HEALTH FACILITY ENERGY NEEDS ASSESSMENT
UGANDA COUNTRY SUMMARY REPORT

August 2015
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Acronyms

ASD  African Solar Designs
CHP  Center for Health Policy
DHO  District Health Office
ERT  Energy for Rural Transformation
FRES  Foundation Rural Energy Services
GIZ  Gesellschaft fur Internationale Zusammenarbeit
HC  Health Center
HIO  High-impact opportunity
HSSIP  Health Sector Strategic and Investment Plan
ICT  Information and Communication Technology
IPP  Independent Power Producers
LPG  Liquid Petroleum Gas
MHCP  Minimum Health Care Package
MoE  Ministry of Energy
MoH  Ministry of Health
NGO  Non-governmental Organization
PHC  Primary Health Care
PV  Photovoltaic
REA  Rural Electrification Agency
SE4ALL  Sustainable Energy for All
UN  United Nations
UNEPIC  Uganda National Expanded Programme on Immunization
UNFPA  United Nations Fund for Population Activities
UNICEF  United Nations Children's Fund
UNMHCP  Uganda National Minimum Health Care Package
USAID  United States Agency for International Development
WHO  World Health Organization

Units of Measurement

km  Kilometer
kW  Kilowatt
kWh  Kilowatt hour
kWp  Kilowatt peak
W  Watt
Acknowledgements

This report was prepared principally by African Solar Designs, with guidance from the UN Foundation. The authors gratefully acknowledge the financial support provided by the Norwegian Ministry of Foreign Affairs for this study. The authors also thank the Government of Uganda – especially the Ministry of Health and the Ministry of Energy and Mineral Development – for their collaboration and support. Also, the team benefited from numerous consultations with practitioners in Uganda, who provided expert advice based on their experiences.
Executive Summary

This report summarizes the findings of an energy needs assessment conducted for 100 healthcare facilities in Uganda. It is one of a series of assessments commissioned by the United Nations Foundation (UN Foundation), with financial support from the Norwegian Ministry of Foreign Affairs, to evaluate the electrification status and power needs of un-electrified and under-electrified health facilities in Africa and to provide recommendations – including proposed energy system designs – for addressing those needs. The assessment was undertaken under the United Nations (UN) Sustainable Energy for All (SE4All) initiative and more specifically under an effort, led by the UN Foundation, the World Health Organization (WHO) and UN Women, to enable universal energy access in health facilities by 2030.

The energy needs assessment carried out in Uganda involved undertaking a “stock-take” of all public health facilities and their electrification status followed by energy audits conducted at 100 health centers (Level 2, 3 and 4) spread across 13 districts, keeping in mind specifically the needs of women and their newborns. This was followed by an analysis of the energy audit data and site-specific recommendations for improved energy solutions. All three activities were designed to address issues particularly relevant to women and their newborns and to help answer the following questions:

1. Do healthcare facilities in Uganda have adequate access to modern energy services? Are gender considerations being sufficiently included in the design of power solutions in healthcare settings, not only in terms of maternal delivery, but also ensuring safety for women to access the health clinic in the evening/night (if open)?
2. If not, which facilities warrant priority/attention?
3. In those facilities, what power solutions are best suited to meet the current and future energy needs of the facility?

Based on the assessment, the report’s key findings are:

1. **Uganda is a leader in sub-Saharan Africa when it comes to delivering decentralized renewable energy (especially solar PV) to community institutions.**
   - The Energy for Rural Transformation (ERT) program has already installed hundreds of decentralized power systems in Ugandan health clinics.
   - The Ugandan off-grid solar market is well-developed and dynamic. It provides a strong base for which future off-grid initiatives can be built.
2. **There is a lack of easily accessible data on energy access within health facilities in Uganda.**
   - To date, the only centralized tracking of energy interventions or the status of energy systems in health facilities in Uganda is provided by the ERT program and its monitoring and evaluation exercises. For the vast majority of non-ERT facilities, however, there is a general lack of easily accessible and reliable data on energy access, making planning and monitoring energy interventions within the health sector difficult.
   - Data is more available at a district-level, which points to district-level data collection (and its aggregation) as a possible strategy for improving the availability of data.
   - Another promising tool for data collection is the mTrac mobile phone-based survey tool developed by the United Nations Children’s Fund (UNICEF) and the Ministry of Health. The tool could be used to collect energy data from health facilities in a relatively reliable, dynamic and cost–effective manner.
3. **Decentralized energy sources (particularly solar PV) provide critical, yet insufficient, energy services to surveyed health facilities not currently connected to the grid.**
   - Almost all surveyed health facilities had access to one form of power, with 82% of surveyed facilities having at least one solar PV system.
   - The majority (82%) of audited PV systems were operational – a relatively high success rate compared with other countries.
   - In those facilities with solar PV systems, the average installed capacity of the systems totaled 440 W per facility; this is an insufficient amount of power for the kind of health services these facilities are meant to provide.

4. **The accessibility, quality and reliability of energy-dependent health services varies from service to service and is generally inadequate for maternal and child health service provision in surveyed facilities.**
   - Ambient lighting was found in most facilities while specialized task lighting for activities such as deliveries, operations and security lighting was rarely found. Kerosene remains a major source of lighting in smaller health centers.
   - Sixty-eight (68%) of surveyed facilities had a refrigerator; most refrigerators were powered by LPG and solar PV systems. All of the audited LPG refrigerators were working, most likely because of the readily available Primary Health Care (PHC) funds that districts use to pay for LPG refills. Seventy-eight percent (78%) of the audited solar PV powered refrigerators were working.
   - Forty-two percent (42%) of the surveyed health centers providing staff housing had electricity for the staff houses. This has important implications for attracting and retaining qualified health staff, including mid-wives.

Based on its findings, this report recommends:

1. **Those surveyed facilities currently connected to the grid (15 in total) should remain on the grid.**
2. **Twenty-eight (28) “off-grid” facilities should be connected to the national grid,** given their close proximity to the grid (typically less than 5 km).
   For times when the grid is unreliable, any existing and functional decentralized power system should be used as a back-up power source for critical needs.

3. **Three (3) facilities should adopt new, stand-alone solar PV systems.**
4. **Fifty four (54) facilities should adopt a new, facility-wide solar PV micro-grid.**
   The rationale for recommending new power solutions in facilities with existing, decentralized power systems is based on the fact that: (i) most existing systems – even where they were functional – were not sufficient to meet the critical power needs of the facility; (ii) adding another system to a facility (to ensure it has enough capacity) could make maintaining the systems extremely difficult.

The recommended solar PV system designs have been carefully tailored to each health facilities’ power needs, including several essential medical devices critical to the provision of maternal and child health services, such as suction machines, vaccine refrigerators and task lights, as well as outdoor security lighting, which is particularly important to ensuring women and children feel safe to visit a health facility at night. The systems have also been “standardized” so that they can be rolled out at scale. Recommended system sizes typically range from 1.25 kWp to 6 kWp with optionally diesel back-up generators in some cases. One larger 11 kW system has also been designed. The proposed solutions represent approximately
USD 1.30 million in upfront costs including both procurement of equipment and installation costs, with additional optional costs for diesel generators and/or remote monitoring systems (both recommended).

Finally, to ensure the sustainability of the proposed solutions, the following considerations should be taken into account when deploying the solar PV solutions recommended in this report:

- **Business model**: The business model should focus on service provision rather than sales of equipment.
- **Ownership**: There should be clear ownership of the systems, including roles and responsibilities for operation and maintenance. Health facility staff should know who is responsible for repairing and maintaining the system and should know who to call when there is a problem. Preferably, this person should be located near the site.
- **Operations and maintenance**: The cost of keeping the systems operational should be realistically budgeted for. Funds should be made available either at the facility-level or through district health budgets to cover repairs, fuels (where applicable) and spare parts.
- **User training and system management**: Health facility staff should be trained in the basic operation and management of the systems.
- **Service, maintenance and spare part provision in contracts**: Service contracts should be put in place with specialists/suppliers/service providers for more technical and in-depth system maintenance and repairs.
- **Remote monitoring and reporting**: Remote monitoring should be adopted where feasible. Online monitoring enables providers and managers to track the status of multiple facilities remotely\(^1\). It allows those monitoring the site to be aware and take action when systems are used beyond the design parameters. Wherever there is a cell phone signal, remote monitoring of PV systems can assist in management and maintenance. If the right technology is used, a manager should be able to know exactly what is happening in real time with a solar system\(^2\).

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1 Virtually all modern PV charge regulators and inverters are equipped with sophisticated control equipment that allow them to monitor, communicate and manage various aspects of energy delivery.

2 M-Kopa Solar tracks the real time performance of hundreds of thousands of systems in Kenya and Uganda.
1 Introduction

1.1 Objective of the Document

This report summarizes the findings of an energy needs assessment conducted for 100 healthcare facilities in Uganda from July 2014 to July 2015. It is one of a series of assessments commissioned by the United Nations Foundation (UN Foundation), under the auspices of the United Nations (UN) Sustainable Energy for All initiative (SE4All), to evaluate the electrification status and power needs of un-electrified and under-electrified health facilities in several African countries and to provide recommendations – including proposed energy system designs – for addressing those needs.

The report has been prepared by African Solar Designs (ASD) – a Nairobi-based consulting firm – for the UN Foundation and its partners, including the Government of Uganda, and other relevant decision-makers and stakeholders in the health and energy sectors.

The report complements 100 individual, facility-specific needs assessment reports, which provide more detailed information/analysis about the facilities studied in Uganda.

1.2 Background

Sustainable Energy for All is a global initiative co-led by the UN and the World Bank to achieve universal energy access, improve energy efficiency and increase use of renewable energy. The initiative mobilizes action from all sectors of society in support of three inter-linked objectives:

- Providing universal access to modern energy services;
- Doubling the global rate of improvement in energy efficiency; and
- Doubling the share of renewable energy in the global energy mix.

Both developed countries and more than 85 developing countries – including Uganda - have partnered with SE4All to advance the three objectives at a country level. Sustainable Energy for All is set up as a multi-stakeholder partnership between governments, the private sector and civil society.

At the request of the Director-General of the SE4All initiative, the UN Foundation, the World Health Organization (WHO) and UN Women are jointly leading an effort focused on the nexus of energy and health, with a particular focus on increasing energy access in health facilities, particularly in support of improved maternal and child health services. The effort, known as Energy for Women’s and Children’s Health, is one of SE4All’s multi-stakeholder partnerships, otherwise known as a “High-Impact Opportunity” (HIO) area.

Formally launched at the SE4All Advisory Board meeting in April 2013, Energy for Women’s and Children’s Health uses the international framework of SE4All to further accelerate and coordinate efforts to expand access to energy in health facilities, with a strong emphasis on gender aspects of service delivery. The HIO galvanizes action on the barriers facing health facility electrification, through a consortium of public, private and civil society partners, expertise and resources, with a view to ensuring universal access to, and sustained use of, modern energy services in health facilities by 2030.
1.3 Scope of Work

Under the auspices of the *Energy for Women’s and Children’s Health* HIO and with initial support from the Government of Norway, the UN Foundation has been working for the past year to evaluate the electrification status and power needs of health facilities in several African countries and providing recommendations – including proposed energy system designs – for addressing these needs, with a strong gender focus. These energy needs assessments have been designed with the help of ASD, which worked, in the case of Uganda, with the Government of Uganda and Konserve Consult, a Ugandan-based consultancy firm led by Abdalla Kyezira, in the implementation of the assessment. The ASD team provided core project management, quality control and energy expertise, while Abdalla and his team offered country-specific technical (energy and health sector), logistical and political support. Two of the six site auditors were women, including one health sector specialist and one community outreach specialist.

The energy needs assessment carried out in Uganda involved the following key activities:

- The development of a comprehensive list of Uganda’s government-owned/managed health facilities alongside information on their size/level (e.g. hospital vs. dispensary), electrification status and other important features (e.g. proximity to the national grid) for the purpose of identifying and prioritizing facilities for subsequent energy audits.
- Conducting energy audits at 100 health facilities.
- Making recommendations - including proposed power system designs – for each facility for how best to meet its power needs, particularly those related to maternal and child health services.

Together, these activities were designed to:

- Highlight the importance of energy access to a well-functioning health system and the need for further prioritization of sustainable energy access within healthcare facilities.
- Demonstrate the benefits of an integrated approach to assessing the power needs of primary healthcare facilities, particularly those services relevant to women’s and children’s health.
- Attract additional investments in the provision of reliable, affordable and sustainable power systems in un-electrified and underserved healthcare facilities.

1.4 Overall Approach

This section describes the overall approach ASD took in carrying out the energy needs assessment in Uganda.

The assessment began with a series of stakeholder consultations, including several bilateral meetings and an inception meeting held in Kampala in September, 2014 (see Annex 1 for a list of stakeholders consulted). Throughout the project ASD consulted with non-government organizations (NGOs) with targeted activities in women’s and children’s health, including the United Nations Fund for Population Activities (UNFPA), UN Women, the president of the Sheema District midwives’ association, and female community and business leaders in several of the areas in which assessments were carried out, in order to gather perspectives on issues specific to these vulnerable groups.

Following stakeholder consultations, ASD began a process of identifying which health facilities to include in the study. A “mapping” exercise of all of Uganda’s public healthcare facilities was undertaken, with the goal of documenting their electrification status and other important features relevant to the study (e.g.
proximity to the national grid). From the mapping data, 100 healthcare facilities were chosen following a consultative process with key energy and health sector stakeholders in Uganda. Priority was given to facilities that are:

- Off-grid;
- Government managed/operated;
- Located in “priority” districts, as determined by the Ministry of Health (MoH), the Ministry of Energy and Mineral Development (MoE), other government agencies, the UN, donors or NGOs;
- Located in districts/areas unlikely to be grid-electrified in the near future
- Actively providing maternal health services (e.g. birthing).

The Government of Uganda, through the MoH, was involved in the identification of facilities to be assessed in this initiative. None of the sites selected are those covered by the MoE/World Bank-led Energy for Rural Transformation (ERT) program\(^3\). Table 1.1 and Figure 1.1 below show the distribution of the 100 health centers that were chosen for the assessment.

### Table 1-1 Identified Health Facilities by District

<table>
<thead>
<tr>
<th>District</th>
<th>No. of Health Facilities</th>
<th>Level of Health Center</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>HC II</td>
</tr>
<tr>
<td>Kamwenge</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Kabarole</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Kyegegwa</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Kiruhura</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Lyantonde</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Sheema</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Kyejonjo</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Bushenyi</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Oyam</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Isingiro</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Mitooma</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Ibanda</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Ntungamo</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td><strong>100</strong></td>
<td><strong>48</strong></td>
</tr>
</tbody>
</table>

---

3 The ERT program aims to increase energy access in rural areas through expansion of energy services to rural health centers and other end-user sectors.
Once the facilities were chosen, ASD conducted on-site energy audits at each facility between 26th November, 2014 and 30th March, 2015. Prior to site visits, ASD conducted a six-day training of auditors, which included modules on gender-related issues such as conducting research on traditionally private or sensitive reproductive topics, engaging women patients in a culturally appropriate and effective manner. Auditors used a survey tool designed by ASD and UN Foundation specifically for this work. The tool is based on the United States Agency for International Development (USAID) Powering Health energy audit tool but adapted to specific needs of this project. This included integrating questions on maternal and child health services throughout the survey. The tool was also informed by the WHO/World Bank report, entitled “Modern Energy Services for Health Facilities in Resource-Constrained Settings”.

Following the audits, ASD carried out a comprehensive analysis of the data collected on site and provided site-specific recommendations for energy solutions, including off-grid system designs for 57 healthcare facilities. ASD used international best practices to evaluate the most cost effective, sustainable systems to meet the power needs of the facilities. The methodology for calculating loads and sizing systems is included in Annex 2.
1.5 Report Structure

The remainder of this document is divided into the following three chapters:

- Chapter 2 provides a general overview of Uganda’s energy and health sectors.
- Chapter 3 summarizes the findings of the energy audits.
- Chapter 4 provides recommendations for how to improve the provision of modern energy services in the healthcare facilities studied, particularly as it relates to women’s and children’s healthcare provision.

Following these chapters are Annexes with supporting information.
2 Country Overview

Uganda is a land locked country in eastern Africa with neighbors Kenya to the east, South Sudan to the north, Democratic Republic of Congo to the west, Rwanda to the southwest and Tanzania to the south. Its capital and largest city is Kampala. The county is divided into 4 administrative regions and 111 districts. A summary of Uganda’s profile is given below.

Table 2-1 Key Country Facts

<table>
<thead>
<tr>
<th></th>
<th>Uganda</th>
<th>Sub-Saharan Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land area (km²)</td>
<td>236,040</td>
<td>23,589,136</td>
</tr>
<tr>
<td>Population (2014)</td>
<td>38.84 million</td>
<td>961.4 million</td>
</tr>
<tr>
<td>Population density</td>
<td>167.5</td>
<td>41</td>
</tr>
<tr>
<td>Rural population</td>
<td>84</td>
<td>63</td>
</tr>
<tr>
<td>Total GDP (USD PPP - 2013)</td>
<td>72.3 billion</td>
<td>3,137 billion</td>
</tr>
<tr>
<td>Per capita GDP (USD PPP - 2013)</td>
<td>1,963</td>
<td>3,588</td>
</tr>
<tr>
<td>Human Development Index rank (2013)</td>
<td>164</td>
<td>N/A</td>
</tr>
<tr>
<td>Rural electrification rate* (2014)</td>
<td>7%</td>
<td>16%</td>
</tr>
<tr>
<td>Maternal mortality</td>
<td>360</td>
<td>510</td>
</tr>
</tbody>
</table>

Source: World Bank Development Indicators; UNDP; International Energy Agency, WHO; UNICEF
*Includes both on- and off-grid sources.

2.1 Energy Access Overview

Access to modern energy services is limited in Uganda; only 15% of the country’s population is connected to the national grid, with distribution mainly centered in urban areas. In rural areas, where 84% of the population lives, only 7% have access to electricity. Uganda’s total installed electricity capacity stood at 822 MW in 2013, mainly consisting of hydro power.

In 2012, the government developed a Rural Electricity Strategy Plan, which aims to achieve a rural electrification rate of 22% by 2022 and universal energy access in Uganda by 2035. The Rural Electrification Agency (REA) is mandated to implement the strategy and is working to connect over 1.4 million new customers to the main or independent grids, or to solar PV systems over the period 2013-22. Uganda is also implementing the ERT program through the MoE. The program aims to increase rural energy access through grid extension, Independent Power Producers (IPP) and solar energy and focuses on end user sectors in rural areas such as health, agriculture, education and water.

In an effort to accelerate the distribution of solar PV systems throughout the country and assist in reaching its rural electrification target, the government is introducing a ‘GET FiT’ program that will fast track 15-20

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4 IEA WEO 2014 Electricity Database, ClimateScope 2014, Electricity Regulation Authority
solar projects a year, through a results-based top-up on the existing feed-in-tariff, as well as providing grant funding to solar PV projects.

2.1.1 Solar PV Use in Uganda

Solar PV is primarily used for off-grid electrification of rural communities and as a source of energy of cooking, boiling water and providing power to public buildings, such as hospitals. Solar PV equipment and pico-solar equipment is widely available for sale over the counter in major commercial towns throughout Uganda. A number of stakeholders have been active to enable access to PV, including:

- Central government efforts: ERT provided subsidies over a decade for tens of thousands of systems.
- Private sector outreach: A number of companies have built up the household and institutional market and have built wide reach to rural areas (they include companies such as Solar Now, Foundation Rural Energy Services (FRES), and many others).
- NGO/donor market: Groups such as Gesellschaft fur Internationale Zusammenarbeit (GIZ) and SNV have supported capacity building and private sector growth in many parts of the country.

Despite the low rural electrification rate, it appears that solar PV use is quite common in Ugandan communities. In virtually all off-grid settlements proximate to the health centers surveyed, entrepreneurs used solar PV to charge phones and batteries, power appliances and operate small businesses. In many centers, PV equipment was for sale from shops. The role of solar power in income generation appeared to be a strong motivator for ensuring that systems are kept operational.

During visits to the facilities, the auditors found that:

- Rural people knew about solar and solar systems, which are ubiquitous in village centers.
- PV-powered businesses were common (cell phone charging, bars, business centers).
- Supply chains were in place and consumers were able to purchase components.
- Solar was seen as a tool to help people generate income, whether through powering their business or as a supplier of solar PV products.
- There appears to be growth in the use of pico-solar systems.
- Pay as you go was being introduced to finance solar PV. For example, SolarNow, M-Kopa Solar (from Kenya) and FRES were actively developing financing options for smaller systems.

Notwithstanding the relative success with smaller, decentralized systems, auditors found that there are a number of issues with solar PV systems:

- The cost of maintaining and replacing batteries on many small systems is quite expensive. Thousands of individual batteries require replacement each year, and this strains budgets and staff of those charged with maintaining services.
- Despite income generation being a key motivator for maintaining systems, many systems fail. This was especially true for systems not funded under government budgets (i.e. those funded by NGOs) or very old systems with no institutional “owner”.
- It is still common to see multiple power systems and multiple PV systems in the same site. Although this redundancy served a useful purpose when PV and balance of system costs were
very high, the lowered costs of PV systems now lends itself to both centralization of systems and to larger systems that provide more power in a more flexible manner.

2.2 Health Sector Overview

Uganda has made significant progress improving its health services over the past two decades with life expectancy improving from 48.8 years in 1970 to 59.2 years in 2013. Maternal health is improving as evidenced by a decrease from 780 to 360 maternal deaths per 100,000 live births from 1990 to 2013. Child health has also improved with under-5 child mortality rates dropping from 179 in 1990 to 66 in 2013. Between 2009 and 2013, 57.4% of births were attended by a skilled health-care professional. Despite this progress, Uganda is not on track to achieve its Millennium Development Goal (MDG) 5 target to improve maternal health.

According to WHO, overall staffing levels have improved due to a targeted recruitment drive increasing staffing levels at HC III and IV from 57% in 2012 to 70% in 2013. However, insufficient resources continue to hamper Uganda’s efforts to improve its ability to deliver adequate health care.

Uganda’s health system comprises health services delivered in the public sector, by private providers and by traditional and complementary health practitioners. In an effort to improve its health services, the Government of Uganda has adopted a sector wide approach, which has included setting up:

- A National Development Plan 2010/11-2014/15,
- National Health Policy II 2010-2020, and
- Health Sector Strategic and Investment Plan (HSSIP) 2010/11-2014/15 to guide the strategic focus for the health sector.

The process of developing the subsequent National Development Plan and HSSIP is underway. The overall development goal of the HSSIP is “the attainment of a good standard of health by all people in Uganda, in order to promote a healthy and productive life”. The program goal is “reduced morbidity and mortality from the major causes of ill-health and premature death, and reduced disparities therein”.

Highlighted in the HSSIP is the Uganda National Minimum Health Care Package (UNMHCP). The concept of a minimum health care package (MHCP) has been used as a means of setting priorities for national health budgets. The aim is to identify a set of health services to which the government can afford to provide free access, which is intended to assist with resource allocation in the face of a huge and growing health burden and small public budgets.

The Ugandan health sector is a decentralized system composed of national and district levels as shown in the Figure 2.1 below.

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Data sourced from UNICEF and WHO

This needs assessment focused on the district level health facilities with maternal and child health services: HC II, III and IV as shown in Figure 2.2 below.
Figure 2-2 Surveyed Health Facilities by Type

- HC IV: 48%
- HC III: 42%
- HC II: 10%
3 Key Findings

This section summarizes the findings of the data “mapping” exercise and energy audits carried out in Uganda. Section 3.1 provides several overall findings while Section 3.2 and Section 3.3 provide findings relevant to the data “mapping” exercise and energy audits, respectively.

3.1 Summary

1. Uganda is a leader in sub-Saharan Africa when it comes to delivering decentralized renewable energy (especially solar PV) to community institutions.
   - The ERT program has already installed hundreds of decentralized power systems in Ugandan health clinics.
   - The Ugandan off-grid solar market is well-developed and dynamic. It provides a strong base for which future off-grid initiatives can be built.

2. There is a lack of easily accessible data on energy access within health facilities in Uganda.
   - To date, the only centralized tracking of energy interventions or the status of energy systems in health facilities in Uganda is provided by the ERT program and its monitoring and evaluation exercises. For the vast majority of non-ERT facilities, however, there is a general lack of easily accessible and reliable data on energy access, making planning and monitoring energy interventions within the health sector difficult.
   - Data is more available at a district-level, which points to district-level data collection (and its aggregation) as a possible strategy for improving the availability of data.
   - Another promising tool for data collection is the mTrac mobile phone-based survey tool developed by UNICEF and the MoH. The tool could be used to collect energy data from health facilities in a relatively reliable, dynamic and cost–effective manner.

3. Decentralized energy sources (particularly solar PV) provide critical, yet insufficient, energy services to surveyed health facilities not currently connected to the grid.
   - Almost all surveyed health facilities had access to one form of power, with 82% of surveyed facilities having at least one solar PV system.
   - The majority (82%) of audited PV systems were operational – a relatively high success rate compared with other countries.
   - In those facilities with solar PV systems, the average installed capacity of systems totaled 440 W per facility; this is an insufficient amount of power for the kind of health services these facilities are meant to provide.

4. The accessibility, quality and reliability of energy-dependent health services varies from service to service and is generally inadequate for maternal and child health service provision in surveyed facilities.
   - Ambient lighting was found in most facilities while specialized task lighting for activities such as deliveries, operations and security lighting was rarely found. Kerosene remains a major source of lighting in smaller health centers.
   - Sixty-eight (68%) of surveyed facilities had a refrigerator; most refrigerators were powered by liquid petroleum gas (LPG) and solar PV systems. All of the audited LPG refrigerators were working, most likely because of the readily available PHC funds that districts uses to pay for LPG refills. Seventy-eight percent (78%) of the audited solar PV powered refrigerators were working.
 Forty-two percent (42%) of the surveyed health centers providing staff housing had electricity for the staff houses. This has important implications for attracting and retaining qualified health staff, including midwives.

### 3.2 Data Mapping

The ASD team assembled available information for both off-grid and grid connected health facilities in Uganda in the form of a country database. The database includes information about each facility, including some basic descriptive information (e.g. facility level, GPS coordinates if available) as well as information on the type of health services provided and the type of modern energy services, if any, available at the facility. The primary sources of information for this database included the MoH’s HID-WHO database and government-supplied lists of ERT Phases I and II sites (Phase III is currently underway).

The main results of the data mapping exercise are:

1. **Data availability is still lacking on health facility energy systems at the national level.** To date the only centralized tracking of energy interventions or the status of energy systems in health facilities in Uganda has been through the ERT program and its subsequent monitoring and evaluation exercises. For the vast majority of sites, however, it was not possible to ascertain key information such as the current grid connection status of a facility. After meetings with the District Health Officer in Sheema and Kiruhura, both districts supplied completed data for this mapping exercise, which points to district level data collection as a possible tool for filling in this database more completely. Another promising tool might be the MoH / UNICEF m-Trac mobile phone-based survey.

2. **Uganda’s health clinic level categories could provide a helpful proxy for health services data.** Site-specific data on health care services and infrastructure is also lacking. The Ugandan government supplied a general characterization of the health services, catchment area and infrastructure typical to an HC II, III or IV. With this relative consistency across each HC level it may be possible to approximate energy needs of a facility by use of data gathered in this assessment.

3. **The ERT program has reached a total of 651 government health centers in Uganda.** 50% are HC II, 43% are HC III and 6% HC IV. Of all the ERT sites, 4% have also received energy equipment through other sources.

### 3.3 Energy Audits

The ASD team conducted 100 audits in 13 districts. Of these sites, 85 were off-grid and 15 were grid-connected (see Figure 3-1 below).
This section presents the findings of these audits as follows:

- First, a discussion of energy demand at health facilities – including an evaluation of the typical energy-dependent health services found at the sites; and
- Next, an assessment of the energy supply found at these facilities (both on-grid and off-grid systems).

### 3.3.1 Energy Demand

The energy needs of the audited health facilities can be understood, in part, by examining their existing, energy-dependent medical services.

#### 3.3.1.1 Health Facility Medical Services

The MoH has created relatively standardized site infrastructure for health facilities. The table below presents the typical types of buildings found in the 100 rural Ugandan health centers audited by this study. In off-grid sites, electricity services are usually only installed in clinic buildings and staff quarters.

**Table 3-1 Current Services and Energy Supply of Health Facilities**

<table>
<thead>
<tr>
<th>Facility/Building</th>
<th>Function, energy requirement</th>
<th>Comments on current energy supply and needs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clinic buildings</strong></td>
<td>In HC II, one building with multiple rooms. In HC III &amp; IV multiple buildings for key activities.</td>
<td>Primary area for energy investment. Often multiple power systems.</td>
</tr>
<tr>
<td><strong>Staff houses</strong></td>
<td>HC II: Usually 1-4 units. HC III: 1 to 28, average 5 houses HC IV: 2 to 17, average 8 houses</td>
<td>Usually a single PV system for each staff house, managed by staff. &gt;60% of visited sites had no electricity on staff quarters.</td>
</tr>
<tr>
<td><strong>Latrines</strong></td>
<td>Provide services for all visitors. No major energy needs.</td>
<td>Most commonly pit latrines. No latrines visited had lighting for night visits.</td>
</tr>
</tbody>
</table>
### Incinerator & placenta pit
- Used to burn medical waste
- Commonly use biomass to burn waste

### Water storage tanks and pumps
- Rainwater harvesting in tanks (69%) or shallow wells were most common solution.
- Gravity flow from rainwater tank taps.
- No observed internal piping delivery in HC II facilities.

### Guardian shelter
- Less common as features in HC than in Malawi. Not found in HC II.
- Cooking facilities only, roofed shelter.
- No electric systems observed.

### 3.3.1.2 Key Appliances & Medical Equipment

After conducting audits of all equipment used in the surveyed health facilities, ASD divided key, power-dependent appliances/services into the six categories below:

- Lighting;
- Refrigeration;
- Staff housing;
- Water supply;
- Sterilization; and
- Information and communication technology (ICT).

Additionally, all energy-dependent medical equipment was considered. Findings in each of these categories are described below.

#### 3.3.1.2.1 Lighting

In the context of healthcare facilities, lighting is generally categorized as **ambient** (general space lighting), **task** (lighting for special tasks which is generally focused and brighter) or **security** (outdoor space lighting around buildings and pathways). Solar PV was the main source of lighting in the audited facilities (see Figure 3.2).

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7 A detailed description of these categories is provided in Annex 2.
Key findings on lighting at the 100 surveyed facilities include:

1. **Ninety-six percent (96%) had some type of lighting system.**
2. **All HC IVs had lighting systems** – 60% of HC IVs were connected to the national grid and 90% had solar PV systems (note that some HC IVs have both grid and PV). HC IVs also had a number of generators that we used as backup.
3. **Kerosene remains a major source of lighting in smaller health centers** – Kerosene supplied 42% of lighting needs in HC IIIs, and was the only source for 25% of the HC IIs.
4. **Whereas ambient lighting was found in most facilities, specialized task lighting and security lighting were less common.** This has implications for women’s and children’s health in terms of adequacy of lighting for tasks that require bright, focused light (maternity, operations) as well as accessibility and safety of the site at night (in particular vis-à-vis outdoor security lighting and ambient lighting for the toilets / latrines).
5. **A total of 107 solar PV systems were found being used for lighting purposes across most of the sites,** with between one and four systems at each health facility with PV. HC IIs and HC IIIs averaged one PV lighting system per facility while HC IVs averaged two.
6. **Eighty-four percent (84%) of the PV lighting systems observed were operational** (see Figure 3.3). The most common causes of lighting solar PV system failure were battery deterioration or age (many were over ten years old).
Figure 3-3 Operational Status of PV Lighting Sources at Surveyed Facilities

3.3.1.2.2 Refrigeration

Key findings on refrigeration include:

1. **Of the 100 health centers assessed, 78 had refrigeration** for storing medicine and vaccines. There was a total of 95 refrigerators audited, with most facilities having one refrigerator. A breakdown of facilities without a refrigerator follows:
   a. HC II – 16 sites (33% of the HC II visited)
   b. HC III – 4 sites (10% of the HC III visited)
   c. HC IV – 2 sites (20% of the HC IV visited)
2. **A variety of refrigerator types remain in use in Uganda**, with some powered by the national grid, solar PV systems, LPG and kerosene (see Figure 3.4).

Photo 3-1 Refrigerator at a Ugandan Health Center
3. The majority of refrigerators were functional (see Figure 3.5). All the LPG refrigerators were working, most likely because of the readily available PHC funds that the district used to refill the LPG when it had been used up. Seventy-eight percent (78%) of the solar PV powered refrigerators were working and only one of the three kerosene refrigerators observed was functional.

4. For most non-functioning refrigeration systems, the cause was a faulty refrigerator rather than an issue with the energy source (see Table 3.2).
Table 3-2 Operational Status of Refrigeration Sources at Surveyed Facilities

<table>
<thead>
<tr>
<th></th>
<th>Total sites</th>
<th>Operational</th>
<th>Non-operational</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid</td>
<td>9</td>
<td>6</td>
<td>3</td>
<td>The refrigerators were broken.</td>
</tr>
<tr>
<td>PV</td>
<td>29</td>
<td>24</td>
<td>5</td>
<td>In 2 of the sites the solar PV modules were stolen while in the rest the refrigerators were broken.</td>
</tr>
<tr>
<td>Gas</td>
<td>54</td>
<td>54</td>
<td>0</td>
<td>All gas powered refrigerators were found to be working well. The refills are provided by the district using the Primary Health Care (PHC) funds.</td>
</tr>
<tr>
<td>Kerosene</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>The 2 refrigerators were broken.</td>
</tr>
</tbody>
</table>

3.3.1.2.3 Water Supply

Key findings on water supply include:

1. **The main supply of water observed at the surveyed health centers was rainwater** (see Figure 3.6). A large number of the health centers assessed are located in wet regions, making rainwater harvesting a viable solution. Water is collected from the roof of health structures using gutters and stored in large tanks (plastic or concrete) usually of 10,000 liters capacity.

Figure 3-6 Water Sources in Health Facilities

![Water Sources in Health Facilities](image)

2. **There was usually no piped water inside the health facility.** Water was fetched from the storage tank as needed.

3. **Gravitational flow was used to deliver both municipal water supply and harvested rainwater, making it the most common water delivery method** (see Figure 3.7).
3.3.1.2.4 Staff Housing

Key findings on staff housing include:

1. **Most health facilities surveyed offered staff housing** (see Figure 3-8).

2. **Thirty-three percent (33%) of staff were housed on-site**, though at some of the larger health centers there was not enough housing on-site for all staff. The remaining 67% cater for their own accommodation outside the health center (especially those that work in HC IVs as such facilities have an average of 32 staff). The average, minimum and maximum number of staff house for observed in every health center level is given in Table 3.3.
Table 3-3 Number of Staff Housed at Surveyed Facilities

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC II</td>
<td>4</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>HC III</td>
<td>5</td>
<td>1</td>
<td>28</td>
</tr>
<tr>
<td>HC IV</td>
<td>8</td>
<td>2</td>
<td>17</td>
</tr>
</tbody>
</table>

3. **Midwives were provided on-site housing at the majority of surveyed facilities with staff housing** – at all HC IVs, 86% of HC IIIs and 50% of HC IIs. Of the 100 sites surveyed, 19 didn’t have midwives.

4. **Only 42% of the health centers providing staff housing had electricity for the staff houses** (see Figure 3.9).
   
a. Sources of electricity for staff houses include: the national grid, solar PV systems and generators. **There were no cases of multiple power sources in the staff houses audited.**
   
b. **Interestingly, a similar number of the HC IIs (23) and HC IIIs (27) had non-electrified staff housing.** HC IIs were using the most off-grid solar PV systems, whereas for the larger HC IV facilities, more of the staff power was provided by the grid (and none by PV).
   
c. **The staff were using electricity, when it was available, for lighting, mobile phone charging, entertainment (television, DVD), computers and laptop charging.**

![Figure 3-9 Electricity Sources in Staff Housing Units at Surveyed Facilities](image)

3.3.1.2.5 **Sterilization**

Key findings on sterilization include:

1. **Many of the surveyed health centers were using heat-based sterilization** for their reusable medical appliances (See Figure 3.10). No heat-based sterilization was observed in the HC II facilities (they use bleach/chemical-based processes). Only one HC IV didn't have heat-based sterilization (the facility was recently upgraded from HC III).
2. **Energy sources used for sterilization were the national grid, LPG or kerosene.** The equipment used for sterilization are autoclaves and steam sterilizers.

**Figure 3-10 Sterilization at Surveyed Facilities**

![Sterilization Graph](image)

3.3.1.2.6 **Information & Communications Technology**

Key findings on ICT include:

1. **A limited number of computers were found at the surveyed HC II and HC III facilities** (see Figure 3.11). Only 1 HC II visited had a computer.
2. **There was a greater investment in ICT in HC IV facilities** due to the services offered and the large number of patients served.

**Figure 3-11 Availability of Computers in Surveyed Facilities**

![Computer Availability Graph](image)
3.3.1.3 Thermal Energy Demand

This report is focused on electric energy systems. However, it is important to note that thermal systems - particularly biomass-energy for heat - play an extremely large role in the operation of health facilities in Uganda. Thermal power sources play an important role in two of the six priority energy areas.

- **Refrigeration**: Off-grid refrigeration can be powered either by PV electricity, LPG or kerosene fuels. LPG powered as many fridges as PV - and may have been more functional.
- **Sterilization**: Sterilization is a high priority of health centers. However, though many centers are equipped with pressure cooker-type units that use biomass or gas cookers, the audit team found that these were used less than chemical sterilization (i.e. bleach-based cleaning of equipment).

Other energy needs that were observed (but whose use was not quantified) at the surveyed facilities include:

- Cooking for staff and patients in the clinic, guardian shelters and staff houses. Biomass was the primary fuel source.
- Water heating for cleaning wards and for in-patient bathing. Again, biomass was the primary fuel source.
- Transport for moving patients to other sites.

3.3.2 Energy Supply

The assessment also explored whether the above energy needs were being met by existing energy systems – both grid and off-grid electricity, as well as thermal – at the facilities. Figure 3.12 shows the energy sources found at the 100 health facilities surveyed.

**Figure 3-12 Energy Sources at Surveyed Facilities**
The key findings on energy supply from the audits include:

1. **Solar PV was the most common source of energy** with 82 of the health centers having at least one solar PV system (average installed capacity of 440 Wp per site), and PV in use across all three HC levels.

   Photo 3-2 Solar PV Systems at an Audited Health Center

2. **The majority (82%) of PV systems were operational – a relatively high success rate compared with other countries.** This may be attributed to the fact that PV systems were in general well managed and maintained. In each health center there is a person responsible for ensuring the systems are in good working condition and for reporting failures to the district health office (DHO). The DHO, in turn, is usually able to fund spare parts. About 70% of the solar PV systems were funded by the district and Uganda National Expanded Programme on Immunization (UNEPI), which have set aside PHC funds for purchasing and maintaining thermal and electrical sources of energy in the health facilities. For the most part, non-functional systems were either over ten years old or had battery failure. The overlap between failed batteries and original system source – most were from NGOs – suggests that NGOs should take long-term training and maintenance budgets in better consideration when donating solar PV systems.

3. **Solar PV systems were generally used to power specific loads** (i.e. lighting PV system only powers lights, refrigeration system only powers the fridge). In the 15 grid-connected facilities solar PV was used to independently power refrigeration.

4. **LPG was the second most common energy source in use,** found in 58 of the health centers across all HC levels (see Figure 3.13). Kerosene was in use in 31 of the sites and is used mainly for lighting.

5. **The nine generators observed served as back-up systems** during grid power outages or to provide power when solar PV systems (or their batteries) failed.

6. **Two health facilities were found to have no source of energy.**
Figure 3-13 Energy Sources by Type of Facility
Box 3.1 Existing Energy System Capital and Operating Costs

Health centers in Uganda do not have an independent operational budget – rather access to PHC funds and other district-allocated resources. Most health services are provided free of charge – leaving facilities without discretionary revenue.

PV equipment is usually centrally procured, either by the government and/or NGOs, usually in small lots. During the survey, it was not possible to collect data on original energy equipment or recurring costs, as no such records were kept at the surveyed facilities. In Uganda, PV prices are (and have been over the last decade, when many of the current systems were installed) several times that of the global market. Informal surveys indicate costs may have ranged from USD 10 to 20 per W for delivered systems (including batteries).

For a typical (sample) off-grid facility with a 0.44 kW solar PV system (which is the average installed capacity in the surveyed health centers) the investment cost is estimated between USD 4,400 and USD 8,800 as shown below:

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Description</th>
<th>USD (Lower value)</th>
<th>USD (Higher value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar PV</td>
<td>0.44 kW system (at USD 15-25/Watt)</td>
<td>4,400</td>
<td>8,800</td>
</tr>
</tbody>
</table>

The same health facility would incur solar PV maintenance costs as well as thermal fuel expenses as shown in the table below. The monthly costs are estimated to be approximately USD 85.35.

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Description</th>
<th>USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar PV system</td>
<td>USD 30/kW/year</td>
<td>5.68</td>
</tr>
<tr>
<td>LPG refrigeration</td>
<td>48kg for 3 months</td>
<td>49.11</td>
</tr>
<tr>
<td>LPG sterilization</td>
<td>6kg per month</td>
<td>18.42</td>
</tr>
<tr>
<td>Kerosene</td>
<td>4 liters per month</td>
<td>4.22</td>
</tr>
<tr>
<td>Diesel</td>
<td>6 liters per month</td>
<td>7.92</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>85.35</strong></td>
</tr>
</tbody>
</table>

3.3.2.1 Grid Connected Sites

Most of the grid connected sites audited reported experiencing power outages, with some outages lasting as long as 12 hours. All but one of these sites has at least one alternative electricity source on site – diesel generator and/or solar PV systems (the remaining one has a UPS) – that power critical loads like

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8 These figures represent indicative estimates, not actual prices, and are meant only to illustrate the general value of equipment currently found on-site.
lighting and fridges during periods of power shortage. The table below outlines challenges reported at these sites.

Table 3-4 Challenges with Grid-connected Systems

<table>
<thead>
<tr>
<th>District</th>
<th>Health center</th>
<th>Health center level</th>
<th>Grid issues – average outages per month</th>
<th>Alternative electricity source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kamwenge</td>
<td>Kyabenda</td>
<td>HC III</td>
<td>2</td>
<td>Has PV system that powers a vaccine fridge</td>
</tr>
<tr>
<td>Kamwenge</td>
<td>Rukunyu</td>
<td>HC IV</td>
<td>4</td>
<td>Diesel generator and a PV system</td>
</tr>
<tr>
<td>Kamwenge</td>
<td>Rwamwanja</td>
<td>HC III</td>
<td>3</td>
<td>Diesel generator and 6 PV systems (3 are working)</td>
</tr>
<tr>
<td>Kamwenge</td>
<td>Ntara</td>
<td>HC IV</td>
<td>8</td>
<td>Diesel generator and 4 PV systems (2 are working)</td>
</tr>
<tr>
<td>Kabarole</td>
<td>Kasuganyanja</td>
<td>HC III</td>
<td>4</td>
<td>PV system that powers surgery theater lights</td>
</tr>
<tr>
<td>Kabarole</td>
<td>Kataraka</td>
<td>HC IV</td>
<td>4</td>
<td>PV system that powers ICT systems</td>
</tr>
<tr>
<td>Kabarole</td>
<td>Kibiito</td>
<td>HC IV</td>
<td>1</td>
<td>Diesel generator and 2 PV systems</td>
</tr>
<tr>
<td>Kabarole</td>
<td>Kicuucu</td>
<td>HC II</td>
<td>4</td>
<td>PV system that powers a vaccine fridge</td>
</tr>
<tr>
<td>Kyegegwa</td>
<td>Hapuuyo</td>
<td>HC II</td>
<td>4 – sometimes last as long as 12 hours</td>
<td>2 PV systems that are not functional</td>
</tr>
<tr>
<td>Kyegegwa</td>
<td>Kakabala</td>
<td>HC II</td>
<td>4 – sometimes last as long as 12 hours</td>
<td>One PV system that is not working</td>
</tr>
<tr>
<td>Kyegegwa</td>
<td>Kasule</td>
<td>HC III</td>
<td>Reliable most of the time</td>
<td>2 PV systems that are not working</td>
</tr>
<tr>
<td>Kyegegwa</td>
<td>Kyegegwa</td>
<td>HC IV</td>
<td>12 – for about 4 hours each. Intensifies in the rainy season.</td>
<td>3 diesel generators and 3 working PV systems</td>
</tr>
<tr>
<td>Kyegegwa</td>
<td>Wekomiire</td>
<td>HC III</td>
<td>8 – sometimes they last for 12 hours</td>
<td>2 PV systems</td>
</tr>
<tr>
<td>Kiruhura</td>
<td>Kiruhura</td>
<td>HC IV</td>
<td>Reliable most of the time</td>
<td>Diesel generator and 2 PV systems</td>
</tr>
<tr>
<td>Sheema</td>
<td>Kabwohe CRC</td>
<td>HC III</td>
<td>1</td>
<td>UPS system</td>
</tr>
</tbody>
</table>

For sites recommended to continue or start using the national grid, it makes sense to rely on any functioning off-grid systems as an alternative power source for critical loads. The feasibility of an appropriate grid-tied backup system – whether PV or battery or other – was outside this scope but may be considered for these sites.

3.3.2.2 Off-grid Electricity Systems – Management and Maintenance

The key findings on the management and maintenance of the off-grid systems at surveyed facilities were:

1. Most of the solar PV systems (over 80%) in the surveyed facilities were in good condition and were
operating well. This can be attributed to the following:

- Seventy percent (70%) of the systems were funded by the DHO and UNEPI which maintains the systems through PHC funds set aside for purchasing and maintaining thermal and electrical energy sources in health facilities.
- In many health centers, the “In-Charge” (ranking medical officer) on-site is responsible for ensuring systems are in good condition and reports system faults to the district health office.
- Systems are well managed, with many powering designated loads (i.e. one PV system for the lights, one system for refrigeration, etc.).

2. Almost all of the non-operating audited PV systems were donor funded and lack a long-term maintenance contract with suppliers and installers. Relationships between donors, equipment suppliers and health centers appeared to be lacking at surveyed health facilities with non-operational off-grid systems. This is unlike in the government-funded systems where the DHO provides funding for maintenance of systems.

3. Service, maintenance, spare part provision were not part of contracts for donor funded systems.

- In almost all cases, there were no arrangements made by donors for maintenance service, spare parts or battery replacement.
- A common cause of system failure is dead batteries – these must be replaced for any PV system.

4. Performance monitoring tools for both donor and government funded systems lacking on-site. Few records were found to be kept on-site with regard to the origin, operational management, maintenance schedule or operational status of PV systems.
4 Recommendations

This section provides recommendations based on the findings of the data mapping exercise and the energy audits conducted at 100 HC sites in Uganda. Further, it recommends solutions based on best practice in rural energy system provision and based on emerging business models for operation of decentralized power systems.

4.1 Approach for Evaluating Design Solutions

ASD used a standard process for evaluating what, if any, interventions are required at the surveyed facilities. The figure below shows the decision tree used by ASD to arrive at the most appropriate solution per facility.

Figure 4-1 Decision Tree for Evaluating Solutions

![Decision Tree Diagram]

As can be seen above, if a facility was within five km of the grid, a grid connection was recommended\(^9\). Where there was no system, a poorly performing system(s) or need for system growth, the ASD team designed a new, centralized power system. Based on the results of the site audits, the ASD team found that with load growth taken into consideration, all facilities where a grid connection was not viable would require a new solution. This is even true for facilities that were found to have an existing system(s) because:

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\(^9\) Five km was chosen as the cut-off for this study following discussions with stakeholders.
- Most existing systems – even where they were functional – were not sufficient to meet the critical power needs of the facility. In no case will an existing system(s) at a site be able to meet future modelled load requirements.
- Adding yet another system to the facility (to ensure it has enough capacity) could make maintaining the systems difficult. Modern technology enables PV (and other electric systems) to more reliably share power onto a grid. Although redundancy of systems at a given site served a useful purpose when PV and balance of system costs were very high, the lowered cost of PV means that over-sizing systems is less costly than five years ago – meaning that larger, more flexible centralized facility-level systems are increasingly considered best practice in contexts where the current model of multiple systems has proved ineffective.

For a more detailed explanation of ASD’s approach to evaluating design solution, please refer to Annex 2.

### 4.2 Proposed Solutions

Of the 100 sites visited in Uganda, it is recommended that 15 facilities continue utilizing the national grid, 28 sites be connected to the national grid, three sites use new, stand-alone PV solar solutions and 54 use new, facility-wide solar PV-powered micro-grids (see Table 4.1).

#### Table 4-1 System Recommendation Summary

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>System description</th>
<th>Total number of systems per district</th>
<th>Total cost per system (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continue with the national grid</td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Connect to the national grid</td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>1.25kW Stand-alone system</td>
<td>24V PV system, 521Ah</td>
<td>4 4 5 1 0 1 0 0 0 0 0 0</td>
<td>4,875 - 8,063</td>
</tr>
<tr>
<td>2kW Stand-alone System</td>
<td>24V PV system, 833Ah</td>
<td>0 2 1 2 2 2 1 1 2 5 2 4 4</td>
<td>7,800 - 12,900</td>
</tr>
<tr>
<td>2kW Facility-level Micro-grid</td>
<td>48V PV system &amp; 573Ah battery storage</td>
<td>1 2 0 0 0 2 0 0 0 0 0 2 0 1</td>
<td>8,640 - 14,300</td>
</tr>
<tr>
<td>3kW Facility-level Micro-grid</td>
<td>48V PV system, 981Ah battery storage, and 4.5kVA back-up generator</td>
<td>1 0 1 1 0 2 6 1 9 0 0 0 0 0</td>
<td>12,960 - 21,450</td>
</tr>
<tr>
<td>5kW Facility-level Micro-grid</td>
<td>48V PV system, 1302Ah battery storage, and 7.5kVA back-up generator</td>
<td>3 0 1 2 3 0 0 1 0 0 1 2</td>
<td>21,600 - 35,750</td>
</tr>
</tbody>
</table>

10 Cost estimates include all power system components, transportation, installation, taxes and a contingency amount. They do not include remote monitoring or any recommended appliance costs. The range represents estimated low and high-end costs for Uganda.
### 4.2.1 Technical Solution Designs

As outlined in Table 4.1, a set of standardized off-grid power solutions has been designed, and one of these recommended for each site for which an off-grid solution has been deemed appropriate. These consist of two sizes of **stand-alone solar PV systems** and four sizes of **solar PV plus battery facility-level micro-grid systems**.

The proposed off-grid solutions consist of a solar PV array generating DC electricity, which is converted into AC for use by the health facility. The individual needs assessment reports outline the proposed technical parameters for the installation\(^\text{11}\). Electrical installations in Uganda are subject to guidelines of the Uganda National Bureau of Standards, which is affiliated with the International Electrotechnical Commission, the global entity overseeing International Standards and Conformity Assessment for all electrical, electronic and related technologies.

These stand-alone and facility-level micro-grid system designs, and the methodology used to evaluate the right system for each site, are described in more detail in Annex 3.

In considering the system recommendations, it is important to note that:

- Before installation of centralized PV systems, health centers should be fully wired for standard AC equipment. The PV system should connect this system through a circuit board in the same way a grid power system would.
- Modern PV, control and storage technology offer many advantages for service provision. It is important that the solutions provided make use of recent developments in energy technology, appliance efficiency (i.e. LED lighting), remote monitoring and communication, and even billing and metering.
- Diesel generators are recommended on systems above 3 kW to increase system flexibility and lifetime. The recommended systems have been oversized, two days’ autonomy provided in the battery bank sizing. A diesel generator would therefore be rarely used and consume a relatively

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\(^{11}\) Parameters specified for each system include the solar array peak capacity in Watts, the total capacity of the inverter in Watts, the battery bank capacity (in Amp-hours) for 2.5 days of autonomy (continued use without additional solar input) and the DC system voltage. The charge controller size (Amps) should be 25% greater than the current coming from the solar array to allow potential overcurrent flows while protecting the equipment.
limited amount of diesel. They would complement the PV system and be used only occasionally for specific purposes: (i) generators enable recharging of batteries during long cloudy periods and thus greatly extend the service life of batteries; (ii) diesel generators allow occasional use of appliances that solar PV cannot power (sterilizers, etc.).

- There may be a need to review the types of appliances for sites according to the electricity system provided. Where DC appliances are used now, they will have to be replaced with 240 VAC appliances. In some sites, existing stand-alone PV systems can continue to power water pumps and vaccine refrigerators alongside new 240 VAC systems.

### 4.2.2 Solution Cost Requirements

The proposed solutions represent approximately USD 1.3 million in upfront costs including both procurement of equipment and installation costs, with additional optional costs for diesel generators and/or remote monitoring systems (both recommended).

A costing estimate for the procurement and installation of the power system solution has been included in each facility-level needs assessment report. Low and high per-Watt costs in USD have been used to generate an investment range for each system that takes into account national tax regimes, component costs, and transport and installation fees.

Depending on the implementation model chosen, it will be important to consider which actor (e.g. donor, government, private operator) will meet the ongoing maintenance costs – battery replacement, fuel (if a generator is included), spare parts, etc. Where public-sector support is required for system maintenance, the system’s long-term sustainability may be subject to budgetary constraints or the longevity of a donor-funded program. Whereas a ‘commercial’ (private sector based) maintenance solution may offer advantages in longevity, efficiency and other areas, a sustainable financing mechanism must be in place (e.g. community fund, non-core revenue source on site, etc.).

### 4.3 Implementation Considerations

This section outlines key considerations and options for the implementation of the solutions recommended in this report.

#### 4.3.1 Prioritization of Facilities

ASD recommends using the following criteria to prioritize facilities for the deployment of solutions (particularly off-grid solutions):

- **Number of patients/size of facility**: Facilities with more activity enable solutions to impact a larger number of patients than at less busy facilities.
- **Distance from grid**: Solutions that are further from the grid will be less likely to become redundant over time.
- **Within a specific focus region**: This will help operators/technicians serve multiple sites more effectively and efficiently.
- **Government priority**: This may include priority from a health service perspective, grid extension plans (or lack thereof), or other rationale.
- **Existing electrical power**: Sites without any electrical power should be given a higher priority.
4.3.2 Sustainability

Experience has shown that one of the key determinants of the sustainability of an off-grid power solution is its management (the arrangements for owning, operating, maintaining, and funding a system after its installation). Without an appropriate management model, off-grid technologies, although increasingly robust in technology terms, can be at risk of failure within a relatively short period. The primary reasons for this can be that the initial solution design and installation are poor, that no actor who is capable of understanding and fixing (sometimes even very minor) problems attends to the fault, and that the funds for any necessary replacement parts/work (or the parts themselves) are not available. There is typically no ongoing revenue stream associated with the installation of these solutions (given that healthcare facilities – especially public ones – typically do not generate revenue) that would support both technical capacity and replacements.

To ensure the sustainability of the proposed solutions, it is recommended that the following considerations be taken into account when deploying the solutions recommended in this report:

- **Ownership**: As already seen in a number of the surveyed facilities in Uganda, clear ownership of the system, including roles and responsibilities for operation and maintenance results in the greater functioning of energy systems.
- **Economical and financial**: The cost of keeping the systems operational should be realistically budgeted for. Funds should be made available either at the facility-level or through district health budgets to cover repairs, fuels (where applicable) and spare parts.
- **Technical**: The systems should supply power as designed. They should be as simple and durable as possible.
- **Equipment supplier/maintenance person and health center staff relationship**: Health facility staff should know who is responsible for repairing and maintaining the system and should know who to call when there is a problem. Preferably, this person should be located near the site, as is the case in many of the health facilities visited in Uganda.
- **User education and system management**: Health facility staff should be trained in the basic operation and management of the system. Training may have to be repeated with new staff and it may have to be “enforced” when equipment is mis-used. Staff should also know what they can do, what they cannot do and which appliances are and aren’t allowed. They need to know how to tell when something is wrong and what to do.
- **Ensure that spare parts are budgeted into solutions**: All technologies have lifetimes and can fail for a number of reasons. Allowances should be made to ensure that equipment can be quickly replaced when it reaches the end of its life.
- **Service, maintenance, spare part provision contracts**: Service contracts should be put in place and suppliers/service providers should fulfill their obligations to ensure the systems work.
- **System monitoring and reporting**: Online monitoring enables providers and managers to track the status of multiple systems. It allows those monitoring the site to be aware and take action when systems are used beyond the design parameters. Wherever there is a cell phone signal, remote monitoring of PV systems can assist in management and maintenance. If the right

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12 Virtually all modern PV charge regulators and inverters are equipped with sophisticated control equipment that allow them to monitor, communicate and manage various aspects of energy delivery.
technology is used, a manager should be enabled to know exactly what is happening in real time with a solar system.\(^\text{13}\)

### Box 4.1 Private Sector-led Implementation Model

Procurement-driven models for equipment supply, which focus on the up-front purchase of systems but not necessarily the supply of the service, have been found to be unsustainable at times due to a lack of ownership and ongoing investment in the long-term operation and maintenance of the systems. An alternative approach worth considering, provided the policy/regulatory environment allows for it in Uganda, is a private sector-led model (or a public-private partnership model), whereby rather than solutions being procured, an experienced enterprise provides energy services to a health facility on a fee-for-service basis. Examples of this model in other sectors include:

- **Mobile solar PV system payments ("pay-as-you-go"):** M-Kopa (Kenya), Mobisol and Off-Grid Electric (Tanzania) have hundreds of thousands of customers that pay for their electricity services on a daily basis. They maintain close links with customers, offer an affordable service and are able to disconnect customers if they don't pay.
- **Telecom base station power:** Telecom base stations achieve a high level of reliability in tens of thousands of African sites by contractually obligating tower operators to provide power according to carefully agreed terms. If the power is not provided, payment is not made from the telecom company to the operator.
- **Off-grid tourism:** Hundreds of lodges keep energy supplies up and running for customers that pay a premium to be comfortable. Dedicated staff maintain the power systems and the costs are covered as part of the business.

These three business models have a number of things in common:

- They are commercial and private sector driven;
- They have been able to innovate and introduce new technology quickly;
- They have strong management and maintenance element at the level of the consumer;
- They are able to control the use of the energy systems and limit misuse;
- The size of the operation has achieved scale. A minimum size of business and number of systems is required for profitability; and
- Payments are made according to the delivery of service, not delivery of equipment.

If such a model is adopted, ASD recommends the following:

1. Where possible, implementation and installation of energy equipment should be based on performance contracts that meet a clear standard of energy delivery.
2. A single enterprise should be hired to own and manage a minimum number of installed systems (perhaps in trust for the government and communities).
3. Ideally, a number of sites should be clustered together to achieve scale within a given geographic region.
4. Use of remote monitoring and reporting as well as state-of-art technology should be encouraged. Mobile metering, billing and monitoring platforms should be required, where feasible.

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\(^\text{13}\) M-Kopa Solar tracks the real time performance of hundreds of thousands of systems in Kenya and Uganda.
5. The operators should be required to involve locally-based, appropriately trained technicians, where available, in the management and operation of the systems they install.

6. Operators should have clear responsibilities to work with staff of health centers to manage use of electricity. They should be responsible for training staff.

7. In addition to providing electricity to health centers at agreed terms, operators should also be required to provide electricity to staffing quarters according to standard terms (because different staff require different amounts of electricity, they can provide various levels of service at different rates).

8. Ideally, operators should be allowed to sell excess off-grid electricity in neighboring communities (with load regulation and monitoring in place to ensure the clinic has primary access to the power).
5 Annexes

Annex 1: Stakeholders Consulted

The following stakeholders were involved in the Inception Workshop. Various others were consulted throughout the course of the project.

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Email Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martin Ninsiima</td>
<td>UN Women</td>
<td><a href="mailto:martin.ninsiima@unwomen.org">martin.ninsiima@unwomen.org</a></td>
</tr>
<tr>
<td>Sam Wanda</td>
<td>Ministry Of Health</td>
<td><a href="mailto:stebales@gmail.com">stebales@gmail.com</a></td>
</tr>
<tr>
<td>Claire Hawkins</td>
<td>UN Women</td>
<td><a href="mailto:claire.hawkins@unwomen.org">claire.hawkins@unwomen.org</a></td>
</tr>
<tr>
<td>Joan Mutiibwa</td>
<td>REA Kampala</td>
<td>Jmutiibwaerea.or.ug</td>
</tr>
<tr>
<td>Ambrose Gahene</td>
<td>District Focus</td>
<td><a href="mailto:gahenebb@yahoo.com">gahenebb@yahoo.com</a></td>
</tr>
<tr>
<td>Muganzi Medard</td>
<td>REA Kampala</td>
<td><a href="mailto:mmuganzi@rea.or.ug">mmuganzi@rea.or.ug</a></td>
</tr>
<tr>
<td>Kiisna Lillian</td>
<td>MT2</td>
<td><a href="mailto:kii@yahoo.com">kii@yahoo.com</a></td>
</tr>
<tr>
<td>Abdalla Kyezira</td>
<td>Konserve</td>
<td><a href="mailto:akyezra@konserve.co.ug">akyezra@konserve.co.ug</a></td>
</tr>
</tbody>
</table>

Additionally, the support and input of Mr. Sitra Mulepo throughout the project was invaluable.
Annex 2: Site Analysis and System Design Methodology

System Designs

A standard process was used to design power solutions. The figure below shows the design decision tree used by ASD to arrive at the most appropriate solution.

As can be seen, if a system was within 5 km of the grid, a grid connection was recommended\textsuperscript{14}. Where there was no system, a poorly performing system or need for system growth, the ASD team designed a new system. Based on the site audits, the team found that with load growth taken into consideration, all sites where grid connection was not viable would require a new solution.

Future Load Requirements

Information from a large sample of sites was reviewed and analyzed, in order to develop a model of the essential energy needs for rural health facilities. Site information was used to define the type and quantity of electrical appliances used at all different types of health facilities as well as their associated power and usage schedule.

The following six categories were identified as the essential energy demands that need to be taken into account for the future energy requirements.

\textsuperscript{14} Five km was chosen as the cut-off for this study following discussions with stakeholders.
1. Lighting – Interior ambient plus security (exterior) and medical (bright task lighting)
2. Refrigeration
3. Water pumping
4. ICT – Mobile phone charging and computer access
5. Staff housing
6. Medical equipment – requirement decisions were based audit information, government advice and industry standards

Electric sterilizers are not recommended for use on off-grid power systems due to the high instantaneous power requirements as well as the lower inefficiency of electricity as an energy carrier for thermal applications compared to thermal fuels. Therefore, thermal fuel powered steam sterilizers are recommended for off-grid facilities.

The following site specific characteristics were determined for each site, (and used in conjunction with the above essential needs) to determine the future energy requirements:

The health facility is assigned to a category depending on its country and level. This allows for generalizing about the typical or prescribed type and number of medical appliances and staff energy requirements at a given site.

**Country** – Uganda, Malawi or Ghana

**Health Facility Level** – This definition depends on the country. In some Uganda, the equipment and services offered at each level are relatively consistent. In Ghana and Malawi, less so. Further explanation of health facility levels are included in each country report.

- **Uganda** health facility levels are clearly defined (HC II, HC III, and HC IV).
- **Malawi** health facilities included in this study are all Tier 1 and therefore a decision informed by the services offered was made to break them into sub-categories of Tier 1 – Basic (resembling Ugandan HC II and Ghanaian CHPS / Clinics) or Tier 1 – Advanced (resembling Ugandan HC III and Ghanaian Health Centers)
- **Ghana** health facility levels are Community-based Health Planning and Services (CHPS) posts, Clinics and Health Centers. From survey information and communication with the Ghana Health services, it was decided that CHPS and Clinics have similar energy needs, whereas Health Centers have higher energy needs.

Numerical parameters individual to each facility were taken in order to calculate the required energy for certain energy applications.

**Number of Buildings** – this determines the lighting energy requirements at the facility. Medical buildings, guardian shelters and toilet blocks were included. Where possible, the number of rooms and size of each building was considered and where more lighting was required, the number of building was increased appropriately.

**Number of Staff Units** - this determines the staff housing energy requirements. A base staff unit energy requirement was calculated on the assumption of 2 lights bulbs, 1 TV and 2 mobile phones per unit. This value has been increased or decreased depending on the country and health center level as differences in staff housing energy requirements is seen.

**Number of Staff** – this determines the mobile phone charging energy requirement. It is assumed that one out of two staff members charged their phone every day.

**Water Storage Capacity** – this determines the water pumping energy requirements. Where the on-site water storage capacity was given, this was taken as the daily pumping requirement. If the
storage capacity seems too large for the daily demand or if there is no on-site storage at present, an assumption of future needs was made. Standard assumption = 10m³/day.

The table below details the appliances associated with the six essential energy demands outlined above, and details on how the site specific parameters are incorporated to calculate the future energy demand.

<table>
<thead>
<tr>
<th>Energy Category</th>
<th>Demand</th>
<th>Appliance</th>
<th>Daily energy requirement [kWh/day]</th>
<th>Uganda</th>
<th>Malawi</th>
<th>Ghana</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>HC 2</td>
<td>HC3</td>
<td>HC4</td>
<td>Tier 1 basic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Number of lights/appliances required</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td>Interior lights</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Security lights</td>
<td>0.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operation lights</td>
<td>0.48</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Refrigeration</td>
<td></td>
<td>Refrigerator</td>
<td>1.14</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>ICT</td>
<td></td>
<td>Mobile phone</td>
<td>0.02</td>
<td></td>
<td></td>
<td>1 phone per 2 staff members each day</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Computers</td>
<td>0.96</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Medical equipment</td>
<td></td>
<td>Printer</td>
<td>0.20</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Microscope</td>
<td>0.16</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oxygen concentrator</td>
<td>1.05</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air conditioner</td>
<td>3.00</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Centrifuge</td>
<td>0.40</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CD 4 machine</td>
<td>0.30</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Suction Machine</td>
<td>0.75</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anesthesia machine</td>
<td>2.00</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Staff housing</td>
<td></td>
<td>Staff unit</td>
<td>0.6 kWh/day</td>
<td>0.7 kWh/day</td>
<td>0.9 kWh/day</td>
<td>0.5 kWh/day</td>
</tr>
<tr>
<td>Water supply</td>
<td></td>
<td>Water pumping</td>
<td>0.14 kWh/day per m³</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: The system has been sized as to account for all loads. For example, where there is an existing solar water pump, this has not been removed from the modelled energy loads. The aim of the system sizing is to account for all possible future energy demands. Sterilization has not been modeled as it is too electricity-intensive for a stand-alone or facility-level micro-grid system to power.

**System Sizing**

Once the future electric load requirement is determined from the table above and the site specific parameters, the system size is determined according to the following steps:

1. Twenty percent (20%) is added to future load in order to capture any unseen growth or energy requirements.
2. A further 25% is added to account for inefficiencies and losses in the power system generation, storage and distribution. The kWh obtained from here is the final future energy demand used to size the systems.
3. The number of equivalent hours of peak insolation is calculated for that sub-national region using industry standard online databases. The European PV GIS radiation database system is used and both databases are considered (Climate-SAF and Helioclim) and the minimum value is taken in order to be conservative.

4. The system size requirement is determined from the final projected future energy demand and the equivalent hours of peak insolation for that region. It is then rounded up to the nearest size category which has already been assigned (i.e. 2.7 kWp system would fall in the 3 kWp category)

5. For sites where the system size is marginally greater than a system category, an objective decision is made whether to round it down or up (i.e. 3.08 kWp would be rounded down to 3 kWp rather than up to 5 kWp). This is to avoid over-sizing systems as the 20% electricity growth allocated ensures that the size will account the sites basis needs in any case.

The systems have been sized according to appliance total kWh usage, with inefficiency factors and storage included in the overall design.

System Configuration

Designing, supplying and installing individual systems for scores of sites would be extremely time-consuming (and impractical to tender and procure). Instead the team designed 6 standard systems which can solve general needs of a site. In order to address the varying supply and demand needs of the audited sites, the team has designed and recommended a number of “standard systems” that allow for load growth and have the capability to power a number of standard appliances.

Two possible configurations are proposed:

Stand Alone Systems – For scenarios where only one building is required to be connected to the Solar PV power unit. This occurs rarely, for example when there is only one medical building.

Facility-wide System (clinic level micro-grid) – One centralized solar PV power unit with all buildings connected in a micro-grid configuration. Appropriate for facilities were there are more than one building and all building are close. On-site distribution costs are assumed to be USD14/m accounting for distribution cable and poles. Where the site dimensions are available from satellite imagery, distances between buildings are calculated. If the price of on-site distribution is greater than 15% of the approximate system cost (country dependent), the micro-grid configuration is not considered financially appropriate.

Decentralized vs Centralized Power Delivery

When considering the implementation of power solutions in off-grid health centers (and rural sites in general), there are two general engineering solutions for supply of power. The first is to independently power devices (and/or buildings) with separate systems that are independently operated and designed. The second approach is to design a facility-wide power system that powers all equipment on site with a single power source and distribute power to each of the appliances/buildings. Both approaches can and do work - and there is considerable debate among practitioners about which approach is more desirable.

The consultants have, in a large majority of the sites surveys, opted to recommend centralized 240 VAC “facility-wide micro-grids because these systems:
• Enable HC administrators to use standard 240VAC lights and appliances (which are lower cost and widely available) rather than non-standard DC devices (which are more expensive and harder to replace).
• Are easier to manage and maintain than multiple small systems.
• Are more economical with regard to electricity cost.
• Are easier for PV system suppliers to quote for because most PV equipment is designed for AC supply.
• Prepare the site for eventual connection to the grid. Appliances in centralized systems will not become redundant when the grid arrives.

We note that smaller low voltage decentralized systems are more appropriate in certain applications. For example:

• Very small clinics and dispensaries are often best served by pico-lighting systems and dedicated vaccine fridges.
• In extremely remote sites where central technical capacity is extremely limited, smaller, more simple systems may be better.
• When there is a need for portable power, or
• Where demand is limited to lighting only and buildings are far apart.

**Grid Connection, Off-Grid Power Systems and Power Back-Ups**

Even though it is recognized that sometimes the grid performs poorly, grid connection for grid-proximate sites was recommended for the following reasons:

• All governments prioritize grid connection for rural electrification;
• Grid electricity is much lower cost than off-grid solutions – between half and one-third the cost in most cases;
• It is a more flexible supply option and allows more appliances to be powered (i.e. electric sterilizers);
• Even poor grid solutions are generally better than poorly managed off-grid solutions.

For small demand (less than 1-2 kWh/day) solar solutions may be viable and actual designs can be re-assessed on a case by case basis. The cost of grid connection is not estimated in this study as it is very difficult to gauge without on-the-ground assessment. A rough estimate of USD 10,000 - 20,000 per km, plus transformer costs, may be used – but the actual distance to a site versus the “as the crow flies” distance must be taken into account. A grid connection, of course, benefits an entire community – and its costs are borne by the larger community – and not only the health facility.

Because of the confusion between the two, it is important to distinguish between off-grid power systems (which supply primary power) and back-up power solutions (which provide power when the grid fails). Either battery-back-ups or generators are used as power back up equipment, but not usually solar. Back-ups present a different technical solution than remote off-grid solar power supply. Because of varying power sources and voltages, there are numerous issues with back-up systems (safety, maintenance, grid connect issues, net-metering). In this solution set back-up power systems have not been designed.
### Annex 3: Design Recommendations by District & Facility

<table>
<thead>
<tr>
<th>Site #</th>
<th>District</th>
<th>Facility Name</th>
<th>Health Center Level</th>
<th>Distance from the grid</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kamwenge</td>
<td>Biguli</td>
<td>HC3</td>
<td>Off-grid over 5km</td>
<td>Micro grid 5kW</td>
</tr>
<tr>
<td>2</td>
<td>Kamwenge</td>
<td>Kyabenda</td>
<td>HC3</td>
<td>On-grid</td>
<td>Continue grid</td>
</tr>
<tr>
<td>3</td>
<td>Kamwenge</td>
<td>Bunoga</td>
<td>HC3</td>
<td>Off-grid over 5km</td>
<td>Micro grid 5kW</td>
</tr>
<tr>
<td>4</td>
<td>Kamwenge</td>
<td>Bihanga</td>
<td>HC2</td>
<td>Off-grid over 5km</td>
<td>Micro grid 2kW</td>
</tr>
<tr>
<td>5</td>
<td>Kamwenge</td>
<td>Bwizi</td>
<td>HC3</td>
<td>Off-grid over 5km</td>
<td>Micro grid 5kW</td>
</tr>
<tr>
<td>6</td>
<td>Kamwenge</td>
<td>Malele</td>
<td>HC2</td>
<td>Off-grid over 5km</td>
<td>Micro grid 3kW</td>
</tr>
<tr>
<td>7</td>
<td>Kamwenge</td>
<td>Rukunyu</td>
<td>HC4</td>
<td>On-grid</td>
<td>Continue grid</td>
</tr>
<tr>
<td>8</td>
<td>Kamwenge</td>
<td>Rwamwanja</td>
<td>HC3</td>
<td>On-grid</td>
<td>Continue grid</td>
</tr>
<tr>
<td>9</td>
<td>Kamwenge</td>
<td>Ntara</td>
<td>HC4</td>
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