Electrification with renewables: Enhancing healthcare delivery in

Zimbabwe

IRENA
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ABBREVIATIONS

A	ampere
AC	alternating current
AMC	annual maintenance contract
CR	charge regulator
DC	direct current
DG	diesel generator
DNI	direct normal irradiance
DOD	depth of discharge
DRE	decentralised renewable energy
GHI	global horizontal irradiance
GPS	global positioning system
HB	hemoglobin
HIV	human immunodeficiency virus
ICU	intensive care unit
IPD	inpatient department
IRENA	International Renewable Energy Agency
kVA	kilovolt ampere
kW	kilowatt
kWh	kilowatt hour
kWp	kilowatt peak
LED	light emitting diode
LOLP	loss of load probability
m^2	square metre
MoECW	Ministry of Environment, Climate and Wildlife
MoEPD	Ministry of Energy and Power Development
MoFEDIP	Ministry of Finance and Economic Development and Investment Promotion
MoHCC	Ministry of Health and Child Care
MoLAFWRD	Ministry of Lands, Agriculture, Fisheries, Water and Rural Development
MoLGPW	Ministry of Local Government and Public Works
MPPT	Maximum Power Point Tracking
MW	megawatt
NDS1	National Development Strategy 1
NGO	non-governmental organisation
NHS	National Health Strategy
O&M	operation and maintenance
OPD	out-patient department
OT	operation theatre
PCU	power conditioning unit
PV	photovoltaic
REA	Rural Electrification Agency
REF	Rural Electrification Fund
RMS	remote monitoring system
SDD	solar direct drive
SDG	Sustainable Development Goal
SOP	standard operating procedure
UHC	universal health coverage
UNDP	United Nations Development Programme
USD	United States dollar
V	volt
VIP	ventilated improved pit
WASH	water, sanitation and hygiene
WHO	World Health Organization
ZERA	Zimbabwe Energy Regulatory Authority
ZESA	Zimbabwe Electricity Supply Authority
ZETDC	Zimbabwe Electricity Transmission and Distribution Company

EXECUTIVE SUMMARY

In line with Zimbabwe's objective of improving its healthcare system to ensure the well-being of all its 15.2 million citizens, providing reliable energy is vital for powering health services, especially in remote and underserved areas.

Zimbabwe's healthcare system comprises five tiers of care, each offering a different level of service, with one tier focused on the development of health technology. The country's healthcare infrastructure consists of 1848 facilities, yet nearly a third of these lack reliable electricity. This power deficit impacts the quality of health services, with frequent power cuts forcing clinics to close after sunset and affecting emergency care, vaccine storage, and the provision of both basic and life-saving health services.

This study assessed 50 public healthcare facilities across Zimbabwe using an ecosystem approach to explore the energy challenges affecting health service delivery. Furthermore, the study aimed to comprehensively assess the health-energy ecosystem, gather data for health-energy initiatives, estimate required investments and propose a roadmap for sustainably powering healthcare with renewable energy. The study included both primary and secondary research to understand current energy conditions and inform the development of energy solutions tailored to the country's needs.

The study found that most health centres and rural hospitals rely on a combination of grid and solar energy, though disruptions in power supply remain common. Issues such as solar system malfunctions, battery and inverter problems, overloading, and theft further compromise reliability. Power disruptions severely impact outpatient services, emergency care and delivery services, with notable disruptions in laboratory work and staff well-being.

Based on these findings, the study proposed technical designs for solar energy systems to meet the energy needs of healthcare facilities. These designs are tailored to various facility types, including health posts, health centres, rural hospitals and district hospitals, and account for both regular and critical energy loads. The total investment required to provide reliable solar energy to all primary healthcare facilities in Zimbabwe, along with staff quarters, is estimated at approximately USD 15.4 (United States dollars) million, and USD 3.75 million for powering critical loads only at all health facilities (estimated at 1000 facilities). However, if the lowest-level facilities were upgraded with additional services such as maternity wards, laboratories, in-patient departments and emergency services, an additional USD 8.4 million would be required for powering all loads at the facilities.

The integration of decentralised renewable energy (DRE) systems into Zimbabwe's healthcare infrastructure represents a significant step toward ensuring the reliability and sustainability of healthcare services, addressing key challenges related to energy access and service delivery. The study provides critical insights and actionable recommendations to ensure the sustainability of powering healthcare with DRE solutions, addressing the key areas described below.

Creating an interministerial committee

An interministerial committee is essential to define roles and responsibilities for stakeholders involved in the electrification programme. This committee should include representatives from the Ministry of Health and Child Care (MoHCC), Ministry of Energy and Power Development (MoEPD), along with the Ministry of Local Government and Public Works (MoLGPW), Ministry of Environment, Climate and Wildlife (MoECW), Ministry of Lands, Agriculture, Fisheries, Water and Rural Development (MoLAFWRD), as well as individuals with experience from previous solar projects. The committee's key tasks will include budget planning – specifically for the operation and maintenance (O&M) of energy systems at every health facility under operational costs – technology benchmarking to ensure products of international standards are procured and installed, capacity building among the ministerial bodies to highlight the importance of long-term sustainability planning for energy systems, and promoting solar adoption through tax concessions. The committee will also document lessons learnt and share successes and challenges with other countries.

Setting up a technical programme unit

A technical programme unit composed of technical experts will oversee the quality of solar installations and the O&M process. This unit will handle fund management based on government allocation and external fundraising, co-ordinate between stakeholders to resolve issues, analyse system data, and address issues raised through the incidence management system. Its role is crucial for ensuring the sustainability of solar systems, with a project manager and data managers overseeing the technical functioning. The unit will also be responsible for ensuring all systems at the health facilities remain functional, which builds ownership within the government.

Financing the programme

The MoHCC must leverage existing health facility maintenance funds and clearly outline a budget for the programme. Funds should be raised specifically for O&M and held in escrow accounts. O&M activities (detailed in Chapter 6) extend beyond maintenance contracts with vendors. They must include fund allocation for out-of-warranty issues and component replacement. Collaboration with the Rural Electrification Fund (REF) will ensure financial resources are available for sustainable operations, as the REF has the mandate to maintain all energy systems within public institutions, along with other development partners who are supporting health system strengthening in the country.

Assessing existing systems and buildings

An independent audit of existing solar energy systems in health facilities must be conducted to assess their functionality, identifying the need for replacements or maintenance. This audit is essential because past programmes in the country have provided solar energy systems. Some of these systems have components that have reached the end of their lives, and some facilities face challenges due to inadequate energy generation. This assessment is also necessary to understand the state of current systems and determine the appropriate steps for improving energy supply for all health facilities.

A building assessment is crucial to ensure health facilities can support solar installations and meet energy demands. Structural damage and substandard conditions could hinder solar panel installation or increase costs. The assessment will guide renovation, construction and improvements to ensure better energy efficiency and address local challenges like resilience to disasters such as drought, flooding and outbreaks like cholera.

Implementation plan

- **Design finalisation**
  Designs for the electrification programme should be finalised based on facility assessments, providing a clear budget indication. These designs must be reviewed by in-country health and energy experts before procurement begins. Price negotiations should follow international guidelines, with funds maintained in USD to mitigate currency fluctuations.

- **Procurement**
  Procurement should follow national and World Health Organisation (WHO) guidelines, with vendors selected through a tendering process. Vendors must demonstrate a local presence, a reliable supply chain for spare parts and past experience in similar health-energy projects to ensure successful implementation and maintenance.

- **Ownership and asset handover**
  A decentralised ownership model for solar energy systems at the facility or local governance level is crucial for long-term sustainability. Staff and community members must be trained on system operations, and non-governmental organisations (NGOs) should be involved in monitoring and ensuring system performance. The systems should be included in the facility's asset registry as well as at the national level to enhance accountability, as the MoHCC will be responsible for budget allocations for ongoing maintenance and integrating maintenance into national health plans.

O&M

Setting up processes and practices for carrying out preventive and corrective maintenance, along with continuing annual vendor maintenance contracts, is crucial to ensure comprehensive maintenance of the system and long-term sustainability. A prioritisation matrix along with clear channels of communication must be defined to undertake O&M for the programme. The process of O&M begins with defining it holistically, which includes different components such as remote monitoring, financial allocation and out-of-warranty issues. The processes for O&M are supported by remote monitoring systems, the regular calls made by the technical programme unit, and issue reporting by the health facilities using digital incidence management systems.

Programme monitoring

A robust monitoring system will track the performance and utilisation of solar energy systems in healthcare delivery. Regular meetings with provincial and district officers will help assess the programme's impact, with learnings from the ground informing future improvements and expanding the programme's reach.

This report presents a roadmap for a sustainable health-energy programme, emphasising an integrated approach that combines energy-efficient systems and optimised infrastructure to enhance the delivery of primary healthcare. Successful implementation of this approach relies on active participation and collaboration among various stakeholders within the country, who are essential in bridging gaps in knowledge, resources and skills to improve population health outcomes.

SUSTAINABLE ENERGY FOR RESILIENT HEALTHCARE

1.1 BACKGROUND OF THE PROGRAMME

The International Renewable Energy Agency (IRENA), SELCO Foundation, and Zimbabwe's Ministry of Health and Childcare (MoHCC) and Ministry of Energy and Power Development (MoEPD), have partnered to support decision making and improve healthcare delivery by creating a roadmap for designing and funding resilient decentralised renewable energy (DRE) solutions across various primary healthcare facilities in Zimbabwe. Recognising the structures in place for a comprehensive energy programme, this document outlines a framework and recommendations for the MoHCC, MoEPD and development partners to accelerate and sustain a country-level DRE-driven health-energy nexus programme. This roadmap will be complemented by a policy framework to support the programmes.

1.2 ENERGY FOR HEALTH

Access to reliable and sustainable energy, as emphasised in Sustainable Development Goal (SDG) 7, is crucial for achieving SDG 3, which aims to ensure healthy lives and promote well-being for all. The relationship between energy access and health outcomes is particularly important for primary healthcare systems, especially in developing countries, where facilities are often under-resourced and face significant operational challenges.

Primary healthcare facilities are the foundation of health service delivery in most rural areas, yet they frequently struggle with unreliable energy supplies. This energy deficit directly impacts their ability to provide essential services, such as emergency obstetric care, neonatal care and immunisations. Lack of reliable power hampers the operation of critical medical equipment, disrupts proper vaccine storage and prevents adequate lighting for night-time procedures, all of which are essential for quality healthcare delivery.

DRE solutions present a viable and increasingly accessible option to address these challenges, as renewable energy allows for a faster transition towards a sustainable future that is in line with the SDG goals. Solar energy, in particular, can significantly enhance the operational capacity of healthcare facilities by providing a reliable, cost-effective and sustainable energy source. In off-grid and remote areas, where conventional energy infrastructure is inadequate or prohibitively expensive, solar energy enables the operation of critical equipment, supports cold chain management for vaccines, and facilitates communication technologies such as telemedicine, thereby strengthening healthcare systems. Along with solar energy, it is also essential to integrate other sources of renewable energy, according to their availability and the structural processes in place to access them. These include wind energy and biogas to sustainably power different kinds of energy needs at health facilities. Several programmes around the world have established the need for sustainable energy, but there have been structural gaps in the felt needs and the solutions deployed (WHO *et al.*, 2023). This necessitates an approach that looks at bridging gaps effectively while delivering impact at scale.

The synergy between SDG 3 and SDG 7 highlights the importance of such integrated development approaches. Achieving universal health coverage (UHC) and other health-related targets under SDG 3 is directly linked to the availability of sustainable energy solutions, making energy access a cornerstone of resilient healthcare systems (SEforAll, 2022).

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HEALTH AND HEALTHCARE IN ZIMBABWE

2.1 DEMOGRAPHIC AND GEOGRAPHIC CHARACTERISTICS

Zimbabwe, a landlocked country in southern Africa, has a population of 15.2 million, with women making up 52% of the total, and an annual growth rate of 1.5%. The median age is 18 years, reflecting a young population. Children under the age of 18 constitute 46.9% of the total, while 38.9% are under 15 years old. The working-age group (15-65 years) makes up 56.9% of the population. Approximately 37.7% of Zimbabwe's population lives in urban areas.

Covering an area of approximately 390 760 square kilometres, Zimbabwe's diverse geography includes the Mashonaland Plateau, known for its granite hills and wooded valleys, and the Eastern Highlands along the Mozambique border, where elevations reach up to 2 134 metres (World Atlas, 2020). It has a subtropical climate influenced by its altitude, with three main seasons: a hot, wet season from November to March; a cool, dry winter from May to August; and a hot, dry period in September and October.

2.2 HEALTH AND HEALTHCARE IN ZIMBABWE

Zimbabwe is committed to achieving the 17 SDGs and supported the Political Declaration on UHC, adopted in September 2019. These commitments form the foundation of Zimbabwe's National Health Strategy (NHS), which aims to achieve UHC by 2030. The NHS 2021-2025 is designed around two primary pillars:

Pillar 1: Enhancing quality and accessibility of healthcare services: This includes strengthening primary healthcare, reducing maternal and child mortality, and improving disease prevention and management through expanded vaccination programmes and targeted interventions for both communicable and non-communicable diseases.

Pillar 2: Decentralisation of healthcare services: This promotes local decision making and resource allocation by empowering district health offices and expanding community-based health services.

The NHS aligns closely with Zimbabwe's Vision 2030 and National Development Strategy 1 (NDS1). Vision 2030 envisions a prosperous and healthy nation, which complements the NHS's goals of UHC and infrastructure development.

2.3 HEALTHCARE INFRASTRUCTURE IN ZIMBABWE

Health service delivery across regions in Zimbabwe

Zimbabwe's health system is structured into five hierarchical tiers of care. The fifth tier promotes advancements in health-related technology. Each tier offers distinct services designed to meet the healthcare needs of the population. In 2015, there were 1848 healthcare facilities in the country, including 6 central hospitals, 8 provincial hospitals and 44 district hospitals (MoHCC, 2021).

Table 1 **Types of health facilities**

Facility level	Type and ownership of health facilities	Number of facilities
Quinary	Research & development	-
Quaternary	Government central hospitals	6
Tertiary	Government provincial hospitals	8
Secondary	Government district hospitals	44
	Mission hospitals	62
	Private hospitals	32
Primary	Government rural hospitals	62
	Municipal polyclinics	15
	Private clinics	69
	Mission clinics	25
	Local authority clinics	1 122
	Urban council/municipal clinics/family health service	96
	Government rural health centre	307
Total		**1 848**

The first and lowest tier is the primary care level. This comprises a network of health centres/clinics/rural hospitals, each serving a ward in rural areas and polyclinics in urban areas. In addition, there are private clinics on farms and commercial entities such as industry and mines. The network of doctors' and nurses' private surgeries falls under this level as well. This level co-ordinates community health work.

The second tier is the secondary care level, which includes district hospitals and equivalent hospitals such as municipal referral hospitals and mission hospitals. They offer emergency, ambulatory and inpatient services. There is one such hospital in each district.

The third tier is the tertiary level, which is made up of a network of provincial hospitals. There is one hospital in each province (except Harare and Bulawayo, which are urban provinces). These offer emergency, ambulatory and specialist inpatient services.

The fourth tier is the quaternary level, offering specialist inpatient services as well as university teaching facilities.

The newly introduced highest tier is the cutting-edge quinary level. This level was introduced to **spearhead research and development** with linkages with higher and tertiary institutions, the manufacturing sector and the MoHCC's new divisions of Biomedical Engineering Science and Pharmaceutical/Biopharmaceutical Production (MoHCC, 2021).

Key services of healthcare facilities in Zimbabwe

Key services provided by healthcare facilities include:

- in-patient and out-patient departments (IPDs and OPDs)
- prevention of mother-to-child transmission of human immunodeficiency virus (HIV)
- tuberculosis treatment
- maternity, postnatal and antenatal care
- integrated management of childhood illnesses
- an expanded programme of immunisation services, including immunisation of under-fives, COVID-19 testing and vaccinations, and HIV testing and treatment
- treatment of general cases
- treatment of non-communicable diseases
- treatment of sexually transmitted infections, including HIV and syphilis testing and counselling
- pharmacy and nutrition services
- health education and promotion
- opportunistic infections services (MoHCC, 2021).

The provision of these services guarantees extensive healthcare coverage addressing the diverse health requirements of the population, in alignment with constitutional obligations and national health goals.

Financing for healthcare

Healthcare financing in Zimbabwe has seen significant growth, increasing from USD 676 million (United States dollars) in 2014 to USD 1 069 million in 2019 (MoFED, 2020). Healthcare funding in Zimbabwe primarily comes from two sources: domestic funding and development assistance. Over the past decades, domestic funding has contributed approximately 55%, while development partners have provided the remaining 45%. This proportion has remained relatively stable since 2014 (MoHCC, 2021).

The Zimbabwean government is focused on increasing public health expenditure per capita and improving domestic funding mechanisms to ensure better resource allocation within the health sector. The initiative encompasses continuous investment in health infrastructure, which involves the construction and rehabilitation of clinics and hospitals, as well as the enhancement of primary health services to ensure coverage for all settlements within a 5 kilometre radius.

Table 2 **Key services across different types of healthcare facilities**

Services	District hospital	Health centres	Rural hospital	Polyclinic	Satellite clinic
Immunisation	✓	✓	✓	✓	✓
Antenatal care services	✓	✓	✓	✓	✓
Delivery	✓	✓	✓	✓	✓
Diagnostic services	✓	✓	✓	✓	✓
Communication systems	✓	✓	✓	✓	✓
Emergency services	✓	✓	✓		✓
Postnatal care services	✓	✓	✓		✓
OPD services	✓	✓	✓	✓	
ICU	✓				
Laboratory	✓	✓	✓	✓	
In-patient services	✓	✓	✓	✓	
Pharmacy	✓	✓	✓		✓
Maternity services	✓	✓	✓	✓	
Surgery	✓	✓	✓		

Source: (MoHCC, 2021).
Notes: ICU = intensive care unit; OPD = out-patient department.

Characteristics of facility buildings

Buildings are designed to cope with Zimbabwe's diverse climate, which ranges from hot and dry in low-lying areas to cooler and wetter in higher elevations. Common building materials include brick and mortar for walling, timber for roofing structures and interior finishes, and corrugated iron metal sheets for roofing. A typical design of a rural health centre uses locally sourced materials like clay bricks and asbestos/corrugated iron sheet for roofing, with an emphasis on functionality and ease of maintenance. Urban health centres are typically constructed using modern materials like concrete, steel and ceramic tiles with designs that incorporate energy-efficient technologies.

To deliver all healthcare services effectively, health facilities must have reliable energy. Hence it is essential to understand the energy ecosystem in Zimbabwe, which is detailed in the following chapter.

ENABLING ENERGY ECOSYSTEM IN ZIMBABWE

3.1 ZIMBABWEAN ENERGY LANDSCAPE

The electricity supply in Zimbabwe comprises 60% thermal power from coal, 37% hydropower and 3% from other renewable sources, such as solar. In 2022, 50% of the population had access to electricity, with urban areas having a coverage of 89%, but only 34% in rural areas of the country (IEA *et al.*, 2024). Electricity usage is distributed as follows: 43% in industry; 29% in households; 22% in commerce and the public sector, including government buildings such as health facilities; and 6% in agriculture and forestry (AFREC, 2020).

In recent years, both government and private entities have been exploring alternative energy sources, driven by the National Renewable Energy Policy. The policy, introduced in 2019, aims to achieve an installed renewable energy capacity of 1 100 megawatts (MW) (excluding large hydro) or 16.5% of total electricity supply, whichever is higher, by 2025. By 2030, the policy aims to achieve 2 100 MW, or 26.5% of total electricity supply, whichever is higher, thereby enhancing the role of renewable energy in the national energy mix (ZERA, 2019).

The Zimbabwe Energy Regulatory Authority (ZERA) approved a 19% increase in electricity tariffs in 2023, reflecting a rise of USD 0.02/kilowatt hour (kWh), bringing the weighted average tariff to USD 0.1328/kWh for all consumers. Prior to this adjustment, Zimbabwe Electricity Transmission and Distribution Company (ZETDC) charged an average of USD 0.1063/kWh for domestic and industrial users (The Herald, 2023). The tariff hike aims to address rising operational costs, including those associated with thermal power generation and the maintenance of transmission infrastructure. However, this increase places a significant financial burden on consumers, particularly in rural areas where electricity access remains limited, and impacts primary healthcare facilities that rely on energy to deliver essential services.

Energy access under NDS1

The government of Zimbabwe has developed the NDS1, which is a national priority to set Zimbabwe on the path of development with a comprehensive five-year plan covering the period from 2021 to 2025. It aims to realise the country's Vision 2030 to transform Zimbabwe into an empowered and prosperous upper-middle-income society. NDS1 outlines key initiatives and strategies to improve access to modern energy, focusing on strengthening the energy sector planning process, building the local capacity for renewable energy product manufacturing, and implementing targeted programmes and projects.

The NDS1 emphasises the need to improve access to modern energy as a critical component of Zimbabwe's economic development. Key initiatives under this goal include:

Strengthening the energy sector planning process: This involves improving strategic planning and co-ordination within the energy sector to ensure that energy policies and programmes are effectively implemented. This is crucial for achieving reliable and sustainable energy access across the country.

Building capacity for local manufacture of renewable energy products: There is a focus on enhancing the ability of local industries to produce renewable energy products. This strategy aims to reduce dependency on imports, promote local industries, create jobs and stimulate economic growth within the renewable energy sector.

3.2 CHALLENGES AND GAPS IN ZIMBABWE'S ENERGY ACCESS AND THEIR EFFECT ON HEALTH SERVICES

Around 32.5% of the 1 848 health facilities in Zimbabwe lack access to reliable electricity, thus impacting the quality of health services (UNICEF, 2022). Approximately 42% of those connected to the national grid experience severe power cuts exceeding 12 hours daily (Newsday, 2023) . These power cuts disrupt health services, forcing primary healthcare facilities to close just before sunset and compromising emergency care and vaccine storage. Energy gaps also result in poor motivation among staff members, as lack of energy hinders their ability to provide a range of services, which also results in referrals to higher levels of facilities. These referrals increase the pressure on the health system and result in increased out-of-pocket expenses for patients, which could deter them from seeking care. Lack of energy or unreliable energy affects the ability of the health system to meet its goals of delivering quality healthcare, which affects the health indicators of the country.

Across Zimbabwe, the United Nations Development Programme (UNDP) has implemented solar energy-based systems in 1 044 health facilities, with installations at an additional 19 facilities underway. The systems are categorised into four types: 5 kilowatt peak (kWp) systems for selected rural and urban health centres; 7 kWp systems for clinics with higher energy demands, primarily in peri-urban areas; 10 kWp systems for high-volume clinics such as polyclinics; and 40 kWp systems for district hospitals. This has added approximately 11 MW to the off-grid energy generation in the country (UNDP, 2024).

3.3 KEY STAKEHOLDERS FOR HEALTH-ENERGY NEXUS

Box 1 Key stakeholders in the Zimbabwe health-energy sector

MoHCC is responsible for the overall co-ordination of health sector initiatives, including the prioritisation of preventive care at community and household levels, and the decentralisation of specialist services to district facilities.

MoEPD plays a central role in improving access to modern energy, which is critical for powering health facilities, especially in rural areas. MoEPD is also involved in promoting off-grid renewable energy solutions that support clean energy initiatives and certifies renewable energy installations.

Ministry of Local Government and Public Works (MoLGPW) inspects and certifies the functionality of health infrastructure and ensures compliance with local regulations and standards.

Ministry of Finance and Economic Development and Investment Promotion (MoFEDIP) is responsible for the overall financial management and allocation of resources. This includes budgeting and disbursements of funds for healthcare improvements, infrastructure development and other critical areas outlined in the strategy.

Zimbabwe Electricity Supply Authority (ZESA) and ZETDC: These entities are crucial for expanding and maintaining the national power grid, which directly impacts the electrification of health facilities and the implementation of telemedicine services.

ZERA regulates the energy market cost effectively, through inventive regulation and in a fair and transparent manner to achieve sustainable energy and plays a key role in facilitating the deployment of renewable energy solutions, which are essential for powering health facilities and supporting telemedicine in rural areas.

Rural Electrification Agency (REA) is responsible for implementing the Rural Electrification Programme, which is essential for providing electricity to rural health facilities, thus enabling the establishment of improved healthcare as well as ensuring the sustainability of solar off-grid systems through O&M. It was set up under the mandate of the Rural Electrification Fund Act.

Provincial and district health offices are involved in the decentralisation of healthcare services, ensuring that quality services are available at the provincial and district levels, closer to the communities.

The development community supports Zimbabwe's health-energy nexus by providing funding and technical expertise and by facilitating the implementation of energy solutions that enhance healthcare delivery.

Tertiary institutions of learning provide solar photovoltaic (PV) training programmes and short courses, covering topics like solar PV system design, installation and O&M.

Religious institutions, missions and associations operate health facilities that include mission hospitals, nurse training institutions, clinics and elderly care facilities. They oversee the O&M of infrastructure including solar energy systems in their health facilities, ensuring consistent and efficient energy use for improved healthcare services.

04

ASSESSMENT METHODOLOGY, ANALYSIS AND INSIGHTS

This chapter outlines the methods used to assess the energy needs at healthcare facilities in Zimbabwe and explores the potential of renewable energy solutions. The assessment follows an ecosystem approach to understand the challenges and suggest solutions across technology and design, local skill development, financing and ownership, and policy-level action. The process includes both primary and secondary research to gain insights about the existing ecosystem.

The overarching objectives of the study were:

- to gain a comprehensive understanding of the health-energy ecosystem in Zimbabwe, including current energy conditions, energy requirements, staff well-being and other key indicators
- to gather crucial information to inform the development of health-energy initiatives tailored to the country's specific needs
- to design a comprehensive roadmap and estimate the required investment
- to formulate an in-depth cost breakdown for the execution of the programme
- to suggest a sustainability plan to maintain the existing and new systems.

4.1 STUDY METHODOLOGY

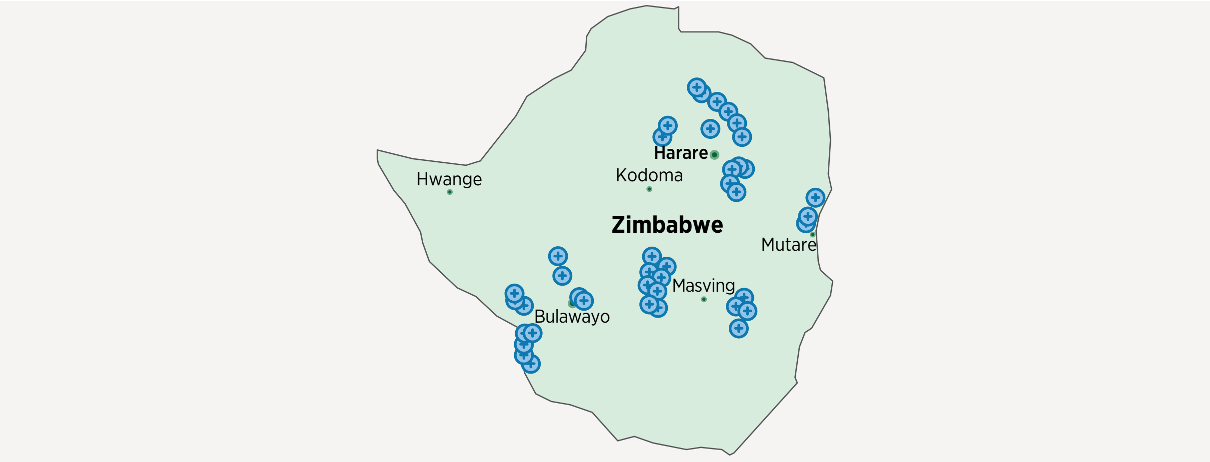
Study approach

The study followed a mixed-method approach to data collection and analysis, where an in-depth analysis of secondary and primary data was conducted. The study followed key steps, as detailed below.

Table 3 **Study approach to data collection and analysis**

Phase 1	▪ Desk research through methods mixed	▪ Formulating sampling strategy
Phase 2	▪ Conducted assessments to the study sample of 50 healthcare facilities (39 rural health centres, 6 rural hospitals, 1 health post, 1 district hospital, 2 polyclinics and 1 satellite clinic)	▪ Interviews through structured questionnaire
Phase 3	▪ Data analysis ▪ Qualitative analysis: Interviews were coded into numerical data for analysis ▪ Quantitative analysis: Utilised statistical, predictive and prescriptive techniques to extract meaningful patterns and conclusions	

Figure 1 **Map of the surveyed health facilities**



Source: (UN Clear Map, 2025).

Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

Details of all the facilities surveyed are presented in Appendix A.

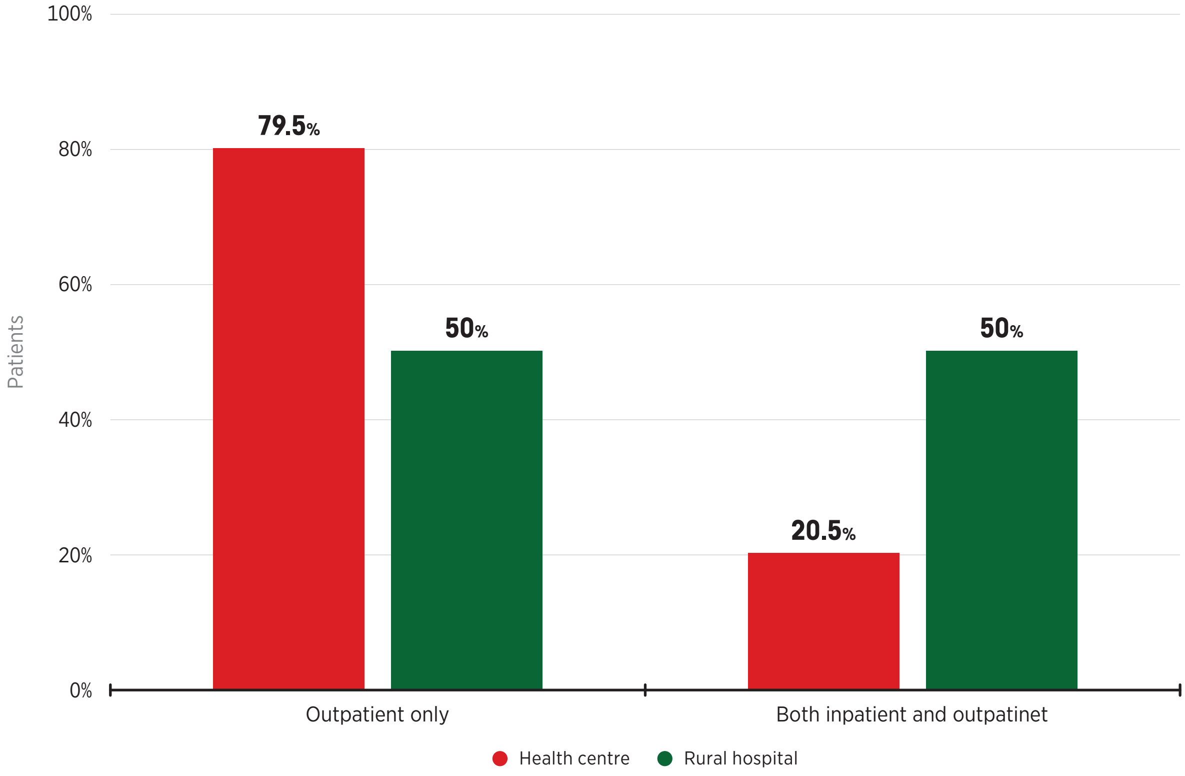
Respondents and tools

Information received through the primary data collection was categorised into themes for analysis. Primary and secondary data were triangulated to provide strong insights for DRE system design and the health-energy programme roadmap.

4.2 KEY FINDINGS

Health service delivery

Figure 2 **Type of patient care across facility type**



Patient care and facility type

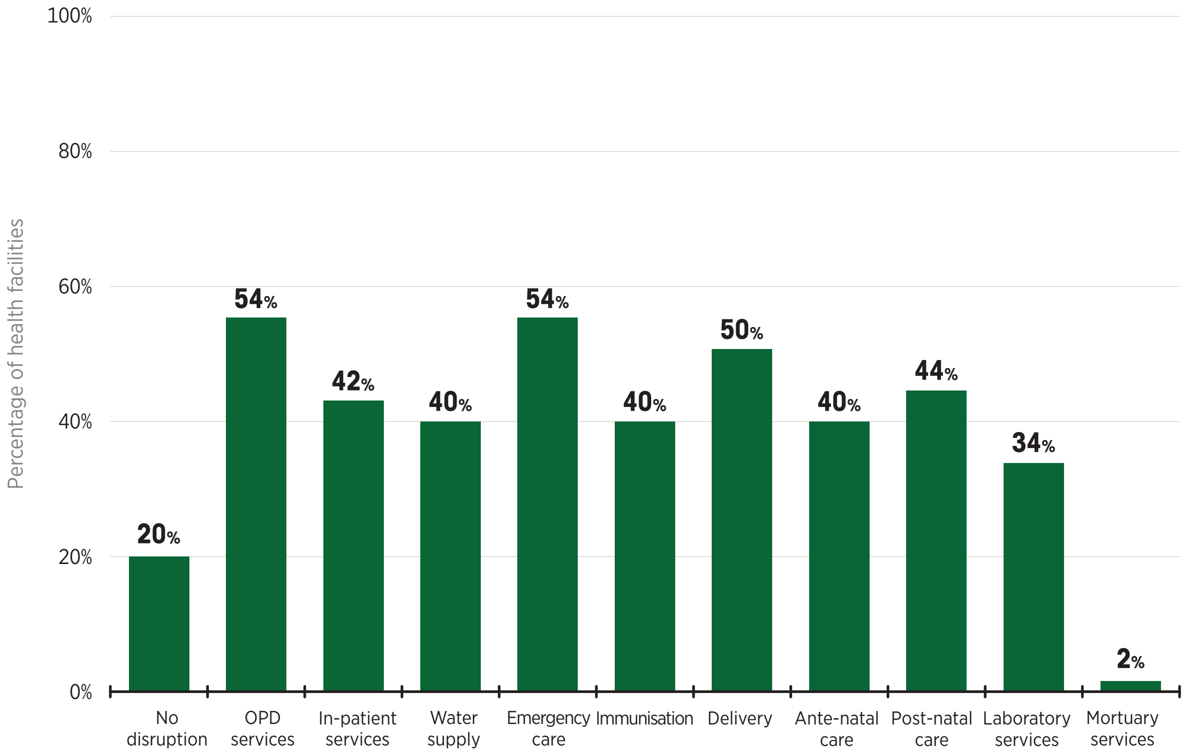
Most health centres (79.5%) in the sample provide outpatient services only; with 20.5% providing both inpatient and outpatient services. However, 50% of all rural hospitals provide inpatient services along with outpatient services. Facilities such as health posts, polyclinics and satellite clinics are assumed to primarily serve outpatients, as indicated by data gathered from a representative sample of one facility from each category.

Services affected by unreliable energy

Unreliable electricity affected out-patient department (OPD) services and emergency services the most, as shown in Figure 3, as reported by 54% of health facilities. This caused delays, longer waiting times and potentially life-threatening situations. Delivery services experienced disruptions at 50% of the health facilities surveyed, due to energy-related challenges. Laboratory services were affected in 34% of the cases, delaying test results and diagnostic accuracy. Notable disruption was also experienced in patient monitoring, medicine administration, hygiene and preventive care.

The health facility assessment indicated that power disruption affected not only services, but also staff and patient well-being. Staff members at 52% of the facilities reported that their work environment was negatively affected due to unreliable electricity. Additionally, 16% of the facilities reported that the staff quarters were not fully utilised due to unreliable electricity, and 32% of the facilities reported that patients experienced discomfort due to inadequate cooling solutions during power outages. Finally, 28% of the facilities also reported that expectant mothers were reluctant to stay at the facilities after delivery due to power outages.

Figure 3 **Services affected by unreliable electricity**



Energy access at the health facility level

Source of energy at health facilities

Health centres predominantly rely on a combination of grid and solar energy, with 57% (as shown in Figure 4) using this mix. A total of 10% of health facilities use a combination of grid, solar (with battery), and diesel generators and another 10% use solar with diesel generators. Only a small fraction (5%) of health centres rely solely on solar energy (with battery) or the grid (13%). The remaining 5% use a combination of grid diesel generators. Rural hospitals have an even stronger dependency on a combination of grid and solar energy, with 83.3% using this mix (Figure 5). The remaining 17% use a mix of grid, solar and diesel generators.

Figure 4 **Source of electricity in health centres**

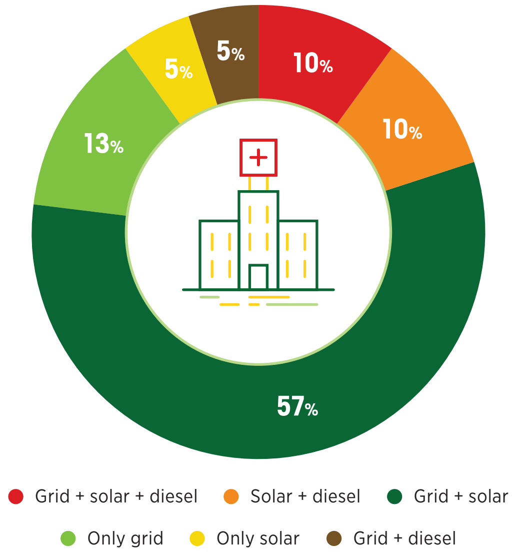
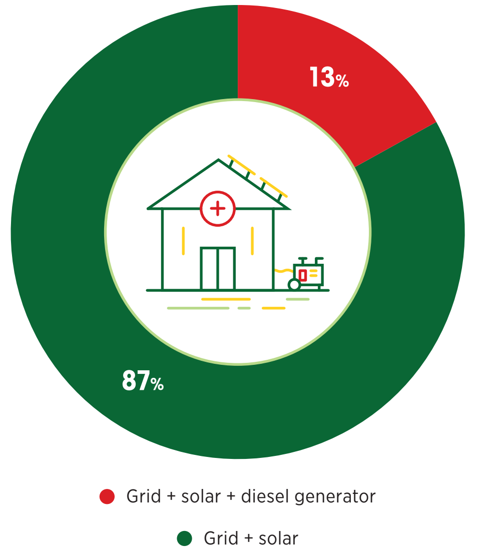


Figure 5 **Source of electricity in rural hospitals**



Status of existing solar energy systems

Of the facilities surveyed, 41 had existing solar energy systems. Among the 39 health centres, 26 (67%) had ground-mounted solar panels, 4 (10%) had roof-mounted systems, and 9 (23%) were either not applicable or not reported. Of the 6 rural hospitals, 4 (67%) had roof-mounted panels and 2 (33%) had ground-mounted systems. In all, 13 facilities (mainly health centres) reported facing technical issues, and another 11 reported issues with equipment and operations of the solar energy system due to battery and inverter-grid connection issues. Other factors, such as battery incompatibility with the inverter, low battery capacity, end-of-life battery, lightning strikes, and theft and vandalism of the components, exacerbated the situation. Staff at 19 facilities with solar reported satisfaction with the system in place.

Reliability of electricity at health facilities

The assessments showed that district hospitals and polyclinics have all-day electricity based on data from one facility of each type. However, most health centres (28.2%; 11 of 39) have 8 to 12 hours of electricity availability, while 20.5% have electricity for 4 to 8 hours a day. Rural hospitals typically have 4 to 8 hours of electricity per day.

For facilities with solar energy systems, the reliability of electricity looks different. Data from one site each for district hospitals, health posts, polyclinics and satellite clinics show the unreliability of solar energy systems during the rainy season. Unreliability is defined as the lack of access to energy due to poor performance or failure of specific components. However, at health centres, almost half of facilities (19 of 39 surveyed) reported that these systems were reliable or somewhat reliable, meaning they received energy from solar even when the grid connection did not provide power. Most rural hospitals (83.3%) perceived solar energy systems as reliable sources of energy, and another 16.7% perceived them to be somewhat reliable.

These data contrast with how facility staff perceive the reliability of solar energy systems in different seasons. Nearly 42% of health centres view solar energy systems as unreliable outside the rainy season. Similarly, only 66% of rural hospitals reported reliable solar energy during other seasons, compared to 83.3% unreliability during the rains. Understanding the reliability of solar energy outside the rainy season is crucial, as it sheds light on the broader challenges and issues that affect the use of solar energy in health facilities year-round.

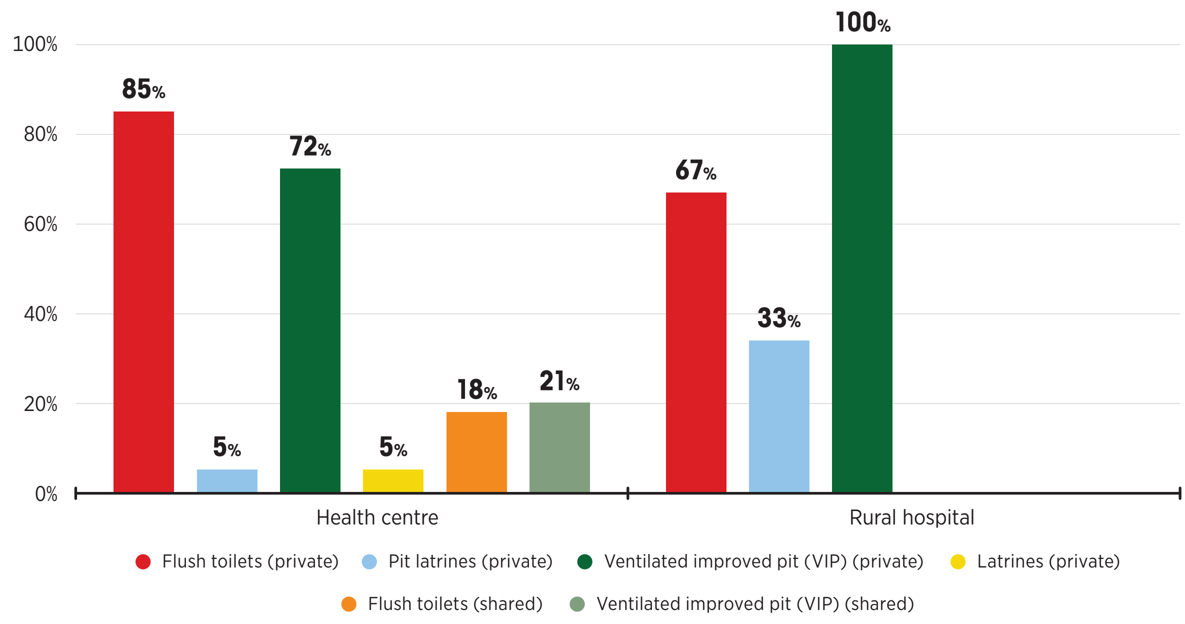
Water, sanitation and hygiene

Water, sanitation and hygiene (WASH) are critical components of healthcare facilities, influencing both patient outcomes and overall public health. Access to adequate toilet facilities is essential for preventing infections, promoting hygiene, and ensuring a safe environment for patients and healthcare workers. It is essential to understand the toilet facilities to assess the required lighting and water usage, which is directly linked to the energy needs of the facility. Such an assessment will also provide suggestions for improving the built environment design to meet sanitation needs.

Toilet facilities

Multiple types of toilet facilities are available at each health facility. Most health centres surveyed rely on private flush toilets (85%, 33 of 39) and private ventilated improved pits (VIPs) (72%, 28 of 39), as shown in Figure 6, with 21% (8 of 39) also using shared pour-flush toilets. All rural hospitals (100%) use VIPs, with some (67%, 4 of 6) also using private flush toilets and a minority (33%, 2 of 6) also using private pit latrines. All the health facilities surveyed are equipped with handwashing facilities, promoting hygiene and reducing the risk of infection transmission among patients and staff.

Figure 6 **Toilet facilities at health centres and rural hospitals**



These assessment findings indicate that a wide range of services are provided by the health facilities that are disrupted due to a lack of energy access. Unreliable power disrupts essential services such as outpatient care, emergency response, deliveries and diagnostics, while also negatively impacting staff well-being and deterring patients, particularly expectant mothers, from staying at facilities. Existing solar systems provide some relief but face challenges like battery failures, maintenance issues and seasonal unreliability. The findings also indicate the need to design for solar energy systems keeping in mind the existing systems at health facilities, with a strong emphasis on O&M planning for the country's health facilities. The following chapters outline the designs for different levels of health facility and the costs of commissioning these systems.

SOLAR ENERGY SYSTEM DESIGN AND COSTING

The assessment of facilities through observation and key informant interviews, as indicated in Chapter 4, supports the understanding of service availability, energy requirements and current usage at each type of facility surveyed. The solar energy system options that best suit the needs of the population the facilities serve were designed based on specific parameters and assumptions. Multiple options for system designs were proposed based on several factors that affect the energy system, such as the availability of a grid connection, any existing solar energy systems, the functionality of existing systems, critical loads that require powering at facilities and other factors. The design options for each level of primary (health post/clinic, health centre, rural hospital), secondary (district hospital) healthcare facility and staff quarters, along with the design parameters and assumptions, are presented here.

5.1 RATIONALE FOR SOLAR ENERGY SYSTEM DESIGN OPTIONS

Considerations taken for the proposed solar energy systems for health facilities

Health facility operational hours: Based on the assessment, 85% and 90% of facilities of health centres and health posts/clinics, respectively, are operational for eight hours daily. In contrast, the rural and district hospitals operate continuously.

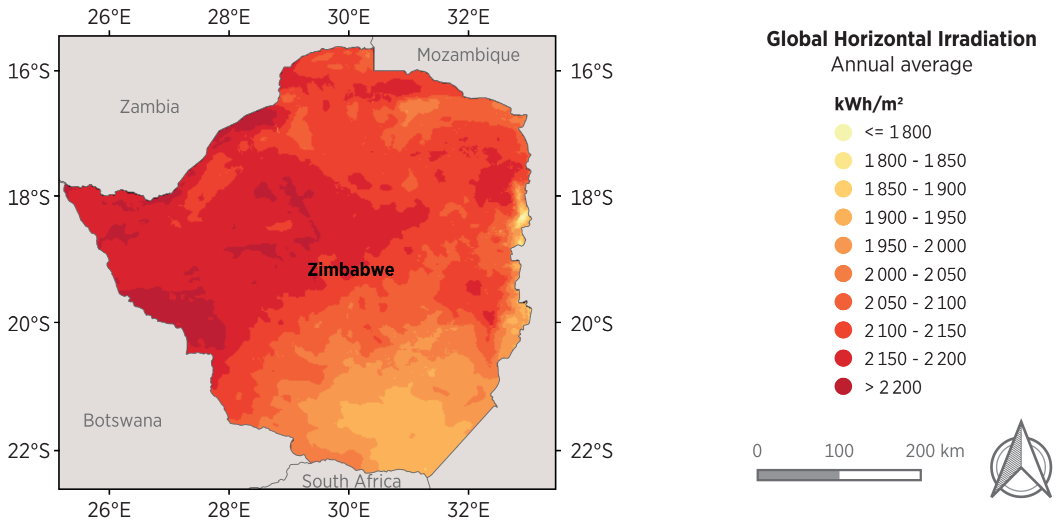
Energy efficiency measures: Facility designs integrate energy-efficient solutions, such as lighting and fans, to maximise energy savings and ensure sustainable operations. Energy-efficient medical equipment – like baby warmers, nebulisers, spotlights, suction apparatuses and needle cutters – has also been prioritised.

Real-time power monitoring: The facilities' real-time power consumption data for some existing appliances, including fridge freezers and other regular loads, are considered to ensure immediate and effective power management and supply.

Services provided in the facility: The medical equipment and the facility's operational hours are determined based on the provided services.

Solar irradiation in Zimbabwe: Zimbabwe has high solar irradiance, with an average solar potential of 5.7-6.5 kWh per square metre (m^2) per day, making it one of the best countries for solar energy development (Figure 7).

Figure 7 **Map of the surveyed health facilities**



Source: Global Solar Atlas (ESMAP, 2019); base map: UN Global boundaries. Maps are also available from the IRENA Global Atlas for Renewable Energy.

Notes: km = kilometre; kWh/m² = kilowatt hour/square metre.

Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

5.2 SOLAR ENERGY SYSTEM DESIGN OPTIONS FOR HEALTH FACILITIES

The following designs are for delivering energy to non-energised health facilities or new health facilities in the country. They can also be used to rectify the backup requirement based on the health facility's needs.

To best represent the facility types and requirements in the country, DRE system design templates have been developed for the types of health facilities and loads shown in Table 4.

Table 4 **Design considerations for solar systems by RHC type**

Type of facility	Solar as the primary energy source
Health post/clinic	✓ Basic loads (only luminaries) ✓ Entire loads (luminaries + regular loads) ✓ Upgraded services loads
Health centre	✓ Critical loads (luminaries + select regular loads + critical medical equipment) ✓ Entire loads (luminaries + regular loads + all medical equipment)
Rural hospital	✓ Critical loads (luminaries + select regular loads + critical medical loads) ✓ Entire loads (luminaries + regular loads + all medical loads)
District hospital	✓ Critical loads (luminaries + select regular loads + critical medical loads) ✓ Entire loads (luminaries + regular loads + all medical loads)

Notes: Luminaries - Light & fans; Regular loads - Desktop, laptop, printer, mobile charging, fridge; Excluded equipment: Machines in the laundry are not included due to high power consumption

All three types of loads vary according to the type of health facility, depending on the services provided. Based on the services provided by each facility, different types of solutions have been offered to power basic loads, regular and critical loads, and entire loads. A basic description of the load options is outlined below. Further details can be found in Appendix B.

Box 2 **DRE system design options**

Option A	Option A covers covers the luminaries and ventilation system that are basic requirements at the health facility.
	Basic loads considered for health post/clinic (direct current [DC] system)
	Rooms: Entrance + waiting area & reception + OPD/consultation + medical officer room + storeroom + toilet + outdoor **Loads:** Ceiling/wall/pedestal fan (3) + LED bulb (8) + LED tube light (2) + outdoor light (2)
Option B	Option B refers to the minimum infrastructure and equipment required to provide services at the health facility. The equipment considered as basic loads is mainly luminaries, regular Loads, and some critical medical equipment.
	Entire load (health post/clinic)
	Medical rooms: Entrance, waiting area & reception, OPD/consultation, medical officer room **Other rooms:** Storeroom, toilet, outdoor **Loads:** Ceiling/wall/pedestal fan (3), desktop (1), laptop (1), LED bulb (8), LED tube light (2), mobile charging (2), outdoor light (2), printer (1)
	Critical loads (health centre)
	Rooms: Entrance + OPD/consultation + pharmacy + labour room + postnatal care unit + toilet + outdoor **Loads:** Ceiling/wall/pedestal fan (5), desktop (1), fridge (1), LED bulb (7), LED tube light (4), nebuliser (1), mobile charging (1), printer (1), oxygen concentrator (1), outdoor light (20), radiant warmer/baby warmer (1), suction apparatus (1), spotlight/examination lamp (1)
	Critical loads (rural hospital)
	Rooms: Entrance + pharmacy + 2 OPD/consultations + labour room + postnatal + maternity ward + emergency room + server room + toilet + outdoor **Loads:** Ceiling/wall/pedestal fan (9), desktop (2), fridge (2), incubator (1), infant phototherapy unit (1), laptop (3), LED bulb (16), LED tube light (11), mobile charging (2), nebuliser (1), outdoor light (5), patient monitor (2), oxygen concentrator (1), printer (3), radiant warmer/baby warmer (1), spotlight/examination lamp (1), suction apparatus (2), ultrasonic device (10), Wi-Fi modem (1), TV (1)
	Critical loads (district hospital)
	Rooms: Entrance + pharmacy + 2 OPD/consultation + labour room + postnatal care unit + maternity ward + emergency room + server room + toilet + outdoor **Loads:** Alternating current (AC) (1), Ceiling/wall/pedestal fan (9), desktop (2), fridge (3), infant phototherapy unit (2), incubator (3), laptop (3), LED bulb (20), LED tube light (11), mobile charging (2), nebuliser (1), oxygen concentrator (1), outdoor light (10), patient monitor (2), printer (3), radiant warmer/baby warmer (2), suction apparatus (5), spotlight/examination lamp (1), TV (1), ultrasonic device (2), wi-fi modem (1)
Option C	Option C accounts for multiple services being offered, per the facility mandate. The services have been categorised as lifesaving critical services and other services that enhance the delivery of healthcare. Critical equipment that has higher energy requirements, such as labour room equipment, laboratory room, vaccine fridges and other equipment, has been considered.
	Upgraded services load (health post/clinic)
	Medical rooms: Entrance, waiting area & reception, OPD/consultation, medical officer room, 2 IPDs, nursing room, pharmacy, labour room, postnatal room, laboratory, emergency room **Other rooms:** Storeroom, toilet, outdoor

Option C	**Loads:** Ceiling/wall/pedestal fan (15), desktop (3), examination lamp (portable) (1), fridge (1), fridge + freezer (1), LED bulb (12), LED tube light (13), mobile charging (3), nebuliser (1), needle cutter (1), oxygen concentrator (1), outdoor light (2), printer (1), radiant warmer/baby warmer (1), spotlight/examination lamp (1), suction apparatus (1), microscope (1), centrifuge (1), Haemoglobin (HB) analyser (1), semi-auto analyser (1), outdoor light (2)
	Entire load (health centre)
	Medical rooms: Entrance, waiting area & reception, OPD/consultation, 2 IPD/admission, medical officer room, medical care/nursing room, pharmacy, labour room, postnatal room, main operation theatre (OT) **Other rooms:** Storeroom, toilet, outdoor **Loads:** AC (1), anaesthesia machine (1), ceiling/wall/pedestal fan (12), desktop (2), examination lamp (portable) (1), fridge (1), fridge + freezer (1), KLS martin electrosurgical unit (1), laparoscopic display TV (1), laptop (1), LED bulb (11), LED tube light (10), mobile charging (4), nebuliser (2), needle cutter (2), OT light (1), OT table (1), oxygen concentrator (2), outdoor light (2), printer (2), radiant warmer/baby warmer (1), spotlight/examination lamp (1), suction apparatus (1)
	Entire load (rural hospital)
	Medical rooms: Entrance, waiting area & reception, manager/admin room, medical officer room, pharmacy, 2 OPD/consultation, medical care/nursing room, 2 observation rooms, male ward, female ward, immunisation room (Solar Direct Drive already exists), storeroom, drug storeroom, labour room, postnatal room, maternity ward, emergency room, main OT **Other rooms:** Server room, toilet, outdoor **Loads:** AC (1), anaesthesia machine (1), ceiling/wall/pedestal fan (30), desktop (4), examination lamp (portable) (1), fridge (3), incubator (1), infant phototherapy unit (1), KLS martin electrosurgical unit (1), laparoscopic display TV (2), laptop (5), LED bulb (29) LED tube light (29), mobile charging (18), nebuliser (2), needle cutter (2), OT light (1), OT table (1), oxygen concentrator (4), outdoor light (5), patient monitor (8), printer (5), radiant warmer/baby warmer (1), spotlight/examination lamp (1), suction apparatus (2), TV (3), ultrasonic device (2), Wi-Fi modem (1)
	Entire load (district hospital)
	Medical rooms: Entrance, waiting area & reception, manager/admin room, medical officer room, pharmacy, 2 OPD/consultation, family and child health, medical care/nursing room, minor OT, 2 radiology/imaging rooms, 2 observation rooms, male ward, female ward, immunisation room (SDD already exists), blood bank, store room, drug store room, labour room, postnatal room, maternity ward, emergency room, main OT, ICU, dental, ophthalmology, lab **Other rooms:** Server room, toilet, outdoor **Loads:** AC (6), syringe driver pump (1), anaesthesia machine (2), auto haematology analyser machine (1), biochemistry analyser (1), biochemistry analyser cuvettes (1), biochemistry- small refrigerator (1), blood bank refrigerator (2), blood collection monitor (1), blood gas analyser (1), cardiac monitor (2), ceiling/wall/pedestal fan (55), cell-DYN haematology analyser (1), dental chair (1), dental chair compressor (1), desktop (5), Drager Savina 300 ventilator (1), examination lamp (portable) (1), fine care immunoassay analyser, microtiter plates (1), fridge (Vestfrost MK 304) (2), fridge (2), HB analyser (1), Genexpert (COVID/tuberculosis test) (1), imager scanner (1), haematology analyser (1), incubator (3), infant phototherapy unit (2), KLS Martin electrosurgical unit (1), laparoscopic display TV (1), lab centrifuge (1), laptop (7), LED bulb (40), LED tube light (53), LISA scan (1), microplate reader (1), microplate washer (1), microscope (2), microscope printer (1), mini rotary shaker (1), mobile charging (29), nebuliser (3), needle cutter (4), needle destroyer (1), OT light (2), OT table (1), oxygen concentrator (7), patient monitor (14), defibrillator (1), plasma thawing bath (1), platelet agitator & incubator (1), printer (8), radiant warmer/baby warmer (2), semi-auto coagulation analyser (1), serology water bath (1), suction apparatus (6), spotlight/examination lamp (1), TV (7), ultrasonic device (4), ventilator (1), Wi-Fi modem (1), x-ray (1), outdoor light (10)

Solar energy system design templates: **Health post/clinic**

Based on the assessment findings and DRE solar design assumptions, the following design templates are recommended for health posts/clinics as the primary system.

Table 5 **Parameters for solar energy system for a health post/clinic**

Parameters	Health post/clinic		Transportation + AMC
	Entire loads	**Basic loads**	**Upgraded services loads**
Loads considered	Lum + RL	Lum (DC system)	Lum + RL + ME
Total connected load (kW)	0.9	0.3	4.8
Total energy (kWh)	2.3	1.5	13.45
Solar panel capacity (kWp)	0.78	0.54	5
Battery bank sizing (kWh)	4.8	3.6	36
Solar MPPT inverter sizing (kVA)	1.5	25 A, 24 V (CR)	6

Notes: A = ampere; AMC = annual maintenance contract; CR = charge regulator; kVA = kilovolt ampere; KW = kilowatt; kWh = kilowatt hour; kWp = kilowatt peak; Lum = luminaries; ME = medical equipment; MPPT = Maximum Power Point Tracking; RL = regular load; V = volt.

Powering entire loads: According to the designs depicted in Table 5, powering a health post/clinic using DRE as the primary system for all equipment during operational hours requires a 0.78 kWp panel capacity, 4.8 kWh battery capacity and 1.5 kilovolt ampere (kVA) inverter size per facility.

Powering basic loads: To energise basic loads, *i.e.* luminaries and fans primarily through DC solar energy system at the health post/clinic, the panel capacity requirement would be 0.54 kWp, with a battery capacity of 3.6 kWh and a charger controller of 25 ampere (A) and 24 volt (V). This system will have three days of autonomy. The use of a DC system in this setup is ideal, as it only powers luminaries and fans. DC luminaries and fans are more energy efficient and minimise conversion losses, contributing to greater sustainability over time.

Powering upgraded services: To achieve the government's intention to upgrade the services offered to its population at the lowest level of healthcare would require a DRE system of 5 kWp panel capacity, 36 kWh battery capacity and 6 kVA inverter size per facility. It would take an additional 0.5 kWp to power pharmacy services, over and above the loads indicated under "entire loads". However, it must be noted that given the current energy demand, the installation of a system of this size would result in energy wastage. Hence, such a design must be considered only if new services (maternity, laboratory, emergency, cold chain and pharmacy) are introduced within a period of six months of installation to utilise the energy generated with this system. If the system is not utilised to its capacity, the risk of the battery failing before its end of life increases drastically and reduces the reliability of the system and thus would increase the O&M cost.

Solar energy system design templates: **Health centre**

Based on the assessment findings and DRE solar design assumptions, the following design templates are recommended for health centres as the primary system.

Table 6 **Parameters for solar energy system for a health centre**

Parameters	Health centre	
	Entire loads	Critical loads
Loads considered	Lum + RL + All ME	Lum + RL + critical ME
Total connected load (kW)	8.2	2.7
Total energy per day (kWh)	25.8	5.2
Solar panel capacity (kWp)	9	1.8
Battery bank sizing (kWh)	60	11.5
Solar MPPT inverter sizing (kVA)	12	3.5
Loss of load probability (LOLP)	0.36 %	0.15 %

Notes: kVA = kilovolt ampere; kW = kilowatt; kWh = kilowatt hour; kWp = kilowatt peak; Lum = luminaries; ME = medical equipment; RL = regular load.

Powering entire loads: Per the designs depicted in Table 6, powering a health centre using DRE as the primary system for all equipment during operational hours requires a 9 kWp panel capacity, 60 kWh battery capacity and 12 kVA inverter size per facility.

Powering regular and critical loads: The panel capacity requirement is 1.8 kWp, with a battery capacity of 11.5 kWh and an inverter size of 3.5 kVA per facility required to energise some regular loads for teleconsultations along with critical medical loads for powering critical services such as maternity services, OPD and pharmacy.

Solar energy system design templates: **Rural hospital**

Based on the assessment findings and DRE solar design assumptions, the following design templates are recommended for rural hospitals as the primary system.

Table 7 **Parameters for solar energy system for a rural hospital**

Parameters	Rural hospital	
	Entire loads	Critical loads
Loads considered	Lum + RL + All ME	Lum + RL + Critical ME
Total connected load (kW)	15.5	6.2
Total energy per day (kWh)	50.5	17.8
Solar panel capacity (kWp)	18	6.6
Lithium ion: battery bank sizing (kWh)	120	45
Solar MPPT inverter sizing (kVA)	20	8
LOLP	0.38%	0.20%

Notes: kVA = kilovolt ampere; kW = kilowatt; kWh = kilowatt hour; kWp = kilowatt peak; LOLP = loss of load probability; Lum = luminaries; ME = medical equipment; RL = regular load.

Powering entire loads: Per the designs shown in Table 7, powering a rural hospital using DRE as the primary system for all equipment during operational hours requires 18 kWp panel capacity, 120 kWh battery capacity and 20 kVA inverter size per facility.

Powering regular and critical loads: The panel capacity requirement is 6.6 kWp, with a battery capacity of 45 kWh and an inverter size of 8 kVA required to energise some regular loads along with critical loads, *i.e.* luminaries, fans, medical equipment for maternity, OPD and emergency rooms.

Solar energy system design templates: **District hospital**

Based on the assessment findings and DRE solar design assumptions, the following design templates are recommended for district hospitals as the primary system.

Table 8 **Parameters for solar energy system for a district hospital**

Parameters	District hospital	
	Entire loads	Critical loads
Loads considered	Lum + RL + All ME	Lum + RL + Critical ME
Total connected load (kW)	43.5	11.0
Total energy per day (kWh)	160.2	34.1
Solar panel capacity (kWp)	55	12
Lithium ion: battery bank sizing (kWh)	360	84
Solar MPPT inverter sizing (kVA)	60	15
LOLP	0.56%	0.60%

Notes: kVA = kilovolt ampere; kW = kilowatt; kWh = kilowatt hour; kWp = kilowatt peak; LOLP = loss of load probability; Lum = luminaries; ME = medical equipment; RL = regular load.

Powering entire loads: The designs depicted in Table 8, powering a district hospital using DRE as the primary system for all equipment during operational hours requires a 55 kWp panel capacity, 360 kWh battery capacity and 60 kVA inverter size per facility.

Powering regular and critical loads: A 12 kWp panel with a battery capacity of 84 kWh and an inverter size of 15 kVA per facility would be required to energise some regular loads along with critical loads, *i.e.* luminaries, fans, medical equipment for maternity, OPD and emergency rooms.

5.3 SOLAR ENERGY SYSTEM DESIGN OPTIONS FOR STAFF QUARTERS

To increase staff work efficiency and comfort, the following DRE system design can be integrated into existing and new health facilities based on the number of staff quarters.

Table 9 **Design considerations for a solar energy system in staff quarters**

Solar as primary source of energy	
Staff quarters	✓ Entire loads (include luminaries and regular loads)
	✓ Basic loads (include luminaries and mobile charging)

Usually, health facilities have between three and five staff houses. The most common housing design includes **three bedrooms, a kitchen, toilet (WC) and shower, a laundry area, a living room, and a passage area**. Considering regular loads and the needs of the staff, two design options are developed for the staff quarters.

Option A	This covers the entire load that is required for the staff members to feel at home at any point in time.
	One staff quarter regular loads
	Rooms: Living room & dinning + kitchen + laundry + main bedroom + 2 bedrooms + passage + shower + W/C + outdoor **Load types:** Ceiling/wall/pedestal fan (5) + fridge (1) + LED bulb (10) + mobile charging (4) + TV (1) + outdoor light (1)
Option B	This covers the luminaries and ventilation system that allow a comfortable stay for the staff members.
	One staff quarter basic loads – this is a DC system with three-day autonomy
	Rooms: Kitchen + main bedroom + shower + WC **Loads:** Ceiling/wall/pedestal fan (1) + LED bulb (4) + mobile charging (1)

Notes: DC = direct current; LED = light emitting diode.

Table 10 **Parameters for a solar energy system for staff quarters**

Parameters	Staff quarters - entire load			Staff quarters – basic load		
	One staff quarter	Three staff quarters	Five staff quarters	One staff quarters	Three staff quarters	Five staff quarters
Total connected load (kW)	0.6	1.8	3.1	0.1	0.3	0.5
Total energy per day (kWh)	2.5	7.6	12.7	0.3	1.0	1.7
Solar panel capacity (kWp)	0.9	3	4.8	0.12	0.36	0.72
Battery bank sizing (kWh)	7.2	24	36	1.8	4.8	8.64
Solar MPPT inverter sizing (kVA)	1	3.5	5	20 A, 12 V (CR)	25 A, 24 V	1
LOLP	0.15%	0.09%	0.15%	0.33%	0.63%	0.13%

Notes: CR = charge regulator; kVA = kilovolt ampere; kW = kilowatt; kWh = kilowatt hour; kWp = kilowatt peak; LOLP = loss of load probability.

Powering entire loads: The designs shown in Table 10, powering one health staff quarter using DRE as the primary system for regular loads will require a 0.9 kWp panel capacity, 7.2 kWh battery capacity and 1 kVA inverter size per residence.

If three staff quarters are in one place, powering regular loads for all three staff quarters will require a 3 kWp panel capacity, 24 kWh battery capacity and a 3 kVA inverter.

Similarly, if five staff quarters are in one place, powering regular loads for all five staff quarters, a 4.8 kWp panel capacity, 36 kWh battery capacity and a 5 kVA inverter will be required.

Note: The reliability of this system will be higher with separate individual systems for each staff quarter.

Powering basic loads: Powering one health staff quarter using DRE as the primary system for basic loads for necessary rooms will require a 0.12 kWp panel capacity, 1.8 kWh battery capacity and 20 A, 12 V charge regulator.

If three staff quarters are in one place, then to power basic loads for all three staff quarters will require 0.36 kWp panel capacity, 4.8 kWh battery capacity and a 25 A, 24 V charge regulator.

Similarly, five staff quarters to power regular loads for all quarters will require 0.72 kWp panel capacity, 8.64 kWh battery capacity and 1 kVA inverter.

5.4 OTHER DESIGN CONSIDERATIONS

To provide reliable health services at all points in time, it is essential to consider the availability of water at health facilities. This requires the availability of water pumps and water heating systems that cater to the needs of the facilities. Solar water pumps and solar water heaters can be designed based on the water consumption needs at each type of facility and support the staff to provide services.

An example of the design of a solar water heater is one that supplies 50 litres per patient at a health facility. Other energy sources such as biogas can be used complementarily to provide water for sterilisation purposes.

Solar water pump designs need to consider the source of water and how the water will be stored for utilisation at the health facility.

Net metering must be considered for facilities that are connected to the grid. This will allow the health facilities to generate income and prevent energy wastage at the facility level.

5.5 SOLAR ENERGY SYSTEM DESIGN COST ASSUMPTIONS

Solar energy system cost assumptions

The cost of the DRE system includes the supply of panels, batteries, inverters and cabling, as well as installation and maintenance. These costs are derived from the information given by the ten vendors from Zimbabwe. The average costs for various components are provided in USD. Based on the requirements for installing the system at various health facilities, the following assumptions were made.

System costs

The AC system costs include solar panels, batteries and inverters. In the DC system, the cost of panels, batteries and charge regulators is considered. Other than these, wiring, module mounting structures and other balance of systems are also considered. Apart from components, the cost includes installation, commissioning and labour, which are approximated to 7% of the system cost in the region. All costs are based on the components available in Zimbabwe, with careful consideration of regional factors and the use of lithium-ion batteries. It must be noted that the cost of labour and installation is based on actual costs and may show significant deviance for certain system designs.

Transportation costs

The cost of transportation accounts for moving all the necessary equipment from the central warehousing facility to each facility located in various provinces. A standard rate of USD 250 is estimated, based on the average distance from the capital city to the facilities located across the country. The costs are likely to be higher for facilities located in rural, hard-to-reach regions.

Remote monitoring system costs

A flat cost of USD 350 is added to take into account remote monitoring systems (RMS) and the data charges required for five years of functioning.

O&M costs

The costs for O&M take into consideration annual maintenance contracts (AMCs). AMCs specify twice-yearly technician visits and the performance of repairs/replacements as and when required. This cost covers any change of parts in warranty and visits to the health facilities for scheduled maintenance that can be utilised to address minor issues before they emerge as major calls for repair. This is taken as 10% of the total system cost.

Solar energy system cost: Health post/clinic

Table 11 **Cost estimate for various designs of health posts/clinics**

Health facility type	Type of load	System size (kWp)	Total system cost (USD)	Cost of RMS (USD)	Cost of O&M (USD)	Total cost (USD)
Health post/clinic	Entire load	0.78	1 970	350	161	**2 481**
	Basic load (DC system)	0.54	1 478	350	115	**1 943**
	Upgraded services load	5	12 114	350	1 109	**13 573**

Notes: kWp = kilowatt peak; O&M = operation and maintenance; RMS = remote monitoring system; USD = United States dollars.

Table 11 shows that the cost of installing and maintaining DRE systems for the entire load would be USD 2 481. However, it would cost USD 1 943 for the DC system to power luminaries and fans as the basic system. The cost for a system at an upgraded facility would be USD 13 573.

These costs cover the sustainability of the system for five years, by considering the maintenance costs for the same period. It is crucial to understand that beyond this period, additional working capital will be necessary for establishing maintenance contracts and for battery replacement and potential inverter replacement.

Solar energy system cost: Health centre

Table 12 **Cost estimate for various designs of a health centre**

Health facility type	Type of load	System size (kWp)	Total system cost (USD)	Cost of RMS (USD)	Cost of O&M (USD)	Total cost (USD)
Health centre	Entire load	9	20 526	350	1 895	**22 771**
	Critical loads	1.8	4 336	350	382	**5 068**

Notes: kWp = kilowatt peak; O&M = operation and maintenance; RMS = remote monitoring system; USD = United States dollars.

Table 12 shows that the cost of installing DRE systems for the entire load at a health centre would be USD 22 771. However, for critical loads, the total cost would be USD 5 068.

Solar energy system cost: Rural hospital

Table 13 **Cost estimate for various designs of a rural hospital**

Health facility type	Type of load	System size (kWp)	Total system cost (USD)	Cost of RMS (USD)	Cost of O&M (USD)	Total cost (USD)
Rural hospital	Entire load	18	40 212	350	3 735	**44 297**
	Critical loads	6.6	15 263	350	1 403	**17 016**

Notes: kWp = kilowatt peak; O&M = operation and maintenance; RMS = remote monitoring system; USD = United States dollars.

Table 13 illustrates that the cost of installing DRE systems for the entire load is USD 44 297. However, the cost of installing the DRE system for critical loads would be USD 17 016.

Solar energy system cost: District hospital

Table 14 **Cost estimate for various designs of a district hospital**

Health facility type	Type of load	System size (kWp)	Total system cost (USD)	Cost of RMS (USD)	Cost of O&M (USD)	Total cost (USD)
District hospital	Entire load	55	120 511	350	11 239	**132 100**
	Critical loads	12	28 184	350	2 611	**31 145**

Notes: kWp = kilowatt peak; O&M = operation and maintenance; RMS = remote monitoring system; USD = United States dollars.

Table 14 shows that installing DRE systems for the entire load at the district hospital would cost USD 132 100, while the cost of installing DRE system for critical loads would be USD 31 145.

Solar energy system cost: Staff quarters

Table 15 **Cost estimate for various designs of staff quarters**

Staff quarters	Type of load	System size (kWp)	Total system cost (USD)	Cost of RMS (USD)	Cost of O&M (USD)	Total cost (USD)
1 staff quarter	Entire load	0.96	2 581	350	218	**3 149**
	Critical loads (DC system)	0.12	833	350	54	**1 237**
3 staff quarters	Entire load	3	7 982	350	723	**9 055**
	Critical loads (DC system)	0.36	1 692	350	135	**2 177**
5 staff quarters	Entire load	4.8	11 905	350	1 089	**13 344**
	Critical loads (DC system)	0.72	2 883	350	246	**3 479**

Notes: DC = direct current; kWp = kilowatt peak; O&M = operation and maintenance; RMS = remote monitoring system; USD = United States dollars.

Table 15 shows that installing DRE systems for staff quarters would cost anywhere between USD 1 237 and USD 13 344 based on the number of staff quarters powered. While critical loads, considered as DC systems, would range between USD 1 237 for a single staff quarter and USD 3 479 for five quarters, the cost of regular loads for a single quarter would be USD 3 149 and USD 13 344 for five quarters.

Tables 16 and 17 present the total cost of systems as well as the cost of O&M separately. An assumption made for the total cost of the programme is the availability of one staff quarter at health posts/clinics, three staff quarters for health centres and rural hospitals, and five staff quarters at the district hospital.

Table 16 **Total cost for all facilities with entire load and staff quarters**

Entire load						
Type of Facility	**No of Facilities**	**System cost per facility (USD)**	**Cost of RMS (USD)**	**Cost of O&M (USD)**	**Cost per Facility (USD)**	**Total cost with staff quarters (USD)**
Health post/clinic	763	1 970	350	161	2 481	4 295 589
		12 114	350	1 109	13 573	12 758 762
Health centre	177	20 526	350	1 895	22 771	5 633 163
Rural hospital	35	40 213	350	3 735	44 297	1 867 334
District hospital	25	120 511	350	11 239	132 100	3 636 112

Notes: O&M = operation and maintenance; RMS = remote monitoring system; USD = United States dollars.

Table 17 **Total cost for all facilities with critical load and staff quarters**

Critical load						
Type of Facility	**No of Facilities**	**System cost per facility (USD)**	**Cost of RMS (USD)**	**Cost of O&M (USD)**	**Cost per Facility (USD)**	**Total cost with staff quarters (USD)**
Health post/clinic	763	1 478	350	115	1 943	2 426 191
Health centre	177	4 336	350	382	5 068	1 282 427
Rural hospital	35	15 263	350	1 403	17 016	671 764
District hospital	25	28 185	350	2 611	3 1145	865 620

Notes: The total number of facilities is based on an assumption that unelectrified facilities and proposed construction will be considered under the programme; O&M = operation and maintenance; RMS = remote monitoring system; USD = United States dollars.

With an assumption of a total of 1000 facilities that require electrification, the total cost of sustainably energising them will be USD 15 432 199 for powering the entire loads at all facilities with staff quarters, or USD 5 246 001 for critical loads with staff quarters. The least cost would be for an option with only critical loads at facilities without staff quarters. The cost for powering the entire loads with upgraded services at the lowest level of health facilities would require an additional USD 8.4 million.

Table 18 **Total programme cost for implementation**

Type	Total programme cost (USD)
Entire load	10 776 377
Critical load	3 753 868
Entire load with staff quarters (entire load)	15 432 199
Critical load with staff quarters (critical loads)	5 246 001

To implement the programme, it is necessary to take into consideration an additional 20% that accounts for carrying out assessments to identify the total number of health facilities for the programme, building the structures, setting up a programme unit that manages all processes (elaborated in Chapter 7), monitoring the programme to gather learnings, and highlighting the programme's impacts.

SUSTAINABILITY OF SOLAR ENERGY SYSTEMS

More than 1044 facilities in Zimbabwe have solar energy systems installed through different programmes, making it essential to continue to maintain the equipment so it remains operational. Along with this, the newly installed systems must have a sustainability plan in place. This chapter examines three essential components for the sustainability of solar energy systems: training, O&M and financing for O&M.

6.1 TRAINING ON SOLAR ENERGY SYSTEMS

Training includes two components: training the vendor and its technicians on quality installation, and training staff on utilisation and maintenance.

Training for health facility staff

Training is integral to equip the staff to utilise energy systems for medical appliances. The staff must also receive training on basic troubleshooting and maintenance. This will ensure that the downtime of equipment is limited. Understanding how to maintain the equipment at the health facility also builds a sense of ownership of the equipment among the staff and boosts the staff's confidence in using the system without fear of damaging it. It also results in proper usage of the equipment, minimising the risk of operational errors and thus extending the asset's life. The facility staff must also be trained to raise complaints with the right stakeholders. This requires establishing a channel for prompt communication for issue resolution and building accountability for maintenance activities. Additionally, it is crucial that new staff replacing current staff undergo mandatory training to ensure the continuity of maintenance activities.

Training for vendors and technicians

Training the vendor and its technicians includes training on quality installation and maintenance activities. This is necessary to reduce the cost of maintenance in the long run and to ensure the functioning of the systems. Training on quality installation must focus on the detailed standard operating procedure (SOP) for installation, including an evaluation of the roof for mounting structures, panel orientation, battery storage, earthing pit, *etc.* utilising an installation quality checklist and preparing handover documents.

Training must also be provided to the local technicians to undertake the maintenance activities. This includes:

- Activities to be carried out during routine visits. The details of the activities are highlighted in the following section on O&M.

- Steps to follow for issue resolution. Based on the established communication channel, the vendor/technician must be equipped to resolve different issues based on a priority matrix.

Institutionalising training

To enable the above-mentioned training activities, it is necessary to develop training modules and institutionalise the training process within relevant ministries among health facility staff and in local technical training institutes.

Strengthen training departments in the ministries

The participation of ministries and their decentralised bodies in training will ensure that the standard guidelines for quality are followed. Strengthening these bodies to carry out the training for solar energy systems will build the capacity of the government in implementation of other programmes in the country as well.

Develop training modules

Key modules that are necessary for the implementation of O&M training must be developed by the MoHCC and MoEPD. The modules must focus on the following:

Health-energy implementation guidelines: This module should provide guidelines for implementing health-energy nexus programmes covering approaches such as stakeholder mapping and their roles, procurement guidelines, standards and certifications for equipment, implementation SOPs, service and maintenance protocols, and monitoring and evaluation.

O&M guidelines: This module should provide guidelines on the O&M of systems, stakeholders and their roles, communication channels for troubleshooting, and the creation of service-level agreements for maintenance.

6.2 O&M

A plan for O&M is vital for the sustainability of health-energy programmes. This is to account for effective health service delivery by maximising the performance of the energy system to enable energy-driven health services and to enhance the safety and well-being of healthcare staff and patients at the health facility.

The degree and frequency of maintenance services depends on the design of the system, installation quality and the location of the facility. For example, facilities in regions prone to rain-related disasters have a higher chance of system breakdown if the installation did not account for these challenges.

O&M consists of preventive maintenance and corrective maintenance. Preventive maintenance focuses on activities that can enhance the performance of the system. This includes the following:

- regular cleaning of solar panels to remove dust, dirt and debris that would otherwise reduce energy production
- electrical system inspections to check for loose connections, damaged cables and proper grounding
- mechanical component inspections of the mounting structures tracking systems (if applicable) and other moving parts
- vegetation control to prevent shading and ensure unobstructed access to the solar panels.

Corrective maintenance includes repairs and replacement of components that have failed or result in frequent issues. It includes replacement of cables, inverters and batteries and repair of mounting structures and wiring between equipment.

Proper repair procedures and safety protocols must be followed to ensure the integrity of the system and the safety of personnel. To carry out the maintenance, it is essential to demarcate responsibilities between the health facility staff and the vendors and the schedule for these activities.

Prioritisation matrix

For an effective O&M plan, it is essential to create a prioritisation matrix that takes into consideration the modality of issue resolution, the time period required to resolve an issue, and an escalation process.

The **modality of issue resolution** can be remote or through in-person visits. For remote resolution, it is mandatory that the staff at the facility be trained in carrying out basic troubleshooting activities. This will allow the vendor to guide the staff into carrying out certain activities for resolving the issue.

The **time period for resolution** determined for different issues depends on the criticality of the issue and the degree to which service provision is affected. Certain issues that shut down the energy system, discontinuing energy supply for the entire health facility, must be addressed within 24 hours and must be followed up every 24 hours.

The **escalation process** must be defined such that the roles and responsibilities of different stakeholders for maintaining the energy system are demarcated. This process improves the accountability of all the stakeholders in ensuring that the issues that emerge are addressed as soon as possible.

Asset tracking through a centralised platform

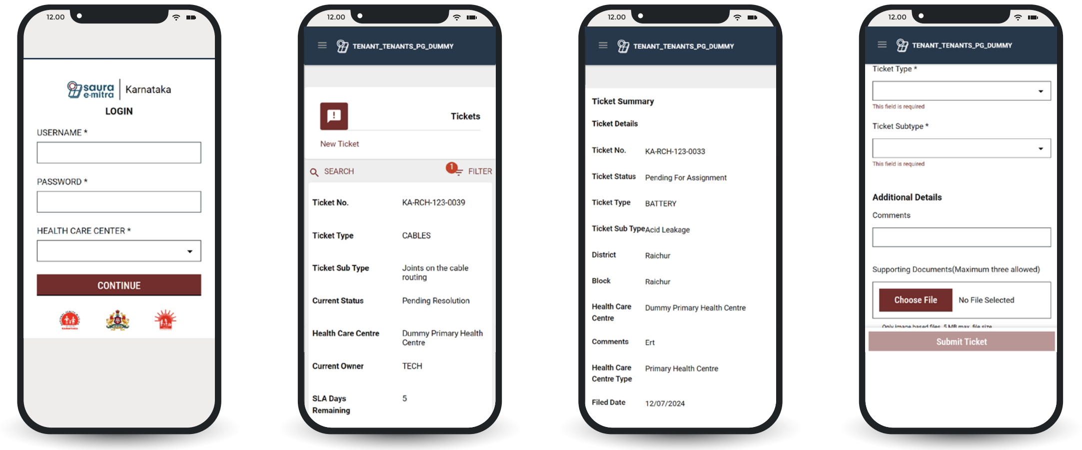
Health facilities in Zimbabwe have received assets through different programmes. This needs a centralised tracking process of all the assets at the facility. This requires the following:

- facility name/unique ID with global positioning system (GPS) co-ordinates and contact details
- asset list tagged to facilities and corresponding vendor and programme details
- date of installation with notification triggers for date of service visits and refresher training
- updates on service visits and any remarks on other maintenance required.

This must be interlinked with an **incidence management system** where the health facility staff raise complaints, which the vendor must then address. This incidence management system will allow the health facility staff as well as a customer relationship executive from the technical cell (discussed in Chapter 7) to raise complaints when they face any issue with the solar energy system. The local service provider and the local NGOs must be a part of the system that is notified when an issue is raised. When issues remain unaddressed within the stipulated time, the technical audit cell will escalate the issue with the stakeholder concerned.

Figure 8 shows an example of an open-source digital incidence management system that has been deployed in a few states within India by SELCO Foundation to bring various stakeholders together for issue management and resolution. This platform ensures prompt and efficient management of issues, streamlining incident reporting and resolution processes.

Figure 8 **Example of Saura e-Mitra: A digital incidence management system**



An annual maintenance contract with vendors

An annual maintenance contract (AMC) is a service-level agreement with the vendor or local service providers to maintain the energy systems at the facilities. AMC services cover a range of predictive, preventive and corrective aspects of the solar energy system installation to ensure optimum performance throughout the expected duration.

Appendix C provides a recommended list of activities to be carried out during the maintenance visits to ensure O&M measures are in place.

Planning for regional differences

Regional differences in terms of terrain and connectivity must be considered for planning O&M.

Regions that have a **higher flood risk** require **higher monitoring and maintenance** to ensure system functionality. Regions prone to thunderstorms also require more monitoring for system functionality.

In regions without local service providers, NGOs focusing on health and/or energy access can be trained to provide the first level of maintenance. This ensures a faster turnaround time for issues that threaten to disrupt the services at the health facility.

Mapping the supply chain and storage facility

The solar technology supply chain is an important indicator of the clean energy market's maturity. It is essential to map the supply chain and storage facilities for creating access to spares and technologies to enable a faster turnaround time. Procuring spares at the time of procurement of all the systems requires storage facilities that can be accessed by technicians as and when necessary.

Building capacity within the government structure

The decentralised bodies within the MoHCC and MoEPD must also account for a trained human resource within their departments to address issues that emerge. These technical resources can provide additional support when the contracts with the vendors have lapsed, carry out quality checks of the installed systems on a regular basis to ensure their efficient functionality, build vendor accountability, and work alongside the technical cell.

These bodies must maintain the asset registry that accounts for all equipment installed. This serves as a record for the solar equipment and thus a reference for allocating budget for maintenance.

Currently, given the status of solar energy systems installed at health facilities across the country, the Rural Electrification Fund (REF) under the MoEPD is set up to take up all activities related to O&M. This includes having technicians visit sites to check for the functionality of systems and undertake all rectification activities necessary for ensuring smooth functioning.

Technical considerations

The technical design for the systems is provided with the perspective of zero maintenance: that is, the need for maintenance of this equipment is almost nil due to the reliability of the system. The **use of lithium-ion batteries** over lead-based batteries is one such design consideration. Another consideration is to include **in-built RMS**s within the inverters. This will ensure that systems are monitored for their functionality and anomalies are noticed and addressed before the system breaks down completely. This will also support the maintenance service provider to recognise issues as and when they receive calls for troubleshooting, thereby making the process easier. Thus, remote monitoring enables early detection of issues, reducing unnecessary travel and allowing for timely interventions. It is essential to consider the operational costs of maintaining a dashboard and making regular payments for internet services for running the RMSs.

6.3 FINANCING FOR O&M

Financing O&M in Zimbabwe must account for the evolving economic landscape, which impacts the cost of services and spare parts. To reduce costs and improve the reliability of maintenance services, a collaborative approach is essential. It should involve stakeholders such as the government, NGOs and private sector vendors.

O&M must be carried out for the lifetime of the system. This includes the cost of spares, servicing and AMCs. Depending on the source of funding for O&M, the approach to O&M will change.

Funding for O&M through philanthropy

While securing funding from philanthropies for energy systems, it is equally critical to raise funds specifically for O&M. Contracts with local service providers should cover a five-year maintenance period and include clauses accounting for inflation to address cost fluctuations. To ensure stability, O&M funds raised through philanthropies should be maintained in USD and managed by a third-party organisation with an established and long-term presence in the country.

Funding for O&M through government

Including operational costs as a dedicated line item within government budgets will create formal institutional structures for allocation, ensuring that long-term maintenance is integrated into the health system. The government can either establish contracts with local service providers or hire in-house technicians to manage the systems. As the MoHCC collaborates with the REF on O&M, the allocated funds must be clearly earmarked for specific O&M activities beyond warranty coverage or AMC. This requires an annual allocation that is utilised to run the technical cell and address all issues outside of warranty, along with covering the operational costs such as transportation and spare part management.

ROADMAP FOR THE PROGRAMME

This chapter outlines broad recommendations to execute a well-rounded programme for delivering health services effectively.

Creating an interministerial committee

Creating an interministerial committee for the programme is essential as it demarcates roles and responsibilities for different phases of the programme. Defining the collaborative relationship between key stakeholders from the government and other non-governmental bodies along with representatives from the ground, such as district health promotion officers, is key to forming this committee.

The participation of the MoHCC and the MoEPD, along with the MoLGPW, Ministry of Environment, Climate and Wildlife (MoECW) and the MoLAFWRD, is integral to this working group and its mission to address the health and energy needs at the facility level and to carry out maintenance activities. It is also important to include stakeholders who have been a part of previous solar projects to bring in their experience with implementation and operations. Establishing ownership of the systems through discussions and deliberations within the committee is essential. This allows the owner to take the initiative to institutionalise maintenance processes and their budgets.

This committee will be the key driver for ensuring sustainability of the installed systems by leading:

- budget planning and allocations for O&M activities
- planning for expansion of the health infrastructure and the services provided at different levels of health facilities
- the establishment of a list of approved technologies (based on quality standards) and certified service providers qualified to handle installation and maintenance
- capacity building of stakeholders, including health staff and other government officials, to emphasise the importance of solar in delivering health services
- the promotion of tax concessions on solar equipment to increase demand for solar within the country
- the documentation of the learnings from the programme to disseminate success and failure stories with other countries that are carrying out similar programmes.

Setting up a technical programme unit

A technical programme unit is a third-party entity that consists of key technical personnel who review the quality of installations and manage the O&M processes. This nodal body will engage in fund management based on government allocation and external fundraising and co-ordination between government and non-government entities for carrying out O&M activities. The programme unit will review the incoming data from the RMS, carry out analysis to understand the utilisation of the systems and direct technicians to address issues that emerge. This cell will co-ordinate with different stakeholders for issues that are raised through the incidence management system. Unit executives will call the health facilities to understand their functioning and raise complaints on their behalf.

This unit will play an integral role in the sustainability of the solar energy systems that are installed. This cell must include a project manager who makes decisions for carrying out activities relevant to the effective functioning of the systems, along with data managers who monitor the incoming data and technicians and/or engineers who are trained to carry out major repairs. With the current processes carried out by REF, it is necessary to define the role of REF or other entities that can house the technical programme unit as this will be an integral component of ensuring accountability for O&M activities.

With the MoHCC leading the programme, it is essential to leverage the existing financing set aside for the maintenance of health facilities. The MoHCC must also clearly outline a budget item necessary for health facilities to outline their needs based on the issues that emerge. While raising funds for the programme, it is essential to raise funds for the O&M of the systems as well. The funds raised for this purpose must be set aside in escrow accounts maintained by a third party. These escrow accounts offer different rates for different durations, which must also be included in the programmatic costs. Engagement with the REF is also essential to ensure that the finances are available for O&M.

Assessment of the existing systems and buildings

Health facilities often have existing energy systems, some powering all their needs, while others focus on specific loads. It is crucial to assess the current condition of these systems to identify which ones need replacement and which require maintenance. An independent organisation should conduct this audit to evaluate the systems' performance, installation, quality and how effectively they are being used at each facility.

Zimbabwe's climate context necessitates that health facilities be constructed in a way that reduces the operational costs and meets the energy demands of the facility. Substandard building conditions can directly influence the number of patients accessing healthcare and staff retention. Structural damage to buildings also complicates the installation of solar panels and related infrastructure. For example, a compromised roof structure will not safely support the weight of solar panels and may require additional reinforcement before installation, increasing costs. Therefore, it is essential to assess the suitability of health facilities' infrastructure for providing energy-driven healthcare services.

This assessment will allow for:

- Planning renovations and improvements in the existing structures for better ventilation and lighting or to enhance the quality of walls to prevent mould.
- Constructing new facilities as indicated in the NHS by taking in account built environment considerations for thermal comfort, lighting, ventilation and temperature control through appropriate building materials guidelines on fenestration, shading devices and complementary efficient appliances (SELCO, 2021).

Implementation plan

Finalising the designs

The designs outlined in this report are based on a sample assessment of facilities. The programme informed by the results of these assessments will finalise the necessary designs and determine the number of facilities to be included in the programme. This will provide a clear estimate of the required budget. The designs must be reviewed and approved by local experts from the MoHCC and MoEPD. This will guide the next step, procurement.

Procurement

Once the designs are finalised and the budget is allocated, the procurement and installation process must be initiated. Vendors for the programme can be identified based on a tendering process that follows national guidelines and guidelines set by the World Health Organisation (WHO). Since there is a possibility that the equipment might not be available locally and so must be procured from a supplier from other countries, it is critical to establish the technical capacities of local personnel to provide servicing and maintenance.

Some of the critical components for onboarding vendors include:

- proof of vendors' local presence (either directly or through associated local technical agencies) showcasing their ability to provide timely quality service in the project area
- availability of local supply chain for spare parts for servicing and maintenance
- past performance of vendors with respect to providing design installation and maintenance service, especially on similar health-energy projects.

Ownership and asset handover

It is critical to integrate a decentralised ownership model for the solar energy systems, either at the facility level or at the local governance structure level. It is also important to ensure the systems will be operated and maintained with long-term sustainability. Once installations are completed, training should ensue for the health facility staff and community members on the basic technicalities of the systems, thereby also building a sense of ownership at the facility level. Sensitisation programmes with the community can reduce the cases of thefts and build accountability and vigilance for the installed systems. Different NGOs that are locally present must be apprised of the systems that are installed. These NGOs can also be trained in carrying out physical monitoring of systems to ensure their performance at all points in time. Along with the facility-level handover, it is also essential to include the data in the asset management registry at the national level to ensure accountability and adequate allocation of budgets when required.

O&M

As detailed in Chapter 6, O&M forms an integral part of the programme. Adequate budget must be allocated for carrying out the various activities under O&M. The technical programme unit must play an integral role in managing these activities as well as raising any issues that emerge with the interministerial committee.

Monitoring of the programme

A robust monitoring system must be set up to evaluate the performance of the systems and understand the utilisation of the systems in enhancing healthcare delivery. Members of the interministerial committee should prioritise holding regular meetings with provincial or district-level officers to appraise them of the impact of energy systems in providing care. Critical learnings can emerge from the ground, highlighting the user experience at the facility level. This would expand the reach of the programme and thus further the impact of the programme.

CONCLUSION

With the Zimbabwean goal of enhancing its healthcare system for achieving healthy lives and the well-being of all people, enabling access to reliable energy plays a crucial role in powering health services that can serve the population located in remote and hard-to-reach areas. This report outlines the approach for a sustainable health-energy programme by taking an integrated approach to delivering effective healthcare through the utilisation of energy-efficient systems and built environment for health facilities delivering primary care. This is recommended with the participation and collaboration among multiple stakeholders within the country who are critical for bridging gaps in knowledge, resources and skills for improving the health of the Zimbabwean population.

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APPENDICES

APPENDIX A: TYPES OF FACILITIES AND THEIR DISTRIBUTION ACROSS PROVINCES

Province	Name of the facility	Type of facility	Grid	Solar	Diesel generator
Mashonaland Central	Foothills Clinic	Health centre	Yes	Yes	Yes
	Glamourgen Clinic	Health centre	No	Yes	Yes
	Rutope Clinic	Health centre	Yes	Yes	No
	Concession District Hospital	District hospital	Yes	Yes	Yes
	Dandamera Polyclinic	Health centre	Yes	Yes	No
	Ardura Clinic	Health centre	Yes	Yes	No
	Rosa Rural Hospital	Rural hospital	Yes	Yes	Yes
Matabeleland South	Ingwizi Clinic	Health centre	Yes	Yes	No
	Tshitshi Clinic	Health centre	Yes	Yes	No
	Madabe Clinic	Health centre	Yes	Yes	No
	Izinyama Clinic	Health centre	Yes	Yes	No
	Dingumuzi Polyclinic	Health centre	Yes	Yes	No
	Macingwane Clinic	Health post	Yes	Yes	No
	Ndiweni Clinic	Health centre	Yes	Yes	No
	Matjinge Clinic	Health centre	Yes	Yes	No
	Gambu Clinic	Health centre	Yes	Yes	No
	Lady Stanley Rural Hospital	Rural hospital	Yes	Yes	No
Matabeleland North	Mbembesi Clinic	Health centre	No	Yes	Yes
	Redwood Clinic	Health centre	No	Yes	Yes
	Fairbridge Clinic	Health centre	Yes	No	No
	Induna Hospital	Polyclinic	Yes	No	No

Province	Name of the facility	Type of facility	Grid	Solar	Diesel generator
Midlands	Chikwingizha Rural Hospital	Rural hospital	Yes	Yes	No
	Zvamabande Rural Hospital	Rural hospital	Yes	Yes	No
	Tongogara Polyclinic	Polyclinic	Yes	Yes	No
	Ruchanyu Clinic	Health centre	Yes	No	No
	Dambudzo Clinic	Health centre	Yes	Yes	No
	Mabasa Clinic	Health centre	Yes	Yes	No
	Mapanzure Clinic	Health centre	Yes	Yes	No
	Maketo Clinic	Health centre	No	Yes	No
	Lundi Rural Hospital	Rural hospital	Yes	Yes	No
Masvingo	Ndanga Clinic	Health centre	No	No	No
	Jerera Satellite Clinic	Satellite clinic	No	Yes	No
	Bota Rural Hospital	Health centre	Yes	Yes	No
	Chinyabako Clinic	Health centre	Yes	Yes	No
	Nhema Clinic	Health centre	No	No	Yes
Manicaland	Premier Clinic	Health centre	Yes	Yes	No
	Zongoro Clinic	Health centre	Yes	Yes	No
	Sakupwanya Clinic	Health centre	Yes	Yes	No
	Mutasa Clinic	Health centre	Yes	No	No
Mashonaland West	Portet Clinic	Health centre	Yes	No	No
	Matoranjera Clinic	Health centre	Yes	Yes	Yes
	RSHM Life Care Centre	Health centre	Yes	Yes	Yes
	Chikonohono Clinic	Health centre	Yes	Yes	No
Mashonaland East	Makanyazingwa Clinic	Health centre	Yes	No	Yes
	Border Church Clinic	Health centre	Yes	Yes	Yes
	Chihota Rural Hospital	Rural hospital	Yes	Yes	No
	Chakadini Clinic	Health centre	Yes	No	No
	Lustleigh Clinic	Health centre	Yes	No	Yes
Mashonaland Central	Nyamhondoro Clinic	Health centre	Yes	Yes	No
	Chipuriro Clinic	Health centre	Yes	Yes	No

APPENDIX B: PARAMETERS AND ASSUMPTIONS FOR SOLAR ENERGY SYSTEM DESIGN

The following are the overarching factors considered for design:

Factors determined energy needs	Loads specifications	System design considerations
Health facility specificities	Standard designs with typical operational hours	Peak sunshine hours
Health facility level		Days of autonomy
Number of rooms	Customisation based on services	Depth of discharge
Services delivered	Critical & non-critical equipment loads	Energy efficiency of equipment
Future growth needs	Load disease burden	
Safety & well-being needs	Disaster context	Load requirements vary across different centres. Two DRE solutions are provided for each facility (full and regular + critical loads).

Solar energy system design assumptions

This appendix broadly outlines the assumptions for the designs of the solar PV system components, *i.e.* solar panel battery and inverter. While this analysis provides a general framework, it is essential to note that customised designs are recommended for specific climatic ecology within the country, considering population density conditions and more detailed requirements.

Solar irradiation

Solar irradiation represents the amount of solar energy available at a specific location. Solar irradiation determines how much energy solar panels can capture to generate electricity. Zimbabwe has an annual average global horizontal irradiation (GHI) ranging from 5.25 kWh/m^2/day to 6.2 kWh/m^2/day, as illustrated in Figure 7. GHI is the appropriate parameter for calculating electricity yield and evaluating the performance of flat-plate PV technologies. The direct normal irradiance (DNI) is between 5.0 kWh/m^2 and 6.8 kWh/m^2. For the designs in the document, sunshine hours are considered 5.5 hours (per DNI) based on the country's geographical presence and climatic conditions in the tropical region.

Days of autonomy

Autonomy is the length of time a battery bank can support a specific load without charging. It is a value used to measure battery reserve capacity and system reliability. Autonomy enables the system to perform as required, even in rainy seasons and cloudy conditions, for specified days of autonomy and enhances battery life (depth of discharge [DOD] *vs*. cycle life). For the designs, a three-day autonomy has been considered for the DC solar energy system and a two-day autonomy for AC systems to operate the designed loads at the health facilities.

Solar PV panel considerations

The solar PV panel wattage is calculated using the energy required to operate the connected load, the available sunshine hours, and other parameters including battery charging, efficiency, load efficiency and dust factor. The PV panel calculation is as follows:

Panel wattage required = (Total energy required [watt hours]) /
(Sunshine hours x Battery charging efficiency x Load efficiency x Dust factor)

Battery considerations

The energy storage requirement is determined by the total energy needed for the load, its efficiency, days of autonomy and battery DOD. Lithium-ion batteries are preferred due to their 95% efficiency, faster charging and longer lifespan of 10-15 years, compared to 5-8 years for lead-acid batteries. They can be fully discharged without damage and offer a higher energy density, making them lighter, more portable and cost-effective by reducing replacement frequency and logistical costs.

Battery capacity required = (Days of autonomy x Total load in watt hours) /
(Load efficiency x System voltage x DOD x Discharging efficiency)

Solar inverter

The solar inverter is chosen based on the power consumption and type of connected load, as well as the capacity of the solar energy system and the battery bank voltage.

Table B.1 **Assumptions for solar energy system design**

Assumptions for solar energy system design	
Battery type	Lithium-ion
Load efficiency	80%
Charging efficiency	95%
Dust factor	90%
DOD	90%
Discharging efficiency	90%
Temperature co-efficient	0.8
Autonomy	
DC systems	3 days
AC systems	2 days
Sunshine hours	5.5 hrs
LOLP	Likelihood that a system will not be able to meet the load demand, expressed in %, under each system design (Health Centres and higher in Chapter 5).

Notes: AC = alternating current; DC = direct current; DOD = depth of discharge; hrs = hours; LOLP = loss of load probability.

APPENDIX C: ACTIVITIES TO BE CARRIED OUT DURING ANNUAL SERVICE VISITS

Table C.1 **Activities to be performed (components)**

Activities to be performed (components)		
Panels	**Inverter/power conditioning unit (PCU)**	**Battery bank**
Cleaning of solar panels and keeping them free from dust grime (droppings, leaves and lichens)	Ensuring inverter displays all parameters	Checking battery health (string/individual) (load testing)
Verifying the physical condition of the panels (at the front and rear sides) from any possible external interferences (man, animal, nature)	Verifying inverter has no faults displayed	Checking the battery's physical condition (body damage, terminal damage)
Verifying the stability of the panels with MMS & roof (clamping torque check, MMS-roof gripping strength, civil work, MMS stability and damages)	Verifying inverter configurations are set per the instructions	Checking cable (connectivity damages)
Verifying there are no shadow causing objects around (if so, they are to be eliminated or panel relocations required introducing Module Level Power Electronics(MLPE)	Verifying inverter inputs lines are connected	**Changeover switches**
Verifying and analysing the panel output power with respect to its designed capacity	Verifying inverter input power lines show normal values and are free from faults	Verifying the functionality
Verifying whether the panel's cable connectivity is at maximum and if cables are protected from external damages	Verifying inverter isolators box (Miniature Circuit Breaker (MCB) fuses, cable enclosure condition and connectivity)	Verifying the input & output lines
Checking the solar cables for any possible electric damages	Verifying inverter has no physical damages and is kept dust free	Checking the solar positioning of the switches
Verifying the Array Junction Box (AJB) setup MCB, Surge Protection Device (SPD) cable & enclosure condition and connectivity)	Verifying inverter room has active ventilation	**Cables**
General Purpose Interface Bus (GIPB)/AJB/ Direct Current Combiner Box (DCCB)	Verifying inverter room has no flammable materials stored.	Verifying cable connectivity
Verifying connection status	**Load side**	Verifying end termination contacts
Checking for any damage to the box	Verifying only the specified critical loads are connected to system	Checking for cable damage
Verifying SPD MCB & fuse condition functionality & positions	Verifying the discipline in power consumption at the Centre	Checking cable protections
Earthing protection	Verifying no new lines are tapped from solar lines	**Lightning arrester**
Verifying connectivity status with equipment and earth pits	Verifying all critical loads receive solar-battery-grid-generator power	Verifying the physical stability of the set up
Verifying physical condition of the pits	Verifying all critical loads installed are functional	Verifying the connectivity status with earth pit

Verifying the resistance of the pits	**Orientation**	Checking for any damage
Warranty cards	Provide a quick orientation to staff on basic maintenance & operations practice	
Ensuring the staff is maintaining the warranty cards/ documents	Listen to staff feedback and address it	
	Share updated contact details with staff	

Notes: MMS- module mounting structure, MLPE - Module Level Power Electronics, AJB - Array Junction Box, MCB- Miniature Circuit Breaker, SPD - Surge Protection Device, GIPB –General Purpose Interface Bus, DCCB - Direct Current Combiner Box

Issue resolution process classified based on chargeable and non-chargeable services

Table C.2 **Issue resolution process (example**

Issue	Chargeable	Process
Technical component-wise issues (except issues related to man-made or animal interventions and natural calamities) within the product warranty duration	Non-chargeable service	Vendors need to visit the facility and replace/repair/service the product and fix the issue/repair/replacement.
Man-made issues like theft vandalism, stone-pelting, overload wall or roof seepage, *etc.*	Chargeable service	Vendors need to visit the facility, inspect the issue and submit quotations for the necessary service/repair/replacement. The health department concerned needs to make 100% payment directly to the vendor before or after the service.
Issues arising from natural calamities like thunderstorms, heavy lightning, floods, heavy wind, *etc.*	Chargeable service	Vendors need to visit the facility, inspect the issue and submit quotations for necessary service/repair/replacement. The health department concerned needs to make 100% payment directly to the vendor before or after the service.
Shifting issues (partial or full) – same room, same premises, other building/premises	Chargeable service	Conduct the site assessment and certify the fitness of the proposed building/premises for shifting or propose alternative solutions. Vendors need to submit quotations for shifting of required solar/electrical equipment per requirements. The health department concerned needs to make 100% payment directly to the vendor before or after the shifting service.
Completion of warranty of the solar/Energy Efficient Medical Equipment (EEME) products	Chargeable service	Vendors need to visit the facility, inspect the issue and submit quotations for necessary service/repair/replacement. The health department concerned needs to make 100% payment directly to the vendor before or after the service.
Rectification done by third-party or external agencies other than the concerned vendor (including opening and servicing of critical components like inverter solar panels, battery tampering, internal or external wirings)	Chargeable service	Vendors need to visit the facility, inspect the issue and submit quotations for necessary service/repair/replacement. The health department concerned needs to make 100% payment directly to the vendor before or after the service.
Growth of tree branches and visible instances of tree shade observed on the solar panels	Chargeable service	The health facility concerned needs co-ordinate with relevant stakeholders to remove the tree branches and allow the panels to generate and store sufficient energy. The health department concerned needs to make 100% payment and depute manpower to perform the necessary services.

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