



Horizon 2020
Programme

Ref. Ares(2021)7515599 - 06/12/2021

LEAP-RE

Research and Innovation Action (RIA)

This project has received funding from the European
Union's Horizon 2020 research and innovation programme
under grant agreement No 963530

Start date : 2020-10-01 Duration : 63 Months
<http://www.leap-re.eu/>



Report on background analysis for pilot villages as deliverable of task 14.2

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LEAP-RE - Contract Number: 963530

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Document title	Report on background analysis for pilot villages as deliverable of task 14.2
Author(s)	Mr. Ari HAAPANEN, Dr Cleophas Mecha and Prof Ambrose Kiprop (Moi University),
Number of pages	45
Document type	Deliverable
Work Package	WP14
Document number	D14.2
Issued by	UVA
Date of completion	2021-11-23 16:09:27
Dissemination level	Error (13) !

Summary

Work package 14 (Energy Village Concept) entails the development of smart standalone solutions for rural areas, testing and implementing components for RE systems in order to increase the TRL and to adapt the technological solutions and related local market business models to the local context. The objective of task 14.2 which is reported in this deliverable was to identify and provide background information on demo villages in the partner countries in Africa. The partnership established criteria for the energy villages which include: identification of at least five villages in each Africa partner country; classification of the selected village rural/urban/industrial; population and population density; current sources of energy; potential renewable energy sources; and percentage of the population connected to the grid. As a result, background analysis was conducted and at least four villages were selected in each country. The selection also took into consideration the similarities of villages across the countries to facilitate a comparative analysis. The villages selected have renewable energy potential ? enough to achieve 100%+ energy self-sufficiency and commitment of stakeholders i.e. villagers.

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LEAP-RE

Long-Term Joint EU-AU Research
and Innovation Partnership on Renewable Energy

Research & Innovation Action

September 2021

Background Information on Prospective Villages

Version N°X



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This project has received funding from the European Union's Horizon 2020
Research and Innovation Program under Grant Agreement 963530.

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Document information

Grant Agreement	963530
Project Title	Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy
Project Acronym	LEAP-RE
Project Coordinator	Vincent Chauvet (Vincent.chauvet@lgi-consulting.com) – LGI
Project Duration	1 st October 2020 – 31 st December 2025 (63 Months)
Related Work Package	WP14
Related Task(s)	14.2
Lead Organisation	University of Vaasa
Contributing Partner(s)	Addis Ababa Science and Technology University Botswana International University of Science and Technology Makerere University Moi University
Due Date	
Submission Date	
Dissemination level	



History

Date	Version	Submitted by	Reviewed by	Comments





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A background information on prospective villages

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Abbreviations and Acronyms

Acronym	Description
WP	Work Package
RES	Renewable Energy Sources
EV	Energy Village
EDS	Economic Development Strategy

Summary

[The executive summary should place the deliverable within the overall project context, provide an overview of the key objectives, methods of development and results of the deliverable.]

Work package 14 (Energy Village Concept) entails the development of smart standalone solutions for rural areas, testing and implementing components for RE systems in order to increase the TRL and to adapt the technological solutions and related local market business models to the local context. The objective of task 14.2 which is reported in this deliverable was to identify and provide background information on demo villages in the partner countries in Africa. The partnership established criteria for the energy villages which include: identification of at least five villages in each Africa partner country; classification of the selected village rural/urban/industrial; population and population density; current sources of energy; potential renewable energy sources; and percentage of the population connected to the grid. As a result, background analysis was conducted and at least four villages were selected in each country. The selection also took into consideration the similarities of villages across the countries to facilitate a comparative analysis. The villages selected have renewable energy potential – enough to achieve 100%+ energy self-sufficiency and commitment of stakeholders i.e. villagers.

Keywords

Energy village; renewable energy; stakeholders



Introduction

The Energy Village Concept aims to bring small, primarily rural regions to a state of 100+% renewable energy self-sufficiency using local renewable energy sources (RES). It seeks to create positive operational environments, where technology providers can establish their devices, and where investments can be placed resulting in a decline in human-caused climate change effect mainly from energy production carbon emissions.

The Energy Village (EV) concept defines an energy village as a small town or region, with a population of between 100 and 12000 inhabitants, with a good mixture of houses, schools, shopping centres, health facilities and farms, but also a surrounding “impact area” (forests, open countryside, cultivation grounds etc.) with associated RES potential. The villages/suburbs/regions in Africa have diverse sources of renewable energies, however, they are neither utilised to full potential nor generated income from renewable energy. The EV concept maps out consumption as well as different sources of energy found within a village. The report presents a background of prospective villages to be studied. The following criteria were considered in choosing the villages:

- a) At least four villages were selected in each country and of different sizes (population-wise/population density) but should be easy to manage.
- b) The village should have renewable energy potential – enough to achieve 100%+ energy self-sufficiency and commitment of stakeholders – villagers
- c) Types of Energy villages
 - Rural villages that have challenges with energy supply and availability and have potential to produce their own energy & sell energy
 - Off-grid villages targeting replacement of fossil fuels to produce energy
 - Industrial ecosystem to enable circular economy
 - University campus area
 - Mobile villages targeting nomad energy
- d) The village should contain three (3) energy vectors:
 - (i) Traffic fuels,
 - (ii) Electricity, and
 - (iii) Heating





Profiling of energy villages for research

Based on the criteria above, the following villages were selected:

Selected Villages in Kenya

Village 1: Moi University, Chebaiwo in Uasin Gishu

1. Population and population density

Chebaiwo village is located in Tulwet ward, Kesses sub-county. The population density of Tulwet ward is 241persons/sq.km (Kimani, 2021). Information on the population of villages within the ward, however, has not been published.

2. Current energy sources

Most households in Chebaiwo depend on firewood and a few on charcoal for cooking. Majority of them use electricity for lighting and very few use kerosene and solar (Kimutai, Kiprop, & Snelder, 2019).

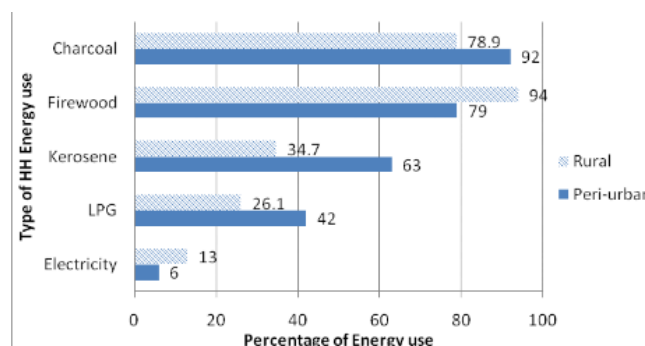


Figure 1: Energy utilization for cooking in Uasin Gishu (Kimutai, Kiprop, & Snelder, 2019).

3. Potential of Renewable energy

Most rural residents in Uasin Gishu County have not adopted use of renewable sources of energy. However, results from a survey conducted showed that most residents have strong interests in solar PV technologies. The main impediment to their investment in renewable energy was high cost of equipment and the intermittent nature of renewable energy sources (Kiprop, Matsui, & Maundu, 2019). The region is famous for the large-scale production of wheat, maize and livestock (mainly dairy farming). Thus, it has great potential for utilization of biomass (agricultural residues) and solar for renewable energy production.

4. % of population connected to the grid





A background information on prospective villages

Research shows that 48% of households in rural areas of Kesses Sub County get their power supply from the national grid (Kiprop, Matsui, & Maundu, 2019).

Village 2: Langas, Eldoret in Uasin Gishu

1. Population and population density

Langas ward is located in Kapsaret Sub County. It has a population density is 679 person's/sq.km. (Kimani, 2021).



Figure 2: Aerial view of Langas Estate (Olengwe, 2018)

2. Current energy sources

Peri-urban households in Eldoret, including Langas estate, are largely dependent on electricity for lighting and charcoal, kerosene and LPG for cooking. Also a small fraction of households use solar panels as their source of energy for lighting among other uses (Kimutai, Kiprop, & Snelder, 2019).

3. Potential of Renewable energy sources

There is less adoption of renewable energy sources in Langas estate. According to a questionnaire survey administered among a few household consumers, analysis showed that about 84% of the respondents were interested in adopting renewable energy (solar, wind and hydro) for their energy consumption. This would solve frequent power outages and high energy costs from the grid system. The livelihoods of most residents (farming and livestock keeping) are directly connected to the environment. This shows a huge potential for easy adoption of renewable energy sources including bioenergy (Kiprop, Matsui, & Maundu, 2019).



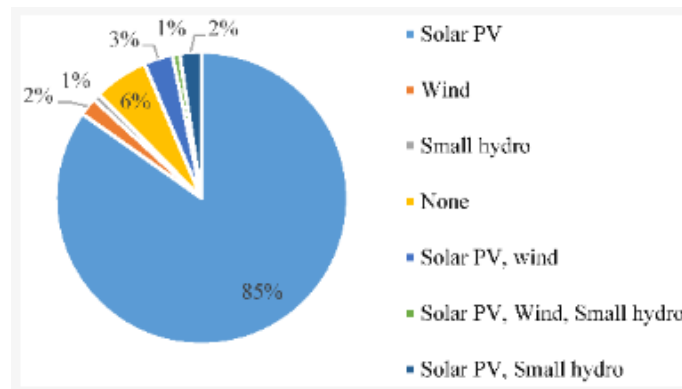


Figure 3: Households' renewable energy choices in the region (Kiprop, Matsui, & Maundu, 2019).

4. % of population connected to the grid

About 74% of the households in peri-urban areas in Uasin Gishu, such as Langas estate, obtain their electricity solely from the national grid (Kiprop, Matsui, & Maundu, 2019).

Village 3: Lelan in Elgeyo Marakwet County

1. Population and population density

Lelan ward is one of the county assembly wards in Marakwet West constituency. It has an approximate population density of 101person/ sq.km. (Kimani, 2021).



Figure 4: A representation of Lelan area (MoALF, 2017)

2. Current energy sources

The main sources of household cooking energy are firewood, charcoal and paraffin. Majority of the population use kerosene for lighting and a few have an access to electricity. Use of firewood for cooking has however contributed to vegetation degradation and increase in health related complications among the population (MoALF, 2017).

3. Potential of renewable energy



A background information on prospective villages

The renewable energy share in the total energy consumption is negligible. The population that relies on clean fuels, which are; solar energy and biogas is less than 1%. Looking at Elgeyo Marakwet County as a whole, currently there are two hydroelectric dams under construction by Kerio Valley Development Authority (KVDA) at Arror and Kimwarer which are projected to generate 45 and 20MW respectively to the National grid. These renewable energy sources are expected to suffice several regions in the county including Lelan region (County Government of Elgeyo Marakwet, 2019).

4. % of population connected to the grid

The number of households with electricity coverage in Marakwet West Constituency is 26.85%. Information regarding electricity coverage among the various wards of Marakwet West Constituency, Lelan Ward included, is however not published (County Government of Elgeyo Marakwet, 2019).

Village 4: Nandi Hills in Nandi

1. Population and population density

Nandi Hills ward is one of the county assembly wards in Nandi Hills constituency. It has a population density of 450 persons/sq.km (Kimani, 2021).



Figure 5: A representation of households in Nandi Hills (Lobo, 2021)

2. Current energy sources

In Nandi Hills, 31% of the population uses electricity as a main source of lightning and 29% uses solar energy. 85% of households rely on firewood for cooking 0.5% uses electricity, 6% use LPG and 8% use charcoal (County Government of Nandi, 2018).

3. Potential of renewable energy

Most tea factories in Nandi Hills rely on wood fuel to run the boilers and other machineries. Alternative fuel is needed in the factories. Over reliance on firewood for cooking energy among households also contribute to deforestation. It is therefore necessary to use clean cooking energy such as energy saving stoves, biogas as well as other renewable energy sources (County Government of Nandi, 2018).





A background information on prospective villages

4. % of population connected to the grid

Approximately 31% of the households in Nandi Hills get power supply from the national grid (County Government of Nandi, 2018).

Village 5: Kerio valley in Kerio

1. Population and population density

Kerio valley is located in Turkana central sub-county. The population density is 40 persons/sq.km. (Turkana County Government, 2019).



Figure 6: Kerio Valley (Kerio Valley, 2016)

2. Current energy sources

Households along Kerio Valley rely on firewood and charcoal for cooking and kerosene for lighting. The Kerio riverine forests are a critical resource in the area in that; charcoal and firewood are the main source of income. A large part (about 50%) of annual cash earnings of majority of the households is made through the sale of charcoal. There is little adoption of solar energy along Kerio Delta. Farming in this region relies on solar-pumped water after the river water levels decrease (The Food Economy Group, 2016).

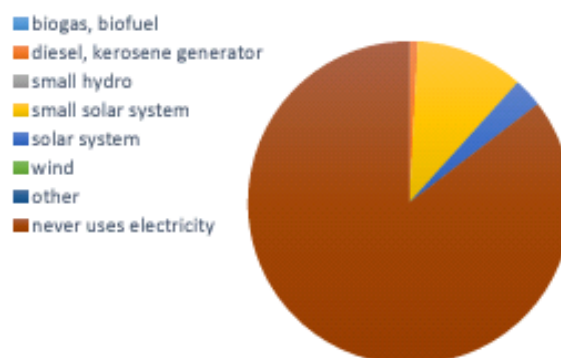


Figure 7: Current energy sources in Turkana County (Ministry of Energy and Petroleum, 2017)





A background information on prospective villages

3. Potential of renewable energy sources

There is little adoption of renewable energy sources in Kerio valley region. Very few farming activities, only along Kerio riverine use solar energy to pump water for irrigation. Many households are dependent on self-employment activities; including firewood and charcoal sale showing that these sources of energy are present in plenty within the region hence the households are reluctant in adopting renewable energy sources. Much of this area is dry. The long-term average annual rainfall in the Kerio Riverine zone is 264mm with long rains falling in March-May and short rains in October-December. It is clear that the sunny season is much prolonged within the year hence a favorable chance to adopt solar energy solutions to curb environmental effects associated with use of charcoal and firewood (The Food Economy Group, 2016).

4. % of population connected to the grid

Little is mentioned on use of electricity as a source of energy in the region. The figure below is a graph that provides a breakdown of total annual cash expenditure according to the category of expenditure and it is clear that there is no data on electricity expense in the region.

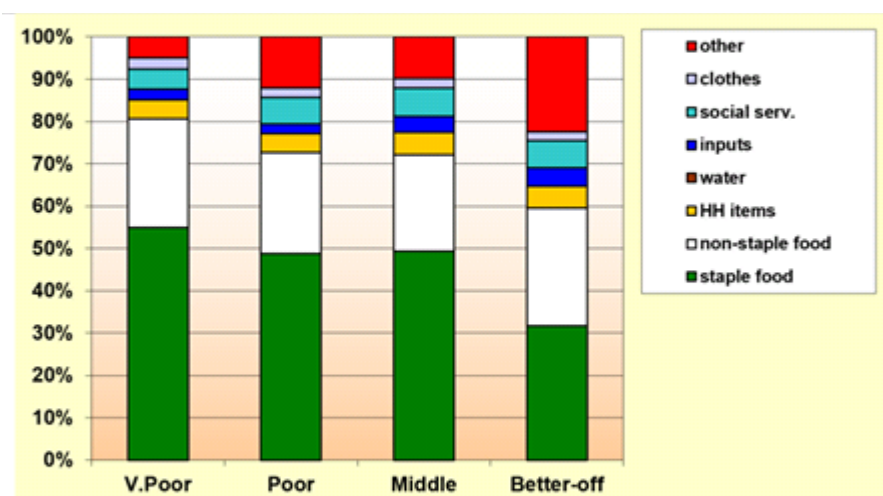


Figure 8: Annual cash expenditure among households in Kerio Valley (The Food Economy Group, 2016).

**Table 1: Summary information about the villages in Kenya**

	Village	Type	Objective	Size	RES
1	Moi University, Chebaiwo in Uasin Gishu (0.2861° N, 35.2943° E)	Rural	Energy efficiency and sufficiency	3000	Solar Biogas
2	Langas in Uasin Gishu (0° 28' 42" N; 35° 15' 18" E)	Semi-urban	Exploiting biomass for energy sufficiency	2500	Solar Waste Biogas
3	Lelan in Elgeyo Marakwet (1.1376°N,35.3795° E)	Rural	Exploiting biomass for energy sufficiency	200	Solar Wind Waste
4	Nandi Hills in Nandi (0.1031° N, 35.1764° E)	Industrial (tea industries)	Utilization of biomass waste as alternative energy supply to industries	1500	Solar Biomass Waste
5	Kerio valley in Kerio (0.6434° N, 35.6095° E)	Rural	Exploitation of solar and small hydro for energy sufficiency	200	Solar Small hydro

Selected Villages in Uganda

Village 1: Nakasengere

1. Location

Nakasengere village is located in Nakasengere Parish, Muwanga Sub-county, Kiboga District. It is located approximately 123 km northwest of Kampala. It is about 78 km, by road, southeast of Hoima (Figure 9). The coordinates of Nakasengere are Latitude: 0.6977720; Longitude: 31.9380530).



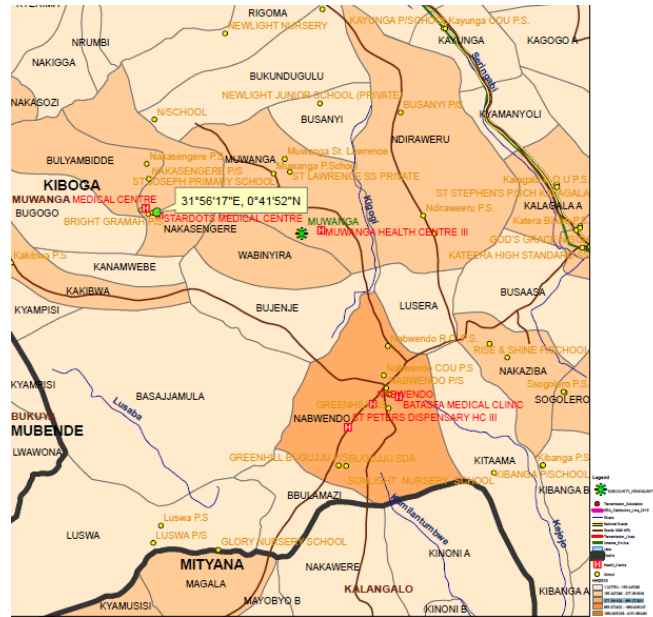


Figure 9: Location of Nakasengere

Nakasengere Climate

The climate of Uganda cannot be categorized into any single climatic zone although it has been generally categorized as a 'modified tropical climate' according to information obtained from the Uganda National Meteorological Authority (UNMA). In reality, Uganda has three sub-climatic zones which are differentiated by the altitude and rainfall received. Weather data from three towns Entebbe, Gulu, and Kabale are representative of these three regions. Entebbe is found to be in the Lake region, Gulu in the Northern Savanna and Kabale in the Southern Highlands. Nakasengere is found to be in the lake region sub climatic zone owing to its proximity to the representative town.

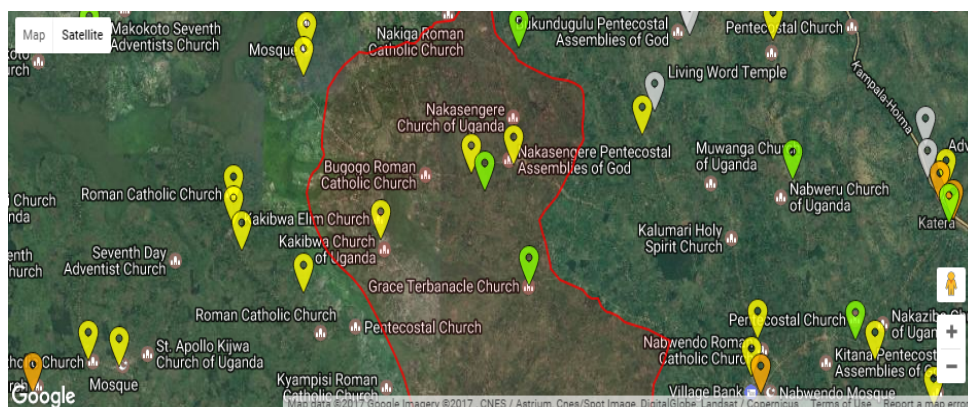


Figure 10: Satellite map of Nakasengere Village (highlighted in red)

2. Population/population density

During the 2014 national population census, the population of the village was enumerated at 148,606 people and projected to be 151,700 in mid-2015 (**UBOS, 2014**).





A background information on prospective villages

This village has a total of 152 rural households of an average size of 5 per household and 604 adults as according to the Community Information System (CIS) carried out in mid-2009 under the Economic Development Strategy (EDS) (**UBOS, 2011**). These are the only statistics that can be found at a village level; in consideration of the growth of 3.0% between 2000 and 2014 (**UBOS, 2016**).

3. Potential renewable energy sources

Solar PV resource

From the yearly weather measurements extracted, it is noted that the month of December records the lowest insolation while the month of August records the highest insolation values in this area. However, the other months are not far in range. Figure 11 and **Error! Reference source not found.12** below show the daily solar radiation in Nakasengere and the monthly radiation, respectively.

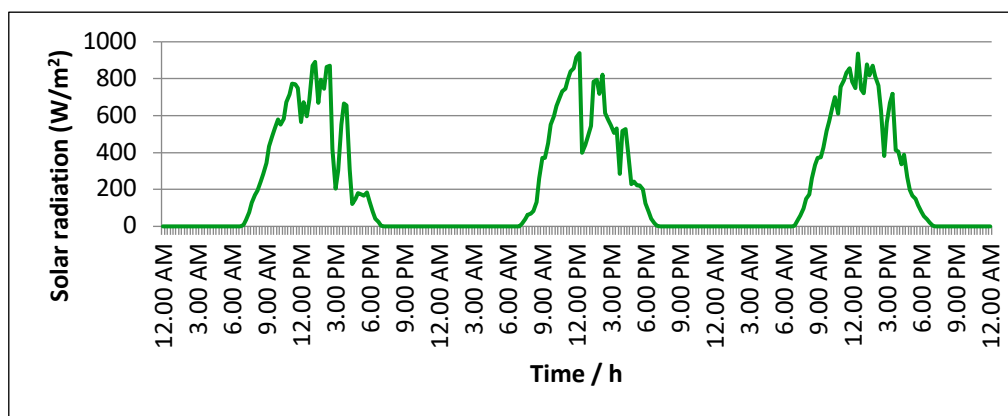


Figure 11: Daily solar radiation received at Nakasengere

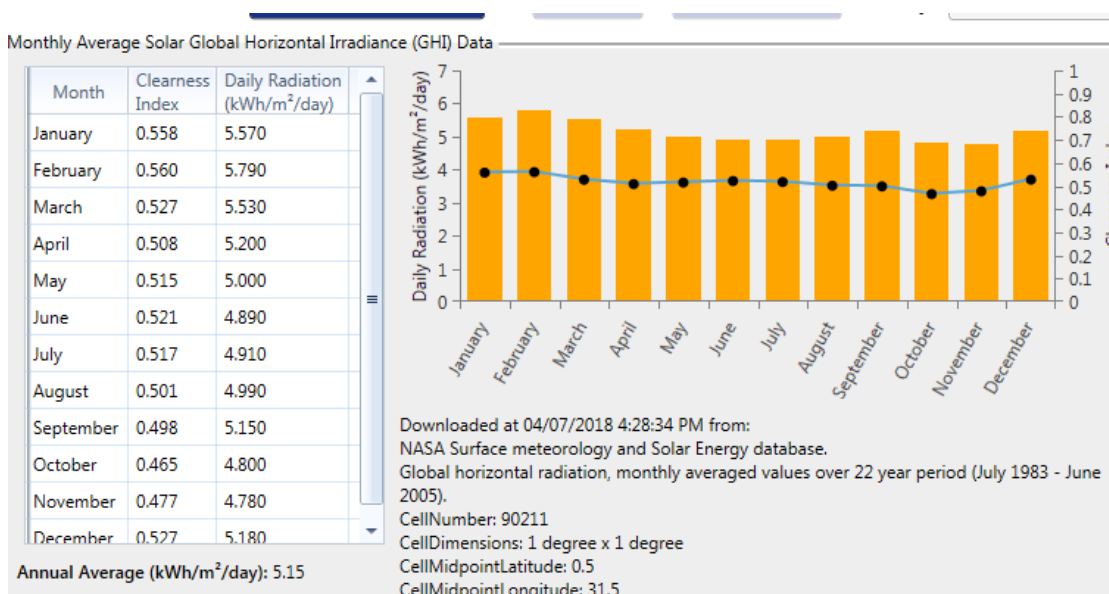


Figure 12: Monthly solar radiation received at Nakasengere





Wind Resource measurement

The extracted weather data from the Uganda National Meteorological Authority (UNMA) database reveals that the lowest wind speed received for 2018 was 0.59 m/s and the highest recorded reading was 45.95 m/s. The average wind speed was 6.45 m/s while the mode was 9.36 m/s. It was also noted that a greater percentage of the time the wind speeds were above 5 m/s as illustrated in Figure 13. This implies that there is enough capacity for electricity generation at the site. However, the NASA readings have variations and reveal less wind speeds. Thus, due to the number of years measured, the NASA measurements are considered for reasons of accuracy and consistency.

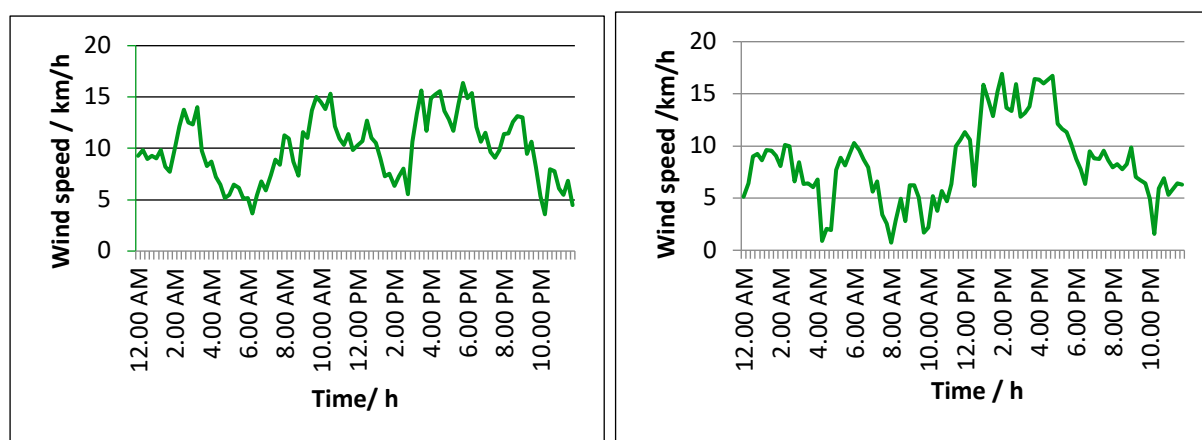


Figure 13: Wind speed profile of Nakasengere as according to UNMA data

The profiles shown in Figure 13 above indicate that there are higher speeds in the evenings. However, the speeds are quite slow in the early morning between 5 am and 8 am.

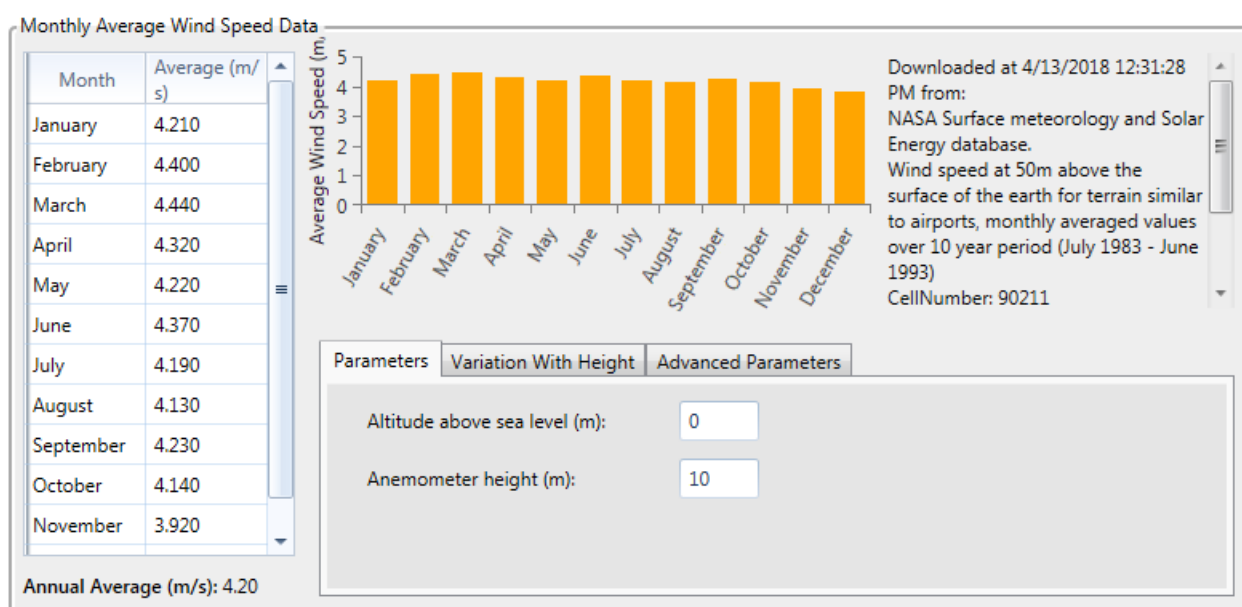


Figure 14: Monthly profile of wind speeds using NASA data



Hydro resource measurement

There are potential sources of hydro generation found in the village. Below are the two water bodies that are found in Nakasengere (Figure 15). However, these do not have enough potential to generate enough electricity from the initial assessments.



Figure 15: River Lusaba in Nakasengere village

Biomass resource measurement

The residents of Nakasengere predominantly grow maize, coffee, and matooke. This is for the purpose of both own consumption and for sale. Basing on information from the village locals, it is assessed that the people of the village own 1,206 acres of land combined. The farmers are also found to be scattered and have enough volumes necessary to produce enough fuel for a possible gasifier technology. They are not organized in groups or associations for joint collection of produce. The village has no thick forests that could act as a source of biomass.

4. % of population connected to grid

There are five schools present in Nakasengere, 3 primary schools and 2 pre-schools all of which have no access to electricity, except for a few stand-alone home systems. The area is not so heavily populated; the lighter the shade the less populated the area; however, the residents tend to build along the established road network and are mainly concentrated there. Notably, most of the facilities are small in size, semi structured housing with plastered walls and iron sheets on the roof.

Village 2: Kayanzi

1. Location



A background information on prospective villages

Kayanzi fishing village is located in Kichwamba subcounty in Kasese district, western Uganda. The location coordinates of the village are (Latitude -0.0917 and longitude 29.7633). The fishing village is located near the shores of Lake Edward (Figure 16) and is only 10 km off the Kasese-Bushenyi highway in the Queen Elizabeth national park. The climate around the village is tropical with an average temperature of 28°C all year round. The precipitation is about 4436 mm. There is no direct access road to the village and therefore it is not possible to visit the village without a guide to show the small paths and farms to find the village. Also, the locals also need help from the locals to find the right way to the village.

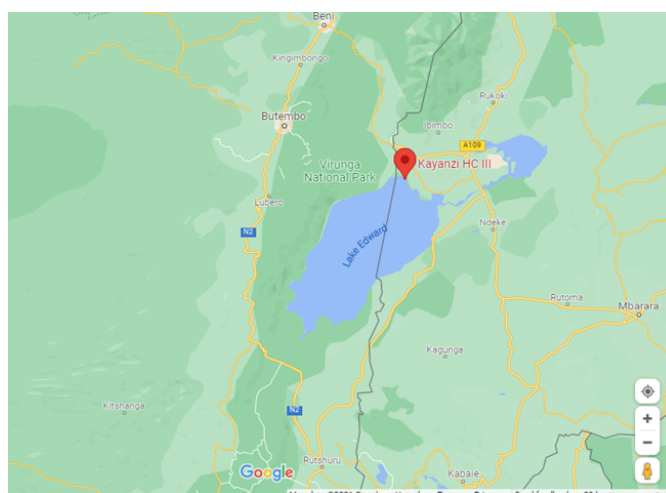


Figure 16: Satellite map of Kayanzi fishing village (highlighted in red)

2. Population/population density

The village has one primary school – Kayanzi Primary School (Figure 17), a small resort hotel and local video halls. The village has a population of about 1,341 people with a total of 320 households.



Figure 17: Kayanzi Primary School

3. Potential renewable energy sources



Solar PV resource

From the yearly weather measurements extracted for 2019 for the solar PV resource, it is noted that the village receives the highest insolation in the months of March and August. The lowest insolation is recorded between the months of November to January as shown in the Figure 18.

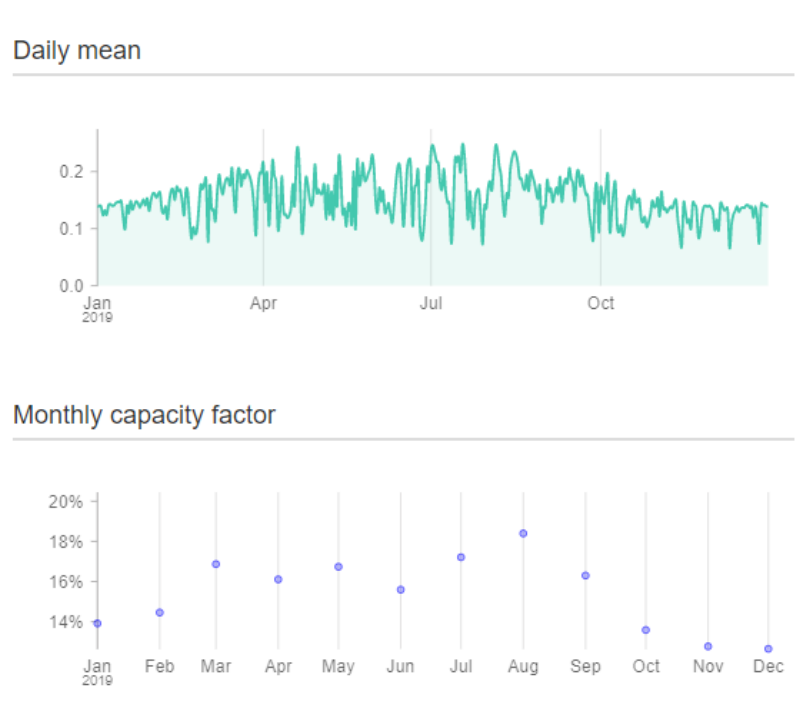


Figure 18: Monthly solar radiation received at Kayanzi

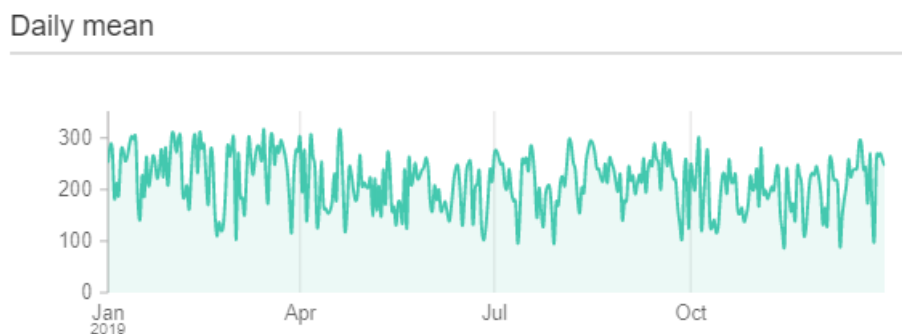


Figure 19: Ground level monthly solar radiation received at Kayanzi in W/m2

Overall, as observed in Figure 19 above, the village has a rich solar energy resource all year round. Previously, there have been plans to set up a solar PV mini grid to enable electrification of some of the households in the village. In this project, we aim to come up with a (pre-) feasibility study for potential investors.



A background information on prospective villages

Wind Resource

The wind resource data at the village extracted for the year 2019 shows that there are intermittent wind speeds all year round. The highest wind speeds are recorded in May with the lowest in the month on June.

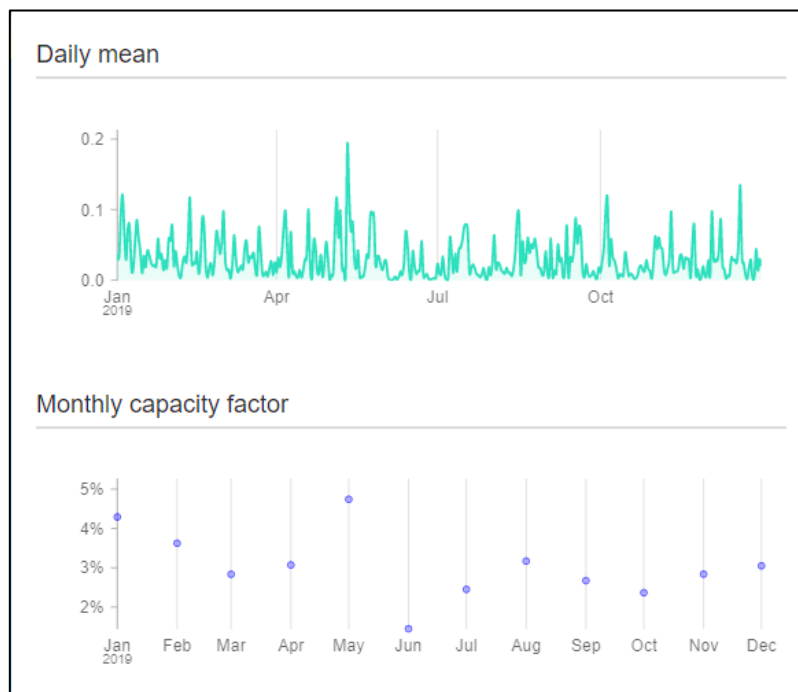


Figure 20: Monthly wind resource received at Kayanzi

Biomass resources

The village has a rich biomass resource comprising of bushes, gullies and trees. Also, the local villagers are mainly cattle keepers. These are potential sources of biomass for energy generation.

4. % of population connected to grid

Without access to electricity from the national grid, at night, the village lies in total darkness. The main economic activity in the village is fishing as it lies on the shoreline of the nearby freshwater Lake Edward.

Village 3: Wanale

1. Location

Wanale village is located in Mbale district, Eastern Uganda with the location coordinates as - latitude 1.07351 and longitude 34.2253 (Figure 21). The district lies approximately 225 km by road northeast of Kampala city.



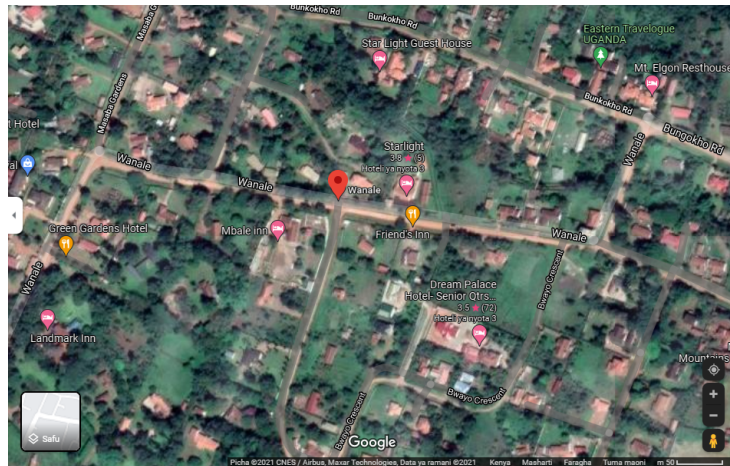


Figure 21: Satellite map of Wanale village (Source: Google Earth)

2. Population/population density

According to the national population and housing census (UBOS, 2014), the total population of Wanale subcounty (division) was estimated at 13,261 people. It is estimated that the village has about 800 households. Wanale trading center is 15 km east of Mbale city on the southern foothills of Mountain Elgon. Traveling from Mbale city center takes about 30 minutes by road to Wanale village. In comparison to most rural areas in Uganda, the community members of Wanale practice subsistence farming. The major crops grown are coffee, maize, matooke (bananas), fruits, onions, tomatoes, and carrots.

3. Potential renewable energy sources

Hydropower resource

The community of Wanale has recognized the potential for generation of hydro-electric power on the nearby Wanale River water falls (Figure 22) that lead into Wanale River. Previous site feasibility studies by Micro Power Group Uganda Limited estimated a design flow rate of 20 l/s at 50 meters head. Thus, it was recommended from the study for installation of a pelton turbine to provide electric power of 4.4 kW at 50% efficiency.



Figure 22: Nearby Wanale Ridge water falls (Uganda Tourism Centre, 2021)

Solar Energy Resource

The region has good solar resources. From the data extracted for the year 2019, Wanale region received the highest insolation in the months of January to April and September to December (Figure 23). The lowest insolation was received in the months of May to July which is normally the rainy season. According to NASA, 2020, on average, the area receives an average solar irradiation of 5 kWh/m²/month with a maximum of over 6.5 kWh/m²/month. Thus, the solar potential the area demonstrates the need for installation of solar PV facilities in the village to meet the energy needs of the community.

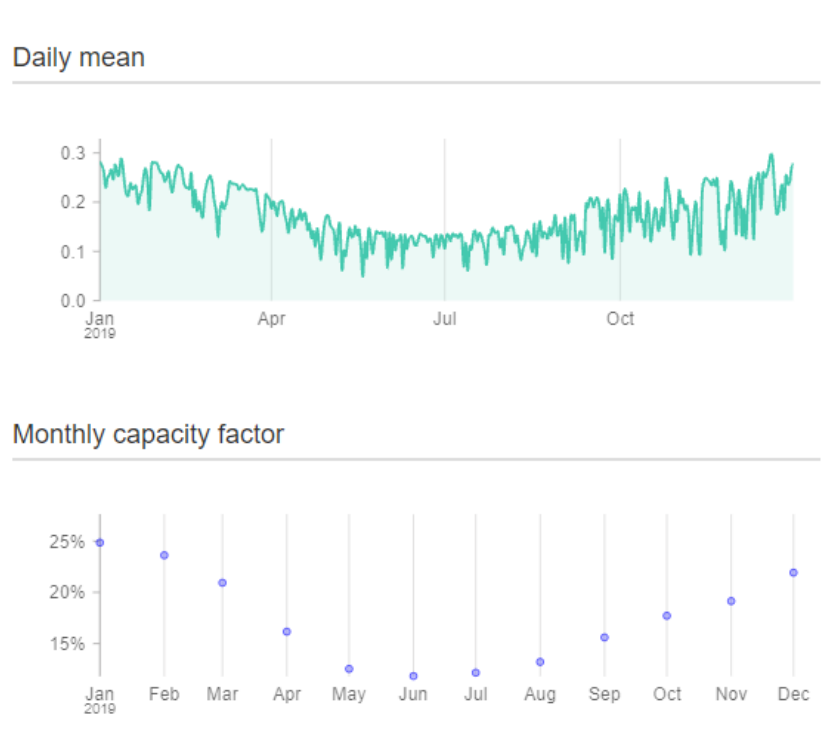


Figure 23: Ground level monthly solar radiation received at Wanale in W/m²

Wind Resource

The wind resource data (daily mean in m/s and capacity factor) at the village extracted for the year 2019 shows that there are intermittent wind speeds all year round. The highest wind speeds are recorded in the months of January to April with the lowest in the months from April to November (Figure 24).

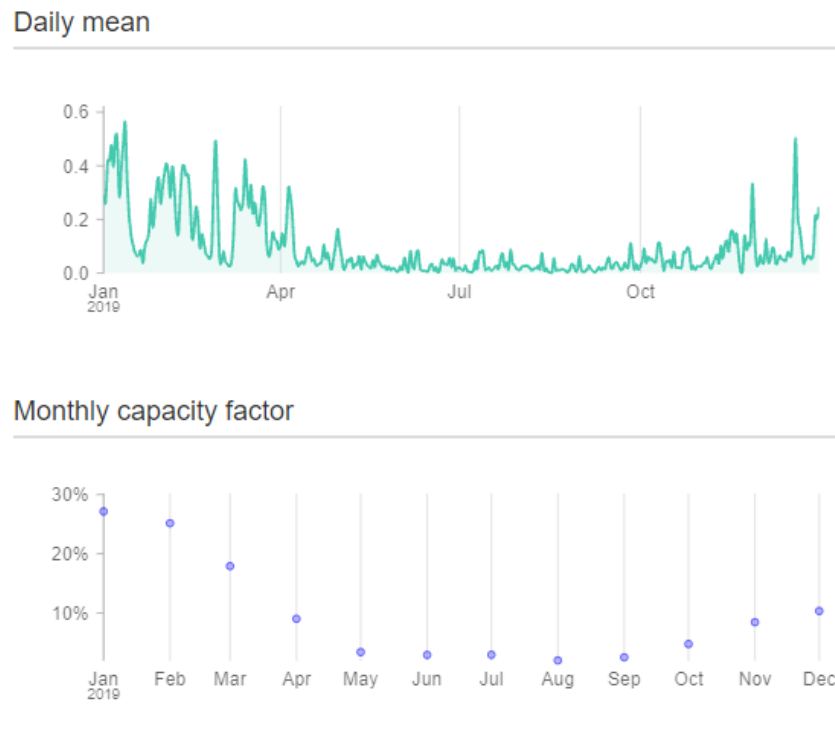


Figure 24: Monthly wind resource received at Wanale (source: Renewables ninja)

Biomass resources

Since the villagers are mainly subsistence farmers, there is generation of biomass resources in the form of crop residues and biomass wastes for energy generation.

4. Current energy sources

The main energy sources are based on traditional fuel wood and charcoal for cooking, candles and kerosene lamps for lighting, and batteries for powering small electrical appliances like radios, mobile phone charging, and television sets.

5. % of population connected to grid

Presently, the nearest electricity grid point is about 5 km away. With the steep terrain of the area, grid extension to the community is a challenge and hence the need to harness alternative sustainable energy solutions for the community.

Village 4: Maziba Murole

1. Location

Maziba Murole village is located in Maziba parish in Mpigi town council, Mawokota county in Mpigi district in central Uganda. The location coordinates are latitude 0.2236 and longitude 32.3460.

2. Population/population density

The parish has a population of 4,500 people in about 1,000 households. The village lies approximately 39.7 km by road, south west of Kampala city towards Masaka city (Figure 25). The majority of the residents are engaged in subsistence farming and small and medium economic activities. Farmers in the area grow crops such as cotton, bananas, cassava, sweet potato, maize, beans, coffee, tomatoes, vegetable, passion fruits, cabbages, and avocado (**UBOS, 2014**).

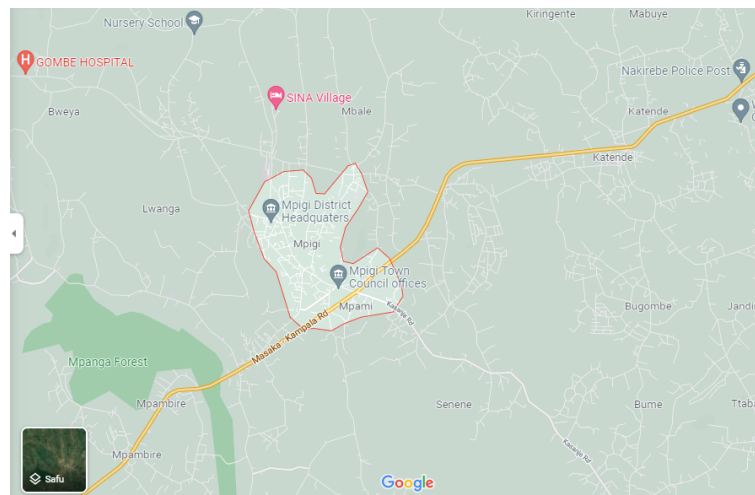


Figure 25: Satellite map showing the location of Maziba Murole village in Mpigi Town Council (Source: Google Earth)

3. Potential renewable energy sources

Renewable Energy Resources

The area received two modes of rainfall, firstly in the early part of the year between March and May and the second one in the last quarter of the year between September and November. On average, the precipitation is about 1320 mm. There is an average annual maximum ambient temperature between 22.5 to 27 °C. The average humidity in the nearby forested areas is 80% to 95%. With the area being located along the equator, this guarantees that it receives some of the highest solar irradiation values throughout the year hence the area climate is mainly warm, muggy, and overcast. This shows the rich and stable annual solar energy resource potential of the area (Figure 26). In regard



A background information on prospective villages

to the biomass resources, the residents of Maziba are predominantly farmers who grow crops for the purpose of both own consumption and for sale. There are also nearby forested areas of Mpanga (Figure 25), Buwama that are a potential source of biomass that could be harnessed for energy generation. The area experiences intermittent wind energy regimes (Figure 27) all year round are making it uneconomical for installation of wind energy resource extraction equipment.

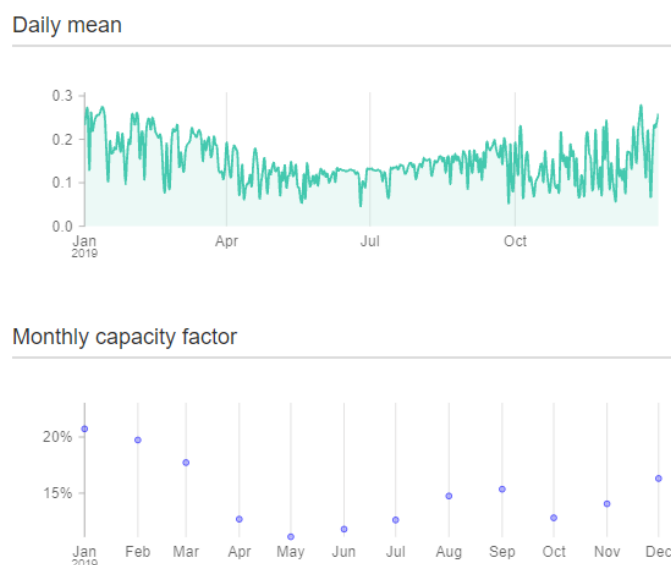


Figure 26: Ground level monthly solar radiation received at Wanale in W/m²

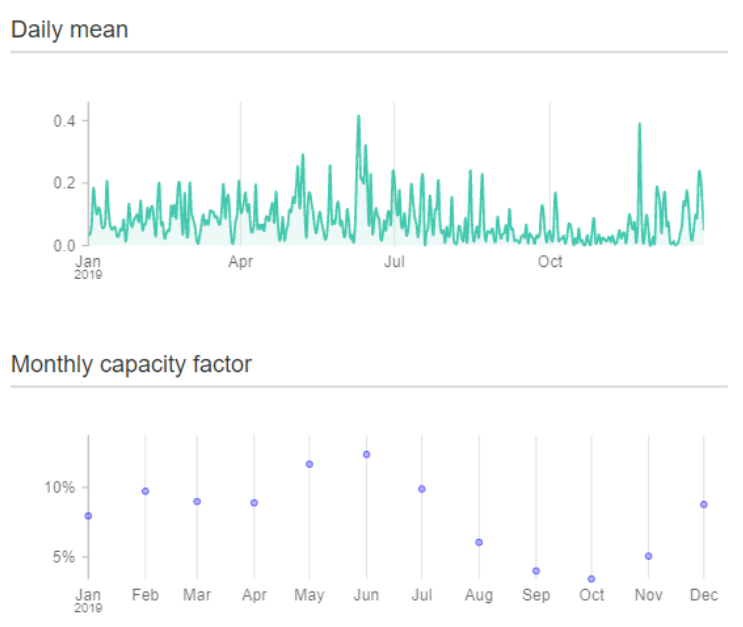


Figure 27: Monthly wind resource received at Maziba, Mpigi Town Council

4. Current energy sources

The major energy sources are biomass in the form of charcoal and firewood for cooking.



Table 2: Summary information about the villages in Uganda

	Village	Type	Objective	Size	RES
1	Nakasengere Latitude: 0.6977720; Longitude: 31.9380530	Rural	Optimize the planning of isolated renewable energy systems for increased rural electrification	1500	Solar PV, Wind Small hydro, Biomass
2	Kayanzi fishing village Latitude - 0.0917 longitude 29.7633	Off grid area	To provide off-grid solutions to increase access to renewable and clean energy as well as its efficiency and supply	1400	Solar PV, Wind Small hydro Biomass
3	Wanale village Latitude 1.07351 Longitude 34.2253	Rural	Promote use/application of mini-grids for rural electrification	800	Solar PV, Wind Small hydro Biomass
4	Maziba Murole village Latitude 0.2236 Longitude 32.3460	Rural	Promote use/application of mini grids for rural electrification	1000	Solar PV, Wind Small hydro

Selected Villages in Botswana

Village 1: School -Regent Hill International School in Gaborone

1. Location





A background information on prospective villages

Regent Hill International High school is located in Gaborone, the capital city of Botswana (**Statistics Botswana, 2020**). It is located at 24°39'33"S and 25°51'50"E in Block 9 of Gaborone.

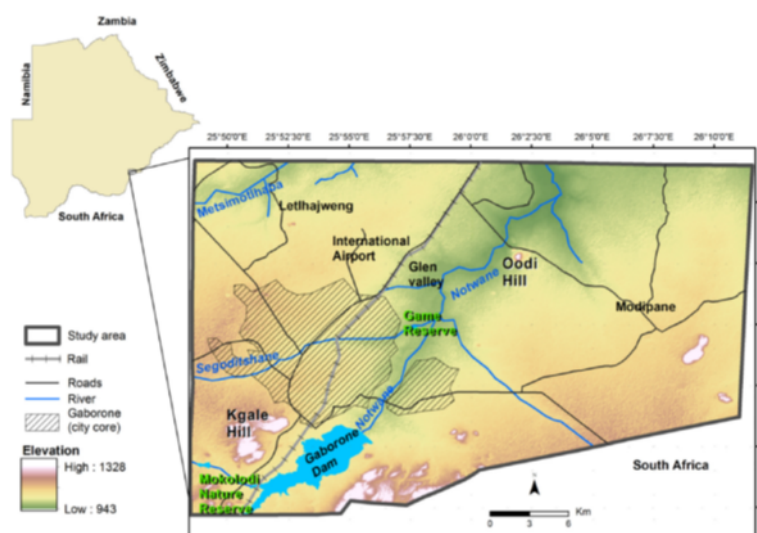


Figure 28: Gaborone region in the South-East district of Botswana (Akinyemi, Ikanyeng, & Muro, 2019)

2. Population/population density

The village is a school campus, which is host for the pre-primary, primary and secondary school classrooms and facilities. The village has a population of about 2,560 people. The school is a day school (open from 7:30 to 16:30 during the week).

3. Potential renewable energy sources

Despite the fact that solar energy is the main sources in Botswana, there is also an opportunity to combine with wind energy and bio mass source in future. That would provide energy supply to the school campus 24/7 all year long with minimal costs for battery storage and would create different business model to generate income for the





school. A solar thermal installation could also be additional sustainable renewable energy source.

4. Current energy sources

The school has access to electricity from the national grid. However, this is Botswana first Grid Tied solar photovoltaic (PV) school. The PV system was installed recently in June 2021 a few months after the LEAP-RE project was started. The school has been accepted in the Pilot Botswana Power Corporation/Power Africa Roof Top Solar program which will enable them to export over production of clean energy into the grid (IRENA, 2021). The installation size is 39 kWp (Figure 29).



Figure 29: PV installation at Regent Hill International School in Gaborone

5. % of population connected to grid

The school has access to electricity from the national grid. Hence, it is 100% grid connected. However, the recently installed 39kWp PV system aims to produce 100% of the electricity by renewable energy sources.

Village 2: Jamataka

1. Location

Jamataka village is located near Francistown, Central district. It is located at $21^{\circ}05'39''S$ and $27^{\circ}09'06''E$ (Figure 30).



Figure 30: Jamataka village in the Central district of Botswana (Source: google earth (left) and African Sun energy (right))

2. Population/population density

The village has a population of about 1,084 people. Jamataka is sparsely populated with roughly 50 people per square kilometre.

3. Potential renewable energy sources

When looking at the annual sunshine hours map of the world, Botswana's annual sunshine duration is estimated at around 3,000 hours and the average total solar radiation is 21 MJ/m²/day, which is approximately 2,100 kWh/m²/yr (**BERA, 2021**). A solar PV installation is planned in Q4 2021 together with an innovative battery exchange scheme. Biomass is also an energy resource that is available.

4. Current energy sources

Many households still using firewood as main energy source. A small portion of the villagers using gas bottles for cooking.

5. % of population connected to grid

Jamataka is a rural village which was recently connected to the grid in May 2021 by Botswana Power Cooperation (BPC). However, most of the houses are off-grid because of the huge cost to connect the house to the grid on the last mile. That cost need to be paid by the customers.

Village 3: Majwanaadipitse

1. Location

Majwanaadipitse village is located near Serowe, Central district. It is located approximately 70 kilometre north of Palapye. The GPS coordinates are Latitude 22°06'30''S and Longitude 26°52'59''E (Figure 31).



Figure 31: Districts of Botswana and the location of Majwanaadipitse village in the Central district of Botswana (Source: wikipedia (left), google earth(right))

2. Population/population density

The village is sparsely populated and has a population of about 400-500 people.

3. Potential renewable energy sources

Solar energy resource is the preferable renewable energy source for that region, which is available the whole year. The measured annual solar data for Majwanaadipitse village are 2267.4 kWh/m² (direct normal irradiation), 2092.5 kWh/m² (global horizontal irradiation), 626.kWh/m² (diffuse horizontal irradiation). The optimum tilt for a PV module is 25° and the global irradiation at the optimum tilt is 2279.1 kWh/m². A second renewable energy source can be wind energy. The annual average wind speed is 6.55 m/s at 100 m elevation. Thick bush surrounding the village as potential biomass source.

4. Current energy sources

The households using firewood as main energy source. A small portion of the villagers use gas bottles for cooking.

5. % of population connected to grid

The rural village is located in an off-grid area.

Village 4: Senyati Lodge/Campsite

1. Location

The Senyati safari camp is located in the northern part of Botswana, Chobe district. It is 15 km far from Kasane. The GPS coordinates are 17°52'33"S and 25°14'17"E (Figure 32).

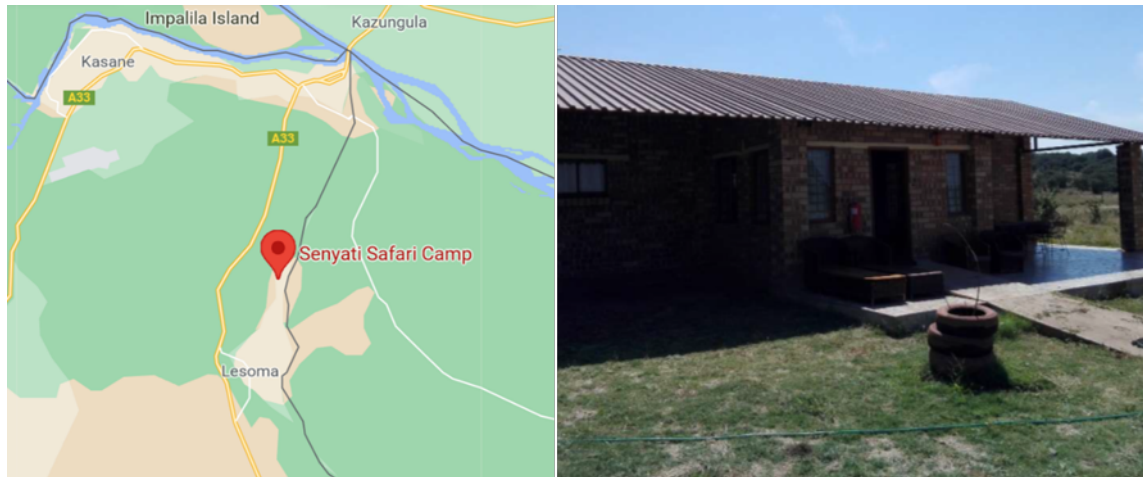


Figure 32: Senyati Safari Camp near Kasane close to the Zambian border (Source: google earth and own image)

2. Population/population density

The village is sparsely populated and has a population of about 50-100 people.

3. Potential renewable energy sources

Solar energy resource is the preferable renewable energy source for that region, A second renewable energy source can be wind energy followed by thorn bush as a potential biomass source. Solar thermal energy source could be used to generate hot water from renewable energy source.

4. Current energy sources

The Camp site has access to electricity from the national grid. Also portion gas bottles are available for cooking.

5. % of population connected to grid

The camp site is 100% connected to the national grid.

Village 5: Matsaudi Learning Centre

1. Location

The Matsaudi village is located in the near Maun, Ngamiland. It is 40 km far from Maun. The GPS coordinates are 19°50'58''S and 23°35'45''E (Figure 33).



Figure 33: Location of the Matsaudi Learning Centre (Source: google earth)

2. Population/population density

The village is sparsely populated and has a population of about 100-200 people.



Figure 34: Matsaudi Learning Centre

3. Potential renewable energy sources

Solar energy resource is the preferable renewable energy source for that region, A second renewable energy source can be wind energy followed by thorn bush as a potential biomass source. Solar thermal energy source could be used to generate hot water from renewable energy source.

4. Current energy sources

The learning centre uses firewood as main energy source

5. % of population connected to grid

The rural village is located in an off-grid area.

Table 3: Summary information about the villages in Botswana

	Village	Type	Objective	Size	RES
1	Regent Hill	School area; it	Exploiting the Solar	2500-	Solar



	International School, Gaborone	is grid connected	Energy efficiency and sufficiency and possible commercialization scenarios for excess electricity	2600	Wind Biomass
2	Jamataka Village	Rural grid connected with only a few households on grid, mainly off-grid households	Establish community DESCO (energy service company) Look to diversify the energy mix Develop community based business utilizing their new energy sources	1000-1100	Solar Biomass Battery exchange scheme
3	Majwanaadipitse village	Off-grid rural area	Exploiting the added value of combining biomass to Solar Energy efficiency and sufficiency	400-500	Solar Wind Biomass
4	Senyati Safari Camp	On grid	Exploiting the added value of combining biomass to Solar Energy efficiency and sufficiency	50-100	Solar Wind Biomass
5	Matsaudi Learning Centre	Off-grid area	Exploiting the solar energy efficiency and sufficiency grid village	100-200	Solar Wind Biomass

Selected Villages in Ethiopia

Village 1: AASTU University Campus, Addis Ababa

1. Location

AASTU village is located at Addis Ababa Science and Technology University in Addis Ababa, the capital city of Ethiopia. It is located at 38.7578°E and 8.9806°N (Mohamed, Worku, & Lika, 2020).

2. Population and population density

The population and population density of the city are estimated to be about 5 million and the population density approximately 10,000 people per square kilometer (Seifu &





A background information on prospective villages

Stellmacher, 2021). The exact location of this energy village is at AASTU campus in Addis Ababa having 4,000 university community.

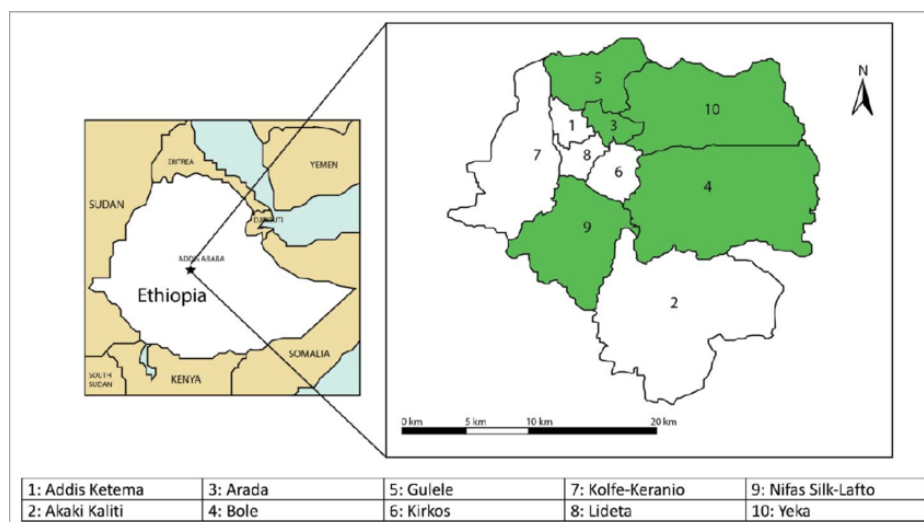


Figure 35: Location of Addis Ababa and the energy village (Dessi, Gari, Mihret, Desta, & Mehari, 2021)



Figure 36: Sustainable energy centre of AASTU

3. Current energy sources

The main energy sources in the city are electricity, fuelwood, charcoal dung and the like (Asfwa, 2012; Gamtessa, 2003; Mondal, Bryan, Ringler, Mekonnen, & Rosegrant, 2018). The electricity is used mainly for lighting and fuelwood is used for baking of injera. In some uncertain times, when power is intermittent, charcoal is at the residents' disposal (Gamtessa, 2003).

4. Potential of Renewable energy





A background information on prospective villages

Ethiopia, by extension Addis Ababa, is found in the tropical part of the world. Therefore, it is believed that there is untapped solar energy resource across the region. On top of that, wind energy, inter alia, is one that need to be exploited yet the more.

5. % of population connected to the grid

Most of the households in the city are grid connected, according to some researches, 80% of the power supply is from the national grid (Meles, 2020).

Village 2: Wonji Sugar factory Village, Wonji

1. Location

Wonji sugar factory is located some 100 km east of the capital city of Ethiopia, Addis Ababa. The factory is specifically 10 km off the Adam city in Oromia region state.



Figure 37: Wonji sugar factory location (Google map)

2. Population and population density

The population of the villages is about 1500.

3. Current energy sources

Large portion of the households use firewood as energy source. Others are using electricity generated from the Adam wind farm and/ or hydropower plants. In the event of good crashing seasons, residents near-by may get power generated from bagasse.

4. Potential of Renewable energy sources

Wind energy, which the village is famous for, is the latent resource untapped year in year out (Tiruye, Beshu, Mekonnen, Benti, Gebreselsie, & Tufa, 2021). Solar energy is not an exception here too owing to the tropical location of the region. Furthermore, bagasse, the by-product of the sugar factory, is supposed to be the potential resource in



A background information on prospective villages

the envisioned village. Yet, bioethanol would be one source of energy in this particular village (Benka-Coker, Tadele, Milano, Getaneh, & Stokes, 2018).

5. % of population connected to the grid

The population connected to the national grid is roughly estimated to be 27 % (Gebrehiwot, Mondal, Ringler, & Gebremeskel, 2019; Gebremeskel, Ahlgren, & Beyene, 2021).

Village 3: Amibera Mobile Village in Afar

1. Location

Households of this village, more often than not, don't have a particular location to reside permanently. Rather they move and relocate their temporal houses according the season and as an effort to feed their livestock.

2. Population and population density

The exact population size of the village is hardly known. Nevertheless, it is estimated to be 200 if less, and 300 if more (Teka, Temesgen Woldu, & Fre, 2019).



Figure 38: Amibera village, Afar (Google map)

2. Current energy sources

Since the residents are mobile, it seems hard to supply power in any form hitherto. The main sources of household cooking energy are firewood and charcoal. Majority of the population use kerosene for lighting. Biomass, animal dung in particular, is also a daily consumable (Teka, Temesgen Woldu, & Fre, 2019).

3. Potential of renewable energy

Solar, wind and biomass are the main resources in the area. The village is known for its solar and wind potential resources due the fact that the region is located in the equator





A background information on prospective villages

(Wassie & Adaramola, 2020). It is assumed that the village is exposed to solar energy for all, if not most, of the year. Biomass also accounts for large share in the area.

4. % of population connected to the grid

The village is total off-grid as of today. As it stands now, the residents have a long way to go to get electricity.

Village 4: Langano, Ziway

1. Location

Langano, is one of the most popular tourist destination in Ethiopia, is located in the Southern part of the country.

2. Population and population density

The population of the village varies from season to season based on the favourable conditions to tourists and local visitors. A 100 to 150 people are estimated to live in this area though (Tilahun & Alhgren, 2010).

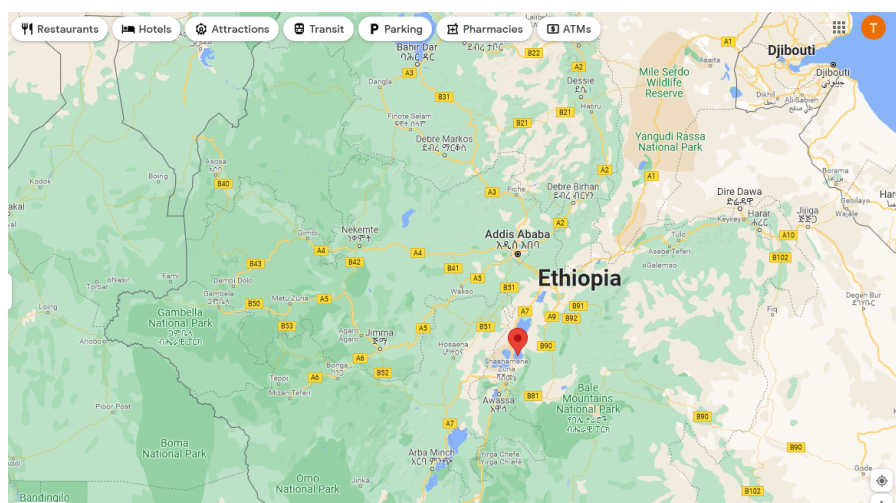


Figure 39: Location of Langano lake (Google map)

3. Current energy sources

The energy source of the village is partly from firewood and partly from Aluto geothermal power station.

4. Potential of renewable energy

Langano village is located alongside of the Great Rift Valley. For this apparent reason, the village is assumed to have a huge geothermal energy. There are pilot scale researches that are underway in the area to tap this potential resource and there is a promising





A background information on prospective villages

lead. Solar and wind energy resources are also availed renewable energy sources that are expected no less.

5. % of population connected to the grid

Some 30 % the population, mostly in the resorts, is believed to have been using electricity from the Aluto geothermal power station and/or national grid.

Village 5: Tulefa village in Debre-birhan

1. Location

The village found in North-east of Addis Ababa near the ancient city of Debre-birhan in Amhara regional state.

2. Population and population density

The village is less populated having 250-300 people in the small area. Some households are densely populated and some are scattered.



Figure 40: Location of Tegulet village (Google map)

3. Current energy sources

This village is located in the outskirts of the Debre-birhan city and it is totally off-grid. Firewood and biomass have always been the main energy sources for each household.

4. Potential of renewable energy sources

Biomass, wind and solar, necessarily in that order, are energy resources that abundantly available in the village.

5. % of population connected to the grid

Thus far, the village is not connected to the national grid.



Table 4: Summary information about the villages in Ethiopia

	Village	Type	Objective	Size	RES
1	AASTU, Addis Ababa 38.7578°E and 8.9806°N	urban	Energy efficiency	4000	Solar, wind Biogas
2	Wonji Sugar Factory 8° 28' 30.32" N 39° 16' 24.2409" E	Semi-urban	Exploiting biomass and bioethanol	1500	Bagasse, biomass
3	Amibera, Afar (9.75 N, 40.34 E)	Rural	Exploiting biomass, solar and wind	200-300	Solar Wind biomass Waste
4	Langano, Ziway (7°35'59.99"N 38°42'59.99" E)	Semi-urban	Utilization of geothermal	100-150	Geothermal
5	Tegulet, Debre-birhan (9°40'46.34" N 39°31'57.43" E)	Rural	Exploitation of solar and small hydro for energy sufficiency	250-300	Biomass Small hydro

Conclusion

The partners provided background information on demo villages in their countries in Africa. The villages were selected based on a criterion that allows for comparison among villages across the countries. A summary of the selected villages across the partner countries is tabled below.

Table 5: On-grid villages selected

Type of village –	Population size	Number of	Country
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On-grid		same type	
Village	1000-2600	2	KE, UG
Recreational facility	50-100	1	BOT
University/School	3000	3	ETH, KE, BOT
Industry	1500	2	ETH, KE

KE-Kenya, BOT-Botswana, ETH-Ethiopia, UG-Uganda

Table 6: Off-grid villages selected

Type of village – Off-grid	Population size	Number of same type	Country
School	100-200	1	BOT
Village	100-200	2	ETH, KE
Village	200-500	3	BOT, ETH, ETH
Village	1000-1500	5	BOT, UG, KE,

KE-Kenya, BOT-Botswana, ETH-Ethiopia, UG-Uganda

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[Use the APA citation style – see <https://www.library.cornell.edu/research/citation/apa> for details]

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