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TECHNICAL REPORT

FOR

SOLAR ENERGY NEEDS ASSESSMENT AT TWO HEALTH CENTERS IN KASESE AND NTOROKO DISTRICTS

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August 2025

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Executive Summary

This report details a solar energy assessment conducted at Bweramule Health Center III (Bweramule sub county, Ntoroko District) and Mukathi Health Center III (Maliba sub county, Kasese District) to address critical power reliability challenges. Bweramule HC III, with its high 36.7kWh/day demand for essential medical equipment like sterilizers and oxygen concentrators, requires a robust 15kW off-grid solar system to replace its failing power infrastructure. Mukathi HC III facing unreliable grid supply despite its modest 3.76kWh/day needs, will benefit from a 10.0kW grid-tied hybrid system to maintain uninterrupted vaccine refrigeration and lighting.

Both locations offer favorable solar potential (5.2 – 5.5 peak sun hours/day), though system designs account for regional climatic variations - including Ntoroko's high temperatures affecting battery performance and Kasese's seasonal rains. The proposed solutions incorporate modern lithium-ion technology, optimized PV configurations, and intelligent energy management to deliver reliable, sustainable power tailored to each facility's operational requirements and environmental conditions, ultimately enhancing healthcare delivery in these underserved regions.

Acronyms

PV - Photovoltaic

Wh - Watt-hour

kWh - Kilowatt-hour

kW - Kilowatt

W - Watt

LiFePO4 - Lithium Iron Phosphate

MPPT - Maximum Power Point Tracking

BMS - Battery Management System

SCADA - Supervisory Control and Data Acquisition

ATS - Automatic Transfer Switch

IEC - International Electrotechnical Commission

UL - Underwriters Laboratories

PID - Potential Induced Degradation

PERC - Passivated Emitter and Rear Cell

HC - Health Center

MEMD - Ministry of Energy and Mineral Development (Uganda)

UMEME - Uganda's main electricity distribution company

ERA - Electricity Regulatory Authority (Uganda)

UNBS - Uganda National Bureau of Standards

DoD - Depth of Discharge

Voc - Open-Circuit Voltage

IoT - Internet of Things

Introduction

Background

Access to reliable and sustainable energy is critical for the effective delivery of healthcare services, particularly in rural and off-grid areas. In many parts of Uganda, including Kasese and Ntoroko districts, health centers often face challenges related to inconsistent power supply, relying heavily on grid electricity or diesel generators, which are costly and environmentally unsustainable. Solar energy presents a viable alternative to improve energy access, reduce operational costs, and ensure uninterrupted medical services.

To assess the feasibility and potential impact of solar power solutions in healthcare facilities, a solar needs assessment was conducted in two selected health centers in Kasese and Ntoroko districts. The assessment aimed to evaluate the energy demands of these facilities, identify gaps in current power supply, and determine the appropriate solar photovoltaic (PV) systems required to enhance service delivery. Key considerations included the energy needs for lighting, refrigeration that is for vaccines and medicines, medical equipment, and other essential operations.

Kasese and Ntoroko districts, located in western Uganda, experience significant energy access challenges, with some health centers either entirely off-grid or facing frequent power outages. The adoption of solar energy could significantly improve healthcare delivery by ensuring reliable power for critical services, reducing dependency on unstable grid supply or expensive fossil fuels, and contributing to environmental sustainability.

This report documents the findings of the solar needs assessment, providing insights into the current energy situation in the selected health centers, estimated solar system requirements, and recommendations for implementation.

Main objective.

To determine actual energy needs required for each respective selected health center in preparation for solar system installation

Specific Objective.

1. Assess the Current Energy Supply System
2. Conduct a load assessment to quantify daily and peak power consumption.
3. Recommend an appropriately sized solar PV system including battery storage based on the load assessment.
4. Provide cost estimates for solar installation and maintenance.

Site Inspection and Data Collection

Mukathi Health Center (Maliba Sub-County, Kasese District)

Power System Assessment

A comprehensive evaluation of the electrical infrastructure was conducted, assessing the photovoltaic (PV) system performance, battery bank condition, and overall power distribution architecture. The assessment covered critical areas including the main building, staff quarters, inpatient ward, sanitation facilities, and storage rooms.

Table 1 Energy Components on premises at mukathi HC III

Component	Specification	Status	Remarks
Solar PV Array	5 panels	Non-functional	Output: 1.0V
Primary Power Source	Hydroelectric grid	Unreliable	Frequent outages reported
Water Pump System	AC-powered pump	Non-functional	Never connected to grid
Antenatal Ward System	Solar-powered	Functional	Supports vaccine fridge only

Key Observations

The assessment revealed critical failures in the primary solar PV system, with only 1.0V output detected across the 5-panel array, indicating complete system degradation likely due to prolonged use exceeding five years without proper maintenance. The lead-acid battery bank and inverter have experienced significant capacity fade, no longer holding sufficient charge to support the health center's operational loads. Notably, while the main system has failed, the dedicated off-grid solar installation powering the vaccine refrigerator remains fully operational, maintaining proper temperature regulation for immunization storage. The water pumping infrastructure, though physically present, has never been commissioned due to the lack of grid connection, representing a missed opportunity for rainwater harvesting utilization. These findings underscore the urgent need for complete system overhaul with modern, high-efficiency components and proper commissioning of ancillary systems.

Bweramule Health Center (Bweramule Sub-County, Ntoroko District)

Power System Assessment

The technical audit encompassed evaluation of the 24V DC solar power system, including PV array performance, battery health assessment, and load distribution analysis across various facility sections.

Table 2 Energy Components on premises at Bweramule HC III

Component	Specification	Status	Remarks
Solar PV Array	6 panels	Partially functional	-
Battery Bank	4 × 24V (series/parallel)	Degraded	-
Inverter	24V system	Partially Functional	Cannot regulate the input current due to poor design.
Charge Controller	Present	Functional	-
Water Pump System	4 PV panels, 2 × 24V batteries	Faulty batteries	Needs full replacement, One battery at 0.9V (non-functional)
Staff Quarters	Pre-installed wiring	No power source	8 bedrooms, 4 sitting rooms
Antenatal Ward System	Solar-powered	Functional	Supports vaccine fridge only.

Key Observations

The water pumping system's solar array remains structurally sound, but the associated battery bank requires immediate replacement as the existing units can no longer maintain the necessary state of charge for reliable operation, its evaluation identified significant imbalance with one of the two units measuring only 0.9V indicating complete sulfation and irreversible capacity loss, while the remaining unit showing 11.5V. This imbalance creates dangerous charging conditions that could damage the charge controller and remaining functional batteries. The staff quarters' electrical infrastructure, while properly wired, lacks any power source connection, representing an opportunity for solar PV integration to support essential staff housing needs. The antenatal ward's standalone solar system demonstrates proper system design with maintained functionality, providing critical power for vaccine preservation. These findings highlight the need for prioritized battery replacements and potential system expansion to maximize renewable energy utilization across all facility operations.

Current Energy Situation and Solar System Sizing Analysis

Bweramule Health Center (Off-Grid Solar System)

Current Energy Demand Profile

The facility's electrical load analysis reveals a substantial daily energy requirement of 36.731kWh with a load profile as shown below;

S/No.	Equipment	Quantity	Rated Power (W)	Usage Hours/Day	Daily Energy (Wh/Day)
1	Projector	1	50	2	100
2	Sterilizer	1	2,000	6	12,000
3	Microscope	1	150	6	900
4	Water pump	1	550	4	2,200
5	Oxygen concentrater	1	770	12	9,240
6	Television	1	50	18	900
7	Fridge	1	150	12	1,800
8	Light bulbs	30	7	12	2,520
9	security light	2	40	12	960
10	Printer	1	600	2	1,200
11	Laptop	2	10	6	120
Total					31,940

Assuming 15% system losses;

Adjusted Energy demand = (0.15*31,940) + 31,940

= 36,731 Wh

Solar PV System Sizing

a) Battery Bank Sizing (48V Lithium-Ion System)

Adjusted Daily Load: 31,940 Wh

Days of Autonomy: 2 day

Depth of Discharge (DoD): 65%

System efficiency: 85%

System Voltage: 48V

Battery Capacity Required: (36,731 × 2) ÷ (0.65 × 0.85 × 48) = 2770 Ah

= 12.2KW

Approx: 15KW catering for expansion.

b) PV Array Sizing

Daily Energy Requirement: 36,731 Wh

Peak Sun Hours (Ntoroko): 5.2 hrs

Factor of safety: 1.2

Array Size: (36,731 × 1.2) / 5.2 = 8,477W

No. of solar panels for (550W) = 8,477 / 550 = 15 panels

c) Inverter Selection

Assuming 30% system losses;

Invertor Size = 4,630 + (0.3×4,630) = 6,019 W

Approx: 8000 W catering for expansion.

Mukathi Health Center (Grid-Tied Hybrid System)

Current Energy Demand Profile

The facility currently demonstrates a modest daily consumption of 3.76 kWh a load profile as detailed below;

S/No.	Equipment	Quantity	Rated Power (W)	Usage Hours/Day	Daily Energy (Wh/Day)
1	Laptop	1	10	4	40
2	Printer	1	300	6	1,800
3	Lights energy saving bulbs	30	7	12	2,520
4	Television	1	50	18	900
Total					**5,260**

Solar PV System Sizing

a) Battery Bank Sizing (48V Lithium-Ion)

Adjusted Energy Demand: 6,049 Wh

Autonomy Period: 2 days

DoD: 65%

System efficiency: 85%

Battery Capacity: (6,049 × 2) ÷ (0.65×0.85× 48V) = 456Ah

Approx: 2KW

b) PV Array Sizing

Daily Offset Requirement: 6,049 Wh

Peak Sun Hours (Kasese): 5.5 hrs

Array Size: 6,049 ÷ 5.5 = 1,100W ≈ 1.5kW

No. of Solar panels (for 550W) = 1500 ÷ 550

= 2.73

= 3 panels.

c) Inverter Selection

Assuming system losses; 30%

Invertor size = 741W ≈ 800W

Recommendations.

Bweramule Health Center (Off-Grid Solar System)

The proposed 15kW off-grid solar system requires careful implementation to ensure reliable 24/7 power for critical medical operations. For the battery bank, we recommend a lithium iron phosphate ($LiFePO_4$) configuration with modular architecture. The system should incorporate a dual MPPT charge controller setup with adaptive charging algorithms to optimize battery life and handle the facility's heavy sterilization loads.

Critical load management must be implemented through an intelligent power distribution system that automatically prioritizes medical equipment during low-power situations. Mounting structures should meet cyclonic wind load requirements (≥60m/s) while maintaining optimal 25° tilt angle for energy yield.

Mukathi Health Center (Grid-Tied Hybrid System)

For this grid-assisted facility, we propose a 10.0 kW solar PV system with a lithium storage capacity to provide uninterrupted power for essential medical services during grid outages. The battery system requires smart cycling algorithms to maximize lifespan while ensuring daily availability for critical loads. We recommend implementing automatic load shedding that sequentially disconnects non-essential circuits when operating on backup power.

All wiring must use UV-resistant, double-insulated cables in conduit with proper derating for tropical conditions. A comprehensive operations manual and staff training program should accompany system commissioning.

Conclusions

The solar needs assessment evaluates the energy infrastructure at Bweramule Health Center (Ntoroko) and Mukathi Health Center (Kasese), proposing tailored solutions to address critical power reliability gaps for life-saving medical equipment. For Bweramule, a 15kW off-grid solar system with a lithium storage ensures full energy independence, prioritizing sterilizers and oxygen concentrators with cyclone-resistant design, while Mukathi's 10.0 kW grid-tied hybrid system with battery backup stabilizes power supply and maintains essential services during hydroelectric outages. These scalable systems incorporate smart load management and remote monitoring, aligning with national health electrification goals to enhance operational efficiency, reduce costs, and improve healthcare delivery through sustainable energy solutions.

References

Ref #1: Bills of quantities for proposed solar system installation for Bweramule HC III

Ref #2: Bills of quantities for proposed solar system installation for Mukathi HC III

Images

Figure 1 Mukathi health center

Figure 2 Bweramule Health Center III