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Four studies on the technical and socio-economic potentials and challenges of the identified demo villages

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Summary

The objective of task 14.3 which is reported in this deliverable was to determine the technical and socio-economic potentials and challenges arising from selected demo energy villages in Africa. Four Energy Villages, one in each country were selected and their technical, social, and economic potentials have been assessed. These energy villages are: Cheboiywo village (Kenya), Majwanaadipitse village (Botswana), Tulefa village (Ethiopia) and Bidibidi refugee settlement (Uganda). It was observed that in all these villages, the residents relied on firewood and other non-renewable energy sources. Data collection from the villages regarding potential renewable sources indicated a strong potential for biogas from agricultural wastes (plant and animal wastes) and solar energy. The integration of renewable energy in the selected villages unfolds a spectrum of socio-economic possibilities, creating a transformative impact on the local community. These include increases access to affordable and sustainable energy; educational enrichment through extended study opportunities; job creation and entrepreneurial ventures; enhanced agricultural practices and agro-processing opportunities; community empowerment through skills development and environmental sustainability through reduced negative environmental impact. There have been several challenges noticed in these demo villages and other potential energy villages. The most important across all energy villages can be generalized in to four major challenges that are: 1) Difficulty in establishing contact and getting accurate data for modelling. 2) Lack of financial means, loan and insurances for renewable energy technologies. 3) Educational training is needed to understand, run and maintain renewable energy technology. Moreover, 4) Overcome fear and resistance to change to new renewable energy technologies. A way forward ideas raised and the main ideas were: 1) There is need for the community to understand and accept the energy village concept. 2) Meteorological and other renewable energy resource data needed to be available for researchers. 3) There is a need for the availability of appropriate financial means, loan, insurance and investments. Moreover, 4) Close working relationship between government agencies and the local community is important and needed.

Approval

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Four Studies on the Technical and Socio-Economic Potentials and Challenges of the Identified Demo Villages

as a deliverable for WP14

Final version

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Abbreviations and Acronyms

Acronym	Description
WP	Work Package
RE	Renewable Energy
RES	Renewable Energy Sources
RERS	Renewable Energy Resources
SDG	Sustainable Development Goal
CRGE	Climate Resilient Green Economy
GoE	Government of Ethiopia
GHG	Greenhouse Gases
AASTU	Addis Ababa Science and Technology University
BIUST	Botswana International University of Science and Technology
MU	Moi University
MaK	Makerere University
UVA	University of Vaasa

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Summary

The objective of task 14.3 which is reported in this deliverable was to determine the technical and socio-economic potentials and challenges arising from selected demo energy villages in Africa. Four Energy Villages, one in each country were selected and their technical, social, and economic potentials have been assessed. These energy villages are: Cheboiywo village (Kenya), Majwanaadipitse village (Botswana), Tulefa village (Ethiopia) and Bidibidi refugee settlement (Uganda). It was observed that in all these villages, the residents relied on firewood and other non-renewable energy sources. Data collection from the villages regarding potential renewable sources indicated a strong potential for biogas from agricultural wastes (plant and animal wastes) and solar energy. The integration of renewable energy in the selected villages unfolds a spectrum of socio-economic possibilities, creating a transformative impact on the local community. These include increases access to affordable and sustainable energy; educational enrichment through extended study opportunities; job creation and entrepreneurial ventures; enhanced agricultural practices and agro-processing opportunities; community empowerment through skills development and environmental sustainability through reduced negative environmental impact.

There have been several challenges noticed in these demo villages and other potential energy villages. The most important across all energy villages can be generalized in to four major challenges that are: 1) Difficulty in establishing contact and getting accurate data for modelling. 2) Lack of financial means, loan and insurances for renewable energy technologies. 3) Educational training is needed to understand, run and maintain renewable energy technology. Moreover, 4) Overcome fear and resistance to change to new renewable energy technologies. A way forward ideas raised and the main ideas were: 1) There is need for the community to understand and accept the energy village concept. 2) Meteorological and other renewable energy resource data needed to be available for researchers. 3) There is a need for the availability of appropriate financial means, loan, insurance and investments. Moreover, 4) Close working relationship between government agencies and the local community is important and needed.

Keywords

Energy Village Concept; Renewable energy; Energy consumption and potential; Technical potentials; Socio-economic potentials; Challenges

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1. Introduction

Transitioning the current fossil fuel-intensive energy system towards one that is cleaner is a major topic of discussion. Through the increased adoption of renewable energy, increased energy efficiency and conservation, this can be realized. Achieving this transformation will bring deep structural changes to societies and economies and contribute to sustainable development. 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 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.

Energy is the backbone of socio-economic development and governments in Africa, particularly in Ethiopia, Botswana, Uganda and Kenya have put in place mechanisms to increase availability and access to energy. In WP14, the partners identified potential energy villages in the various countries and collected data regarding the current sources of energy, current energy needs and potential of renewable energy sources to fill the demand-supply gaps. In this report, we present an analysis of the technical, social, and economic potential of the EV concept as applied in the selected villages in the partner countries. The studying Universities are AASTU in Ethiopia, BIUST in Botswana, Makerere University in Uganda, and Moi University in Kenya. The energy villages for which extensive energy potential, consumption and demand and social-economic potential have been studied are listed in Table 1. There are four Energy Villages, one in each country for which technical, social, and economic potential have been assessed.

Table 2. List of energy villages in Africa chosen.

S/N	Energy village	Country
1	Cheboiywo	Kenya
2	Majwanaadipitse	Botswana
3	Tulefa	Ethiopia
4	Bidibidi refugee settlement	Uganda

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2. The Cheboiywo Energy Village in Kenya

2.1. The chosen demo village in Kenya

The Cheboiywo Village is in Tulwet ward, Kesses sub-county, Uasin Gishu county in Kenya. The population density of Tulwet ward is 241 persons/sq.km (Kimani, 2021). Information on the population of villages within the ward, however, has not been published. Most households in Chebaiwo depend on firewood and a few on charcoal for cooking (Fig 1). Majority of them use electricity for lighting and very few use kerosene and solar (Kimutai, Kiprop, & Snelder, 2019). 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. Approximately, 48% of households in rural areas of Kesses Sub County get their power supply from the national grid (Kiprop, Matsui, & Maundu, 2019).

The socio-demographic characteristic of the residents of this village were identified. About 55% of the respondents were female and 45% male. Three quarters of the respondents fell within an age bracket of 21–49 years old. Only 5% of the respondents had no formal education and 60% had at least attained high school education. Regarding the household size, 60% had six or fewer persons. 15% of the respondents had permanent employment; 55% were self-employed, and 20% were unemployed.

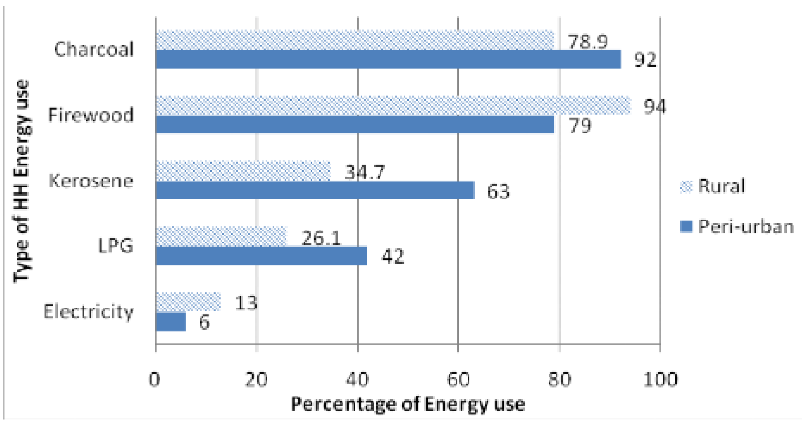

Figure 1. Energy utilization for cooking in Uasin Gishu (Kimutai, Kiprop, & Snelder, 2019).

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2.2. Technical potentials of the model village in Kenya

95% of the households in Cheboiywo depend on firewood and 5% use biogas for cooking. 85% use electricity from the grid for lighting and 5% use kerosene and 10% use solar. The energy potential of different substrates used for biogas production was determined as shown in Table 2.

Table 2. The energy potential of different substrates used for biogas production.

Biomass sources	Estimated Quantities	Calorific value kCal/kg	Total Energy in kCal	Quantity (m^3) of Biogas in 1 kg	Possible Biogas (m^3)	Equivalent electricity, KWh
Cow dung	495.0	4,199.0	2,078,505.0	0.036	17.820	160.38
Kitchen waste (Food waste)	17.0	2,091.3	35,552.1	0.03	0.510	4.59
Agricultural waste (Maize waste)	12.0	4,225.6	50,707.2	0.02	0.240	2.16
Market waste (Fruits +vegetable)	2.0	3,286.0	6,572.0	0.031	0.062	0.56

2.3. The socio-economic potentials of the Cheboiywo village

The integration of renewable energy in Cheboiywo Village, Moi University, unfolds a spectrum of socio-economic possibilities, creating a transformative impact on the local community:

1. Access to Sustainable Energy:

    - Improved Health and Well-being: The adoption of renewable energy sources, such as solar or wind power, eliminates reliance on conventional, health-hazardous energy options like kerosene. This positively affects the community's health by minimizing indoor air pollution and associated respiratory issues.

    - Affordable Energy Access: Renewable energy provides a sustainable and cost-effective alternative, leading to reduced energy costs for households. The financial relief allows residents to allocate funds to other essential needs like education, healthcare, and entrepreneurial endeavours.

2. Educational Enrichment:

    - Extended Study Opportunities: Renewable energy facilitates longer study hours, especially in the evenings, enabling students to enhance their educational pursuits.

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This increased access to light positively impacts academic performance and educational outcomes for the village's youth.

- Technological Integration: The availability of renewable energy supports the integration of technology in education, providing students and educators with access to electronic devices, online resources, and information, thereby enriching the learning experience.

3. Job Creation and Entrepreneurial Ventures:

- Local Employment Opportunities: The implementation and maintenance of renewable energy infrastructure create employment opportunities within the community. Roles such as technicians, maintenance personnel, and support staff contribute to local economic development.

- Entrepreneurial Initiatives: Renewable energy opens avenues for entrepreneurial ventures, such as small-scale energy-related businesses and maintenance services. Community members can explore opportunities that align with the sustainable energy sector.

4. Enhanced Agricultural Practices:

- Sustainable Farming: Renewable energy can power irrigation systems, promoting sustainable farming practices. This innovation allows farmers to diversify crops, improve agricultural yields, and contribute to overall food security in Cheboiywo Village.

- Agro-Processing Opportunities: With a consistent and clean energy source, the village can engage in agro-processing activities, adding value to agricultural products. This not only boosts local economies but also expands market opportunities for the community's agricultural output.

5. Community Empowerment:

- Skill Development: The adoption of renewable energy technologies necessitates skill development programs, empowering community members with valuable technical expertise. These skills not only contribute to the success of the current project but also enhance employability in related fields.

- Participatory Decision-Making: The introduction of renewable energy involves the community in decision-making processes, fostering a sense of ownership and

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empowerment. Active community engagement ensures that the renewable energy initiatives align with the specific needs and aspirations of Cheboiywo Village.

6. Environmental Sustainability:

- Reduced Environmental Impact: Renewable energy reduces the environmental footprint of the village by relying on clean and sustainable sources. This aligns with global efforts to combat climate change and promotes a community-wide commitment to environmental stewardship.

- Preservation of Natural Resources: By decreasing dependence on non-renewable resources, renewable energy contributes to the conservation of natural resources. This aligns with sustainable development principles, promoting responsible resource management within the community.

In summary, the introduction of renewable energy in Cheboiywo Village, Moi University, signifies more than a mere energy transition. It signifies a positive force driving socio-economic progress, community empowerment, and environmental sustainability, laying the foundation for a resilient and thriving future for the residents of Cheboiywo village.

2.4. Challenges identified in Cheboiywo energy village

The following challenges were identified and will need to be addressed for the successful implementation of the EV concept:

1. Difficulty in establishing contact with potential villages and in bringing people together and discuss the project.

2. Vested interests in various stakeholders that require careful navigation and balance.

3. Mistrust arising from previous failed projects in the communities resulting in lack of interest.

4. Difficulty in getting accurate data for modelling. In most of the villages located in remote areas, most people do not even have a record of the quantities and costs of their energy sources.

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3. The Majwanaadipitse Energy Village in Botswana

3.1. The chosen demo village in Botswana

When looking at the five demo villages in Bowswana the most inspiring case is Majwanaadipitse. Thus, Majwanaadipitse village will serves as our model village in this deliverable. The village is a rural, off-grid community consisting of 500 villagers with a low income and high unemployment rate. The village has for example, tuck shops, a clinic and a primary school. Moreover, Botswana's villages have a village development committee (VDC) elected at the Kgotla. In Majwaanadipiste, most of the villagers only use firewood for cooking, candles and paraffin lamps for lighting at night and self-made PV set-ups with lead-acid batteries for charging mobile phones. There is 50 kWh solar PV mini-grid with storage that provides electricity only to the primary school and the staff houses. This off-grid solar power system is comprised of 150 x 300-Watt solar ground-mounted panels on a mounting structure 2 m above ground and a 4 x 40 kWh Lithium Iron Phosphate battery system (1 master, 3 slaves), inverters and solar charge controllers. The mini-grid renewable energy system is 60 kVA three-phase off-grid system. Moreover, the import restriction imposed by the government has cause serious shortage of food in the region although the villagers doing a lot of agriculture. We identified lack of a cooling system (refrigeration) for agriproducts.

To extend the selling time window for farmers and therefore for the improved income and revenue, innovative concepts and viable business models needed to be based on renewable energy sources. Another aspect is to underutilize an off-grid PV system at school to introduce further services for villagers, such as powering the VDC/Kgotla buildings. Another aspect is that the village is not connected to the North-South water carrier pipeline. The drinking water for the villagers come from a borehole drilled and operated by water utilities cooperation Botswana. The water supply is 100% powered by diesel generator. A water borehole is close to the PV-mini-grid. There is great potential to use the access energy, produced by the mini-gride, to replace the diesel generator with renewable energy source. Another option is to provide electrical energy for water utilities in Botswana. Looking at Figure 2, there is also a possibility to grow crops under the panel.

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Figure 2. Underutilized PV micro-grid with battery storage.

In summary, from all our meetings, the villages searching for support from the government and academia to help in establishing a sustainable socio-economic-driven income possibility. Because of the initiative of Botswana to boost local food/vegetable production, the community would like to develop their agricultural farming land of 1 ha, which is equipped with a drilled water borehole and a fence. Government programmes can help in supporting irrigation infrastructure (LIMID II programme).

3.2. Technical potentials of the model village in Botswana

The energy potential in Majwanaadipitse village is given by solar energy potential and biomass potential, respectively. Most of the villagers only use firewood for cooking, low-quality solar lamps as light at night and self-made PV set-ups with lead batteries for charging mobile phones. The clinic and the primary school as well as the staff house use electricity generated by 50 kWh microgrid. There is huge potential to develop additional renewable energy services to use the under-utilized 50 kW micro-grid efficiently. The battery storage is already at 100 % capacity 11 a.m. in the morning. Our survey reveals also huge potential of agricultural waste as well as invasive a thorn bush as biomass source. The village and each farming ground are cleared every year from invasive a thorn bush (see Figure 3).

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Figure 3. Invasive thorn bush potential (about 300-400 m3 every year).

3.3. The socio-economic potentials of the Majwanaadipitse village

Besides the extension of existing renewable energy installation, the integration of productive renewable energy sources in Majwanaadipitse Village enables a wide spectrum of socio-economic possibilities, creating a transformative impact on the local community:

1. Job Creation and Entrepreneurial Ventures:

   - Entrepreneurial Initiatives: Renewable energy opens a way to found a Distributed Energy Services Companies (DESCO) in villages to provide productive renewable energy services for energy and financial poor companies. Such as battery exchange service or services to run essential agricultural process in the agricultural value chain.
   - Local Employment Opportunities: The implementation and maintenance of renewable energy infrastructure create employment opportunities within the community. Roles such as technicians, maintenance personnel, and support staff contribute to local economic development.
   - Local business opportunities: Tuck shops providing cool services through replacing LPG gas refrigerators through renewable energy sources

2. Enhanced Agricultural Practices:

   - AgriSolar Farming: Renewable energy can be utilized to power irrigation systems or introduce the growth of crops under PV panels. Contribution to overall food security in Majwanaadipitse Village.
   - Cooling and Heating Environment: We realized that the villagers sell their farming products in a very short period due to the lack of cooling possibilities. Renewable

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energy sources can be used to increase income of farmers by extending the selling period of agricultural products through establishing cooling facilities. That will significantly increase the selling period of agricultural products. In addition, farmer can use solar head technologies to dry products.

3. Increasing Living standards:

- Affordable Energy Access: Battery exchange concepts can provide electricity to households.
- Access to Educational Knowledge: sustainable renewable energy access is the foundation enabling villagers to enhance their educational pursuits.
- Technological Integration: The availability of renewable energy is prerequisite for the integration of technology in education, providing villagers with access to electronic devices, online resources, and information.

4. Community Empowerment:

- Skill Development: The adoption of renewable energy technologies necessitates skill development programs, empowering community members with valuable technical expertise. As second important skill set are entrepreneur skills. Both can be achieved by the development of training and short courses for the villagers in Majwanaadipitse.
- Participatory Decision-Making: The introduction of proper decision-making processes is key to found and run DESCO in of Majwanaadipitse Village. This implies an active community engagement to make sure that the renewable energy initiatives align with the specific needs of Majwanaadipitse Village.

In summary, the implementation of productive renewable energy in Majwanaadipitse Village can support the green energy acceleration together with a sustainable socio-economic impact for the villagers Majwanaadipitse village.

3.4. Challenges identified in Majwanaadipitse village

Major challenges are the non-availability of resilient and affordable technological solutions and socio-economic factors that hamper the implementation of self-sustaining renewable energy systems in rural areas of Botswana. The poverty trap, generated by low income and high unemployment, in rural areas, is a further key reason for long cashback cycles in villages (Kumur, Prasad, Samikannu, 2018). Also, the lack of innovative investment strategies offered by the banking sector the access to investment is a major obstacle in

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Botswana. Loan products like microcredits and crowdfunding opportunities are of crucial importance to purchase renewable energy technologies for villagers with no equity capital. Based on several visits with stakeholders, another obstacle to social innovation in Botswana is the fear of changing from traditional cooking using firewood to renewable energy solutions.

In summary, the following challenges were identified and will need to be addressed for the successful implementation of the EV concept:

1. Difficulty in getting accurate data for modelling. In most of the villages located in remote areas, most people do not even have a record of the quantities and costs of their energy sources.

2. Lack of financial loan products for purchasing renewable energy technologies.

3. No insurances products are in place to minimize purchase risks for renewable energy technologies.

4. Educational training is need to run and maintain renewable energy technologies.

5. Overcome fears when applying new renewable energy technologies.

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4. The Tulefa Energy Village in Ethiopia

4.1. The chosen demo village in Ethiopia

Tulefa Energy Village, located approximately 65 kilometres from Addis Ababa, boasts a breath-taking landscape characterized by rolling hills and valleys. This region is blessed with abundant renewable energy resources, including solar, wind, and biomass, that remains largely untapped. Its proximity to the equator (9° 14'49'' N, 39°14'59.9'' E) ensures an average of 12 hours of sunshine daily throughout the year, providing a consistent source of solar energy. Furthermore, the steady wind patterns offer a 24/7 source of energy, while the substantial biomass resources hold promising potential for biogas production and electricity generation. Despite these abundant renewable resources, Tulefa Energy Village currently relies heavily on wood, charcoal, and kerosene for cooking and lighting, highlighting a disparity between its energy potential and current practices. The Figure 4 shows the Tulefa Energy Village region.

Figure 4. Tulefa Energy Village.

4.2. Technical potentials of the model village in Ethiopia

The energy sources are cow dung (CD), firewood (FW), charcoal (CC), crop residue (CR), solar, electricity (EC) and kerosene (KS). The statistical analyses shown that each household on average basis consumes more non-renewable energy (60%); mostly from firewood and charcoal compared with renewable energy consumption which accounts for 40%. Based on the data survey made, it was found that the households in the energy village use firewood most frequently (53.5%) and cow dung (37.3%) next to firewood. Others like charcoal (4.8%), crop residue (3.3%), kerosene (1%), electricity (0.02%), and

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solar (0.01%) account for only small portion (9.2%) of the total energy consumption in the village as is illustrated in Figure below. It can also be stated that the households in the village use biomass (98.96%) as a resource of energy and solar, electricity and kerosene amount to 1.04% combined altogether. Figure 5 shows the energy consumption.

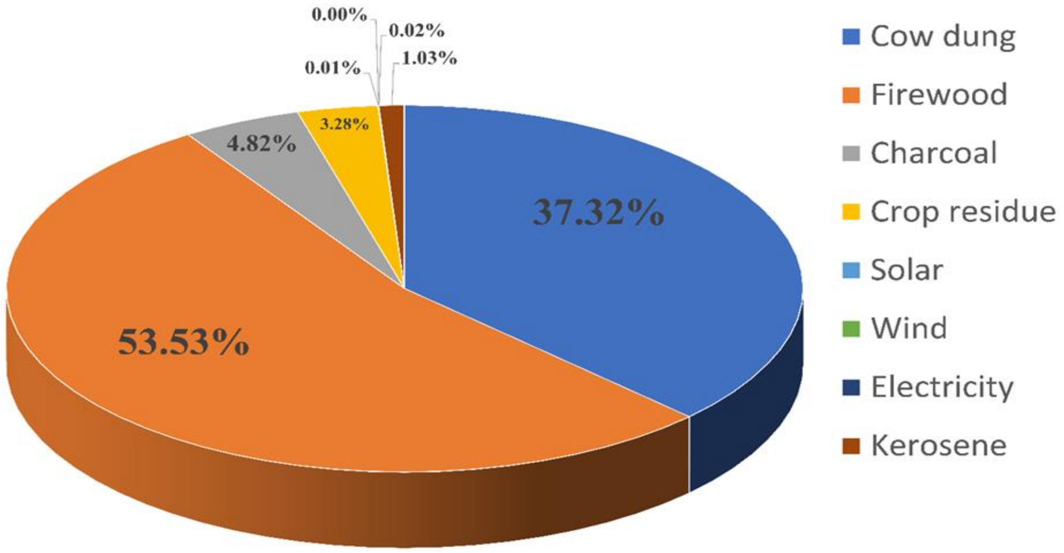

Figure 5. Energy consumption from different resources in Tulefa energy village.

A preliminary study showed that the total manure production in the village is estimated to be 10,650 Kg per day. Tulefa energy village also receives almost for 12 hours in a day for most of the seasons. On daily average basis, the data analyses showed that the minimum solar intensity was 2.25 kWh/m2 and the maximum solar intensity was 7.97 kWh/m2. The most available solar intensity during the day time was 5.98 kWh/m2/day which was used as the average intensity available for solar panels.

Tulefa energy village is also endowed with untapped wind energy manifested by its considerable wind speed throughout the year. Furthermore, the village has a landscape convenient for wind turbines that could receive wind speed unhindered. The site is a barren open space in the environ of most households' residences. Based on the meteorological data obtained from the National Meteorological Agency (NMA), the most frequent wind speed that the village receives is 5 m/sec, 6 m/sec being the second as shown in Figure below. Figure 6 shows normal distribution of wind speed of Tulefa energy village.

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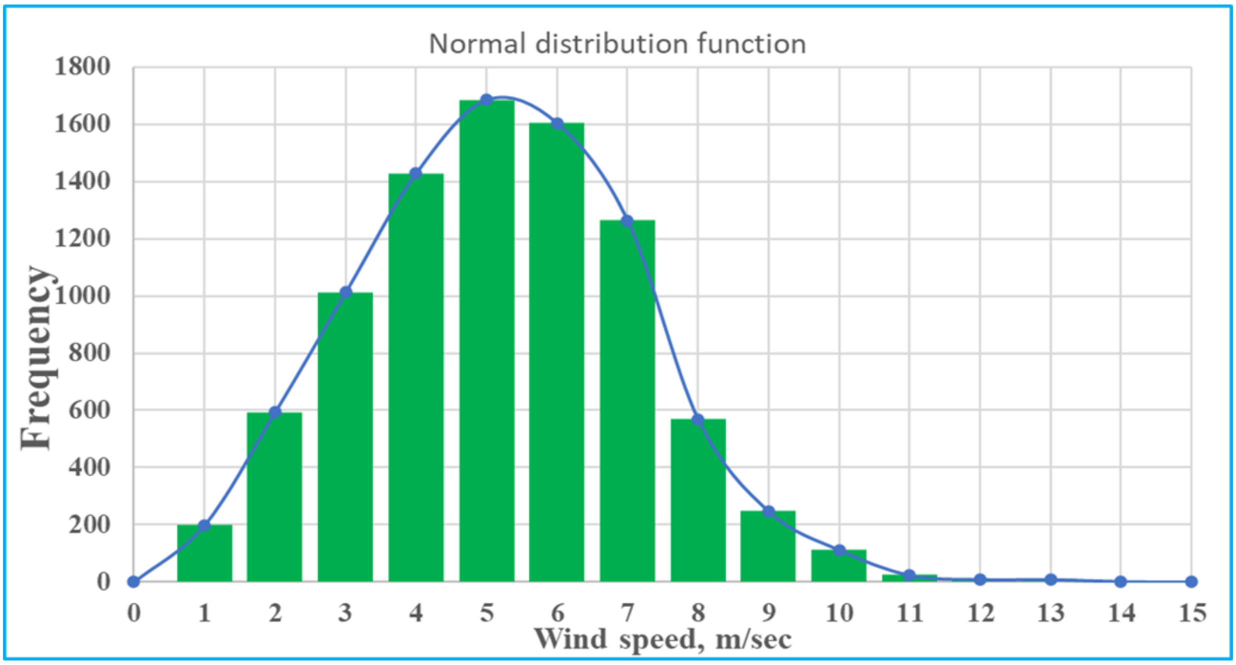

Figure 6. Normal distribution of wind speed of Tulefa energy village.

Moreover, meteorological data were illustrated using probability distribution function and cumulative distribution function as in Figure 6. It can be observed from the graph that wind speed which blows at 5 m/sec accounts for almost 20% of the time in the village. All wind speed occurrence taken into consideration, the average wind speed was come out to 5.9 m/sec.

4.3. The socio-economic potentials of the Tulefa village

Energy villages are communities that aim to become self-sufficient in energy production, typically through a combination of renewable sources like solar, wind, and biomass. These villages hold immense potential for positive socio-economic transformation, impacting various aspects of community life. The main socio-economic potentials of the would-be-energy village are:

1. Job creation:

   The construction, operation, and maintenance of renewable energy infrastructure can create new jobs in the community. Additionally, businesses that rely on clean energy sources may be attracted to locate in an energy village, further boosting the local economy.

2. Increased productivity:

   Access to reliable and affordable energy can help businesses operate more efficiently and increase their productivity. This can lead to increased income and profits for businesses, as well as expanded employment opportunities.

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3. Reduced energy costs:

   By generating their own energy, residents of an energy village can reduce their dependence on traditional energy sources, which can be expensive and unreliable. This can free up household income for other essential needs, such as food, healthcare, and education.

4. Improved health:

   Access to clean energy can improve health outcomes by reducing exposure to air pollution from traditional energy sources. Additionally, reliable energy can obviate the burden of women from fetching bundles of wood from remove area that has physical impact on them.

5. Enhanced education:

   Reliable energy can power schools and other educational facilities, creating a more conducive learning environment for students.

6. Stronger community bonds:

   The shared commitment to sustainability and collaboration required to develop and maintain an energy village can foster a sense of community pride and belonging. This can lead to increased social cohesion and support networks within the community.

4.4. Challenges identified in Tulefa village

When the establishment and visiting of the village, the following challenges were encountered:

1. Lack of long-term data of renewable energy resources.
2. Lack of technologies to measure some renewable energy resources.
3. Optics of the energy village concepts.
4. Less financial support.

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5. The Bidibidi Refugee Settlement Energy Village in Uganda

5.1. The chosen demo village in Uganda

Bidibidi Refugee Settlement Energy Village is located in the Northwestern part of Uganda, in Yumbe district. It was chosen as a model village because of the energy dynamics in the settlement. It hosts over 250,000 refugees (January, 2020) and a number of host community or nationals. This settlement is divided into five administrative zones, namely; zone one, zone two, zone three, zone four, and zone five. Zone two was selected. This is because it is the zone that contains the average number of households and administrative units for the settlement. Daily load demand for the zone of three primary energy use areas of cooking, water pumping and electricity is as shown in Figure . The total annual energy demand for the over 8,000 households in the zone is estimated as 24,218 MWh per annum. The social demography of the settlement sees service provision by both the refugee agency and the government. The ratio of the population planned for in the service provision is 30% host community and 70% of the refugees. This cuts across all areas of health, education, energy, security among others.

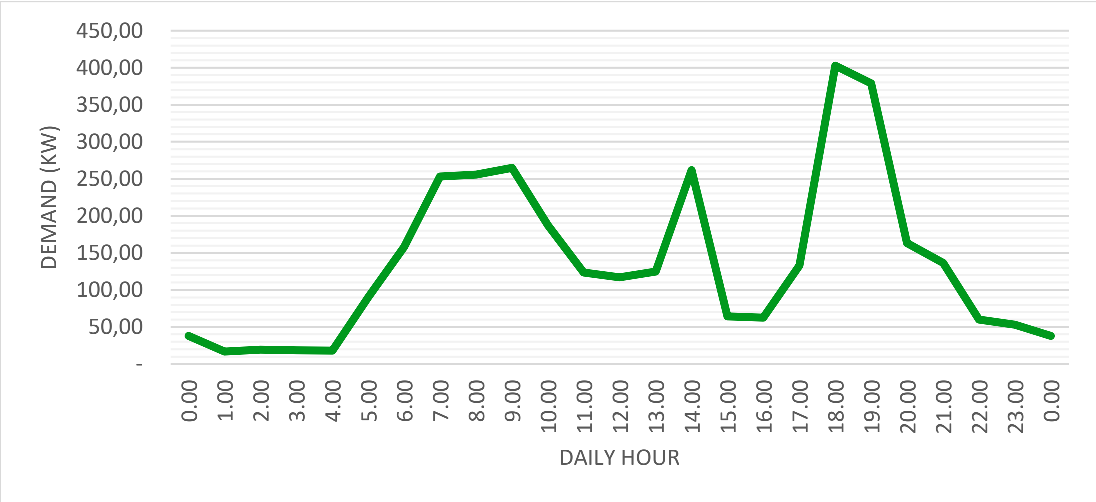

Figure 7. Average daily combined energy demand.

From the field surveys and the meetings conducted in the settlement, it has been established that the settlement is characterized by spheroidic poverty. Most basic services are provided by agencies and government. For the case of energy needs, the refugees and host communities depend on available natural resources to meet their needs. Inefficient technologies, such as three stones (open fire) for cooking are predominantly used for

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cooking practices. Some agencies have introduced some better energy use practices such as the use of briquettes (Figure) and other efficient energy use practices.

Figure 8. Charcoal briquettes used in the zone.

5.2. Technical potentials of the model village in Uganda

The energy profile in the settlement is dominated by dependence on the available natural resources. From the survey findings, over 92% of the settlement community depends on firewood to meet their cooking needs as shown in Figure 9. Most of these energy sources end up in the inefficient conversion system like open fire (three stone stoves), clay stoves and metallic fabricated stoves.

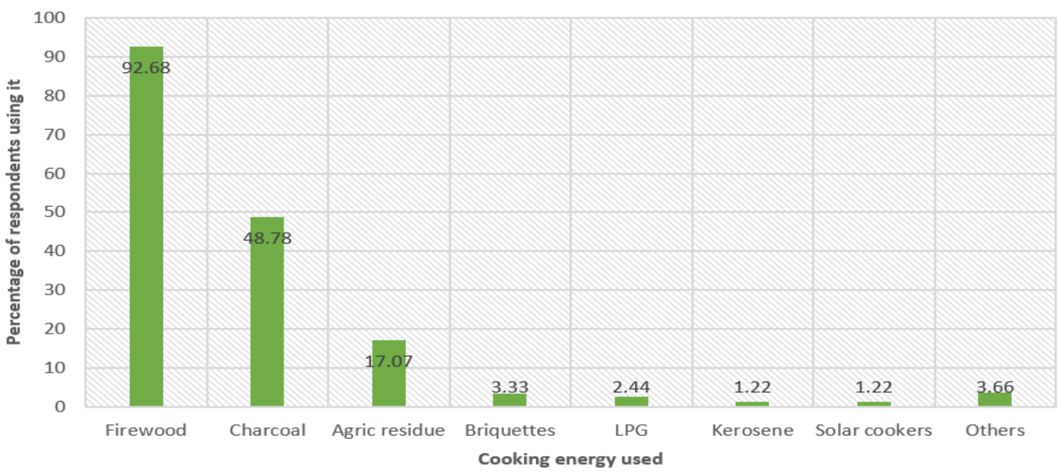

Figure 9. Cooking energy use big picture.

Findings have revealed a great potential for biogas generation. This is through the different sources namely; human waste, chicken droppings, cow dung and goats' manure as shown in Table 3. Full exploitation of such resources has a potential to generate over 24,000 MWh of electricity per annum.

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Table 3. Waste potential for biogas production.

Waste Source	**Production**	**Total number of heads**	**Total Waste Production**	**Total Waste production**
	(kg/head/day)	**(persons or animals)**	**(kg/day)**	**(tones/yr.)**
Human faeces	0.42	43,142.00	18,119.64	6,613.67
Chicken droppings	0.08	42,070.00	3,365.60	1,228.44
Cow dung	4.60	117.80	541.88	197.79
Goats manure	0.30	41,000.00	12,300.00	4,489.50

The solar sector displays a great potential with an average hourly irradiation of 5.94 kWh/m2 for an average of 9 sunshine hours per day. This, when harnessed can generate a considerable amount of energy in the energy mix. The wind potential is a bit low with a hourly average wind speed of 2.1 m/s.

There exists a potential in financing options. This is because the Government of Uganda and Refugee Agencies already spend billions of Uganda shillings in supplying energy and energy solutions to the settlement. This is being done in form of restoring depleted energy sources such as natural forest covers, provision energy conversion systems such as stoves, solar lantern, among others.

5.3. The socio-economic potentials of the Bidibidi refugee settlement

Bidibidi Refugee Settlement Energy village in Uganda has a number of socio-economic potentials. These range from individual benefits to the overall big picture.

1. Socially, the energy village has a potential to:

    - Reduction in refugees-host community tension: Often times, the refugees and the host community have tensions and conflicts arising from access for these natural resources specially to meet their energy needs. Cutting a tree within another person's catchment area can result into a serious tension. Therefore, through this EV, such conflicts will be eliminated.

    - Social cohesion: The camp community will be able to live socially peacefully and concentrate on developing their community through the available energy supply.

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- Reduction on gender burden: Responsibility for meeting energy needs for the households especially for cooking is predominantly upon women and girls. This lessens their time for other productive and energy generating activities. Therefore, this energy village will ensure easy access to reliable energy sources hence reduction on that burden on the female gender.

- Access to education and improvement of literacy level for both the refugees and the host communities.

2. Economically, the energy village has a potential to:

- Job creation: Many people from the community will be employed in the energy supply projects. This will reduce on the unemployment levels within the community.

- Improved livelihood of the refugees and host community: Access of better and reliable energy will come handy with improved livelihood and standards of living.

- Improved household incomes: Currently, the average household income in the settlement is low. This will tremendously improve when the community starts engaging in productive activities because of the available reliable energy sources.

- Improved productivity in the farms: Through supply of irrigation energy, productivity in the farms will be able to improve. This will result in to resilience and food security in the settlement.

- Reduction on dependence on stipends: UNHCR through the WFP supports the refugees within the zone with food stipends through a designated ration. For that matter, if food production increases, this dependence will be no more hence self-dependence.

5.4. Challenges identified in Bidibidi refugee settlement village

The following are some of the challenges identified and being faced in Bidibidi Refugee Settlement Energy village.

1. Resistance to change: From the survey, most of the respondents were not willing to adopt the use of biogas generated from human waste for cooking. They look at it like something not realistic.

2. Land ownership and mobility of the refugees: The land ownership for such project needs a stable lease system. Most of the land in the settlement are owned by the community and their fore their acquisition for energy is not easy.

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3. Unpredicted population increases in the settlement: The refugees keep on moving back and for to their countries of origin. This makes it difficult to estimate the exact population to plan for. For some cases when there is outbreak of civil unrest, the population in the camp increases abnormally.

4. Lack of much needed technologies for implementation: The technological requirement for implementation of the EV is lacking in the settlement. However much the EV shows a lot of potential, the much need funding is still lacking.

5. Hostility within the settlements: The environment within the camp is not as peaceful as one would think. This especially when there are new arrivals. There are several tribal clashes that results in to heavy security deployment within the settlement.

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6. Way forward

We have so far defined in the WP14 Energy Village Concept that in most African villages there is a huge potential for utilizing renewable energy sources and that doing so could bring various socio-economic benefits for the people living in the villages as well as to the broader society. However, there are also different kinds of challenges related to utilizing renewable energy potential. Some of these issues are discussed in this chapter.

There is need for the communities to be supported to realize, understand and accept the energy village concept. To create more awareness of the energy village to the community, can be done by organizing community outreach events such as educational workshops, demonstrations, and site visits. Besides, it may be important to showcase examples of thriving energy villages to inspire and demonstrate the energy village concept viability. And moreover, addressing concerns proactively and open discuss on potential challenges with environmental and economic benefits of energy villages are seen to be ways forward. Extensive community sensitization is needed. Community sensitization is key in changing mind-set in adoption of new technologies. This will also improve on peaceful coexistence between the communities.

Meteorological and other renewable energy resource data are limited. However, some freely available data from satellites can provide insights into renewable energy potential of a village. People living in the villages can also be taught how to follow and calculate the amount and types of energy they use. This is especially important regarding biomasses.

Finance, as is always the case, is a bottleneck to implement projects. Yet, this study can be used as showcase the latent potential of the village to attract investor and even governmental body for the realization of the project. In addition to this, strategies to attract investment in the renewable energy sources available in the area should be encouraged. Close working relationship between government agencies and the local community can facilitate the realization of this worthy goal. Subsidies in the cost of energy systems are also required. Since some villages are characterized with poverty and dependence on donor aids, subsidies on the energy technologies will increase on the acquisition rate. Increasing on funding advocacy is needed. Government and refugee agencies pump in millions of shillings in energy projects. Increasing advocacy to ensure that this funding is used in sustainable systems can make villages energy independent.

In some cases designing resilient systems can promote utilizing renewable energy. For example due to fluctuating number of refugees in the refuge settlement, the designed

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systems should be able to flex with these changes. These changes come with change in demand for energy and subsequently supply.

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7. Conclusions

In this deliverable 14.3 report four Energy Villages, one in each country were selected and their technical, social, and economic potential have been assessed. These energy villages include: Cheboiywo village (Kenya), Majwanaadipitse village (Botswana), Tulefa village (Ethiopia) and Bidibidi refugee settlement (Uganda). It was observed that in all these villages, the residents relied on firewood and other non-renewable energy sources. In these four villages, there are strong potential for biogas from agricultural wastes (plant and animal wastes) and solar energy. The main socio-economic potential noticed in these model villages were: 1) Increases access to affordable and sustainable energy; 2) educational enrichment through extended study opportunities; 3) job creation and entrepreneurial ventures; 4) enhanced agricultural practices and agro-processing opportunities; 5) community empowerment through skills development and 6) environmental sustainability through reduced negative environmental impact.

There have been several challenges were noticed in these model villages and other energy villages. These were: 1) Difficulty in establishing contact and getting accurate data for modelling. 2) Mistrust arising from previous failed projects. 3) Vested interest in various stockholders that require carful navigating and balance. 4) Lack of financial loan to renewable energy technologies. 5) No insurance for products. 6) Educational training is needed to understand, run and maintain renewable energy technology. 7) Overcome fear and resistance to change to new renewable energy technologies. 8) Lack of much-need new technology implementations. 9) Lack of technology to measure renewable energy resources and lack of knowledge the way how in which an implementation action proceeds. 10) The land ownership and mobility of refuges. Moreover, 11) hostility within the refuge settlements.

A way forward ideas raised and the main ideas were: 1) There is need for the community to be supported to realize, understand and accept the energy village concept. 2) Meteorological and other renewable energy resource data needed to be available for researchers. 3) Finance is the bottleneck to implement projects. There is a need for the availability of appropriate financial means, loan, insurance and investments. Moreover, 4) Close working relationship between government agencies and the local community in important and it is a must to the achievement of future project implementations. All in all, these four model villages demonstrate the example of technical and social-economic potential and challenges arising from the energy villages in Kenya, Botswana, Ethiopia and Uganda. It is important to address the need and means of access to natural energy resources to local villages by means of implementing energy village concept across Africa.

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