SIGMA

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Sustainability, Inclusiveness and Governance of Mini-grids in Africa

TANZANIA FIELDWORK REPORT

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DISCLAIMER

The views expressed in this report are those of the authors and do not necessarily represent the views of the institutions they are affiliated to or those of the funding agencies.

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FEEDBACK

If you have any comments, suggestions, or feedback, please send them to the SIGMA project lead by email: s.c.bhattacharyya@surrey.ac.uk

ABBREVIATIONS AND ACRONYMS

Ah	Ampere hours
CHP	Combined Heat and Power
COD	Commission Operation Day
CT	Current Transformer
DARESCO	Dar es Salaam and District Electric Supply Company
EASTRIP	East African Skills Transformation Regional Integration Project
ECOWAS	Economic Commission of West Africa
ECREE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EEP	Energy and Environment Partnership (Finland)
EPC	Engineering Procurement Construction
EU	European Union
EWURA	Energy and Water Utilities Regulatory Authority
FBO	Faith Based Organisation
hh	household
hrs	hours
IPP	Independent Power Producer
km	kilometer
KPGC	Kikuletwa Public Power Generation Company
KPLC	Kenya Power Lighting Company
kV	Kilovolt
kVA	Kilovolt Ampere
kW	Kilowatt
kWh	Kilowatt hour
MFP-SVO	Multi-Functional Platform - Straight Vegetable Oil
MoE	Ministry of Energy
MW	Mega Watts
O&M	Operation and Maintenance
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PV	Photovoltaic
REA	Rural Energy Agency (of Tanzania)
REF	Rural Energy Fund
RC	Roman Catholic
SIGMA	Sustainability, Inclusiveness, Governance of Mini-grids in Africa
SMEs	Small and Micro Enterprises
SPP	Small Power Producer
SPPA	Standardised Power Purchase Agreement

SPPT	Standardised Small Power Projects Tariff
TANESCO	Tanzania Electric Supply Company Limited
TANWAT	Tanganyika Wattle Company
TaTEDO-SESO	TaTEDO-Sustainable Energy Services Organisation
TPC	Tanganyika Planting Company
TPDC	Tanzania Petroleum Development Company
TShs	Tanzania Shilling
UNCDF	United Nations Capital Development Fund
USADF	United States African Development Foundation
USD	United States Dollar
VSPP	Very Small Power Producer
W	Watt
Wh	Watt-hour
w.e.f.	with effect from

1 USD = 2,700 Tshs (May 2025)

GLOSSARY

Combined heat and power (co-generation): Generation of power and process heat at the same time.

Distribution Net Operator (DNO) / Small Power Distributor: These are licensed small capacity bulk power importers who distribute/retail power to customers at medium voltage networks or below; they may own small generating plants**.**

Independent power producers (IPPs) are private power producers with plants of capacity more than 10 MW for export to the national grid system.

Power purchase agreement (PPA): A contract between power producer and power off taker or distributor with provisions on rights and obligations on both parties regarding price, quantity and quality of electricity to be exchanged at a specified duration of time.

Small power producers (SPPs): Small independently operated power plants having an export capacity 100 kW to 10 MW to the decentralized or national grid.

Standardised small power purchase agreement (SPPA): A standard non-negotiable contract between a small power producer and an off taker with provisions on rights and obligations on both parties regarding price, quantity and quality of electricity to be exchanged at a specified duration of time.

Standardised power purchase tariff: A fixed tariff between a mini-grid and an off taker (main or decentralized grid) providing price as determined by the regulator.

Very small power producers (VSPPs) are small independently operated power plants with less than 100 kW capacity **s**upplying power to a decentralized mini-grid.

EXECUTIVE SUMMARY

This report presents field visit findings from 18 mini-grids of different technologies/energy sources consisting of 4 mini-hydro, 4 biomass, 4 solar PV, 1 wind, 1 diesel and 4 hybrid systems located in 9 regions of Tanzania Mainland. It is part of a study project on **Sustainability, Inclusiveness, Governance of Mini-grids in Africa (SIGMA)** involving Nigeria, Senegal, Kenya and Tanzania. The study aim is to obtain evidence based on mini grid performance in Sub-Saharan Africa, analyse political economy of energy access and sustainability framework of mini-grids and undertake in depth case studies from the four countries.

Sustainability

The field visit findings indicate that 13 mini-grids were operational and 5 were non-operational, 3 of which had been dismantled and shifted to other sites. The contributing factors included technology being obsolete, spare parts problems, lack of feed stock and fuel supply problems. 10 mini-grids out of 18 had been encroached by main grid, 5 of which were co-existing with the national grid for SMES security of supply. Mini-hydro and biomass combined heat and power (CHP) are robust technologies, solar PV and wind technologies are becoming competitive while biomass gasification and Multi-Function Platform propelled by straight vegetable oil/diesel technologies face feed stock shortages and technology performance challenges.

As such, mini-grids technical and environmental sustainability is possible if training of operators, readily availability of fuel/feedstock and spare parts, planned and non-planned maintenance of the plants adhered including operating standards and safe guard requirements.

Financial sustainability of small power producers (SPPs) selling power to anchor customers the national grid and large consumers appears possible if the tariffs are regularly revised so that they are cost reflective to the SPPs. As for the very small power producers (VSPPs) mini-grids, financial sustainability is highly questionable as cost of providing services is high and attendant tariffs borne by majority rural poor households are high and non-affordable to them.

Community based and faith-based charity business models have demonstrated weakness in revenue collection. Mini-grids employing pay-go billing system along with business models tend to perform financially better.

Notwithstanding the above, financing and risk management of mini-grid projects has been indicated as a barrier to accelerated deployment of mini-grids whereby

more efforts is needed to overcome this challenge, including financing O&M of the mini-grids.

Inclusiveness

Most of the village communities are closely involved in mini-grid development, construction and operations with a fair number of them observe gender aspects.

Governance

The country has a robust regulatory framework for small power producers and mini-grids, innovative financing arrangements and feed-in tariffs to main grid /decentralized distribution network operators. Tariff aspect is the most controversial issue due to diverse interests- political, development partners aid, investors, banks and rural households' livelihood.

Customer Aspects

Wood and charcoal are the dominant cooking fuel for households (hh) with minority cooking on LPG and electricity in all visited sites. Mini-grid electrified hh largely benefit from improved lighting, powering radios, phone charging and a few powering their TVs. Most of the poor rural areas cannot afford mini-grid tariffs, as such do not connect to the services.

In turn, small and micro enterprises (SMEs) benefit from powering welding, carpentry, grain milling, oil pressing, food/drinks kiosks, and other productive use equipment. Some mini-grid operators offer loans to their customers to acquire efficient productive use equipment as a strategy to expand energy demand as well as improve revenue collection and financial sustainability if the tariffs are cost reflective and services provision is undertaken efficiently.

Public institutions benefit from improved services like health, education, street lighting and water supply services. Electrification reduces rural to urban migration and improves rural household's livelihood.

Conclusion

These field findings provide inputs in addressing the key research questions on the main research theme on sustainability, inclusiveness and governance of mini-grids in Tanzania.

Electrification by renewable mini-grids is indeed an option for remote rural areas located far from the national grid in Tanzania with abundant renewable energy resources. Strategic investment partnership between Rural Energy Fund (REF) and

international stakeholders is needed to augment financing resources, risk mitigation, optimize developers' benefits and hence accelerate deployment of mini-grids in Tanzania and Sub-Saharan Africa.

1. INTRODUCTION

1.1 Background

Electrification by mini-grids in Sub Saharan Africa is considered an important approach that will assist many remote rural Africans from the national grids to access electricity needed in transforming their livelihood. In that regard, partners from University of Sussex and De Mont Fort University in UK, International Centre for Energy, Environment and Development in Nigeria, the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREE) in West Africa, ICFI-Kenya Hub and TaTEDO-SESO of Tanzania are collaborating in a research project called **Sustainability, Inclusiveness, Governance of Mini-grids in Africa (SIGMA).** The project is funded by UK Research and Innovation-Global Challenge Research Fund.

The main project objectives are: a) develop an evidence base on mini-grid performance in Sub-Saharan Africa, b) develop a framework to analyse political economy of energy access and sustainability framework of mini grids; and c) undertake in-depth case studies of mini-grid sustainability, inclusiveness, and governance in for countries of sub-Saharan Africa namely Nigeria, Senegal, Kenya and Tanzania.

The SIGMA project sought to answer the following questions: a) Which business models have succeeded to deliver financially and technically viable mini-grids in Africa? b) Who and what have been the key beneficiaries of mini-grids in the case study countries and in what way? c) Who drives or hinders the proliferation and the speed of adoption of mini-grids in East and West Africa? d) What governance, regulatory and policy frameworks for decentralised systems of electricity provision exist in each case study country, how successful have they been and how do they differ?

This field report presents selected mini-grid case studies undertaken in Tanzania Mainland by TaTEDO-SESO for the SIGMA project.

1.2 Country Mini Grid Context

As of 30th June 2022, Tanzania had an installed capacity of 1,740.77 MW of which 1,489.56 MW was owned by TANESCO, 189 MW was IPP (EWURA 2023). Data compilation by authors indicates that installed capacity of 31.29 MW was traded by SPPs, 28.74 MW as own consumption by non-traded small producers and 2.18 MW was traded by VSPPs (EWURA 2023). Table 1 provides an inventory of existing mini–grids and embedded generators connected to medium voltage network of

11 and 33 kV of Tanzania Mainland. A total of 176 mini-grids/embedded generators existed in Tanzania Mainland in 2022.

Table 1: Summary of mini-grids and distributed types, numbers, capacities and number of customer connections in 2022

Mini -Grid Type/ Source	Number	Capacity in kW	Number of Connections	Connected to		
				Mini grid	National grid (s)	National grid (access)
Mini hydro	57	33,484.9	8,929	38	8	11
Biomass	26	48,918.0	634	17	2	7
Solar	72	7,268.3	81,633	70	0	2
Wind	1	2,400.0	-	0	1	0
Hybrid	6	265.6	1,299	4	0	2
Diesel & Gas	14	68,332.0	181,951	14	0	0
Total	**176**	**160,668.8**	**274,446**	**143**	**11**	**22**

Source: Authors compilation

2. METHODOLOGY

2.1 Research Design

In order to achieve the research objectives and answer the questions posed to the project, the study used an embedded case study design. Tanzania was identified as a case study, which entailed more than one unit of analysis. The mini-grids selection for case studies in Tanzania was to cover a range of various technologies, energy sources, sizes and ownership / business models. The selected number of mini-grids to be investigated was 18 (see Table 2).

Table 2: Selected mini-grids by technology and ownership model

Technology/ Energy Source	Total Number	Ownership / business model				
		Public	Private	PPP	FBO	Community
Mini-hydro	4	1	2		1	
Wind	1		1			
Biomass	4		2	1		1
Solar	4		4			
Hybrid systems	4		4			
Diesel & natural gas	1	1				
Total	**18**	**2**	**13**	**1**	**1**	**1**

2.2 Research Area

The study was conducted in 9 regions of Ruvuma, Iringa, Kilimanjaro, Morogoro, Dodoma, Njombe, Kigoma, Pwani and Tanga in Tanzania Mainland whereby 18 mini-grids were visited. The study areas were selected because there are mini grids existing in those area. From the selected regions, 18 mini grids with different energy sources and technologies were investigated so as to understand their sustainability, inclusiveness and governance aspects (see Table 3 and Figure 1).

Table 3: Location, technology, energy source, capacity, operating status and type of operating network

S/No	Mini Grid Name/ village	Energy Source/ Technology	Region	Capacity kW	Operating status	Connection
1	Tulila	Hydro	Ruvuma	5,000	Operating	National grid (s)
2	Chipole	Hydro	Ruvuma	400	Non-operating	National grid (access)
3	Mwenga	Hydro	Iringa	4,000	Operating	Integrated mini-grid & National grid (s)
4	Mwenga	Wind Power	Iringa	2,400	Operating	
5	Kikuletwa	Hydro	Kilimanjaro	1,650	Non-operating	National grid (access)
6	TANWAT	Biomass CHP	Njombe	1,500	Operating	National grid (s)
7	TPC	Biomass CHP	Kilimanjaro	17,500	Operating	National grid (s)
8	Kibindu	Biomass gasifier + solar PV hybrid	Coast	30+20	Operating	National grid (access) *
9	Kigoma TANESCO	Diesel	Kigoma	6,250	Operating	

10	Kigoma NextGen	Solar PV	Kigoma	5,000	Operating	Integrated mini-grid (decentralised)
11	Leganga	Solar PV	Dodoma	15	Operating	National grid (access) *
12	Ngutoto	Solar PV	Dodoma	15	Operating	National grid (access) *
13	Songambele/Kitaita	Solar PV + diesel hybrid	Morogoro	6 + 8	Operating	National grid (access) *
14	Leshata	Solar PV + diesel hybrid	Morogoro	6 + 8	Operating	National grid (access) *
15	Mji Mwema MFP	MFP Biodiesel/diesel	Kilimanjaro	8.8	Non-operating ^	National grid (access)
16	Mpale	Solar PV + diesel hybrid	Tanga	8.8	Operating	National grid (access)
17	Mvuha	Solar PV	Morogoro	20	Non-operating ^	National grid (access)
18	Biro	Biomass gasifier	Morogoro	50	Non-operating ^	National grid (access)

NB: Non-operating^ imply mini-grids dismantled and relocated elsewhere
National grid (access) implies mini-grid encroached by national grid
National grid (access)* imply mini-grids encroached and co-exists with the national grid
National grid (s) imply mini-grid/embedded plant synchronised to the national grid as SPP

Source: Authors compilation

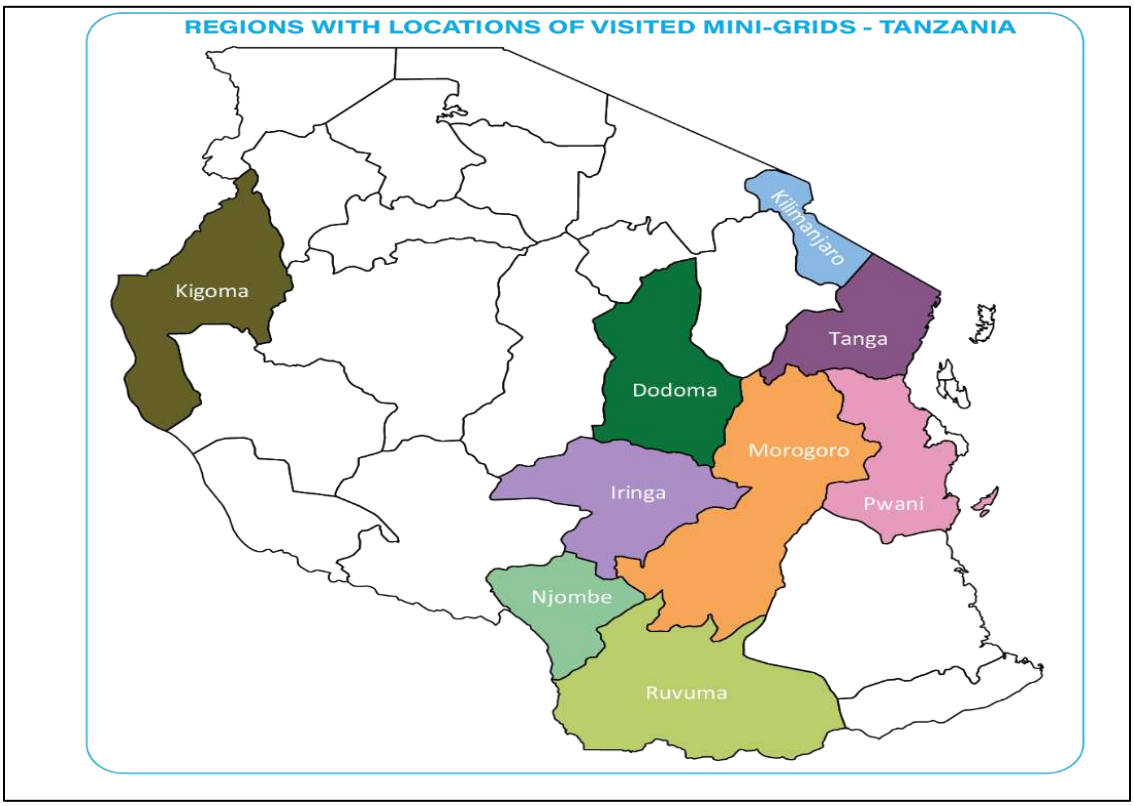

Figure 1: Visited site regions

Source: Authors compilation

2.3 Data Collection

Data was collected from primary and secondary sources. The study used a purposive sampling technique to select key stakeholders of electricity mini grids for interview i.e., Ministry of Energy, EWURA, TANESCO, REA, EU delegation, Swedish International Development Agency (Sida), small power producers (SPPs), very small power producers (VSPPs) and electricity end users. The study selected those informants because they can share diverse experiences concerning the country's electricity mini grids. Primary data was collected through interviews and focus group discussion from site visits, plant operators, households, SMEs and community institutions like schools, dispensaries and community offices. Specific interview questionnaires were prepared by the project and used to collect data/information from targeted stakeholders to be interviewed.

Interviews were recorded in English and Kiswahili national language of Tanzania. Data collection was done using a combination of audio recorders during face- to-face interviews and note-taking to capture observations and additional information. Some of the data was obtained from secondary sources of the visited institutions' publications.

The main challenge faced was a fair portion of interviews was conducted in Kiswahili national language which later on had to be translated into English. The level of awareness among the rural people on how electricity is being generated, transmitted, distributed and metered was low. In particular, most of the rural energy end use customers especially households had difficulties in understanding electricity tariffs based on the various types of metering and billing systems being used by mini-grids and energy distributers.

Mini-grid field visits were undertaken in nine regions mentioned above. Key informant interviews were done in two regions of Dodoma the national capital city and Dar es Salaam the country's commercial city. Field work observations and findings are covered in section 3, key informant interviews' findings in section 4 and crosscutting findings in section 5.

3. FIELD VISITS FINDINGS

The information presented here provides a concise overview of our observations and findings and does not delve into the detailed outcomes of the fieldwork (refer Table 3).

3.1 Ruvuma Region

Ruvuma region is located in Southern Highlands, bordered by Njombe and Lindi regions in the north, Malawi country in the west, Mozambique country in the south and Mtwara region in the east.

3.1.1 Tulila Mini-Hydro Based Mini-Grid[1]

Plant development

Tulila is a 5 MW (2x2.5 MW) mini-hydro plant that supply a small mini-grid at 0.4 kV for own use by Chipole Sisters offices and residence at Mpepai village and is integrated to the former Mbinga, Songea and Namtumbo diesel based decentralized grid in Ruvuma Region at 33 kV about 55 kilometres away, as well as Tanzania national grid. Plant construction began in 2014. It was commissioned on 15th September 2015. Albert Korch from Switzerland owns 80% shares and 20% is owned by Benedictine Sisters of St. Agness Chipole Tanzania.

Power plant financing came from Swiss bank credit USD 18.5 million at 5% interest for 13 years, Albert Foundation USD 0.75 million, Benedictine Sisters USD 1,000 and labour contribution worth USD 2 million. The land consisting of 500 acres each was purchased by Benedictine sisters from Mpepai and Mipeta villages. The 33 kV line to Songea was funded by Rural Energy Fund and was erected by TANESCO. Planning, design and construction was done by foreign experts assisted by local experts.

Governance

Tulila mini-grid is owned by the Tulila Hydro Electric Company Ltd which has a SPPA with TANESCO, an anchor customer, with most of its power sold to previously decentralised Songea-Mbinga-Namtumbo mini grid network and currently the national grid via a standardised feed-in-tariff provided by the regulator. The feed-in-tariff is computed based on avoided costs of the off-taker. During 2015-2018 the tariff was Tshs 480/kWh sold to the Songea-Mbinga-Namtumbo mini-grid. The tariff changed to TShs180/kWh in 2018 following Ruvuma region being connected to the national grid via a 220 kV line. Currently the tariff is denominated in US

[1] The plant was visited on 13th September 2021.

dollars. The operators said the prevailing tariff during the visit was not cost reflective. However, since plant's commission, the plant owners and operators have never defaulted on Swiss bank loan payments. Previous good year's revenue accumulated was being used to offset current reduced revenue collections.

It be noted that the plant did not directly supply any village. All nearby villages' customers were TANESCO customers supplied by Tulila mini-grid.

Sustainability

Financial sustainability

Long term financial sustainability of the min-grid exists as it sells its power to an anchor customer (TANESCO) via regulated feed in tariff approved by the regulator. However, the prevailing tariff needs to be revised regularly to remain cost reflective. Optimal revenue collection sometimes in the past was not reached due to an anchor customer's insolvent situation that no longer exists.

Technical sustainability

Operation and maintenance are undertaken by local experts – seven Benedictine sisters assisted by two male employees. The plant is web-connected and monitored by Swiss experts. Minor maintenance is undertaken by local technicians consisting of one sister and two men whereas major maintenance is done by foreign technicians.

Figure 2: Tulila Mini Hydro Based Power Plant

Spare parts availability is a challenge as it has to be imported from overseas. They experienced a breakdown of the circuit breaker in April 2021 which they had to order from outside the country; so, they had to stop the plant operation. In the meantime, in June 2021 the sisters were helped by ABB (the suppliers) of the particular spares to bypass the system and continue to generate while waiting for plant's required spare part. It was also revealed that in a month's time the electronic card also blew out and had to be ordered from Switzerland.

Onsite training of plant operators was undertaken by two TANESCO experts from Kihansi and Kidatu hydro plants for one year. During that time, TANESCO experts were positioned at the plant to run the facility along with Benedictine sisters. TANESCO experts left the plant when they were sure the plant owners had developed the capability to operate it.

Environmental sustainability requires the communities surrounding the project to disassociate from deforestation activities, avoid agricultural practices that contribute to soil erosion and siltation of the plant's reservoir and also collectively to uproot bad weeds whenever they surface in the project catchment area. As part of the mini-grid social responsibility, the mini-grid has built four class rooms and one church.

The main challenge is water flow in the river substantially diminishes during August to November months affecting power production. Also, there is a coffee farm developed upstream the plant that is involved in consumptive water usage via irrigation that has diminished water flow for mini-grid power generation.

Affordability

Chipole mini-grid customers obtained free connectivity and energy. The current connection fee of TShs 27,000 and pan-territorial subsidised lifeline energy tariff of TShs 100/kWh paid by end use TANESCO's customers is affordable.

Business model

The prevailing business model whereby most of the electricity produced by the mini-grid is sold to the national grid based on the computed feed-in-tariff made available by the regulator is financially sustainable if the prevailing feed in tariff is regularly revised so that it is cost reflective. There is a challenge of the mini-grid inability to produce at full capacity (only 3MW) due to the reason that TANESCO has reduced the quantity of electricity bought from the mini-grid after the arrival of the national grid in the Region.

Inclusivity

During project development from site selection, plant construction, operation and maintenance, the communities surrounding the project area have been closely engaged with the project. Compensation was paid in acquiring the project site. Gender balance was exercised during project development and during O&M whereby seven out of nine plant operators are women (Benedict's sisters). Local content in the project was observed whereby Benedictine sisters have 20% ownership of the plant.

The existence of the mini-grid in the area has had positive contribution including employment creation for the village youths during the construction period as well as during clearance for the line way leave; electrification has made village life more comfortable, improved services like health and education facilities and has curbed rural to urban youth migration. Indeed, electrification has enforced social justice in the project community.

Customer Aspects

Initially, Tulila SSP supplied TANESCO at 33 kV as the only customer who supplied households and SMEs along the 55 km Mbinga-Songea-Namtumbo decentralized integrated mini-grid. The situation has remained so even after the decentralized integrated mini-grid connection to the national grid.

Challenges and Lesson Learnt

- Despite having the SPPA with TANESCO, the 11 Benedict sisters living in 3 main houses near the mini hydro plant do access electricity directly from the plant as part of mini-grid non metered consumption including ancillary equipment.
- Tulila dam head is 747.55 meters and amount of electricity produced is 3MW during a day from 8am to 10pm and switch off one turbine during the night to produce 2MW.
- The power plant has been developed with an option of adding another turbine of 2.5MW into the future.
- It is a routine that every November in a year the penstocks and the trash racks are cleaned ready for the heavy rains, the effects of the water hyacinth are also controlled by cleaning 2-3 times during rain seasons.
- Despite the awareness campaigns/education to the surrounding communities, still there are water conflicts upstream with a coffee plantation drawing water for irrigation which lead to reduced water flow

downstream especially during the dry season months of July to October each year.

- There are times they face challenges with their computers and internet connectivity, so they are forced to undertake operations manually.
- During repair of the machines, the residue oil extracted is given for free to local technicians and villagers for other personal uses.

3.1.2 Chipole Mini-Hydro Based Mini-Grid[2]

Plant development

Chipole is a 415-kW mini-hydro plant that is connected to 11 km of 11 kV network at Magagura village in Songea District, Ruvuma Region; consisting of a Roman Catholic church and mission, grain mills, schools and residential area for the staff.

During 1999 to 2000 feasibility studies were undertaken by local Tanzanian experts. Financing in a form of aid grant to Benedictine Sisters of St. Agness Chipole was secured during the 1990s from Robert Fuchs of Switzerland who had a passion for extending electrification access to rural areas. Plant construction began in 2000 and was commissioned in 2005. Plant equipment and construction cost was in the tune of USD 200,000. The mini-grid is wholly owned by Benedictine Sisters of St. Agness Chipole.

Since 9th March 2021, the plant has not been producing power following heavy floods that washed away part of the earth dam and the machine hall flooded.

Governance

The plant was developed and operated as a faith based (charity) business model. Chipole mini-grid owned, run by the Benedictine Sisters of St. Agness of Chipole was part of the Magagula Roman Catholic Mission. The plant had a committee responsible for operation and maintenance. Power was supplied free of charge to the Roman Catholic Community including a church, offices, schools, residences and grain milling plants. There was no tariff set for end users.

Sustainability

Financial sustainability

Long term financial sustainability of the min-grid does not exist since the mini-grid does not receive any revenue therefore there exist difficulties in meeting

[2] The plant was visited on 14th September 2021.

operating and maintenance costs. At the time of field visit, financing for the repair of the plant had not been secured. Owing to the expected huge costs involved in the repair of the dam and power house, financing of the repair shall have to be accompanied by adoption of a sustainable and resilient business model to propel the hydro based mini grid.

Technical sustainability

Operation and maintenance were undertaken by local experts – Benedictine sisters who were trained in Switzerland and were assisted by male employees. Minor maintenance was undertaken by local technicians. Major maintenance was done by foreign technicians. Spare parts availability was a challenge as there were no proper funds available for such activities and it was imported from overseas. They often depended on the donor Mr. Robert Fuchs. In year 2006 the donor Mr. Robert Fuchs died and was succeeded by his daughter who continued to provide assistance. In such donor dependency arrangement technical sustainability of the mini-grid could not be guaranteed.

Training of the plant operators was undertaken in Tanzania by foreign experts who installed the plant. Also, whenever they ran into problems, they sought assistance from other experts in Benedictine Sisters owned mini-grids e.g. Imiliwaha of Njombe.

Environmental sustainability of the mini-grid was questionable since communities surrounding the project are involved in deforestation activities, agricultural practices along the river banks (water rights conflicts) that contribute to soil erosion and siltation of the plant's pondage. The mini-grid had no social responsibility to the surrounding communities.

Figure 3: The Chipole Hydro Power Dam after washed by floods

The main challenge experienced was intense floods that occurred in 2007, resulting into the plant machine hall being flooded for three months, and power generation was stopped. Since then, there have been constant machine failures due to lack of spare parts and proper maintenance. On 9th March 2021 occurred another intense flood which washed away part of the earth dam connected to the spillway. The concrete spillway remained with sustained cracks. Power generation was stopped. The power plant stopped power generation.

Affordability

When the Chipole mini-hydro was operating, electricity was provided free of charge to all those connected to the RC mission community. Currently, Chipole RC Mission is served by TANESCO. Connection fee at Tshs 27,000 and pan-territorial

subsidised lifeline energy tariff of Tshs 100/kWh paid by end use TANESCO's customers is affordable.

Business model

Chipole mini-grid own generation model is common among faith-based organisations (FBO) in the country.

Inclusivity

During project development from site selection, plant construction, operation and maintenance, the communities surrounding the project area have been closely engaged with the project. Compensation was paid in acquiring the project site. Water right and environmental clearance to go ahead with the project was obtained from the government institutions. Gender balance was exercised during project development and during O&M whereby some of the plant operators are Benedictine sisters. Local content in the project was observed whereby Benedictine sisters have 100% ownership of the plant.

Existence of the mini-grid in the area has had positive contribution including employment creation to the village youths during construction period as well as during line way leave clearance; electrification has made village life more comfortable, improved health and education facilities' services and has curbed rural to urban youth migration. Fishing was being practices in the pondage. Indeed, electrification has enforced social justice in the project community.

Customer Aspects

When the Chipole mini-hydro plant was operational, it supplied the Roman Catholic church and mission, grain mill, edible oil press mill, a boarding secondary school, a day primary school, a vocational training school and residential area for the various staff. Student enrolment: secondary school 400, primary school 400, trade school 10 and orphanage centre 60. Peak demand was 290 kW whereas average demand was 195-200 kW. Currently all the above customers are supplied by TANESCO along the Tulila-Mbinga-Songea-Namtumbo decentralised integrated grid and national grid.

Since March 2021 Chipole RC Mission imports power from TANESCO at an average monthly bill in the tune of Tshs 1.5 million. If the mini hydro can be repaired, the mini hydro can sell power to the national grid sold at feed in tariff established by the regulator.

Lessons learnt

- There was no long term nor short term hydrological data available during plant design to construction
- The dam was built by a Chinese contractor based in Tanzania not to optimal design due to financing shortages as well
- Construction period was five years due to funding difficulties
- The dam failure is so huge that its repair may require it to completely be built afresh
- Financing solicitation for the dam repair is ongoing without much hope
- Since March 2021, Chipole network imports power from TANESCO at Tshs 1.5 million per month.

3.2 Njombe Region

Njombe region is located in the Southern Highlands, bordered by Iringa region in the north, Morogoro region in the east, Ruvuma region in the south and Mbeya region in the west.

3.2.1 TANWAT Biomass Fired Mini-Grid[3]

Plant development

TANWAT biomass combined heat and power (CHP) based mini-grid located at Kibena Njombe township has existed since colonial times. During 1950s to 1995 it was based on a wood fired steam engine technology that provided about 540 kW. In 1995 it was replaced with a 2.5 MW steam turbine technology employing the same amount of feed stocks. In both cases the plants were developed to provide process steam to the mill for extraction and processing of tannin from the wattle tree backs, electrical power to the saw mill, pole treatment plant, plywood factory and a carpentry workshop. The plant also provides power to the offices, housing estate and a hospital.

In about 1996, the mini-grid started selling excess power to TANESCO Njombe-Makambako-Uwemba decentralised diesel and mini-hydro integrated mini-grid via a negotiated PPA. The negotiated tariff was slightly cheaper than TANESCO own diesel generated power. TANESCO grid was extended to the Njombe-Makambako-Uwemba mini grid in 1998 following erection of a 220/132/33 kV substation at Makambako. As such, TANESCO stopped importing TANWAT power as own grid power was much cheaper than TANWAT imported power.

[3] The plant was visited on 15th September 2021.

The World Bank, via TEDAP project, developed a standardised small power producer's regulatory framework that was non-negotiable and would facilitate renewable mini-grids to sell power to TANESCO distribution networks via standardised feed in tariffs to be set by the regulatory authority. As such on 17th September 2009, TANWAT was the first mini-grid to sign a SPPA with TANESCO and power supply to TANESCO national grid started on 15th June 2010.

In November 2019 the turbine ruptured into pieces and generation stopped. The turbine failed due to reverse power that occurred and also the equipment had lasted its lifetime. Since then, TANWAT has been importing power from TANESCO at an average bill of Tshs 75 million per month.

When visited on 15th September 2021, a new 2 MW turbine and alternator system was being erected by local engineers and technicians. The old boiler would continue to be used. Development cost was Tshs 4 billion. The plant was expected to be commissioned within two months. Also, would resume selling excess power of about 1.2 MW (864,000 kWh/month) to TANESCO and 0.8 MW (576,000 kWh/month) own consumption. The SPPT during the dry season is Tshs 243.73/kWh and during the wet season is Tshs 182.80/kWh. The plant is wholly owned by Mr. Ray from Kenya.

Governance

Tanganyika Wattle Company (TANWAT) is a private company that owns a large wattle tree plantation, a tea estate, a biomass based mini-grid, a wattle processing factory, saw mill, pole treatment plant, plywood factory and carpentry workshop, offices, housing estate and a hospital. The company is run by management under guidance of a board of directors.

Governance is via standardised small power producers' regulatory framework, standardised power purchase agreement and associated standardised feed-in-tariff set by the regulator.

Sustainability

Financial sustainability

Potential for long term financial sustainability of the min-grid exists by selling power to an anchor customer via standardised feed-in-tariff if it can be regularly revised by the regulator so that it is cost reflective as well as TANWAT mini-grid strives to minimise its operational costs.

Technical sustainability

Mini-grid operation and maintenance was undertaken by local engineers and technicians. Spare parts availability was a challenge as was imported from overseas. The staff are well trained and have long experience in running the mini-grid. Whenever they ran into major problems they sought assistance from equipment manufacturers. Funds for O&M were allocated. With the new turbine in place, operators will also be equipped on how to run it for sustainable service provisions.

When the grid went out, the plant had to import power from the grid so as to synchronise with the national grid which tended to be expensive if the grid went out frequently and for long durations.

Environmental sustainability of the mini-grid, could be maintained by implementing environmental safeguard standards being regularly given by the environmental regulator via regular environmental audits of the mini-grid. Also, the mini-grid was expected to maintain its social responsibility to the surrounding communities.

Affordability

Electricity produced was sold to TANESCO and customers faced affordable uniform pan-territorial tariffs including subsidised lifeline tariffs of Tshs 100/kWh and connection fee of Tshs 27,000). TANWAT Staff that staid in the company housing estate did not pay for electricity.

Business model

TANWAT mini-grid operated a private business model.

Inclusivity

The mini-grid has not allowed local content in ownership of the mini-grid. During project refurbishment with a new turbine and alternator system, the communities surrounding the project area have been engaged in one way or another for denied services and goods from the various factories that have stopped production. The surrounding communities are involved in wattle harvesting and there is out-growers' arrangement with the company. Gender balance has not been exercised during project development and during O&M.

From colonial times in the 1950s to-date, existence of the mini-grid in the area has contributed in employment creation to the surrounding village youths;

electrification has made village life more comfortable, improved services like health and education facilities and has contributed to reduced rural to urban youth migration.

Customer Aspects

TANWAT mill, workshops, offices and housing estate are supplied by the biomass CHP as own generation. Excess power is sold to TANESCO a single anchor customer along Uwemba-Njombe-Makambako integrated mini-grid and national grid.

Lessons learnt

- The TANWAT mini-grid PPA was suspended upon extension of national grid to the interconnected Njombe-Makambako-Uwemba mini-grid due to difficulties to re-negotiate a tariff.
- Standardised SPPA and SPPT are key to the financial performance of the mini-grid.
- When the grid goes out, the plant has to synchronise with the grid and has to import power from the grid which tends to be expensive if the grid goes out frequently and for long durations.

3.3 Iringa Region

Iringa region is located in the Southern Highlands, is bordered by Dodoma and Tabora regions in the north, Morogoro region in the east, Njombe region in the south and Mbeya region in the west.

3.3.1 Mwenga Hydro and Wind Integrated Mini-Grid[4]

Plants development and ownership

The 4 MW Mwenga hydro based mini-grid at Itipi village in Mufindi District was commissioned in October 2012. Feasibility study, business plan, and construction of the project was undertaken by foreign companies. Project financing came from REF, EU, DFID and World Bank. Project development was undertaken by Rift Valley Energy Company.

It was integrated with the 2.4 MW Mwenga wind based mini-grid located at Usokami village 55 km away commissioned in June 2020 forming an integrated

[4] The hydro plant was visited on 2nd February 2016, the wind plant on 16th September 2021 and the Usokami, Ifupila and Ludilo villages' customers were interviewed on 5th April 2022.

renewable mini-grid. The integrated mini-grid comprises 430 km MV and LV distribution network and 70 transformer stations. As of February 2022, the integrated mini-grid provided power to the Rift Valley Energy offices, housing estate, hospital and more than 5,000 customers in 32 villages in Mufindi District. The integrated mini-grid was also connected to the national grid. As such, it supplied power to Luponde tea estate and factory whenever there was a power supply failure of the national grid.

The 4 MW Mwenga hydro based mini-grid signed an SPPA with TANESCO on 19th January 2010 and started selling excess power to the national grid on 21st October 2012 employing standardised feed-in-tariff issued by the regulator. During the dry season the river flow is so low that Mwenga Hydro plant cannot provide the national grid the contracted 4 MW power. Since June 2020 the 2.4 MW Mwenga wind plant supplements the hydro plant so as to meet the contracted capacity. Mwenga wind plant does not have a signed SPPA with TANESCO. As such, the integrated mini-grid cannot sell more than the contracted 4 MW to the national grid.

Mwenga hydro and wind integrated mini-grid is wholly owned by Rift Valley Energy Company which is registered in Mauritius and has activities in Mauritius, Zimbabwe and Tanzania.

Governance

Mwenga hydro and Mwenga wind plants are owned and operated by Rift Valley Energy Company. Others are Luponde Hydro and Suma Hydro plants not integrated with the Mwenga Hydro and Wind Integrated Mini-Grid. The company is run by management under guidance of a board of directors.

Governance is via standardised small power producers' regulatory framework, standardised power purchase agreement and associated standardised feed-in-tariff set by the regulator as well as the national grid code.

Other governance aspects include environmental management in operation and maintenance aspects of the plants and power networks and health and safety.

Figure 4: Mwenga Mini-grid Wind Turbines with transmission lines

Sustainability

Financial sustainability

About 95% of electricity generated is sold to an anchor customer TANESCO via the feed-in-tariff. 5% is sold to customers located in the 32 villages integrated mini-grid via the regulated year 2022 tariff of Tshs 100/kWh which is the same as that of TANESCO for lifeline tariff (single phase D1) category consuming less than 50 units against 100 units for TANESCO customers. D1 consumers that consecutively exceed 50 units per month in less than three months pay a higher tariff of Tshs 273/kWh. After three months they are automatically transferred to T1 single phase category. The tariff for large customers like domestic, factories and grain mills in the 32 villages (single phase and three phase T1) is Tshs 292/kWh (see Table 4).

Table 4: Energy Charge Tariff 2012 to February 2022 for Mwenga and TANESCO

Mwenga Hydro & Wind Integrated Mini-Grid			TANESCO		
Tariff Category	2012-Jan 2022	February 2022	Tariff Category	1st April 2016	February 2022
	Tshs/kWh	Tshs/kWh		Tshs/kWh	Tshs/kWh
D1< 50 kWh	60.00	100.00	D1<75 kWh	100	100
D1> 51 kWh	273.00	273.000	D1>75 kWh	350	350
T1-1 phase	234.00	292.00	T1-1 phase	292	292
T1-3 phase	234.00	292.00	T1-3 phase	292	292

NB: The tariff is exclusive of VAT 18%, REA 3% and EWURA 1%

Source: EWURA, Rift Valley Energy

It be noted that 5% of the energy distributed in its integrated mini-grid is largely used for lighting the households as most of the consumers are on D1 lifeline category that is cross subsidised by T1 category. Owing to the low tariff paid by the customers, Rift Valley Energy often conducts energy efficiency awareness campaigns to its customers so as to minimise such consumption. Also provides incentives for productive energy consumption like T1 customers' connection fees are lower than D1 customers (see Table 5) but their energy tariff is cost reflective.

Connection fee is Tshs 27,000, 25,000 and 150,000 for D1 single phase, T1 single phase and T1 three phase connection respectively (see Table 5). Upon connection with a meter, each customer is provided with initial 50 energy units. In February 2022, there were more than 5,000 customers in the 32 villages.

Furthermore, existing customers can obtain loans to purchase efficient productive use equipment supplied by the Rift Valley Energy Company like fridges, grain mills, oil presses, welding sets, hair saloon gadgets, wood working and carpentry gadgets. Reimbursement is done in monthly instalments whereby during energy purchases a customer pays for energy as well as for loaned productive use gadgets.

Table 5: Connection Charges for Mwenga Hydro and Wind Customers

Tariff Category	Oct 2012-Nov 2018		Dec 2018-Jan 2022		Feb 2022	
	Application fee Tshs	Connection fee Tshs	Application fee Tshs	Connection fee Tshs	Application fee Tshs	Connection fee Tshs
D1	5,000	150,000	5,000	150,000	0	27,000
T1-1phase	5,000	150,000	5,000	25,000	5,000	25,000
T1-3phase	5,000	380,000	5,000	380,000	5,000	150,000

NB: The tariff is exclusive of VAT 18%; upon connection each customer is provided with 50 kWh. Pre-paid kWh metering and PAYGO revenue collection system employed.

Source: Rift Valley Energy

Detailed TANESCO energy tariff for all customer categories and connection fees are attached as Appendix A below. Feed in Tariffs are summarised in Appendix B below.

Potential for long term financial sustainability of the integrated min-grid exists by selling most of the power generated to TANESCO, an anchor customer via standardised feed-in-tariff if it can regularly be revised by the regulator so that it is cost reflective as well as Mwenga hydro and wind integrated mini-grid strives to minimise its operational costs. The potential also exists to sell excess power from the 6.4 MW integrated system above the contracted 4 MW SPPA as well as expand the wind plant by additional 2 units of 0.8 MW each if the signed SPPA with Mwenga hydro can be re-negotiated with the regulators consent.

Technical sustainability

Hydropower technology is robust, reliable and durable. Wind technology is currently commercialised in many parts of the world. If both plants are optimally designed to resources availability, regular scheduled maintenance is undertaken, and optimally operated, the plants can last 20 to 30 years.

The integrated mini-grid operation and maintenance is undertaken by local engineers and technicians trained locally and abroad. Spare parts availability is not a challenge as adequate budget is allocated for importation from overseas. The staff are well experienced in running the integrated mini-grid. They are assisted by foreign experts who regularly visit the generating plants. Whenever they run into major operational or maintenance problems they seek assistance from equipment manufacturers.

Environmental sustainability of the mini-grid, could be maintained by implementing environmental safeguard standards being regularly given by the environmental regulator via regular environmental audits of the integrated mini-grid. Also, the integrated mini-grid is expected to maintain its social responsibility to the surrounding communities.

Affordability

About 95% of electricity generated is sold to TANESCO and 5% is sold to customers who pay the same pan territorial TANESCO tariffs including affordable lifeline tariff of Tshs 100/kWh for monthly consumption of less than 75 kWh and connection fee is Tshs 25,000 (refer Table 4 and 5 above).

Business model

A private business model is employed, smart pre-payment energy metering, payment for energy services is via cell phones. As regards single phase consumers of categories D1 and T1 purchase electricity via pay as you go web-based system. The same system is used for disconnecting the consumers when purchased energy is exhausted.

Inclusivity

The integrated mini-grid has not allowed local content in ownership of the mini-grid. During project development, the communities surrounding the projects were engaged in the project. Compensation was paid to project affected people who gave their land to the project. Gender balance efforts have been exercised during project development and during O&M. There are four female technicians involved in the operation and maintenance of the MV and LV network. One female technician is involved in operation of the wind plant. There is none female technician involved in operation of the hydro plant.

Customer aspects

Households

5 households (hh) were interviewed in Mwenga Hydro premises and 6 hh in Mwenga Wind premises. Average age of interviewees was 40-45 years. All hh use firewood and charcoal for cooking with none on e-cooking. On average each hh has 5 to 6 bulbs, 1 radio, 1 phone charger. 40%-50% of households have TVs and fridges.

Figure 5: Productive Uses powered by Mwenga Mini-grid Electricity

Productive uses

5 SMEs were interviewed in Mwenga Hydro premises and 6 SMEs in Mwenga Wind premises. Average age of interviewees was 30-40 years. Productive usage involved grain milling, bakery, bars, shops, stationery, saloon and welding workshops.

Lessons learnt

- The Mwenga 4 MW hydro plant cannot supply the contracted power all year round due to low river flows during the dry season.
- Mwenga 2.4 MW wind plant supplements the hydro plant with part of its plant capacity being idle for a fair portion of the year with fair wind resources availability due to existing SPPA contract limitations.
- The wind resources at Usokami have a potential for expansion with additional 2x0.8 MW wind units if the Mwenga Hydro SPPA can be re-negotiated
- Standardised SPPA and SPPT are key to the financial performance of the integrated mini-grid.

Electrification challenges

- Power supply reliability is poor with several power cuts in a day especially during the wet season
- Frequency and voltage drop especially on Saturdays and Mondays.
- Tariff increase in 2022
- Energy meters shortages
- Wooden poles shortages
- Sometimes purchased energy units do not get coded in the meter and therefore it is lost
- Customers complaints that they are never informed of power cuts even during planned O&M of the plant or network
- The plant operators inform the customers of planned outages by WhatsApp messages to customers with smart cell phones

Electrification contribution to the rural communities:

- Existence of the mini-grid in the area has contributed in employment creation to the surrounding village youths;
- Electrification has made village life more comfortable,
- There are improved services like health and education facilities
- Electrification has reduced rural to urban youth migration.
- Businesses and productive energy consumers' hours of service provision increased, income increased, their customers pay lowered fee for services rendered and customer relations have significantly improved.
- Productive energy users have access to loans from the owners of the mini-grid.
- The mini-grid provides better services than the national grid

3.4 Dodoma Region

Dodoma region is located in the central plateau, is bordered by Manyara region in the north, Morogoro region in the east, Iringa region in the south and Singida region in the west.

3.4.1 Leganga Solar PV Mini-Grid[5]

Plant development

Leganga 15 kW Solar PV based mini-grid was established at the village in Kongwa district in 2015 with Swiss Government's financial support. In the said year, the mini-

[5] The plant was visited on 3rd February 2022.

grid supplied power to 60 customers. In August 2018, the plant failed to operate due to charge control unit malfunctioning and power supply services stopped. The plant could not be repaired due to shortage of funds for financing its repair.

During 26th December 2021 to January 2022 the plant was repaired by ELICO Foundation from USA that privatised the mini grid with consent of the Ministry of Energy. The main obligation was to rehabilitate the solar mini-grid and operate it to attain financial sustainability. The repair consisted of replacement with new 23 solar panels[6] each of 270W, 1 charge control unit, replacement of 11 electric poles and 24 batteries each of 1,000Ah. In February 2022 there were 64 connected customers receiving reliable power supply from a plant that was still on trial operation. Customers consisted of 4 small SMEs, 2 large SMEs, 3 public institutions, 52 households, and 3 churches.

In October 2021, the national grid was extended to the village. Large productive users in the village connected to the national grid. However, power supply reliability of the national grid network was rather not satisfactory during the wet season. As such, for security of supply of SMEs providing various services in the village negotiated for the mini-grid to co-exist with the national grid.

Governance

The plant was registered by the regulator but was not being regulated. During 2015 to January 2022 the village community committee was responsible for management and revenue collection leaving operation and maintenance to a contractor. Tariffs levels were agreed upon during the annual meetings as presented by the community committee. Revenue collection was poor since some of the customers did not pay for rendered services. Enforcement of revenue collection was lacking,

Since February 2022 tariffs are set by the power supplier, a private contractor and customers have shown commitment to pay for services rendered to them. The payments are online monitored with support from local based software development firm.

[6] Solar PV panels were broken by children hunting birds with their catapults.

Figure 5: Containerized Leganga Solar PV Mini-grid

Sustainability

Financial sustainability

Potential for long term financial sustainability is questionable since revenue collected can meet O&M costs but not providing enough margin as profit. With more customer connections and use of smart metering and pay as you go business model there is limited potential for financial sustainability of the power services due to lack of productive users and/or anchor customers. Plans from June 2022 was to introduce productive uses such as a compressor, popcorn machine, milk chillers so as to improve revenue collection towards achieving sustainable financial cash flow of the business.

Technical sustainability

The solar mini-grid O&M is being undertaken by a village local technician. Spare parts availability is no longer a challenge as there are adequate spare parts within the country. The staff are well trained and have long experience in running the solar PV plants.

Environmental sustainability of the mini-grid could be maintained by implementing environmental safeguard standards being regularly given by the environmental regulator via regular environmental audits of the mini-grid.

Affordability

During 2015-2022 electricity produced was expensive Tshs 325/kWh and not affordable to some of the households in the village; thus, why some of them had not connected. From February 2022 tariff was Tshs 5,000/month for households

and Tshs 10,000/month for SMEs. Currently village is also connected to national grid, power is affordable via subsidised pan-territorial lifeline tariff of Tshs 100/kWh.

Business model

The mini grid employs a private business model, smart prepayment metering and pay as you go billing and revenue collection system.

Inclusivity

Initially, the solar mini-grid was community owned whereby participation of the community in the operation and maintenance as well as tariff setting and approval process was very inclusive. Following the community failure to repair the mini grid due to lack of financial resources, the mini grid was privatised. The privatisation process did not consider land and other contributions made by the village community. Gender balance is not exercised as there is a single male operator.

Customer Aspects

Households

10 households (hh) were interviewed in Leganga premises. Average age of interviewees was 37 years. All hh use charcoal supplemented by firewood in 2hh and LPG in 4 hh for cooking with none on e-cooking. On average each hh has 3 bulbs, 1 radio, 60% hh have phone chargers. 70% hh have radios, 40% TVs.

Productive uses

2 SMEs were interviewed in Leganga. Average age of interviewees was 40 years. Productive usage involved welding, carpentry workshops and drinks kiosks.

Lessons learnt:

- The community owned business model practiced during 2015 to 2018 lacked leadership and competent management, as such revenue collection was poor and when the plant failed, they could not repair it due to lack of funds.
- Flat rate metering employed was bad since it did not encourage consumers to be energy efficient in their electricity consumption.
- The current private business model employing pay-as you-go billing and revenue collection system has opened up hopes for improved financial performance of the mini grid.

- The village is currently also supplied by national grid whereby five customers are connected to both the solar mini grid and national grid.
- Large productive uses cannot be supplied by the solar mini grid due to capacity limitations of the solar plant.
- Solar power sometimes exhibits weak illumination, flickering though rarely is completely out during the day times.
- Co-existence of the solar mini-grid and national grid requires the regulator to revisit existing regulations and rules. Alternatively, to enforce existing rules and regulations for entry and exit conditions of the mini grids when the national grid encroaches their premises.
- Financial sustainability of the plant though limited, improved revenue collection has also been contributed by water services and charges from the village water pump which is connected to the mini grid. Customers are charged Tshs 100/ bucket of water and more than 4,000 animals at the village are charged Tshs 50/animal when served from the village pump.

3.4.2 Ngutoto Solar PV Mini-Grid[7]

Plant development

Ngutoto 15 kW Solar PV mini-grid was established in Ngutoto village of Kongwa district in 2015 with Swiss Government financial support. In the said year, the mini grid was supplying power to 60 customers. During 2018 to 2022 the plant remained operational though often stopped and needed restart.

During 26th December 2021 to January 2022 the plant was repaired by ELICO Foundation from USA that privatised the mini with consent of the Ministry of Energy. Obligations were to rehabilitate the solar mini-grid and operate it towards achieving financial sustainability. The plant's repair consisted of replacement with new 12 solar panels[8] each of 270W, and 24 batteries each of 1,000Ah. In February 2022 there were 53 connected customers receiving reliable power supply from the solar mini grid.

In April 2021, national grid was extended to the village. Large productive users were able to be connected. However, power supply reliability of the grid network was rather not satisfactory especially during the wet season. Following the solar PV mini-grid repair it provided quite reliable power supply services during day time. Exemptions were limited generation observed due to insolation levels

[7] The plant was visited on 03rd February 2022.
[8] Solar PV panels were broken by children hunting birds with their catapults.

contributed by heavy clouds overcast. As such, SMES negotiated the mini-grid to co-exist with national grid for their security of power supply.

Governance

The plant is registered by the regulator but is not regulated. During 2015 to January 2022 the village community committee was responsible for management and revenue collection leaving operation and maintenance to a contractor. Tariffs were agreed upon during the annual meetings. Revenue collection was poor as some of the customers did not pay for rendered services.

Since February 2022 tariffs are set by the power supplier and customers have shown commitment to pay for services rendered.

Sustainability

Financial sustainability

Potential for long term financial sustainability is questionable since revenue being collected cannot meet long term O&M costs. With more customer connections especially productive end uses and use of smart metering and pay as you go business model there is potential for improved financial performance. Long term financial sustainability remains questionable due to size of plant since cannot serve more large productive uses who can act as anchor customers.

Technical sustainability

The solar mini-grid O&M is being undertaken by a village local technician. Spare parts availability is no longer a challenge as there are adequate spare parts within the country. The staff are well trained and have long experience in running the solar PV plants.

Environmental sustainability of the mini-grid could be maintained by implementing environmental safeguard standards being regularly given by the environmental regulator via regular environmental audits of the mini-grid.

Affordability

During 2015-2021 electricity produced was expensive and not affordable to some of the households in the village thus why some of them did not connect. Tariff was Tshs 5,000/month for households, Tshs 10,000/month for SMEs. However, the village is connected to the national grid energy tariffs are affordable via subsidised pan-territorial lifeline tariff of Tshs 100/kWh for consumption of less than 75 kWh/month.

Figure 6: Focus group discussions participants at Ngutoto Village, Dodoma Region

Business model

The mini grid employs a private business model, smart prepayment metering and pay as you go billing and revenue collection system.

Inclusivity

Initially, the solar mini-grid was community owned whereby participation of the community in the operation and maintenance as well as tariff setting and approval process was very inclusive. Following the community failure to repair the mini grid due to lack of financial resources, the mini grid was privatised. The privatisation process did not consider land and other contributions made by the village community. Gender balance was not exercised as there was a single male operator.

Customer Aspects

Households

12 households (hh) were interviewed in Ngutoto mini-grid premises. Average age of interviewees was 49 years and average size of hh is 3. All hh use firewood and charcoal for cooking with none on e-cooking. On average each hh has 2 bulbs, 30% radio, 75% phone chargers. And 10% TVs.

Figure 7: Part of the Mini-grid Distribution Network at Ngutoto Village

Productive uses

1 SME was interviewed in Ngutoto mini-grid premises. Average age of interviewee was 37 years. Productive usage involved a beauty salon.

Lessons learnt:

- The community owned business model practiced during 2015 to April 2021 lacked leadership and competent management, as such revenue collection was poor. Flat rate metering that was being employed was bad since it did not encourage consumers to be energy efficient in their electricity consumption.
- The current private business model employing pay as you go billing and revenue collection system has opened up hopes for improved revenue collection, even though financial sustainability of the mini grid remains questionable. The relatively small size of the plant cannot take much productive uses that can act as anchor customers.

- The village is currently also supplied by national grid whereby seven customers are connected to both the solar mini grid and national grid whose services coexist.
- Co-existence of the solar mini-grid and national grid requires the regulator to revisit existing regulations and rules. Alternatively, to enforce existing entry and exit rules and regulations for mini grids when encroached by the national grid.

3.5 Morogoro Region

Morogoro region is located in the east, is bordered by Tanga region in the north, Pwani and Lindi regions in the east, Ruvuma and Njombe regions in the south and Dodoma and Iringa regions in the west.

3.5.1 Songambele/Kitaita Solar PV-Diesel Hybrid Mini-Grid[9]

Plant development

Songambele/Kitaita 6 kW Solar PV and 10kVA diesel hybrid mini-grid was established in 2016 by PowerGen Company. In 2016, the mini grid was supplying power to 103 solar customers. In May 2020, the national grid was extended to the village. Since then, large productive users have been connected. In 2022, national grid connected customers were 103. Both solar mini-grid and national grid supplied customers were 15. Power supply reliability of the grid network is rather not good.

Governance

The plant is registered by the regulator but is not regulated. Since power supply establishment in the village as of 2020, tariffs are set by the power supplier and customers do pay for services rendered. Those who fail to pay for services are denied services.

Sustainability

Financial sustainability

Potential for long term financial sustainability of the mini-grid is questionable as coexistence with the national grid power supply that offers subsidised affordable lifeline tariff if grid power supply reliability is maintained. Also, mini-grid's plant small size does not guarantee connection of productive uses that can improve revenue collection hence financial sustainability.

[9] The plant was visited on 7th February 2022.

Technical sustainability

The solar and diesel hybrid mini-grid O&M is being undertaken by a village local technician. Spare parts are available within the country. The staff has experience in running the solar PV and diesel hybrid plants.

Environmental sustainability of the mini-grid could be maintained by implementing environmental safeguard standards being regularly given by the environmental regulator via regular environmental audits of the mini-grid.

Affordability

When new customers connected for services, they paid Tshs 40,000 which included wiring of 1 bulb. Electricity produced was expensive and not affordable to some of the households in the village thus why some of the households did not connect. The tariffs charged was Tshs 1,000 per day and after payment sometimes it did not activate power services to the customer. However, national grid power available in the village is affordable: connection fee is Tshs 27,000 and lifeline tariff is Tshs 100/kWh. As such customers have a choice of who to supply them.

Business model

The mini grid employs a private business model, smart prepayment metering and pay as you go billing and revenue collection system.

Inclusivity

The solar-diesel hybrid mini-grid is privately owned. Gender balance is not exercised as there is a single male operator.

Customer Aspects

Households

13 hh were interviewed in Songambele/Kitaita premises. Average age of interviewees was 47 years. All hh use firewood and charcoal for cooking with none on e-cooking. On average each hh has 3 to 4 bulbs, 50% radio, 40% TV, and 90% phone chargers.

Productive uses

2 SMEs were interviewed in Songambele/Kitaita premises. Average age of interviewees was 41 years. Productive usage involved drinks kiosks and TV shows.

Lessons learnt:

- Mini grid power services are not reliable with frequent outages, poor customer care, expensive tariff, power supply is not available for 24 hours and when you purchase electricity it takes at least 20 minutes to be connected. In case power supply services is not connected, there is no means of recovering the electricity token.
- When main grid power is out and there are only a few less than 18 mini grid customers who have paid for services i.e. attain the critical mass, the solar-diesel gen set cannot be switched on to provide power supply.
- Grid power supply is available for three to four days a week. As such large productive users have installed own backup diesel gensets to address the problem. For households, some opt to use kerosene lamps and batteries for lighting.
- The solar diesel hybrid mini grid coexists with national grid in the village so as to guarantee security of supply for customers especially SMEs connected to both systems.
- Co-existence of the solar mini-grid and national grid requires the regulator to revisit existing regulations and rules. Alternatively, to enforce existing entry and exit rules and regulations for mini grids when encroached by the national grid.
- The private business model employing pay as you go billing and revenue collection system is a good business model for revenue collection.
- Coexistence of the national grid offering affordable tariff with the solar PV and diesel hybrid mini grid offering expensive tariff cannot guarantee long term financial sustainability of the mini-grid whenever grid power supply reliability is guaranteed.
- Some customers use electricity for cooking through efficient electric pressure cookers (EPCs). This has proved the potential for mini-grids to address challenges in accessing clean cooking solutions in the rural areas.

3.5.2 Leshata Solar PV – Diesel Hybrid Mini-Grid[10]

Plant development

Leshata 6 kW Solar PV and 10kVA diesel hybrid mini-grid was established in 2017 by PowerGen Company. In 2022, the mini grid was supplying power to 155 customers consisting of 4 public institutions, 5 religious institutions, 21 SMEs and 125 households. However, in August 2021, the national grid was extended to the

[10] The plant was visited on 7th February 2022.

village. Since then, large productive users have been connected. As such, in February 2022 grid supplied customers numbered more than 200 compared to the 155 connected to the mini-grid. Power supply reliability of the national grid network was rather not good a fact that has contributed for the national grid to coexist with the mini-grid.

Governance

The plant is registered by the regulator but is not regulated. Since power supply establishment in the village from 2017, tariffs are set by the power supplier and customers do pay for services rendered. Those who fail to pay for services are denied services.

Figure 8: Leshata Solar PV-Diesel Hybrid Mini-grid in Morogoro Region

Sustainability

Financial sustainability

Potential for long term financial sustainability is questionable as the coexistence with the national grid power supply that offers subsidised affordable lifeline tariff if grid power supply reliability can be maintained.

Technical sustainability

The solar and diesel mini-grid O&M is being undertaken by a village local technician who appears to be quite competent and experienced in running the solar PV and diesel hybrid plants. For reliability of power supply, the genset is serviced twice a year. Spare parts are available within the country.

Environmental sustainability of the mini-grid could be maintained by implementing environmental safeguard standards being regularly given by the environmental regulator via regular environmental audits of the mini-grid.

Affordability

Electricity produced by mini-grid was expensive and not affordable to some of the households in the village thus why some of the households did not connect. The operation costs are also very expensive; genset uses 5 liters of fuel in 1 hour which costs Tshs 12,500/. The tariff packages charged were expensive whereby at Tshs 1,000/ day was unlimited for all appliances. Due to low ability to pay; tariff review was done and currently three packages operate ranges from Tshs 500-2,000/ day. The difference is only on number and type of appliances customer connects. However, national grid power available in the village is affordable via pan-territorial lifeline tariff Tshs 100/kWh. As such customers have a choice of which service provider to supply them.

Business model

The mini grid employs a private business model, smart prepayment metering and pay as you go billing and revenue collection system.

Inclusivity

The solar-diesel hybrid mini-grid is privately owned. Gender balance is not exercised as there is a single male operator.

Customer Aspects

Households

11 hh were interviewed in Leshata premises. Average age of interviewees was 30 years. All hh use firewood and charcoal for cooking with one on e-cooking. On average each hh has 3 bulbs, 90% radio, 30% tv,10% computer, and 80% phone chargers.

Productive uses

6 SMEs were interviewed in Leshata premises. Average age of interviewees was 42 years and average hh size 5. Productive usage involved drinks kiosks, food vendors, stationery shops, and beauty salon.

5 Public institutions, 1 office, 1 primary school, 1dispensary with 1deep freezer, 1 computer, 1 incubator and lights; 1 church and 1 mosque with amplifiers, guitars, church organ and speakers.

Lessons learnt:

- Mini grid power service is not reliable with frequent outages, expensive tariff, power supply is not available for 24 hours and when you purchase electricity it takes at least 20 minutes to be connected.
- When national grid power is out and there are only a few mini grid customers who have paid for services not reaching the critical mass, the diesel gen set cannot be switched on to provide power supply.
- Grid power supply is available for three to four days a week. As such large productive users have installed own backup diesel gensets to address the problem.
- The solar diesel hybrid mini grid coexists with national grid in the village so as to guarantee security of supply for customers connected to both systems.
- Co-existence of the solar mini-grid and national grid requires the regulator to revisit existing regulations and rules. Alternatively, to enforce entry and exit rules and regulations for mini grids when encroached by the national grid.
- The private business model employing pay as you go billing and revenue collection system is a good business model for revenue collection.
- Coexistence of the grid offering affordable tariff with the solar PV and diesel hybrid mini grid offering expensive tariff cannot guarantee long term financial sustainability of the mini-grid whenever grid power supply reliability is guaranteed.

3.5.3 Mvuha Solar PV-Diesel Hybrid Mini-Grid[11]

Plant development

Beginning in 2015, a solar PV mini-grid plant of 20 kW and 5.6 km distribution network was developed by Husk Power System company (HPS) Limited and was installed at Mvuha Village. It was commissioned in 2016. The initial connected customers were 20, and the number increased up to 72, which included 60 households and 12 SMEs. The SMES were stationeries, tailors, retailers, barbershops, and beauty salons. Village government office and other social centres were connected to the mini-grid.

In June 2020, the national grid was extended to the ward/ village, which led most of the customers to abandon the mini-grid and got connected to the national grid network. This was due to both low connection costs and subsidised tariff charges. The energy system faced management and technical challenges that led to its shutdown in 2021. The owner sold it to another buyer, who disassembled it and shifted all the major components to other places. When the team visited the village in September 2022, only a few poles of the distribution network existed. This information was provided by the local operator who was working with the power plant.

Governance

The Solar PV plant was neither registered nor regulated, and since its establishment, management and setting of tariffs were done by the operator/ owner and presented at meetings with customers. The tariffs were categorized for households and businesses, which were also based on the number and type of appliances and equipment used by a particular customer.

Sustainability

Financial sustainability

Based on the challenges that emerged in the management of the Solar PV power plant, the potential for long-term financial sustainability was lacking. The higher operational costs surpassed the revenues, which led to the retrenchment of some of the staff working with the system. Furthermore, the arrival of the national grid, which was offering an affordable tariff, made customers abandon the mini-grid, hence there was no revenue to sustain the operations.

[11] The site was visited on 22nd September 2022

Technical sustainability

The operation and maintenance of the Solar PV was undertaken by local technicians who were trained and had developed experience in system management aspects. There were no major technical issues experienced during the operations of the plant, and no challenges with spare parts of the system, as they were readily available in the market.

Affordability

Customers were connected to the mini-grid at a fee of Tshs 55,000, that included house wiring with 2 bulbs, a socket and a bracket. The customers were charged Tshs 700 to Tshs 1000 per day based on the tariff category. This was expensive to some households and businesses; hence, some didn't get connected. The arrival of the national grid with connectivity charges being Tshs 27,000 with lifeline tariffs demonstrated to be affordable to the majority, led to a shifting wave from the mini-grid services.

Business model

The mini grid employed a private business model, smart pre-payment metering and revenue collection system.

Inclusivity

The solar PV system was privately owned, but the community was engaged from the beginning. Essentially, they were involved in the community mobilisation meetings, site identification and selection to install the power plant. During system operations, gender balance was not observed as was done by the male staff.

Customer Aspects

Customers in the village were being served by the national utility facing affordable subsidised connection fees and lifeline energy charges. As such productive energy usage by SMEs mushroomed along with improved public institutions' services in health, education and religious activities.

Lessons learnt

- The arrival of the national grid in the village, which is highly subsidized, led to a total shifting of the customers from Mini-grid due to affordability issues, hence the beginning of the Mini-grid business downfall.

- As the PV mini-grid components have been sold out, customers still face challenges of unreliable power supply, hence, some have gone back to using generators and other alternatives to access electricity.
- Despite the reliability challenges of the grid electricity, the mini-grid developer couldn't see this as an opportunity to coexist with the grid to provide services when grid electricity is not available.
- Despite being connected to the national grid since 2020, firewood and charcoal are the main sources of energy used for cooking in all families in this village. More awareness of the benefits related to eCooking is required.

3.5.4 Biro Biomass Gasifier Mini-Grid[12]

Plant development

The Biro Gasifier Mini-grid Power system with 32 kW installed capacity was designed, developed and constructed in year 2015 and then commissioned in 2016 at Biro village, Malinyi District, Morogoro Region. This was done in partnership with three organisations which are Husk Power Systems, TaTEDO-SESO, and Spanish NGO-ONGAWA Engineering. This project was financed by the Energy and Environment Partnership (EEP S&EA) under the Finish Government. The project cost was EURO 263,950.

The 5.3 km distribution network was erected and about 70 customers were connected. This included SMEs, households, primary school teacher's quarters, the Catholic Mission dispensary and nurses' quarters. The project also was designed to fuel production and commercialisation of briquettes using by products from the gasification processes. Both the gasifier unit and the briquette machine were procured, erected, commissioned and operated for some time. However, both units faced challenges in operations especially on the feedstock availability; hence unreliable power supply and biochar.

In year 2020, the national grid was extended to the village, a number of mini-grid customers opted out and connected to the national grid whose tariff was subsidised, low and affordable. In view of the above, the mini-grid stopped operations hence forth.

Governance

The plant was developed as build own operate arrangement under ONGAWA Engineering, Husk Power and TaTEDO-SESO. The power plant was operated in

[12] The plant was visited on 7th February 2022.

partnership of Husk Power Systems, ONGAWA Engineering, TaTEDO-SESO and Biro village government a rather loose form of PPP arrangement without proper documentation. Efforts to private the business, formulation of the Special Purpose Vehicle (SPV) was initiated and the registration process with BRELA started but couldn't be formally registered due to numerous operation and management challenges which emerged.

Sustainability

Financial sustainability

Financial sustainability of the power plant was not possible due to the facts that the number of connected customers to the mini-grid was not significant to generate revenues that could support the operations. The mechanisms to collect tariff was through the electricity committee which comprised representatives of village leadership and consumers of electricity. Revenue collection was challenging as some customers did not pay on time, hence negatively impacted to the entire operations. If the briquettes manufacturing business would have been successfully operational as expected, it could have assured stable financial flow and probably sustainability.

Technical sustainability

The power plant was designed to use rice husks and various tests were done to establish the calorific value of the husks produced within and around the village. The operations of the gasifier required up to 16 bags of the husks to run the plant for 6 hours from 16 hrs to 22 hrs. Adequate feed stock availability was sometimes experienced but had to be procured from outside the village for Tshs 1000/ bag. During gasifier operation, they used petrol fuel for ignition of the plant when batteries were at low voltage.

Further, there were a number of other technical challenges experienced which led to change some spares some of which were available in the market while others had to be ordered from India which took a lot of time for some services to resume. Regular maintenance was supposed done approximately every two weeks but the operator could not maintain. This was largely so because there were not enough revenues collected to cover costs for replacement of some key items like oil, gas filters and expired pipes of the gasifier.

Affordability

Due to affordability issues, only 70 customers managed to connect against a forecasted potential of more than 150 customers. The connection charges were Tshs 20,000 per households, energy charge was flat rate Tshs 10,000 per month. The said agreed energy tariff was not affordable to some households as they defaulted several times. The connection charges were also perceived high to some of the unconnected households but were affordable to SMEs and the institutions. The connection charges covered for one ready board, two bulbs, one socket and one earth rod. It was mandatory for the customers wiring to be done by the developer to ensure quality standards are observed as well as safety aspects.

Business model

Biro power plant was operated in the public private partnership which involved the Ongawa Engineering, TaTEDO-SESO and HPS and Biro village government. In this mode, the SPV was conceived and set for its registration, to oversee the operation. This started by also establishing the village electricity committee which operated the system in transition to SPV which its registration didn't mature.

Inclusivity

The project partners followed procedures by first involving the district authorities on the plans and identification of the village, later the villagers. The site identification, land allocation, involvement of the community on the project activities, the formulation, registration of the SPVs and its operation were well stipulated and agreed with villagers.

The local artisans were involved in construction of the powerhouse, the storage of the rice husks and even the distribution network. Two of the village youth were employed as security guard and operator. On the management of the operation, 40% of the formulated electricity committee were women.

Customer Aspects

Households

8 hh were interviewed in Biro premises, average size of hh 4-5 and average age of interviewees was 45 years. All hh used firewood and charcoal for cooking with three used LPG. On average each hh had 5 bulbs, 100% radio and 3 hh owned tv.

Productive uses

1 SMEs was interviewed in Biro premises, age 41 years and hh size 4. Productive usage involved a shop and a restaurant.

2 Public institutions a dispensary and a primary school was interviewed. The dispensary had 3 staff houses, 2 fridges, 1 microscope, 2 computers, 1 steriliser, 26 lights, and 1 radio. A primary school had five staff houses.

Lessons learnt:

- The project partners wanted to be sure on the energy generation from the feedstock, hence several tests on the calorific values of the rice husks from the village and nearby areas were done. The tests were expensive but there were no results provided.
- The power plant design did not consider or project on the availability of sufficient feedstock from the village, thus the system started to experience the challenges of getting enough feedstock after 9 months. Had to incur costs to buy rice husks from nearby villages which proved to be expensive and costly to transport.
- The gasifier operator was technically competent in electrical technology, thus even after the mini-grid stopped operation, he was subcontracted by the power utility to support on the immediate technical challenges as TANESCO offices are far from the village.
- It was learnt that during site identification, one family at village provided land with a "verbally" agreement that when the grid arrives the project will take out the equipment but would hand over the power plant house to them. This has been controversial as national grid arrived, the gasifier was not operating, the equipment had not been taken out and that family had not been handed over the particular house. If there was a written agreement, things could have been different.

3.6 Pwani Region

Pwani region is located in the eastern coast, is bordered by Tanga region in the north, Indian Ocean in the east, Lindi region in the south and Morogoro region in the west.

3.6.1 Kibindu Gasifier – Solar PV Hybrid Mini-Grid[13]

Plant development

The Kibindu mini-grid power system was developed in 2015 by Sustainable Energy Services Company (SESCOM) Limited, whereby a 20 kW gasifier system was installed under the support of the USADF Power Africa Grant. Initial connectivity was 21 customers and the reliability of the power supply was low due to various reasons including seasonal availability of the feedstock needed for preparation of the fuel. To increase the reliability of the electricity supply services, SESCOM, and Husk Power hybridised the mini-grid in 2017 by adding another 20 kW of Solar PV. After the hybridisation of the two power plants, the reliability of the power supply improved and inspired more connectivity which increased to 104 customers. In the year 2020, the national grid was extended to the village, whereby some customers in particular the SMEs, chose to have dual connections to the mini grid and national grid.

Figure 9: Solar PV -Gasifier Hybrid Mini-grid at Kibindu Village

[13] The plant was visited on 21st January 2022.

Governance

The mini grid system was developed on a build, own and operate model. The system was registered by the regulator but was not regulated. The customer's tariff establishment was based on the possession, type, and usage of energy appliances. The packages were billed on a weekly and monthly basis and they were not affordable to the majority of customers.

Sustainability

Financial sustainability

The arrival of the national grid in the village provided customers with alternative electricity sources that assured productive usage and financial sustainability. The mini-grid tariffs were high and not affordable to majority community residents but the national grid tariffs were subsidised and affordable. Due to this fact if the national grid power supply is reliable, the long-term financial sustainability of the Kibindu mini-grid is highly questionable.

Technical sustainability

The gasifier plant was designed to use different types of biomass feed stock of maize cobs and rice husks. It consumed 6 to 7 bags of rice husks each weighing 30kgs to run the engine for 4-5 hours. Since the feed stocks are agricultural products available seasonally, there were times when it fell short to sustain the operations. Some spares parts for the gasifier systems were available in the nearby market while others had to be ordered from India as the technology is still not common in the country.

The by-products from gasification and biochar are useful products for the briquette production. The developer had previously thought of introducing briquette machines as a mechanism for ensuring environmental sustainability. Prevailing various other national environmental safeguard guidelines and standards are being regularly followed by the operator.

This hybrid system is operated and maintained by a trained local technician who is based at the village. The schedule for the gasifier maintained was adhered to the manufacturer's O&M manuals. The Venturi was maintained weekly, oil is changed every 2 months, and engine overhaul including change of pistons and valves was done every 4 months or based on the operating hours. On solar components, there were regular checks on the batteries, inverters, and panels which were washed once a month but solar panels dust was cleaned weekly.

During operation, when the synchronization was taking place, shifting from solar PV to the gasifier caused power blackouts for some minutes before power supply stabilized.

Figure 10: Kibindu Public Health Centre Powered by Solar PV-Gasifier Hybrid Mini-grid

Affordability

The rate of customer connectivity was very low in the first six months after the plant was installed. This was due to high connectivity charges and energy tariff. The customers paid Tshs 50,000/ for connectivity including house wiring. The package included 1 bulb holder, 1 switch, 1 bulb, 1 switch socket, 1 main switch, 5m earth wire, 1 conduit pipe, earth rod, and 5m of 1.5mm^2 cable. Some villagers were not able to connect due to the high costs of electrical accessories. The developer had to explore other mechanisms that could help customers to easily connect. They installed a ready board in houses which allowed connectivity and customers could extend wiring in their houses at their own convenient time. The energy tariff was Tshs 15,000/month. Since the village is connected to the national grid customers have access to affordable subsidised lifeline tariff of Tshs 100/kWh for 75 kWh consumption in a month. Some customers e.g. SMEs opted for both sources.

Business model

The Kibindu mini-grid operates as a joint private business by SESCOM and Husk Power Systems. The connected customers are installed with the smart meters and they purchase electricity using their mobile phones. The payment system is computerized and is in a pay-as-you-go mode; customers can see their balance of the paid charges at the powerhouse control room.

Inclusivity

During the setup of the mini grid power system, villagers were involved in different steps, including participation in the meetings to decide on project site identification, distribution networks, and powerhouse/ feedstock storage construction. Both the operator and the power plant guard originate from Kibindu. The plant is also operated by a female operator which indicates how valuable gender issues were considered by the developers.

Customer Aspects

Households

10 hh were interviewed in Kibindu premises. Average age of interviewees was 36 years and hh size was 4. All hh used firewood and charcoal for cooking with none on e-cooking. On average each hh had 2 bulbs, 50% radio, 50% tv, 100% phone chargers, and 50% TVs.

Productive uses

5 SMEs were interviewed in Kibindu premises. Average age of interviewees was 39 years and hh size 4. Productive usage involved 2 food and drinks vendors, 1 shop, 1 TV show, 1 stationery and pharmacy shop.

2 public institutions: 1 office and 1 health centre with following gadgets: 1 microscope, 1 full blood picture (FBP) machine, 1 computer and 1 photocopy machine.

Lessons learnt:

- Since its installations in 2015 to 2017, the power plant especially on the solar part has been operated with minor technical challenges, and whenever they occurred, they were immediately solved. In the case of the biomass gasifier, there have been some technical challenges that have led to the use of the solar PV part of the plant most of the time. The use of solar has been possible

because of the small load of the mini-grid as there was not much productive use.

- When there are low agricultural harvests there are challenges in getting sufficient biomass feed stocks which poses operational risks, especially on the gasifier power systems.
- The gasifier-solar hybrid mini-grid coexisting with the national grid in the village has guaranteed the security of supply for customers especially SMEs who were connected to both systems. Despite the stimulated energy demand for other productive uses such as milling, carpentry, brick making, welding, and eCooking services in the village, the mini-grid system's capacity is small hence cannot power all these equipment.
- The villagers appreciate the presence of the developers, both HPS and SESCOM, as their technicians provide immediate technical responses whenever there is a challenge even to the grid-connected houses, as TANESCO offices are more than 100km away from the village.
- There were low frequency and voltage fluctuations performance with the gasifier power system whereas power supply was much stable with when the solar power plant system was operating.
- The medium voltage supplying the village is extended from Chalinze about 100 km away, often suffers from breakdowns, restoration of services is done in two days of each week involving complete line shut down.
- TANESCO does not have a resident technician in the village, as such the mini-grid technician voluntarily assists customers with emergency problems.

3.7 Kilimanjaro Region

Kilimanjaro region is located in the north, is bordered by Kenya country in the north and east, Tanga region in the south and Arusha and Manyara regions in the west.

3.7.1 TPC Biomass Fired Mini-Grid[14]

Plant development

Tanganyika Planting Company (TPC) biomass combined heat and power (CHP) based mini-grid is located at Langasani village, near Moshi township. It has existed since colonial times in 1930. During 1931 to 2010 it was based on a bagasse fired steam engine technology. In 2010 it was replaced with a 17.5 MW steam turbine technology employing the same amount of feed stocks. In both cases the plants

[14] The plant was visited on 22nd April 2022.

were developed to process sugar from sugar canes, to provide power to the offices, workshops, irrigation pumps, hospital, primary school, secondary school, three mosques, six churches, a kindergarten and housing estate. Owing to the boiler limitations, the plant can generate up to 14 MW capacity only. Also, there exist standby diesel generators of 2MW and 4MW.

On 6th October 2009, TPC signed a SPPA with TANESCO and 9 MW contracted excess power supply to TANESCO national grid was commissioned on 13th September 2010.

Development cost for the plant could not be availed. Amount of excess power contracted is 9 MW. The SPPT during the dry season is Tshs 243.73/kWh and during the wet season is Tshs 182.80/kWh. 75% shares of the plant are owned by Alteo Company of Mauritius and 25% is owned by the government of Tanzania Mainland.

Governance

The company is run by management under guidance of a board of directors. Governance is via standardised small power producers' regulatory framework, standardised power purchase agreement and associated standardised feed-in-tariff set by the regulator.

Sustainability

Financial sustainability

Potential for long term financial sustainability of the min-grid exists by selling power to an anchor customer via standardised feed-in-tariff if it can be regularly revised by the regulator so that it is cost reflective as well as TPC mini-grid strives to minimise its operational costs. Revenue from electricity sales is in the order of 2-3 billion Tshs per annum. Sugar production is about 100 tons per annum which is sold at 2.8 million Tshs per ton.

Technical sustainability

Mini-grid operation and maintenance was undertaken by local engineers and technicians. Spare parts availability was a challenge as it was imported from overseas. The staff are well trained and have long experience in running the mini-grid. Most of the spare parts for the plant are manufactured at the company's factory. Others are imported from India. Whenever they ran into major problems, they sought assistance from equipment manufacturers. Funds for O&M are allocated.

Environmental sustainability of the mini-grid, could be maintained by implementing environmental safeguard standards being regularly given by the environmental regulator via regular environmental audits of the mini-grid. For instance, the liquid waste from sugar production is processed at the open bio digester to lower the pH before it is drained to sugar cane estate as fertiliser. Also, the mini-grid is expected to maintain its social responsibility to the surrounding communities.

Affordability

Electricity produced is sold to TANESCO and TANESCO customers pay based on regulated tariffs including uniform pan-territorial tariffs of Tshs 100/kWh. TPC Staff that stay in the company housing estate and the connected institutions i.e. dispensary do not pay for electricity. However, junior staff are limited to 100 kWh consumption per month while senior staffs' consumption is not limited.

Business model

PPP ownership whereby 75% shares are private and the balance is government owned. However, TPC mini-grid trades via SPP and feed-in tariff for sale of surplus energy.

Inclusivity

The mini-grid has allowed local content in ownership of the mini-grid. During project refurbishment with a new turbine and alternator system, the communities surrounding the project area have been engaged in the project. Gender balance has not been exercised in the power plant staff recruitment but has been exercised in the network O&M whereby female staff are employed.

Customer Aspects

TPC CHP plant provides power to workshops, offices and 11 staff housing estate each with 100 hh, water wells pumping stations, 1 hospital, 1 primary school, 2 secondary schools, 1 kindergarten, 3 mosques, and 6 churches as own generation. Excess power is sold to TANESCO a single anchor customer/national grid.

Lessons learnt:

- The TPC generating plant produces only 14 MW due to boiler capacity limitations.

- The generating plant is shut down during off-season i.e. April to May so as to allow maintenance of the plant can be done. If the plant had a redundant boiler, plant shut down could be avoided.
- Standardised SPPA and SPPT are key to the financial performance of the mini-grid.
- TPC bagasse based mini-grid has contributed in employment creation to the surrounding village youths; electrification has made peri-urban life more comfortable, improved services like health and education facilities and has contributed to reduced rural to urban youth migration.

3.7.2 Mjimwema MFP SVO/Diesel Mini-Grid[15]

Plant development

Mjimwema Rosilini 8.8 kW Multi Fuctional Platform straight vegetable oil (MFP/SVO) or diesel powered mini-grid is located at Matadi Village, Ndumiti Ward in Kilimanjaro region. It was established in 2012 with EU, HIVOS financial support and implemented by TaTEDO-SESO. The plant was installed and operated by the Community Group well known as Bank Imani Upendo. The plant was a representation of the early initiatives of promoting the productive uses of energy in off grid areas using biofuels powered solutions. The sets consisted of a 20 HP Lovson diesel engine and other productive uses machines such as milling, dehusking, oil press and battery charging machines.

The 8.8kW generator was supplying power to 25 to 38 customers in years 2012 and 2013 respectively. Straight vegetable oil from jatropha was the desired fuel for the genset. However, due to land and other farming issues, very few jatropha trees were planted in the village. As such there was not available straight vegetable oil for the plant. The plant had to run on expensive imported diesel fuel.

The plant was not registered by the regulator. Development cost for the plant and associated accessories was estimated to be USD 50,500.

Daily fuel costs for power generation were in the tune of Tshs 525,000 to 703,000 per month. The operational costs included salaries for a plant guard of Tshs 100,000 per month, plant operator Tshs 50,000 per month and repayment charges of Tshs 200,000 every three months. Daily revenue collections were much less than operational costs. Customers complained that power supply services lasting 6PM to 10 PM was inadequate and the bills were very high. As such 7 customers left

[15] The plant was visited on 22nd April 2022.

the MFP mini-grid and joined a scheme introduced by Mobisol company to acquire solar PV systems of different capacities with flexible repayment terms in the village. As such, the MFP mini-grid was running at a loss. Power supply services stopped on 14th September 2013.

High operational costs and stiff competition from solar schemes were the main contributing factors. A solar Mobisol connection cost was 250,000 Tshs for 200W metered power services that was recovered as a loan in 36 months at Tshs 71,000 per month. Though the solar option tariff proved cheaper than the MFP tariff, the solar service also wound up upon national grid extension to the Matadi and Mjimwema Rosilini area undertaken by REA.

However, grain milling continued until 28th February 2016 when it was stopped. High fuel costs and non-availability of spare parts were the main contributing factors. By then monthly financial loss was in the tune of Tshs 72,000 per month. In view of the circumstances, the village community entered into an agreement with an individual private person who repaired the MFP and was able to continue with grain milling services. Ultimately the village community sold the MFP to the individual at Tshs 7 million.

Governance

The village community via Benki Imani Upendo Group owned and operated the facility and had a committee that was responsible for supervising the operator, revenue collection and overall management of the MFP facility. Tariff was set during meetings with their customers. The tariffs agreed upon were not regulated by the regulator. The MFP facility was not registered by the regulator either.

Sustainability

Financial sustainability

Potential for long term financial sustainability was lacking due to higher operational costs than revenues, and problems of securing fuel and spare parts from distant major towns.

Technical sustainability

MFP mini-grid O&M was undertaken by village local technicians. There were regular breakdowns of the engine and spare parts availability was a challenge as was imported from major towns in the country. The staff were well trained and had a long experience in running the diesel plants.

Environmental sustainability of the mini-grid, could be maintained by implementing environmental safeguard standards being regularly given by the environmental regulator via regular environmental audits of the mini-grid.

Affordability

Electricity produced was expensive and not affordable to majority in the village thus why some 7 customers out of 38 customers dropped out from the services in 2013. Owing to shortage of feedstock for running the plant, diesel fuel was used for power generation. The tariff was as high as Tshs 1000/kWh. The MFP mini-grid was out shined by the solar PV systems introduced in the village by Mobisol as they had flexible terms in repayments.

Business model

MFP mini-grid operated under a community business model.

Inclusivity

The MFP mini-grid being community owned, had 100% local content in ownership. During project development, the village community was closely engaged. Gender balance was exercised with female members in the organising committee.

Customer Aspects

9 hh and 1 SME were interviewed at the time of visit. The MFP had been sold to a private person. The village had been connected to the national grid. There was no plan to reintroduce the MFP straight vegetable oil/diesel based mini-grid technology into the village.

Lessons learnt:

- MFP straight vegetable oil fueled mini-grid failed due to non-availability of adequate jatropha plants that were supposed to provide the raw material for preparation of straight vegetable oil as fuel.
- In the absence of vegetable fuel, MFP based mini grid fueled by expensive imported diesel and spare parts, as well as spare parts availability problems in rural areas render MFP mini-grids technically and financially not sustainable.
- MFP diesel based mini-grids cannot compete with solar based mini-grids and systems in the same village.
- MFP mini-grids and solar mini-grids cannot compete with subsidised REA power services connected to the national grid

- It turns out that Lovson engine which was installed was not very popular in Tanzania and therefore started to be one of the major reasons of failure to timely secure its spare parts.
- Lack of a clear biofuel policy at the time of the project implementation led to contradictions in information regarding benefits of Jatropha, its potential in operation of the mini grids and power systems.

3.7.3 Kikuletwa Mini Hydro Based Mini-Grid[16]

Plant development and ownership

Kikuletwa is a 1.65 MW mini-hydro based plant located at Kikuletwa harmlet, Chemka village, Hai District, Kilimanjaro Region that is connected to the national grid. The plant was built and commissioned during colonial time of Tanganyika, a mandated territory to Great Britain, by a private individual who supplied power to Moshi in 1937 under an agreement with Dar es Salaam and District Electric Supply Company Limited (DARESCO). The said undertaking was purchased by DARESCO in 1950. DARESCO was owned by Tanganyika Electric Supply Company Limited (TANESCO) with majority shares of Kenya Power and Lighting Company Limited (KPLC) and minority shares of Tanganyika (currently Tanzania Mainland Government). In 1964 the government of Tanzania reached an agreement with KPLC to purchase all the shares it owned. Hence the two power companies merged to form a single company with a new name of Tanzania Electric Supply Company Limited (TANESCO). Tanzania Mainland government slowly purchased TANESCO shares and by 1975, all the shares were public.

In 1989, the plant ceased to operate due to spare parts non-availability as it could no longer be purchased anywhere in the world. The original plant manufacturers no longer existed by then.

From above, feasibility studies, construction and operation of the plant and network were undertaken by foreign experts. Nearby villagers were engaged as non-skilled labourers during construction and operation. Later on, local staff were trained to operate and undertake minor maintenance leaving major maintenance to foreign experts. Financing for the plant development came from Europe whose cost cannot easily be retrieved.

[16] The plant was visited on 23rd April 2022.

In 2003, Arusha Technical College was granted by the Government to own the plant, refurbish it and make it a renewable energy training centre for Tanzania.[17] Arusha Technical College is receiving Wold Bank assistance via East African Skills Transformation Regional Integration Project (EASTRIP) benefiting countries of Tanzania, Kenya and Ethiopia. In Tanzania recipient colleges and areas of excellence are Arusha Technical College, renewable energy; Dare es Salaam Institute of Technology (Dar es Salaam Campus), ICT; Dar es Salaam Institute of Technology (Mwanza Campus), tanneries technology; National Institute of Transport (Dar es Salaam), aviation. EASTRIP aims at advancing accessibility of vocational training and improvement of infrastructure in the project areas.

EASTRIP has facilitated at Kikuletwa, new project offices, classrooms, hostels, water supply, sanitation and electrification of the vocational training college. Currently a number of vocational students are benefiting from various courses being provided at Kikuletwa renewable centre of excellence.

Furthermore, a Kikuletwa Public Power Generation Company (KPGC) has been formed, water rights been renewed, Environmental Impact Assessment (EIA) and Environmental Impact Management Plan (EIMP) have been conducted.

[17] Considerations to include a solar PV plant, wind power plant and biogas plant as back-up facilities at the centre were being considered.

Figure 12: Obsolete Kikuletwa Hydro Power Plant in Kilimanjaro Region

Procurement of a consultant to redesign the plant layout and documentation work for engaging a contractor to construct a 1.65 MW plant as an SPP to supply power to an anchor customer TANESCO is ongoing.

Governance

Kikuletwa mini-grid is to be re-developed as a SPP by KPGC as a public project or by PPP arrangement depending on financing arrangements to be secured. As such, the existing SPPA, SPPT, national grid code and associated rules and regulations with SPPs to be followed. If PPP arrangement will be secured, then KPGC will operate as a private company with private and public shares.

Sustainability

Financial sustainability

Long term financial sustainability of the min-grid exists if development will culminate into a SPPA signed with TANESCO and SPPT arrangements that guarantee adequate revenue to the mini-grid.

Also, potential exists for the intact old plant to be made a tourist attraction for all those interested in seeing traditional and outdated technologies so as to improve the financial sustainability of the plant.

Technical sustainability

The old generation plant is technically non sustainable due to non-availability of spare parts. A refurbished plant with new and optimal inlet gates, water conveyance structures, turbine, generator, control and switching equipment need to be relocated and installed. Training of the plant operators need to be undertaken and provision of adequate running spare parts need to be made available.

To maintain sustainable flow into the power house during low flow season, the mini-hydro is fed by two tributaries of Mbuguni and Kware rivers both of which originate at Mount Meru in Arusha. The two rivers join at the plant to form Kikuletwa river which ultimately drains into Nyumba ya Mungu Reservoir located downstream.

Various project stakeholders have been closely engaged by the project, awareness campaigns are being conducted so as ensure environmental sustainability of the planned mini-grid project. Communities surrounding the project are involved in activities to curb deforestation activities, avoid agricultural practices along the river banks that could contribute to soil erosion and siltation of the plant's pondage. Also, the mini-grid will protect tourist attractions in the area e.g. the waterfall, Chemka hot spring and the surrounding natural forest.

Affordability

Electricity to be generated by the proposed refurbished mini-grid would be sold via SPPT arrangements to TANESCO and end use customers to benefit from TANESCO tariffs including affordable subsidised lifeline tariff of Tshs 100/kWh and connection fee of Tshs 27,000.

Business model

A public commercial business model is to be employed if KPGC is funded purely as a public utility. Alternatively, a private model will be employed if the project will be developed via PPP arrangements.

Inclusivity

The project development process from EIA, EIMP, feasibility studies to design and construction is inclusive of various stakeholders- international, national, regional to surrounding villagers' interests are accommodated. Water rights been renewed, gender aspects are observed in the EASTRIP projects and via KPGC local content in the project will be observed.

Customer Aspects

During 1939 to 1989 Kikuletwa mini-hydro based mini-grid supplied power to Moshi town. In 1989 the plant stopped generation due to technology being obsolete. However, the outdated mini hydro can be preserved for future generations to learn technology evolution in electrical power generation. 60 m downstream the plant, there exist magnificent Kikuletwa water falls, Chemka hot spring located 2 km away, and rare monkey specie resident in the forests surrounding the said outdated mini hydro which are tourist attractions for the area.

A new plant to be located at a downstream position is expected to be done under PPP arrangement and to be governed by SPPA and PPT tariffs whereby TANESCO will be a single anchor customer whereby the plant will supply the national grid.

Lessons learnt

- Mini-hydro based mini-grids are robust, have low O&M costs and long lives as demonstrated by Kikuletwa that operated from 1937 to 1989 roughly 52 years whereby portions of the civil structures are still intact.
- To maintain sustainable flows into the power house two intakes from two tributaries of Mbuguni and Kware rivers are used and the two join at the power house to form Kikuletwa river that drains into downstream Nyumba ya Mungu Reservoir.
- Out dated mini-hydro plants built many years ago are technically non-sustainable due to unavailability of spare parts for O&M.[18]
- The Kikuletwa renewable centre created employment to the surrounding villages during its construction.
- Gender aspects have been observed in the centre's staff recruitment and students being trained.

[18] Other mini-hydro plants built during the colonial times and are currently non-operational are 1,220 kW Tosamagamga mini hydro in Iringa Region commissioned in 1951 and 336 kW Mbalizi in Mbeya region commissioned in 1958.

- The Kiluletwa renewable centre of excellence is already providing much needed vocational training to the youth in the district, surrounding villagers sell some of the food and basic centre's requirement thereby contributing positively to the community's economic development.
- Potential exists to make the min hydro plant a tourist attraction for those interested in viewing outdated and obsolete technologies and equipment.

3.8 Kigoma Region

Kigoma region is located in the west, is bordered by Burundi country and Kagera region in the north, Shinyanga and Tabora regions in the east, Katavi region in the south and Lake Tanganyika in the west.

3.8.1 Kigoma Diesel Based Mini-Grid[19]

Plant development and ownership

Kigoma town has had decentralised diesel based mini-grid power supply from Railway Corporation since German colonial times, about 1912. In 2021 TANESCO a public utility owned and operated a 6.25 MW diesel plant located at Kigoma town close to the lake. It was the sole source supplying the decentralized Kigoma-Ujiji-Uvinza mini-grid. During our site visit, construction extension of the diesel plant by 2x1.25 MW was ongoing.

In March 2021, a 5 MW solar PV plant was commissioned and was integrated with the 6.25 MW diesel plant via a dedicated 11.4 km 33 kV line. As such, a solar PV and diesel integrated decentralised grid was established. The maximum demand of the decentralised integrated-Kigoma-Ujiji-Uvinza mini-grid was 8 MW.

In turn, the 5 MW solar PV plant is wholly owned by NextGen Solawazi Company registered in Tanzania. The Ministry of Energy via REF allocated Tshs. 1.4 billion for erection of 11.4 km dedicated 33 kV line from the solar plant to TANESCO substation. The substation was also upgraded.

Governance

The plant was developed as a public property to be run commercially. TANESCO Company is run by its staff assisted by management team under the guidance of board of directors. Its operations and services are as per national grid code, national standards as monitored by the regulator. Customers pay for services as per authorised tariff by the regulator (refer Appendix A and B).

[19] The plant was visited on 11th October 2021.

Sustainability

Financial sustainability

Diesel generation is expensive. Potential for long term financial sustainability of the Kigoma-Ujiji-Kasulu diesel mini grid will involve substitution of diesel generation with cheap renewable solar PV power commissioned in March 2021, connection to the national grid via Tabora to Kigoma 132 kV line under construction slated for commission end of year 2024, and commission of Malagarasi 49.5 MW hydro plant under construction slated for 2025. Moreover, TANESCO tariffs need to be cost reflective.

Technical sustainability

Diesel generation involve expensive imported fuel and spare parts requiring a lot of foreign currency. TANESCO technicians are experienced in running diesel plants. Often, inadequate supply of spare parts is one of the challenges experienced. Kigoma town distant location from fuel sources in Dar es Salaam, sometimes suffers from fuel supply logistics chain resulting into disruptive power supply or load shedding.

Air and soil pollution associated with diesel generation is a challenge for environmental sustainability of the diesel mini-grid if environmental safeguard standards being regularly given by the environmental regulator via regular environmental audits are neglected.

The installed capacity of the diesel 6.25 MW and solar 5 MW hybrid system for Kigoma is in total 11.25 MW against the maximum demand of 8 MW at 19-21 hrs. Load shedding has to be undertaken since the solar plant does not have the battery storage facilities to augment capacity provision during the night.

Affordability

All connected customers are served by TANESCO whereby lifeline tariff category exists for small consumption of less than 75 kWh per month at Tshs 100/kWh, a tariff which is affordable.

Business model

TANESCO is a public utility wholly owned by the government. Most of its retail domestic and small commercial customers are on pre-payment metering system whereby customers pay up front for energy services. Large customers are on credit energy metering, are billed and pay for services rendered. TANESCO's energy services are regulated by the regulator. The tariff is set by the regulator.

Inclusivity

The diesel plant mini-grid is 100% public. During project development, environmental impact assessment was undertaken. The communities surrounding the project area were engaged in the project. Gender balance efforts have been exercised during project development and during O&M. Some of the staff employed are female. During plant erection a number of people from surrounding community obtained employment.

The plant does not observe community charity aspects to the surrounding population.

Customer Aspects

Households

1 hh interviewed in Kigoma premises. Average age of interviewee was 36 years and hh size was 5. The hh uses firewood and charcoal for cooking and without e-cooking. On average hh has 12 bulbs, 2 radio, 2 TVs, and 4 phone chargers.

Productive uses

53 SMEs were interviewed in Kigoma premises. Average age of interviewees was 40 years, hh size 5. Productive usage involved grain milling, welding workshop. A big hotel.

1 public institution, a dispensary with 1 autoclave, 1 boiler, 1 suction machine, 1 oxygen machine, 3 fridges, 1 ultra sound, 1 microscope, 4 computers and 18 lights.

Lessons Learnt

- Diesel fired based mini-grids are propelled by very expensive fuel which is supplied from coastal areas located more than 1000 km away, and the same for spare parts render cost of providing services is very high.
- Environmental concerns are high associated with diesel generation, transportation of fuel and residues disposal.

3.8.2 Kigoma Solar PV Based Mini-Grid[20]

Plant development

The 5 MW Solar PV plant is located at Kigoma Special Economic Zone. It is the first solar SPP in the country that sells power to TANESCO via a decentralised Kigoma-

[20] The plant was visited on 10th October 2021.

Ujiji-Uvinza mini-grid. The plant is integrated with the 6.25 MW TANESCO diesel plant located at Kigoma town by 11.4 km 33 kV line supplying power to 15,135 customers.

The 5 MW solar PV plant signed a SPPA with TANESCO on 16th January 2013 with expected COD in October 2016. However, construction started on 17th May 2017. Owing to construction loan disbursal timelines, contractual dispute with the original EPC contractor, an alternate EPC contractor was hired to complete the project. Also, COVID travel restrictions contributed to project construction delays. These events necessitated a re-negotiation of the PPA tariff with TANESCO. Commercial operation started on 3rd March 2021 employing a revised PPA with TANESCO.

The 5 MW solar PV plant is wholly owned by NextGen Solawazi Company registered in Tanzania. The Ministry of Energy via REF allocated Tshs 1.4 billion for erection of 11.4 km dedicated 33 kV line from the solar plant to TANESCO substation. The said substation was also upgraded.

Figure 13: NextGen Solar-Wazi 5MW Power Plant in Kigoma

Governance

The mini grid was developed on a build own and operate model. The NextGen Solawazi company is run by staff assisted by management team under the guidance of a board of directors.

Governance via standardised small power producers' regulatory framework, negotiated power purchase agreement and feed-in tariff.

Sustainability

Financial sustainability

All the NextGen Solawazi generated energy is sold to TANESCO mini-grid at the negotiated tariff of USc 9.24/ /kWh. Potential for long term financial sustainability of the solar plant exists by selling power to an anchor customer (TANESCO mini-grid) via negotiated tariff. The potential also exists to expand the solar plant so that generation from expensive diesel plant can be further minimised or completely substituted if storage batteries can be installed at the solar plant.

Technical sustainability

Mini-grid operation and maintenance is undertaken by local engineers and technicians trained locally and abroad. The local operators are running the solar plant assisted by a resident foreign expert. Spare parts are available.

Environmental sustainability of the mini-grid is maintained by implementing environmental safeguard standards being regularly given by the environmental regulator via regular environmental audits of the mini-grid. Also, the mini-grid is expected to maintain its social responsibility to the surrounding communities.

Affordability

All connected customers are served by TANESCO whereby lifeline tariff category for small consumption less than 75 kWh per month at Tshs 100/kWh.

Business model

The solar plant employs a private business model with credit energy metering, jointly monitored and read by the Solar plant and TANESCO staff once per month for billing and payment offset within specified period as per negotiated PPA. In turn, TANESCO is a public utility wholly owned by the government of Tanzania.

Inclusivity

The solar plant has not allowed local content in plant ownership. During project development, the communities surrounding the project area have been engaged in the project. Gender balance efforts have been exercised during project development and during O&M. Four out of ten trained employees are female.

During erection of the solar plant 170 people from surrounding community obtained employment. Also, solar PV panels' cleaning is done every three months by casual labourers from the surrounding community.

Customer Aspects

Households

1 hh interviewed in Kigoma premises. Average age of interviewee was 36 years and hh size was 5. The hh used firewood and charcoal for cooking and without e-cooking. The hh had 12 bulbs, 2 radios, 2 TVs, and 4 phone chargers.

Productive uses

3 SMEs were interviewed in Kigoma premises. Average age of interviewees was 40 years, hh size 5. Productive usage involved grain milling, welding workshop. A big hotel.

1 public institution, a dispensary with 1 autoclave, 1 boiler, 1 suction machine, 1 oxygen machine, 3 fridges, 1 ultra sound, 1 microscope, 4 computers and 18 lights.

Lessons Learnt

The integrated solar and diesel decentralised mini-grid is facing the following challenges:

- The solar plant is a live production plant without storage battery facility; whenever solar insolation level is low the diesel plant automatically takes over supply services.
- Synchronisation of the solar plant with the diesel plant is one of the major challenges faced due to problems of lack of experience in proper CT ratings resulting into frequent power interruptions since the solar plant operations began.
- Power supply is inadequate and not reliable as such the diesel plant is being expanded with additional 2x1.25 MW diesel sets to address the matter.
- Power quality is rather poor and some customers complain of damaged electrical equipment due to power fluctuations especially during the day time when the solar plant was running in initial months of solar and diesel plants synchronisation.
- The solar and diesel integrated mini-grid capacity cannot meet Kigoma-Ujiji-Uvinza peak energy demand as such load shedding for some portions of the network is exercised during the peak periods.

3.9 Tanga Region

Tanga region is located in the northern coast, is bordered by Kenya country in the north, Indian Ocean in the east, Pwani and Morogoro regions in the south and Manyara region in the west.

3.9.1 Mpale Solar PV Based Mini-Grid[21]

Plant Development

Mpale Solar PV-Diesel Hybrid Power System is located at Mpale village, Korogwe District in Tanga Region. The plant was developed by Ensol limited whereby its construction was done in year 2017. The power plant comprised of 48 kW solar PV power plant with a total of 192 solar panels, 12 charger controllers, 4 inverters of 32 kVA and a total of 48 batteries which make a storage capacity of 265 kWh. The power plant generated electricity up to 70-80 kWh/day and was backed up with an automatic genset of 50kVA.

The development of this system was co-financed by different partners at different stages whereby 80% was grant from the USADF-Power Africa, EEP under the Finish Government, UNCDF, and Rural Energy Agency (REA) and 20% was a contribution of Ensol as equity

At the beginning of the operation, only 79 customers were connected, but as awareness and demand increased, the connectivity rose to 256 customers by the time of visit on 16th March 2022. The plant had a potential and capacity to connect up to 500 households. The power plant operated 24 hours/7 days a week. The plant could connect large productive users but due to affordability and financial challenges, a few had connected to the mini-grid.

Governance

The power system was developed on a build, own and operate model. Mpale power system was registered by regulator but not regulated. The payments were prepaid; each customer had a card for making payments. New customers' services were installed with load limiter meters so there were no monthly service charges paid by customers. The developer and the villagers had agreed on the tariffs structures grouped into categories and levels of households and businesses respectively. Tariff level 1 and level 2 were for households and level 3 and 4 were for businesses. Level 1 tariff was for households which used 275 Wh/day, level 2

[21] The plant was visited on 16th March 2022.

used 276-550 Wh/day, level 3 was for businesses who used 1,100 Wh/day and level 4 used 1,650 Wh/day.

Due to the government's announcement on the adoption of uniform tariff charges for mini grid, the operations of the power plant were affected by poor revenue collection and it was closed for almost a year.

Figure 14: Part of the 48kW Solar PV Mini-grid at Mpale Village, Korogwe, Tanga Region

Sustainability

Financial sustainability

The plant was capable of connecting up to 500 customers but the already connected number was still low and majority of the customers used electricity for lighting and powering small accessories. This was not a good indication of revenue collection. To ensure financial sustainability, the developer introduced and stimulated energy demand by customers' incentives on the productive uses of energy by providing loans at a low interest rate to interested customers. The loan was for energy efficient equipment such as carpentry tools, compressors, refrigerators, television sets, barber and beauty salons gadgets, and stationery machines. Since the power supply was reliable, the productive uses had increased electricity consumption and assured increased revenues. Revenue collection was also a challenge after government ordered on adoption of subsidised uniform tariffs used in the national grid, revenue collection dropped from Tshs 2,000,000/month to Tshs 280,000- 300,000/month.

Technical Sustainability.

The Mpale power plant's feasibility study and project design were jointly done by the Spanish experts and Ensol technical team. However, the entire plant installation was done by Ensol experts. Ensol has built an in-house capacity on a number of issues which have enabled them to undertake the operation and maintenance of the power plant using local village technicians. The operators had Grade I Test Certificates on electrical technology from Vocational Education and Training Authority (VETA). The power plant was located at a hilly area which was not close to the villagers which also reduces risks of panels being stoned by children or any act of vandalism.

Some spare parts especially for the load limit meters were expensive whereby a single unit costed up to Euro 100, and were not available in the local market. The said often was affected by lightning strikes and could take up to 2 months to procure them from Spain.

There appeared minimum challenges on the environmental perspective; the sustainability was well taken care at Mpale Power plant especially when they were undertaking regular services of the diesel generator. They ensured that there was no contamination to the environment from the lubricating oil or diesel fuel in the process. If the accessories reached their life time, the developer sold the accessories to the authorised scrap metals dealers.

Affordability

Mpale villagers are farmers and most of them were not able to afford the upfront connection costs. Developers got funds from Rural Energy Agency (REA), through result-based financing scheme which helped to reduce connection costs which initially was pegged at Tshs 400,000 to Tshs 200,000. Connected customer services included a ready body and a package of 4 lights as well as a socket for phone charging.

Furthermore, to address affordability issues, tariffs were developed based on the level of usage at household or businesses. Households were paying at a range of Tshs 11,000 -20,000/ month while business were paying Tshs 32,000- 44,000/ month. The Government announcement on the adoption of uniform tariffs of Tshs 100/kWh used in the national grid affected revenue collections and mini grid operations but since Mpale customers already liked and needed the services, they arranged a community meeting with the developer and agreed that their

case should be treated differently whereby they paid Tshs 100/kWh and the rest of the charges were treated like services charges.

Business model

The power plant was owned and privately operated by Ensol Limited. Customers ware connected with load limit meters and were provided with a card which was activated following payment for recharging the electricity units.

Inclusivity

The villagers were involved at different stages from the setup of the project to the sustainable and safety uses of electricity. The villagers agreed with the developer during the initial meetings on land provision, types of tariffs, mode of payment whereby tariffs were set based on the ability to pay and appliances of the end users. They also agreed that there would be no compensations to villagers for infrastructure way leave, there would be employment for the local technicians as operators. The local villagers were involved in construction of distribution networks and the powerhouse. There has been no any community resistance to project activities, rather the political leaders have been using the power system as part of their political campaigns. The supervisor of the entire operation is a woman.

Figure 15: Customers Meetings under the roof of 48kW Mpale Solar PV Mini-grid Customer Aspects

Households

6 hh interviewed in Mpale premises. Average age of interviewees was 42 years and hh size was 4. The hh used firewood and charcoal for cooking and without e-cooking. On average hh had 3 bulbs, 1 radio, and 1 phone charger.

Productive uses

6 SMEs were interviewed in Mpale premises. Average age of interviewees was 40 years, hh size 4. Productive usage involved grain milling, welding workshop and a big hotel. 1 public institution, a dispensary with 1 autoclave, 1 boiler, 1 suction machine, 1 oxygen machine, 3 fridges, 1 ultra sound, 1 microscope, 4 computers and 18 lights.

Lessons learnt

- The inclusivity was vividly practiced when villagers decided and agreed to continue paying higher tariff rates despite the government order on adoption of uniform subsidised tariffs. This indicated the villagers high level ownership in the existence of the plant via their appreciation of high-quality services provided to them.
- The power plant had become a learning centre for many researchers who come to study various aspects in relation to the mini grids.
- The in-house technical capacity in operation and maintenance of the power system immensely contributed in reducing the overall operational costs.
- The Mpale power system was oversized, only 40% of its capacity was being utilised, there is a need to plan power plants that can meet immediate demand and then expand it later on as demand grows.
- Many other villagers were interested in venturing into productive uses and the developer was planning to procure such equipment and loan them for financial sustainability of the mini-grid.

4. KEY INFORMANT INTERVIEWS

Key informant interviews were conducted in Dodoma and Dar es Salaam cities.

4.1 Ministry of Energy

The Ministry of Energy (MoE) is responsible for formulation and implementation of energy policy as well as overseeing a number of government owned public institutions including TANESCO, REA, TPDC and EWURA. Further, MoE is responsible for soliciting financing for public projects undertaken by institutions under its mandate; attracting private sector energy investments; and also supposed to promote energy trade with neighbouring countries.

Challenges:

- Tanzania is a large country, there are difficulties to raise enough funds to electrify remote rural areas and to raise electricity connectivity levels to address MDG 7.
- Electrification by mini-grids faces high initial installation costs, developers face financing difficulties, collateral and risk guarantees issues, end use tariffs tend to be high and thereby end users complain of lack of equity considerations.
- Cultural issues and lack of awareness, rural electrification is largely lighting neglecting productive uses.
- Many developers obtain licenses but fail to develop mini-grid sites, others tend to be middle men for other developers with financial resources.
- Developers take a long time to develop their sites sometimes grid extension and mini grid projects converge in one area.
- Solar PV provides power only during the day time only in the night they need battery packs.

Lessons learnt:

- The country has a robust and innovative regulatory frame work for development of mini grids is an incentive for mini-grid accelerated deployment.
- Mini grid investors be offered a longer period 20-25 years to operate so as to recover their investments.
- Role plaid by REA and EWURA in assisting mini grid developers is key to rural households' livelihoods transformation.

- Lack of coordination in project development can be reduced if initial planning and project development is done by the government via REA/TANESCO and lease arrangement be floated to private sector.

4.2 Energy Sector Regulator

Energy and Water Utilities Regulatory Authority (EWURA) is responsible for registration, provision of licenses for energy trade, approving PPA, SPPAs and tariffs as well as monitoring the energy sector performance against key performance indicators. Also is involved in mediation between customers and power suppliers.

Challenges:

- Deriving cost reflective tariffs for remote mini-grids due to diseconomies of scale associated with such investments and market size they face.
- Difficulties to monitor VSPPs who are unregulated and are located in very remote areas.
- Protecting the private sector and ensuring the private sector grows over time.
- Permits for mini grid project development involve many institutions and steps that contribute to delays beyond project commission operating dates speculated in the SPPA.
- Entry and exit conditions for mini-grids when encroached by the national grid need to be reviewed.

Lessons leant:

- Existence of a robust regulatory framework for small power producers/mini-grids has attracted other African countries to come to Tanzania to learn and adopt.
- Regulation was limited to SPPs via SPPAs and SPPTs, VSPPs was waived; however, following many complaints about high tariffs, beginning 2022 regulation of VSPPs of PowerGen, PowerCorner and Jumeme is being implemented and customer retail tariffs have gone down.
- Government intervention VSPPs to charge subsidised lifeline tariffs during 2018 to 2021 resulted in many VSPPs to stop provision of services; services resumed when VSPPs were allowed to charge tariffs that they deemed cost reflective.
- Five mini-grids visited were coexisting with national grid due to security of supply needs especially SMEs.

4.3 National Utility

The national utility TANESCO generates, transmits, distributes and retails power to end users on Tanzania Mainland as well as bulk supply to Zanzibar. It is the main power off taker to IPPs and SPPs as well as cross boarder imports. As the main off taker, has to enter into PPA and SPPA with IPPs and SPPs respectively as well as efficiently manage the contracts with them.

Challenges

- Integration/ synchronization of SPPs to the national grid is a challenge whereby SPPs face high connection charges if the national grid is not stable as they have to import expensive power.
- Intermittent renewable mini-grids are non dispatcharble therefore cannot be dependent upon in load management.
- Feed-in-tariffs for renewable SPPs tend to be higher than average selling price of the utility in the national grid.

Lessons Learnt:

- SPPS connected to the main grid in strategic areas e.g. distant locations tend to improve frequency and voltage regulation of the system.
- 10-15% of the installed capacity of the intermittent renewable SPPs can be connected to the national grid to maintain national grid stability during instantaneous power fluctuations.
- SPPs and mini-grids connected to the national grid improve rural energy reliability in such areas as avoids power black outs and load shedding in such areas.

4.4 Rural Energy Agency

The Rural Energy Agency has following responsibilities: a) promote, stimulate, facilitate and improve modern energy access in rural areas, b) promote the rational and efficient production and use of energy, c) finance eligible rural energy projects via Rural Energy Fund, d) set conditions and procedures to access grants, and e) provide capacity building and technical assistance to project developers and rural communities.

Challenges:

- Decentralised mini-grids capacities tend to be small hence experience overloading and inability to connect all the customers who electrical power services.

- Limited financial resources at REF for mini-grid development is a challenge as it appears developers lack own resources for such investments.
- Mini-grids introduced in islands which lack roads infrastructure make operation and maintenance of the mini-grids cumbersome and expensive.
- VSPP mini-grid developers often do not erect the networks to specified TBS standards and as such do not get compensated when the national grid enchonches their premises.
- Politicians tend to favor REA projects that extend the national grid against mini-grids due to limitations for productive energy uses, low tariff arrangements via lifeline tariff and very low connection fees.

Lessons learnt

- Small capacity solar based mini grids do not provide 24 hours service as such do not meet customer aspirations.
- Financial sustainability of mini –grids in particular VSPPs appear questionable owing to high cost of providing services and hence high tariffs against the majority rural households with low incomes who cannot afford it.
- SPPs financial sustainability appears possible if the tariffs are cost reflective and the SPPs provide efficient services/ control costs of providing services.

4.5 Development Partners

Development partners interviewed involved the Delegation of the European Union and Swedish International Development Agency.

Challenges

- They would like to see mini-grids deployment heightened and free from political interventions.
- Owing to relatively small size in capacity nature of most mini-grids developed, tariffs be left to be determined by investors so as they can recover their cost within lifetimes of the equipment.

Lessons learnt

- Development partners are willing to provide capacity building and training associated with mini grid development, operation, maintenance, financing and addressing environmental issues associated with various technologies.
- Mini-grids improve the livelihood of the rural households and are in line with their development assistance programmes they are involved in, as such financing opportunities and risk guarantees to rural investments can be considered/availed.

5. CROSS CUTTING FINDINGS

The following are cross cutting findings from field visit to18 mini-grids comprising 4 mini-hydro, 4 biomass, 4 solar PV, 1 wind, 1 diesel and 4 hybrid systems located in 9 regions.

Sustainability

13 mini-grids were operational and 5 were non-operational 3 of which had been dismantled and shifted to other sites. The contributing factors included technology being obsolete, spare parts problems, lack of feed stock and fuel supply problems. Mini-hydro and biomass combined heat and power (CHP) are matured and robust technologies for mini-grids. Solar PV and wind technologies are fast catching up and are becoming competitive. However, biomass gasification technology based mini-grids face feed stock shortages and technology performance challenges. Equally Multi-Function Platform propelled by straight vegetable oil /diesel face feedstock shortages hence succumb to use of expensive diesel fuel. It be noted that 10 out of 18 visited mini-grids had been encroached by the national grid 5 of which were co-existing with the national grid to ensure security of supply for SMEs.

As such, mini-grids technical and environmental sustainability is possible if training of operators, readily availability of spare parts and O&M of the plants is adhered including quality of supply and safe guard aspects.

Financial sustainability of small power producers selling power to anchor customer the national grid and large consumers appears possible if the tariffs are regularly revised so that they are cost reflective to the SPPs. 5 out of 18 visited sites were connected to the national as SPPs. 1 mini-grid was integrated to a decentralized mini-grid as an SPP. As for the very small mini-grid power producers (VSPPs) mini-grids, financial sustainability is highly questionable as cost of providing services is high and attendant tariffs are high borne by majority rural poor households who cannot afford it. Flat rate meters, load limiters and credit energy meters are inefficient in revenue collection. In turn, pre-payment meters along involving on line pay-go billing and revenue collection lessens mini-grid financial losses.

Community based and faith-based charity business models have demonstrated weakness in revenue collection. Mini-grids employing pay-go billing along with business models tend to perform financially better.

Notwithstanding of the above, financing and risk management of mini-grid projects including their operations has been indicated as a barrier to accelerated

deployment of mini-grids whereby more efforts is needed to overcome this challenge.

Inclusiveness

Most of the village communities are closely involved in mini-grid development, construction and operations with a fair number of them observe gender aspects.

Governance

The country has a robust regulatory framework for small power producers and mini-grids, innovative financing arrangements and feed-in tariffs that ensure the independent small producers either sell to the anchor customer the national utility main grid or licensed decentralized distribution network operators. However, tariff aspect remains the most controversial issue in the country as it touches on diverse interests- political, development partners aid, investors, banks and rural households' livelihood.

Mini-grids with capacity 100 kW to 10 MW are regulated and provide services via feed-in tariffs derived and approved by the regulator. Mini-grids with capacity below 100 kW before year 2022 were unregulated as such they developed their own tariffs. Owing to customer complaints, since 2022 tariff derivation for mini-grid operator companies owning many mini-grids started.

Customer Aspects

Wood and charcoal are the dominant cooking fuel for households (hh) with minority cooking on LPG and electricity. Mini-grid electrified hh largely benefit from improved lighting, powering radios, phone charging and a few powering their TVs. Most of the rural poor hh cannot afford mini-grid tariffs, as such do not connect to the services.

In turn, small and micro enterprises (SMEs) benefit from powering welding, carpentry, grain milling, oil pressing, food/drinks kiosks, and other productive use equipment. Some mini-grid operators offer loans to their customers to acquire efficient productive use equipment as a strategy to expand energy demand as well as improve revenue collection and financial sustainability if the tariffs are cost reflective and services provision is undertaken efficiently.

Public institutions benefit from improved services like health, education, street lighting and water supply services. Electrification reduces rural to urban migration and improves rural household's livelihood.

BIBLIOGRAPHY

Energy and Water Utilities Regulatory Authority (EWURA), 2023. "Electricity Sub-Sector Regulatory Performance Report for the Financial Year 2021/2022", United Republic of Tanzania, Dodoma.

APPENDICES

APPENDIX A: TANESCO Tariff

a) Energy charges

Customer Category	Component	Unit	Approved Tariff
D1	Service charge	Tshs/month	0
	Energy charge (O-75 kWh)	Tshs/kWh	100
	Energy charge (above 75 kWh)	Tshs/kWh	350
T1	Service charge	Tshs/month	0
	Energy charge	Tshs/kWh	292
	Maximum Demand charge	Tshs/kVA/month	0
T2	Service charge	Tshs/month	14,233
	Energy charge	Tshs/kWh	195
	Maximum Demand charge	Tshs/kVA/month	15,004
T3-MV	Service charge	Tshs/month	16,769
	Energy charge	Tshs/kWh	157
	Maximum Demand charge	Tshs/kVA/month	13,200
T3-HV	Service charge	Tshs/month	0
	Energy charge	Tshs/kWh	152
	Maximum Demand charge	Tshs/kVA/month	16,550
Key:			
D1: Low usage tariff for domestic customers who on average consume less than 75 kWh per month. Any unit exceeding 75 kWh is charged a high rate of Tshs 350 per kWh. Under this category, power is supplied at a low voltage single phase (230V).			
T1: General usage tariff for customers including residential, small commercial and light industrial use, public lighting and billboards. Power is supplied at low voltage single phase (230V) as well as three phases (400V).			
T2: Applicable to general use customers where power is metered at 400V and average consumption is more than 7,500 kWh per meter reading period and demand does not exceed 500kVA per meter reading period.			
T3-MV: Applicable to customers connected to medium voltage.			
T3-HV: Applicable to customers connected to high voltage including ZECO, Bulyanhulu and Twiga Cement.			

NB: Pre-paid energy metering for D1, T1 and T2 tariff categories. Credit metering for T2, T3-MV and T3-HV.

b) Connection charges

i) Single phase charges

Service Line	Approved connection charges (Tshs)	
	Urban rate (VAT exclusive)	Rural rate (VAT exclusive)
Within 30 meters	272,000	27,000
Within 70 meters (one pole)	436,964	27,000
Within 120 meters (two poles)	590,398	27,000

ii) Three phase charges

Service Line	Meter Type	Approved connection charges (Tshs)	
		Urban rate (VAT exclusive)	Rural rate (VAT exclusive)
Within 30 meters (Cable 16 mm^2)	Pre-paid	772,893	772,893
Within 30 meters (Cable 16 mm^2)	AMR		
Within 30 meters (Cable 35 mm^2)	Pre-paid		
Within 30 meters (Cable 35 mm^2)	AMR		
Within 70 meters (one pole)	Pre-paid	1,058,801	1,058,801
Within 70 meters (one pole)	AMR		
Within 120 meters (two poles)	Pre-paid	1,389,115	1,389,115
Within 120 meters (two poles)	AMR		

Source: TANESCO

APPENDIX B: REGULATED SPP TARIFF

Standardised Small Power Projects Electricity Tariffs (w.e.f. 21st June 2019)

a) Tariffs for SPPs Selling Electricity to the Grid Based on Specific Technology Under Second Generation

Capacity (MW)	Mini hydro USc/kWh	Wind USc/kWh	Solar USc/kWh	Biomass USc/kWh	Bagasse USc/kWh
0.1-0.5	10.65	10.82	10.54	10.15	0.71
0.51-1.00	9.90	9.95	9.84	9.34	9.09
1.01-5.00	8.95	9.42	9.24	8.64	8.56
5.01-10.00	7.83	8.88	8.34	7.60	7.55

Source: EWURA

b) Tariffs for Main Grid Connection Under the First Generation SPP Framework (Avoided Cost)

Description		Approved Tariff w.e.f. 1st May 2019 (Tshs/kWh)
Standardised Small Power Purchase Tariff		203.11
Seasonally Adjusted Standardised SPPT Payable in	Dry Season	243.73
	Wet Season	182.80

Source: EWURA

c) Tariffs for Mini-Grid Before and After Grid Connection Under First Generation SPP Framework (Avoided Cost)

	Before 2018 Grid Connection (Tshs/kWh)	After 2018 Grid Connection (Tshs/kWh)
Standardised Small Power Purchase Tariff	480	180

Source: TaTEDO-SESO Field Data

RESEARCH PERMIT

UNITED REPUBLIC OF TANZANIA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY

RESEARCH PERMIT

Permit No.	2022-02-NA-2021-242
Date issued	13th January, 2022
Researcher's Name	Estomih Ngaya Sawe
Nationality	Tanzanian
Research Title	Sustainability, Inclusiveness and Governance of Mini-grids in Africa (SIGMA)
Research Area(s)	Dodoma, Njombe, Kilimanjaro, Ruvuma, Kigoma, Coast, Dar es Salaam and Tanga
Validity	From: 13th January, 2022 to 12th January, 2023
Contacts of local collaborator (*with affiliated institution*)	

PROGRAM OFFICER

FOR: DIRECTOR GENERAL

IMPORTANT REQUIREMENTS

- ***A PI who wishes to continue with a research beyond the expiry date of the research permit should write to COSTECH two months before the operational permit's expiry date, to request for an extension or renewal of the permit.***
- *Research permit that involves collecting human, plant or animal materials / data that will be exported outside Tanzania must submit a signed Material Transfer Agreement (MTA), Data Transfer Agreement (DTA) between Tanzania host institution and the foreign counterpart. The MTA/DTA will indicate terms for collecting, storing/managing, transporting, disposal or returning of the materials/DATA to Tanzania after the closure of the research project.*
- *Any patent or intellectual property and royalty emanating from any research approved by the National Research Registration Committee (NRRC) shall be owned as stipulated in the research proposals and in accordance with the IP policy of the respective research institutions.*
- *All researchers are required to report to a Regional Administrative Secretary (RAS) of the study area and present the introduction letter and activity schedule(plan) prior starting any research activity.*
- *All researchers are required to submit quarterly progress reports and all relevant publications made after completion of the research.*
- *All communications should be addressed to COSTECH Director General through rclearance@costech.or.tz; dg@costech.or.tz or +255 (022) 2700749; +255 (022) 2771358. Terms and conditions of the permit are found at www.costech.or.tz*

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QUESTIONNAIRES

SN	Respondent	Questionnaire
1	Donors and Development Finance Institutions	Questionnaire 1 - Donors and Developr
2	Focus Group Discussion for Customers	Questionnaire 2 - Focus Group Discussi
3	Government Departments	Questionnaire 3 - Government Departm
4	Household Questions	Questionnaire 4 - Household Questions
5	NGOs and Community Organisations	Questionnaire 5 - NGOs and Community
6	Organizations and Productive User	Questionnaire 6 - Organizations and Pr
7	Owners and Operators	Questionnaire 7 - Owners and Operator
8	Private Investors or Financiers	Questionnaire 8 - Private Investors or Fi
9	Project Developers	Questionnaire 9 - Project Developers.dc
10	Technology Suppliers EPCs and OMs	Questionnaire 10 - Technology Suppliers
11	The Regulator	Questionnaire 11 - The Regulator.docx
12	The Utility	Questionnaire 12 - The Utility.docx