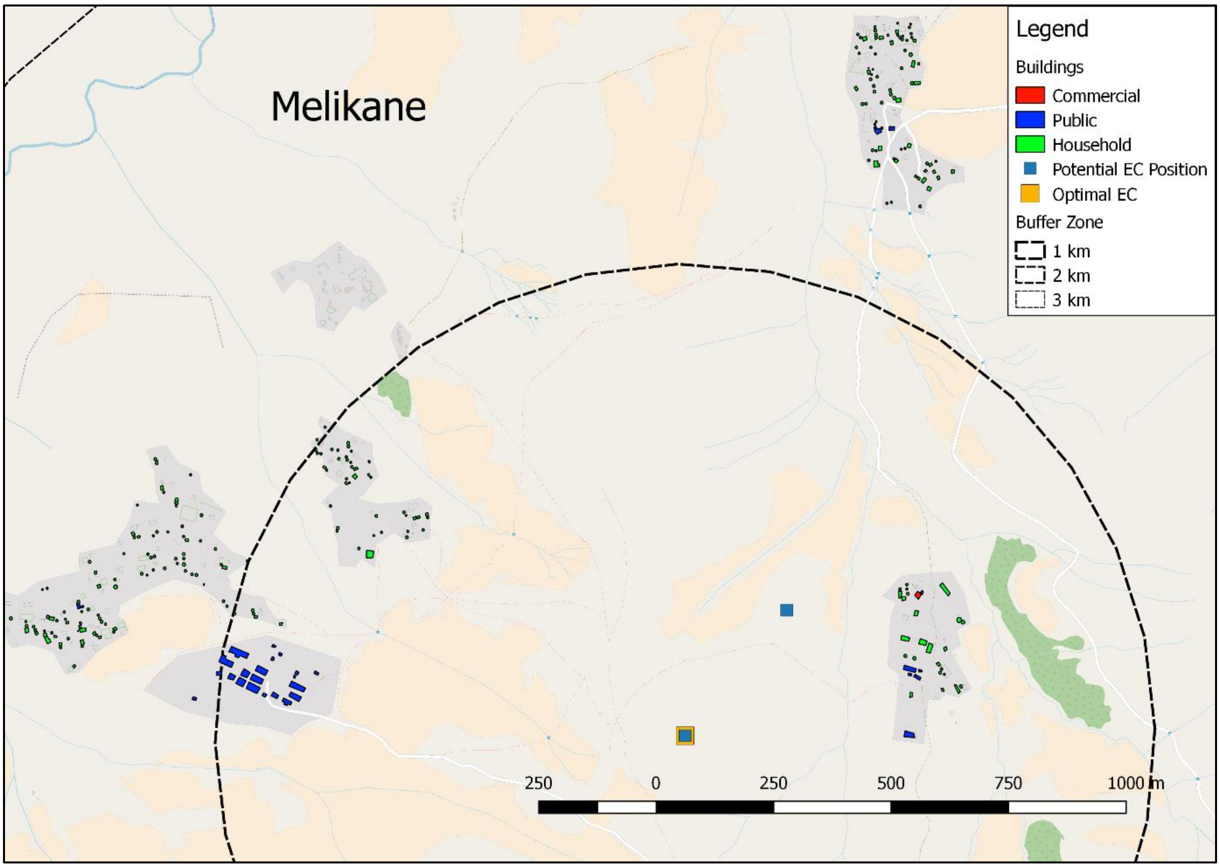


Figure 18: Spatial distribution of customers and positions of energy center in Melikane

6.3 Economic Viability

Melikane belongs to the smallest villages in our sample, with its 100 households and few anchor loads. So, the energy centre constructed in here should also be smaller in dimensions. 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 45 below.

To supply an energy demand of potential customers for battery and phone charging, as well as cover electricity demand for the services provided through the energy centre, a combination of a solar PV and battery storage is optimal. Rather a small power plant with capacity of 5.63 kW and battery with nominal capacity of 15 kWh. One may consider to build up this plant in stepwise along the expected increase in power demand and power related services.

We calculated cash flow generated by energy centre activities over a period of ten years after establishing the energy centre (Figure 19). 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 M81,485, i.e. the energy centre is economically feasible and even more well-positioned than other similar energy centres.

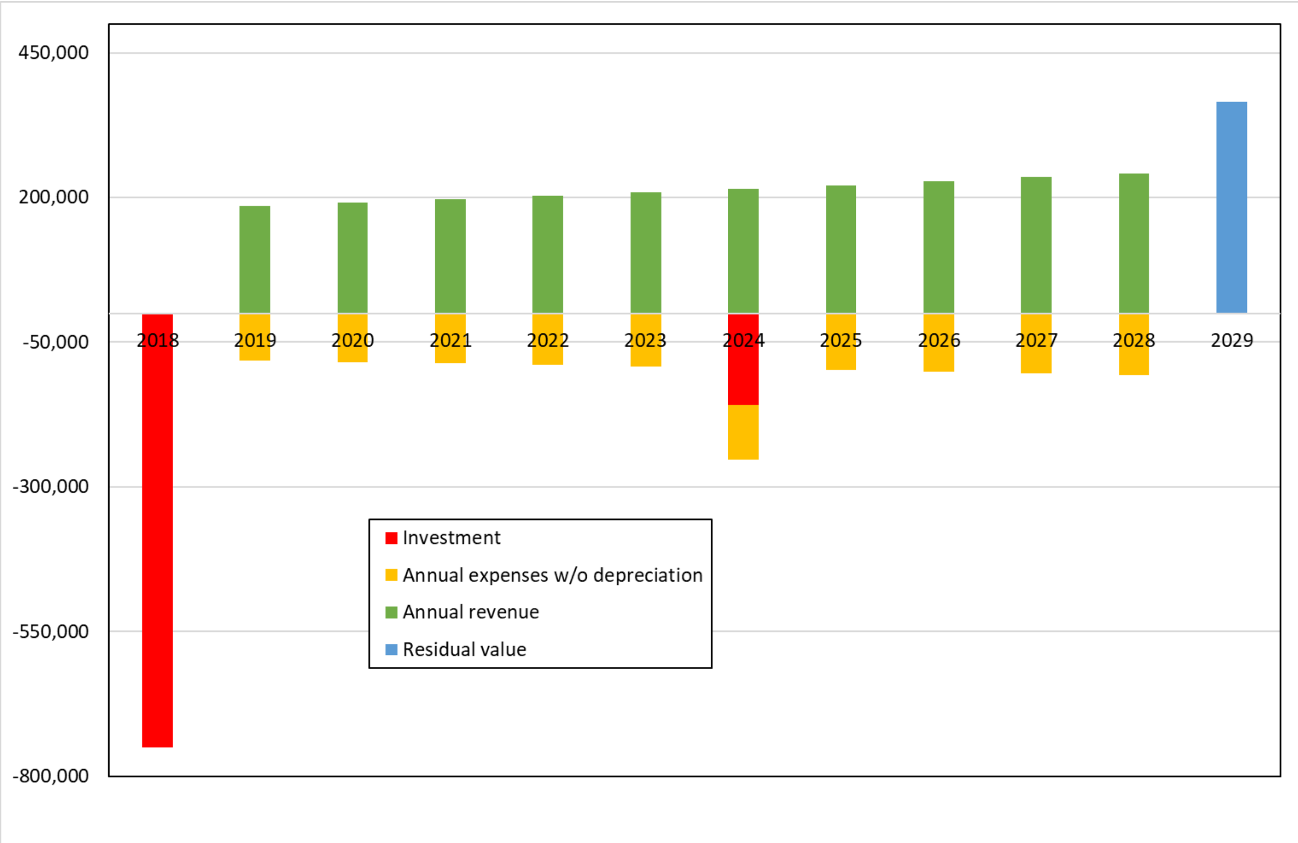


Figure 19: Cash flow of the energy centre in Melikane in 2018-2029

Table 45: Main features and financial parameters of an energy centre in Melikane

Features	
Number of households in the village	100
Building area, m2	50
Vehicle, #	0.5
Employees, #	2
Capacity PV	5.63
Capacity storage	15
Initial investment	
Building costs, M	100,000
Vehicle, M	100,000
PV+storage, M	157,758
Initial Stockage, M	236,550
Equipment, M	25,800
Staff Training, M	5,000
Contingencies	125,022
Total initial investment	**750,130**
Annual costs	
Salaries, M	50,000
Maintenance PV, M	3,155
Depreciation on hardware investment	30,160
Vehicle Maintenance and fuels	10,000
Contingencies	18,663
Total annual costs	**111,978**
Replacement costs	
Inverter+ storage	58,500
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	78,879
Initial Stockage, M	236,550
Equipment, M	0
Total residual value	**365,429**

6.4 Summary

Melikane is a small village with relatively small number of households and anchor customers. Consequently, the energy centre should also be small. It should have an area of about 50 m^2 to accommodate stocked goods, display them to the public and have office facilities. Two employees, one sales assistant and one maintenance agent, will support customers by purchasing decisions, explain features and usage pattern of energy technologies and advantages of energy efficient products, make demonstrations of products, take over small repairs. One vehicle of a pick-up type will be needed to deliver products and spare parts to the customer's doorstep. Vehicle can be shared with other energy centre or business or public institution located in the vicinity of the centre for cost-cutting purposes. 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 extended. Given that offered goods will find demand by households and anchor customers, and service of a battery and phone charging in the centre will become popular among the village population, the establishment of energy centre is economically profitable with initial investment of M750,130 and provides a rate of return of 10% in the period till 2029 (after ten years of operation).

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