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"Power for Health" Masterplan for Malawi
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We would like thank our local partners, Mr. Charles Chibambo and Mr. Hilton Msamali for their support and valuable inputs in course of the load assessments and stakeholder consultations.

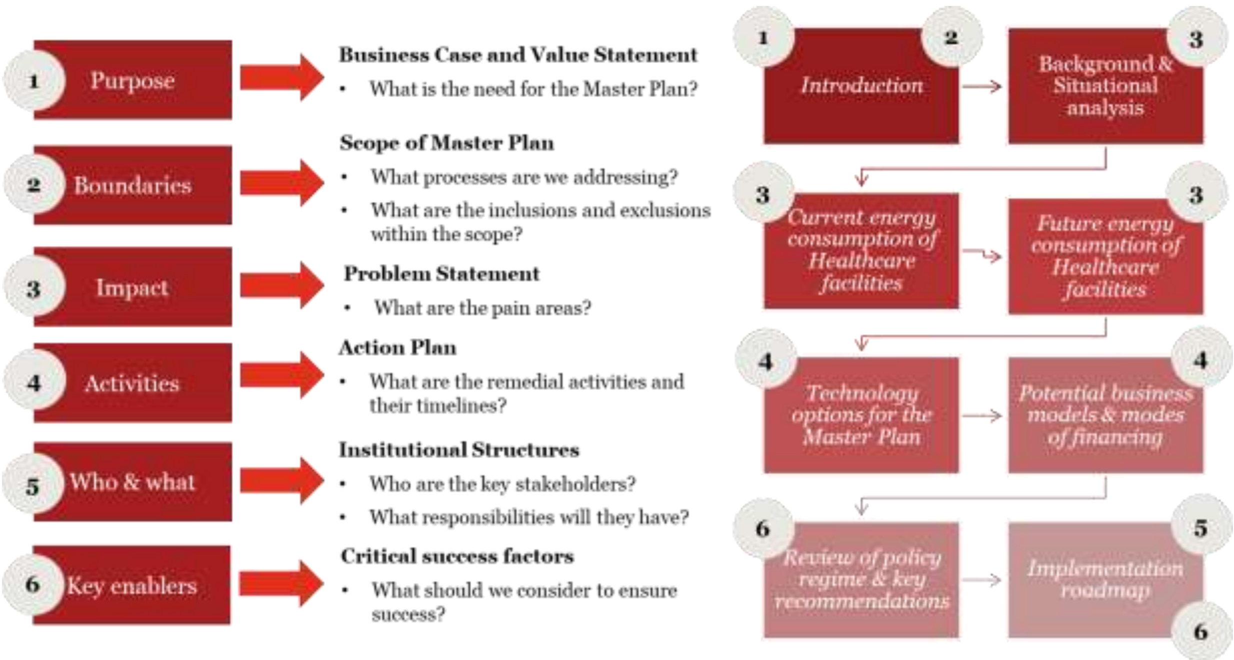
Executive Summary

This document details the guiding principles, institutional framework, operating models and implementation roadmap for the ***'Power for Health' master plan*** proposed by the Ministry of Health and Population, Malawi. It seeks to establish a specialist function, called the 'Energy Services Management Unit' within Ministry of Health and Population (with Malawi Electricity Regulatory Authority, ESCOM, Department of Energy, Ministry of Local Government, Ministry of Finance, Buildings Department and Health Sector Task team as its most important stakeholders), which would be responsible for delivering the Master Plan, managing the dedicated staff to include specialist manpower and liaise with development partners to ensure the most optimal utilization of resources provided by them. It is expected that its recommendations will be used to guide the implementation process for Renewable energy and energy efficiency implementation in health sector in Malawi over the next 10 years (2018-2028).

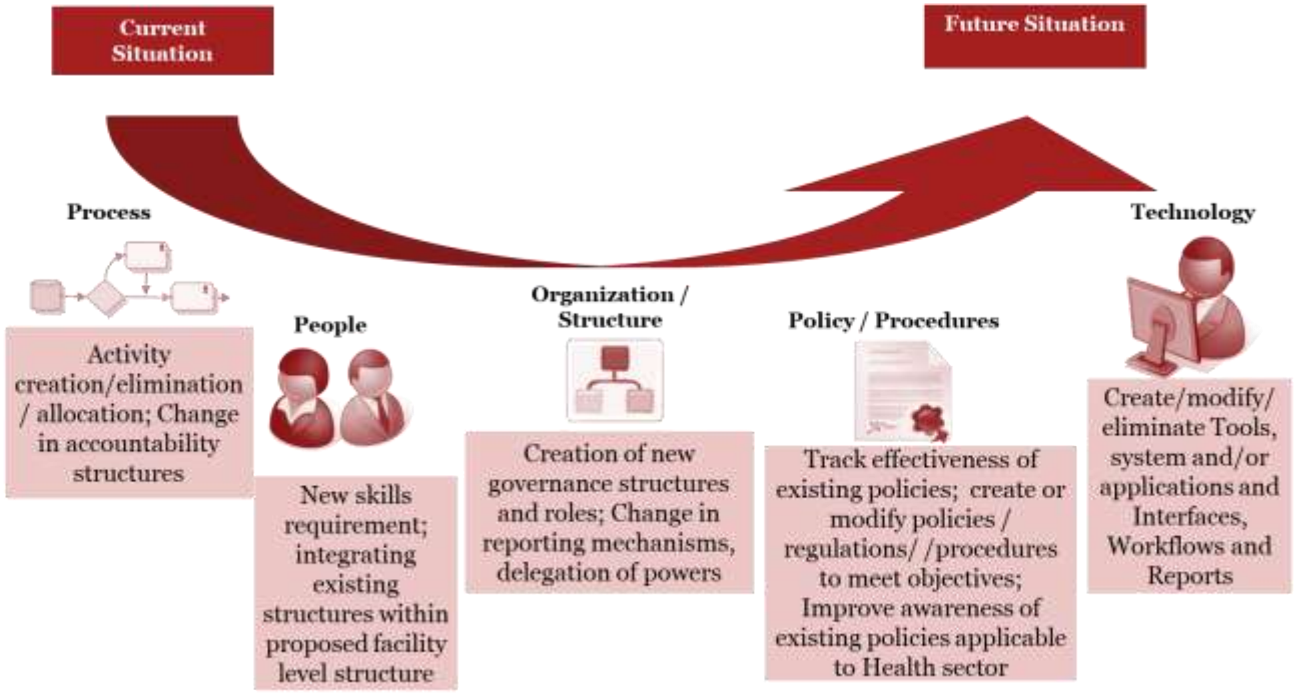
Specifically, the "Power for Health" Master Plan provides:

- Situational analysis, existing institutional framework for Healthcare and Energy sector and energy situation in healthcare facilities;
- Overview of current energy demand of Healthcare facilities including options for meeting electrical and thermal energy demand, drivers of demand and current usage patterns;
- Overview of future energy demand – assumptions used to estimate the future demand, forecasted demand and their alignment with government plans for healthcare sector;
- Sustainable energy / technology options for meeting future energy demand;
- Potential business models and modes of financing;
- Policy recommendations;
- Implementation roadmap including institutional framework, goals and timelines, funding requirement and financing options;
- Annexures containing backup data.

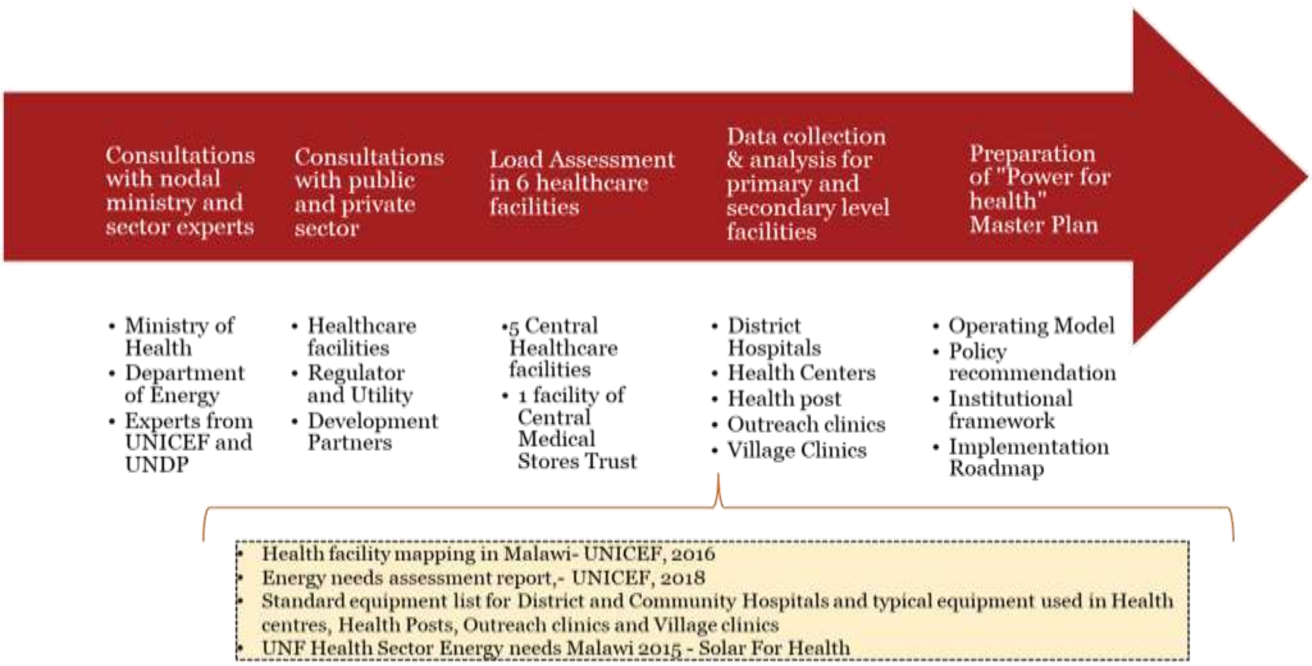
To contents of the Master Plan have been focused according to a well-defined structure presented below. The key elements and the Chapters, in which they have been covered are presented in the infographic below.



The Master Plan envisages multiple dimensions of change as depicted below:



The preparation of the Master Plan consisted of five phases, which are presented in the infographic below:



A total of twenty five (25) meetings and 6 load assessment studies in healthcare facilities was carried out from September 10th, 2018 to October 23rd, 2018 in Malawi. A national level workshop was carried out among the key stakeholders to elicit feedback and incorporate the same into the draft for finalization. The key outcomes of the load assessments, stakeholder meetings and National Workshop and the recommendations are given below.

Energy situation in the Healthcare sector of Malawi in a state of disrepair; Long term planning crucial to address chronic issues

Access to modern energy services is very limited in Malawi with only 10% of the country's population connected to the national grid and distribution system, almost entirely limited to urban and peri-urban areas. The installed generation capacity falls short of the demand and consequently power quality and reliability are major issues. The power deficit issue is compounded by high transmission and distribution system losses (17%) and an over-reliance on hydro energy for power generation. The electricity tariffs in Malawi are not cost-reflective, which poses an entry barrier for the market penetration of renewables. In the healthcare sector, 59% of the facilities enjoy regular electricity from the Grid as on 2013-14. Progress of grid connection has been slow and there is a need for clear demarcation on facilities, which would be powered through grid extension and otherwise.

Resource constraint is a theme that cuts across all tiers of healthcare facilities in Malawi; Recovery of costs and greater accountability of beneficiaries key to greater sustainability of interventions

The Government of Malawi has maintained a commitment to provide ***free healthcare at the point of access***. Since 2004, Malawi has implemented an EHP (Essential Health Package) containing cost-effective interventions, which are delivered free of charge at the point of use to Malawians. However, this ***presents financial implications for healthcare facilities, which would only increase over the next 10 years as the population grows***. This underscores the need for future interventions to be based on a sound business case, in which the accountability on the part of beneficiaries (healthcare facilities) is also ensured.

Commendable efforts made by International Development Partners in providing financial support to the Healthcare sector; Lack of coordinated effort for programmatic interventions led to missed opportunities

An analysis of the performance of the earlier programs reveals that while the quantum of financial support provided by development agencies and their handholding during the installation phase was commendable, it was done in isolation from other concurrent programs. At present, there are multiple stakeholders with mandates governing the provision of energy services to healthcare sector and the likelihood of overlapping responsibilities is high. Clear demarcation of roles and responsibilities and greater co-ordination across key stakeholders could go a long way in creating synergies for the master plan by optimizing investment and ensure continuing success across its 10 year time horizon.

National policy on decentralization of power to district level a welcome move; Greater empowerment of District Health Offices crucial for ensuring progress at district and sub-district levels

A new government policy on national decentralization has been approved in order to devolve administrative authority to the district level. Even at the central Level, efforts are underway to enable autonomy of the Central Hospitals. Going forward, the DHO will have the responsibility for the management of all health services in the district. District Health Management Teams (DHMTs) are accountable to the District Assemblies for decisions on financial planning and expenditures. Considering this, the involvement of District Administration representatives in the Energy Services Management Unit has been proposed.

Programmatic Interventions need to transition from an 'equipment based operating model' to a 'Service-based operating model'

Past programmatic interventions related to energy provision in the healthcare sector facilitated installation of energy generation/saving equipment using grants, without institutionalizing a proper post-implementation support system for service, maintenance and spare part provision. In general, such interventions were not able to inspire accountability on the part of the healthcare facilities. Consequently, the installed equipment witnessed premature failure and the programs could not meet their stated objectives to a sustainable manner. 'Service based operating models' which offer the output (e.g. electricity) as a service based on performance contracts that meet a clear standard of delivery present an attractive proposition by greater process control in the implementation and post-implementation stages.

Analysis of the performance of past interventions reveals gaps in technical, procedural and management related aspects

On many occasions, equipment design and performance was less than adequate due to poorly defined tender specifications, non-compliance with tender and weak quality assurance. At the facility level, a need for following a standard process was felt in the implementation and post-implementation stages, with poor data management, inadequate safety measures and skill shortage emerging as core issues. At the macro level, processes related to governance, procurement, contract management and budgeting were largely absent.

Load assessment in 6 Central Healthcare facilities revealed significant scope for improving on the system design and O&M front; Energy supply and distribution at facility level is saddled with inefficiencies and in need of refurbishment

Poor load matching, improper system sizing, improper battery sizing, disregard to safety related aspects, poor data management, lack of proper hand-over, lack of skills for O&M, under-utilization of installed solar PV systems and significant share (on an average 27%) of non-functional equipment were common issues observed across all the surveyed facilities. These observations validated the gaps identified through secondary research.

The existing energy supply infrastructure at facility level is in a poor state across all the surveyed hospitals. The Diesel Generators are operating very inefficiently and found to be consuming a higher quantity of diesel per unit of electricity generated. On the power distribution front, healthcare facilities were found to perform poorly with regard to maintaining Power Factor. Current imbalance was observed to be a common issue.

Energy Efficiency and Renewable Energy interventions found to have a strong and robust business case

For energy efficiency measures, the financial analysis involved calculation of the yearly energy savings, which was multiplied by the cost of energy to arrive at cost savings. The cost savings with respect to the baseline was used to calculate the Simple Payback period. The financial analysis has incorporated the costs of integrating the proposed systems into the existing systems. The recommended Renewable energy and Energy Efficiency measures were found to be techno-commercially attractive in all 5 central hospitals and 1 central medical stores trust.

Name of healthcare facility	Total Investment required for EE (MK million)	Total Annual monetary savings (MK million)	Simple payback period for all recommendations combined (months)
Mzuzu Central	39.3	22.4	21
Kamuzu Central	119.1	55.2	26
Zomba Central	25.9	21.3	15
Zomba Psychiatric	15.4	6.8	27
Queen Elizabeth Blantyre	80.4	28.9	33
CMST	24.2	10.1	29

Significant scope for load reduction was identified through implementation of EE measures. EE measures were found to have quick paybacks and save the facility a significant amount on their current energy bills. This cements the case for inclusion of energy efficiency and demand side management measures as a part of the master plan. To address the issues of low power factor, it is recommended to install Automatic Power Factor Correction systems in the health facilities and for current imbalance in the distribution system, evenly distributing electrical loads across three phases is recommended. With regard to Diesel Generators that are used as backup systems in health facilities, the load assessment identified substantial scope for improving the Specific Electricity Generation ratio (SEGR) i.e. number of units of electricity provided by DG for consumption of one litre of diesel. This would require overhauling of DG sets.

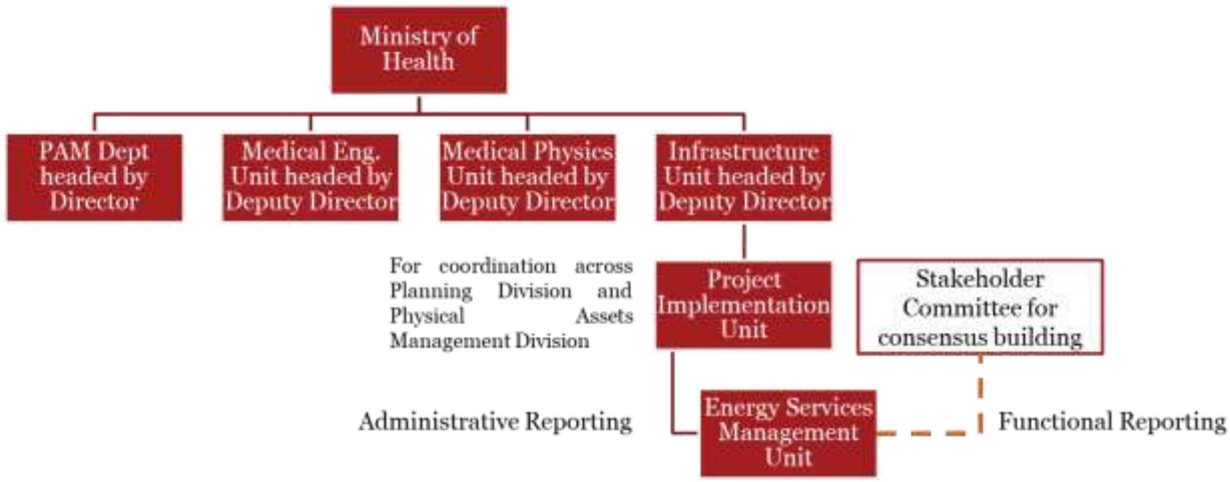
Name of healthcare facility	Total Investment required for RE (MK million)	Total Annual monetary savings (MK million)	Simple payback period for Solar PV generation systems (Years)
Mzuzu Central	1012	66.4	15
Kamuzu Central	971.6	69.2	14
Zomba Central	532.9	57.9	9.2
Zomba Psychiatric	639.1*	103.8*	6.2*
Queen Elizabeth Blantyre	1047.1	81.8	12.8
CMST	298.4*	39*	7.7*

* refers to Grid connected systems without battery

As with Energy Efficiency measures, the Renewable Energy Measures are also found to be techno-economically feasible in the prevailing market conditions with payback periods ranging between 6 to 15 years. The Project Internal rate of return (Project IRR) for the Renewable energy projects, i.e Solar PV systems is estimated at 12.11% and the equity IRR is estimated at 15.47% with a Viability Gap Funding of 61.25% of the project cost. The payback period of the Solar PV systems with Battery storage is estimated to be 8.6 years.

ESMU can comprehensively address the challenges encountered in earlier efforts

Currently, the decision-making structure for provision of power to the healthcare sector is complicated by a multiplicity of players that have a role in key decisions. MoH urgently needs to enhance its capabilities in project management and donor-aid coordination. The information sharing is relatively good within government ministries, but less so between ministries. Equipment donations, or procurement with donor funds, are not in line with national needs and standards, and rarely include budgets for maintenance, infrastructure needs or training. The capital investment rate has been very low, at only 5.4 % of total health expenditure (THE) is not in alignment with the level of health spending. There are systems for sharing some forms of information (consumption and generation) but this is not fully functional. In addition, there is lack of a common platform for posting and sharing power sector information leading to lack of transparency and accountability.



The Energy Services Management Unit (ESMU) is envisaged as the implementation arm for energy service provision to healthcare facilities in Malawi and ***would have technical, project management, Information technology, public relations, fund advisory and contract management capabilities***. It is proposed to be led by a steering committee which can have representation from MoH&P, ESCOM, MERA, DoE, District Administration, Ministry of Finance and Technical Working Group for Health Sector Finance. Subsequent to its mobilization, the ESMU is expected to carry out surveys and make recommendations on the improvements/augmentation required on the supply-side infrastructure of the ESCOM and make recommednations on designing systems on the demand side.

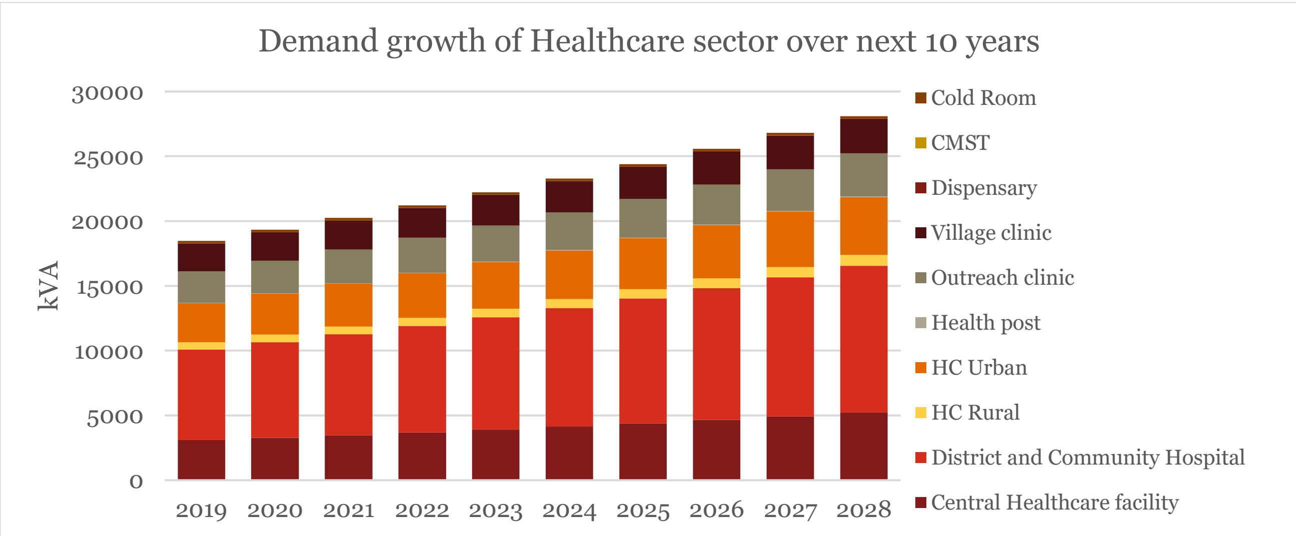
Owing to the reliance of healthcare facilities on electricity for both electrical and thermal energy needs, poor reliability and quality of power is observed to substantially restrict demand

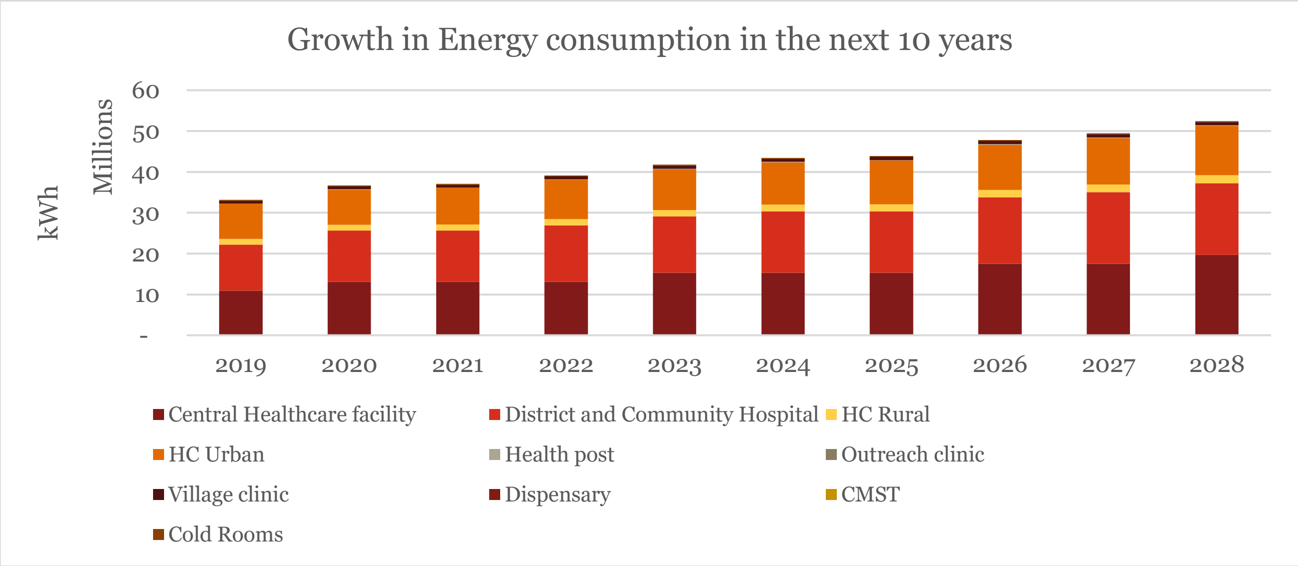
Healthcare facilities meet their electrical as well as thermal energy needs using electricity, which majorly comes from grid and partly from diesel generator sets. At present, the demand is restricted due to poor reliability of power as well as non-functioning equipment. An analysis of the energy use shows a significant jump in the energy demand when the reliability of power supply is increased from the current levels.

The increase is found to be the most pronounced (16%) for Central healthcare facilities. This shows that the extent of unmet demand due to poor reliability is highest in Central healthcare facilities. In addition to switching to alternate methods of generation, it is important to manage the energy demand better and that the equipment used within the healthcare facilities be replaced with their energy efficient versions.

Energy demand projected to reach 28 MVA by 2028, the final year of the master plan

The energy demand modeling of the healthcare sector estimates the demand of the healthcare sector to increase to over ***28 MVA by 2028, the final year of the master plan***. ***The share of District and Community Hospitals is expected to be the highest among all other type of healthcare facilities***. The master plan seeks to equip the healthcare sector with the necessary renewable generation systems to meet the future demand comprehensively.





Given that a significant share of this demand would be met by renewable energy systems, the capability of the Malawian electricity grid to accommodate renewable generation is a real concern. A recent study on grid capacity indicated that ***renewables developments of 15 to 17MW could be accommodated across the network up to a maximum total capacity of 70MW***[1]. Assuming that the adoption of renewable energy will be at a fast pace in the residential and commercial sectors as well, MERA and ESCOM would need to conduct detailed technical studies to understand the impact of renewable penetration on the electricity grid.

Solar PV generation systems, Solar Water heating systems, Biogas generation systems, Solar Direct Drive refrigerators and Solar Lanterns evaluated as feasible technology options for energy service; Energy Efficient Air Conditioners, Energy Efficient Fans and Energy Efficient Lighting among other options for reducing energy consumption

The Master Plan aims to deploy different technology options for different categories of hospitals. These technology options would be the cross-cutting technical interventions (a combination of energy efficiency and renewable energy technologies), which the master plan would support by making budgetary provisions.

Central Hospital, District and Community Hospitals			
Solar PV systems	Solar Water heaters	Biogas systems	Waste heat recovery from Incinerators

Health Centre		
Solar PV Generation systems	Biogas systems- Urban health centers	Solar Water Heater systems

Health Post
Solar PV Generation systems

Outreach clinic and Village Clinic
Solar Lantern

Dispensary and Sub-district cold rooms	
Solar Direct Drive Refrigerators	Solar Lantern

[1] Draft Malawi Renewable Energy Strategy 2015

Standalone devices have been recommended for the primary level facilities as their demand is low and requirements are very basic. Moving up towards the tertiary healthcare facilities, the energy demand and diversity of equipment used increases, so Solar PV generation systems are, inter alia, recommended as a technology option.

For the critical healthcare facilities i.e the Central Hospitals, it is recommended to have a dedicated ESCOM feeder and amendment in the grid code to guarantee power supply for designated number of hours per day. It is recommended that storage facility be mandatorily included in proposed solar photovoltaic systems even they are grid interactive. Storage system with grid interactive solar photovoltaic systems will ensure uninterrupted power supply during power outage and reduce the impact of fluctuating solar power on the grid.

Build Own Operate (BOO) and Conditional grants model recommended for electricity related interventions; for thermal interventions, Supplier's Credit/ Shared savings model and Energy supply contracting (ESA) model are recommended

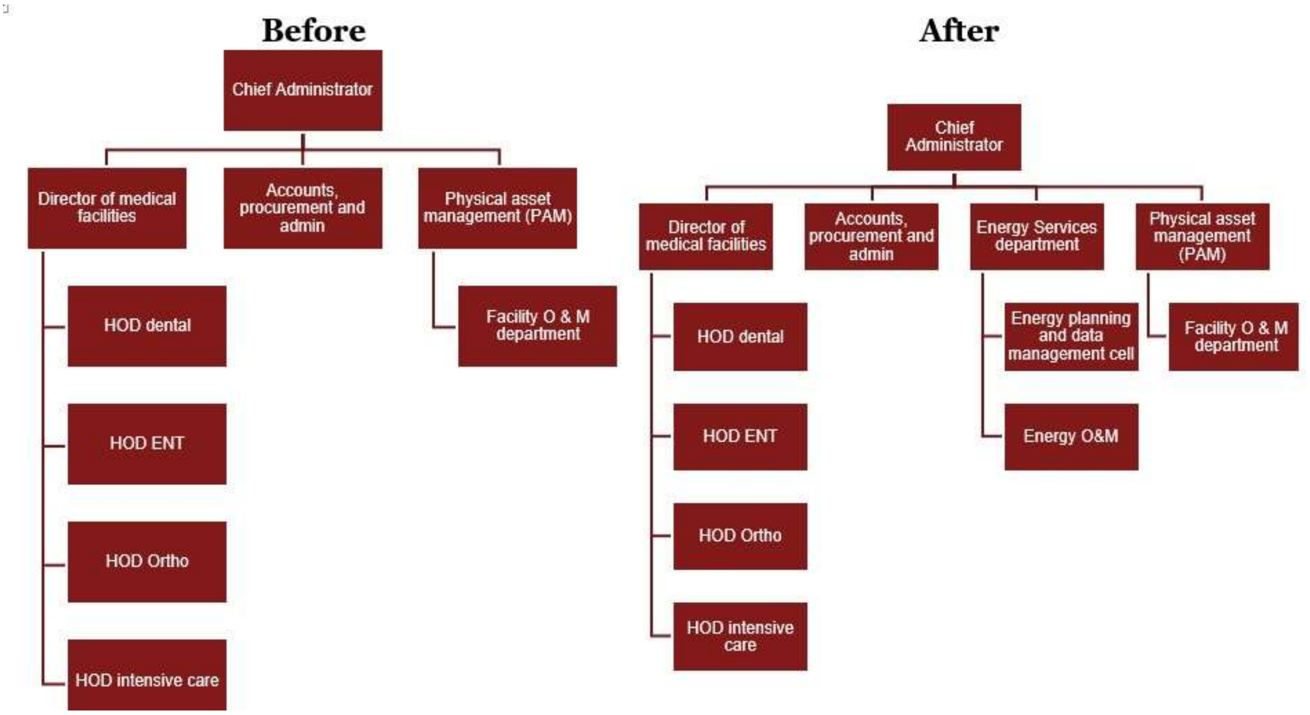
The business models recommended as a part of the master plan attempt to provide energy efficiency and renewable energy as a service rather than in the form of only equipment, which has been an important reason why previous programs for energy access have not been able to create lasting impact. A conscious effort has also been made in the design of business models to bring about greater participation of the private sector in the development agenda of the Government of Malawi, which would bring in skills as well as efficiency that is greatly missing in the present set-up.

Introduction of National Mini-grid policy and Net metering regulations recommended on the policy front

The objective of the National Mini-grid policy would be to promote the deployment of micro and mini grids powered by RE sources such as solar, biomass, Pico-hydro, wind etc. in un-served and under-served parts of the country by enabling participation of RESCOs. Net metering regulations would apply to the Distribution Licensees, eligible consumers of the Distribution Licensees and third party owners of net metering arrangement of rooftop solar PV system in Malawi. The objective of such regulations is to ensure that the ***surplus power that is produced by captive generation systems in healthcare facilities can be sold back to the grid to earn revenue***. To enable a transition towards renewables based on a sound business case, net metering is very important. Therefore, ***it is recommended that the Government of Malawi conduct detailed techno-commercial studies to enable the launch of net metering regulations in the medium term (by end of 2020)***.

Organizational structure change recommended at facility level for Central, District and Community Hospitals and health centers

It is proposed to create a ***new department at the health facilities, called the Energy Services Department, which would report to the ESMU***. The change in the organizational structure is presented below:



The Energy Services Department would have the following capabilities:

1) **Energy Planning and Data management cell:** This team shall comprise of supervisory staff to maintain the inventory of working and non-working energy generation equipment including Renewable Energy generation equipment and back-up power assets.
2) **Energy O&M:** This team shall comprise officials trained and certified by the ESMU who shall report to the Lead supervisor of the Energy Planning and Data management cell. For the sub-district level healthcare facilities, the terms of procurement of equipment such as Solar Panels, Refrigerators and Solar Lanterns would require the vendor to provide extended on-site warranty and maintenance services on call.

Training at capacity building of facility level manpower on RE and EE technologies to be a crucial component of the Master Plan.

Training and capacity building of the facility level manpower (existing and proposed) would be a key mandate of the ESMU. Therefore, it is recommended that the ESMU carry out training and refresher courses for all categories of health facilities in all the 10 years of the Master Plan. Presently, undergraduate and specialized courses are offered by the University of Malawi and the Malawi University of Science and Technology (MUST) and MoH&P provides scholarships to its staff for the same. In collaboration with the Ministry of Education, the ESMU shall refine and enhance the existing courses to align them to the requirements of the master plan.

Total ESMU budget for 10 years is estimated at USD 214.24 million

The total ESMU budget for 10 years is estimated at USD 214.24 million, which shall be further used for preparation of the District Implementation Plan, which would govern the budget for various districts under the master plan.

Cost head	Modality of Investment	Total budget (USD)	Budget implication for ESMU (USD)	Budget implication for other partners (USD)
Capex- Solar Generation system	80% as concessional debt from pooled fund of MoH&P	61,384,869	49,107,895	12,276,974 (for RESCO that participates in

Cost head	Modality of Investment	Total budget (USD)	Budget implication for ESMU (USD)	Budget implication for other partners (USD)
(Renewable Energy Measure)	20% from RESCO equity			competitive bidding)
Capex- Solar Water Heater *(Energy Efficiency Measure)*	80% as concessional debt from pooled fund of MoH&P 20% from ESCO equity	11,592,000	9,273,600	2,318,400 (for ESCO that participates in competitive bidding)
Capex- Solar Lanterns *(Renewable Energy Measure)*	100% Grant (conditional) from pooled fund of MoH&P	39,864	39,864	-
Capex- Solar Direct Drive Refrigerator *(Renewable Energy Measure)*	100% Grant (conditional) from pooled fund of MoH&P	3,633,000	3,633,000	-
Capex- Biogas generation systems *(Renewable Energy Measure)*	80% as concessional debt from pooled fund of MoH&P 20% from ESCO equity	147,287	117,829	29,457 (for ESCO that participates in competitive bidding)
Capex- Waste Heat Recovery from Incinerator *(Energy Efficiency Measure)*	80% as concessional debt from pooled fund of MoH&P 20% from ESCO equity	46,000	36,800	9,200 (for ESCO that participates in Competitive bidding)
ESMU manpower cost	Entirely met from ESMU operating budget	13,200,372	13,200,372	-
IT based Monitoring system & Dashboard/App	Entirely met from ESMU operating budget	100,000	100,000	-
O&M charges	Entirely met from ESMU operating budget	1,541,215	1,541,215	-
Dissemination charges	Entirely met from ESMU operating budget	50,000	50,000	-
Quality Assurance	Entirely met from ESMU operating budget	1,320,037	1,320,037	-
Training and capacity building	Entirely met from ESMU operating budget	5,040,000	5,040,000	-
Manpower Cost of facility O&M dept	70% from ESMU operating budget and 30% by Human Resource Division of MoH&P	186,840,000	130,788,000	56,052,000 (For Human resource Division of MoH&P)
Total		**284,934,644**	**214,248,613**	**70,686,031**

Out of the total budget for capital expenditure for the ESMU, ***the share of Renewable Energy systems and Energy efficient systems is USD 52,898,589 and USD 9,310,400 respectively.***
It is further estimated that the equity required to be contributed by the RESCOs that participate in the competitive bidding would be USD 12,276,974 for works to be executed in the entire 10 year duration. Similarly, the equity

contribution from ESCOs that participate in competitive bidding for implementing Biogas, Waste heat recovery systems and Solar Water heating technologies is estimated at USD 2.3 million.

In addition to the line items mentioned in the table above, there are certain other line items for which the ESMU would need to determine the costs in discussion with the relevant stakeholders. Few such areas are provided below:

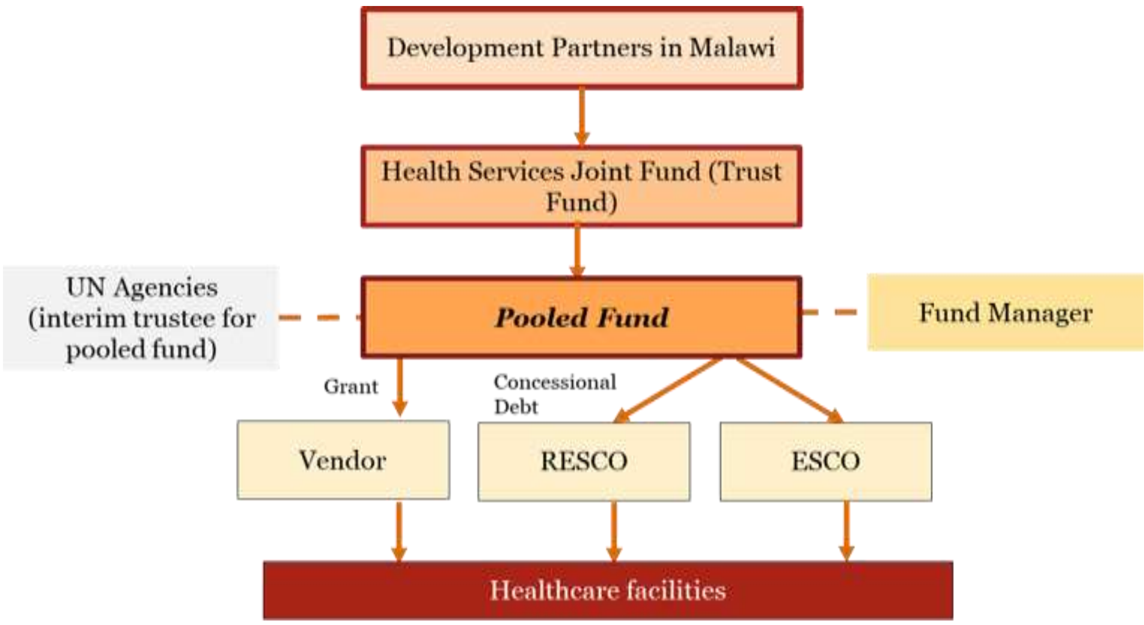
- Cost of carrying out Load assessment in District and Sub-district level facilities
- Cost of refurbishments in the distribution systems in District and Sub-district level facilities for improvement of power supply condition including uninterrupted supply and improvement of quality of power through management of reactive power and total harmonic distortion (TDH).
- Cost of Fund administration of Pooled Fund
- Cost of augmentation of grid on supply side for the healthcare facilities

Pooling of funds from various Development Partners recommended for meeting the stated objectives of the Master Plan; Funds to be disbursed as Concessional Debt to RESCOs/ESCOs and Conditional Grants to the health facilities

Presently the funding needs of the health sector in Malawi for infrastructure as well as payment of energy bills are being met through the Health Services Joint Fund, which has a trust fund structure. Given that the proposed pooled fund would also need to have capability and mandate to disburse debt, the pooled fund is proposed as a separate entity, for which UN Agencies can act as interim trustees until the Fund Manager is appointed.

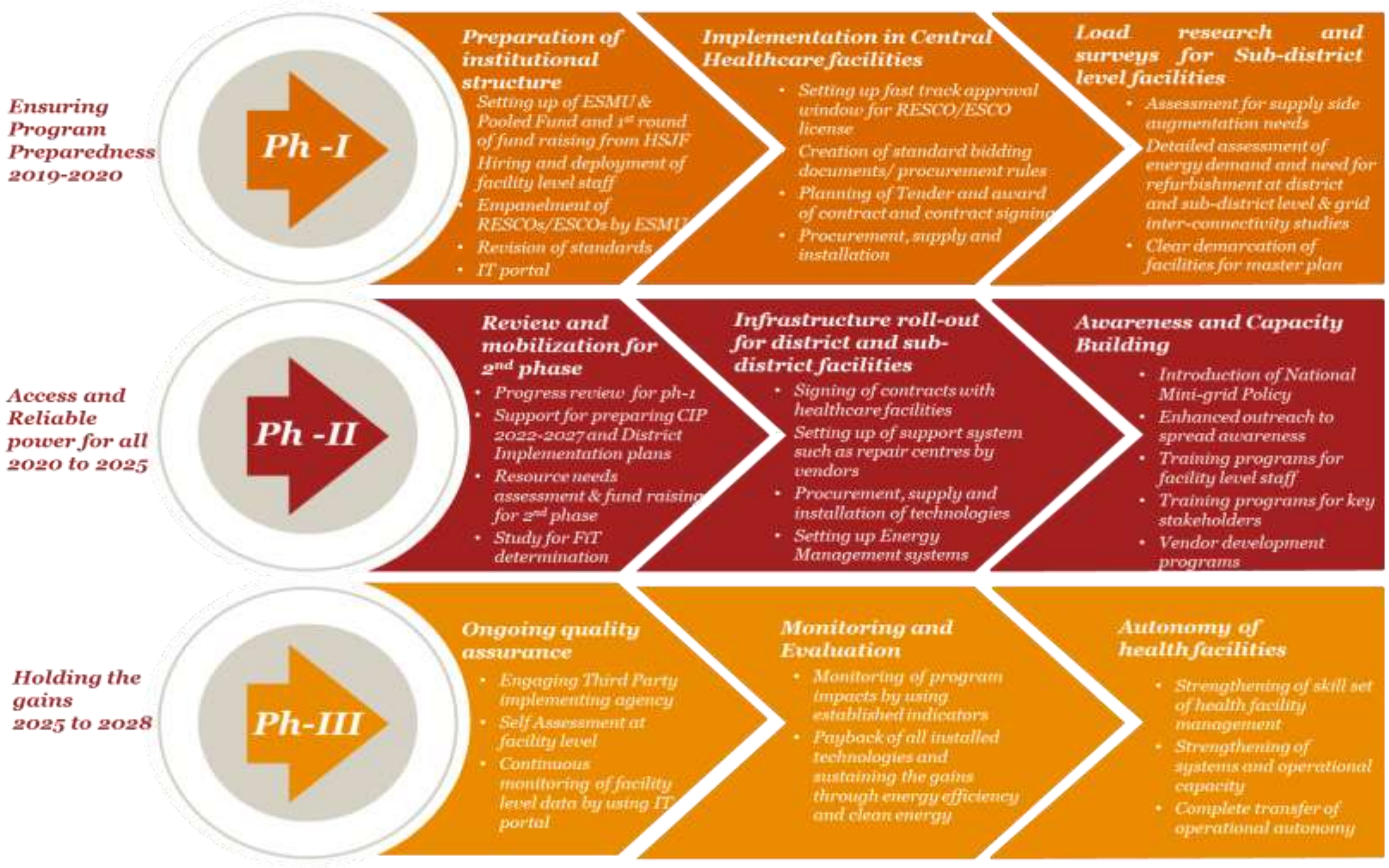
The operationalization of the pooled fund would involve the following steps:

- Development of Concept Note stating scope and purpose of the Pooled Fund, Theory of Change, financial and governance arrangements and demonstration of the financial viability (expressed or anticipated donor interest)
- Formal decision on the selection of Administrative Agent
- Development and Finalization of the Terms of Reference of the Pooled fund
- Signing of Memorandum of Understanding between MoH&P and Administrative Agent
- Standard Administrative Arrangements with the donors to receive contributions which they wish to provide.



The activities of the Master Plan have been divided into 3 Phases; 1st Phase would ensure preparedness to implement, 2nd Phase would focus on implementation and 3rd Phase would aim to sustain the benefits

The list of activities under each phase has been provided in the infographic below:



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1. Introduction

Malawi has made significant progress improving its health services over the past two decades with respect to life expectancy (improvement from 40.6 years in 1970 to 55.3 years in 2013), maternal health (Decrease from 1100 to 510 maternal deaths per 100,000 live births) and child health (drop in under 5 child mortality rate from 245 in 1990 to 68 in 2013). However, it continues to face a range of challenges in delivering universal health care, which could be attributed to ***insufficient financing, and inadequate infrastructure, equipment and human resources***. The Health of Malawians is a core pillar of development, as defined in the Malawi Growth and Development Strategy. The health sector is guided by the Malawi Health Sector Strategic Plan- II, which emphasizes "***increasing coverage of high quality essential health services and strengthening the performance of the health system to improve equity, efficiency and quality of essential health services across Malawi***".

The vision and mission set by government of Malawi for the health sector towards achieving universal healthcare are outlined below:

Vision

"To achieve a state of health for all the people of Malawi that would enable them to lead a quality and productive life."

Mission

"To provide strategic leadership for the delivery of a comprehensive range of quality, accessible, and efficient health services to all Malawians through the creation and sustenance of a strong health system"

The provision of energy services of high quality and reliability to healthcare facilities is of supreme importance to attain the Vision and Mission laid out for the health sector. However, with chronic power deficit, obsolete and non-functioning energy supply infrastructure in healthcare facilities, lack of skilled human resources, inefficiencies in governance structure and insufficient budgetary resources, the current state of energy services to the health sector has significant scope for improvement. Out of the issues faced by the health sector, ***the most critical issues are related to power supply as well as demand***:

- ***Supply-Demand Gap:*** The existing installed generation capacity of the country is 439 MW, as against a demand that is projected to reach 757 MW by 2020. The currently operating power stations are old and need revamping to operate at full capacity. To add to this, the energy generation is predominantly hydropower based and hence prone to seasonal fluctuation. Consequently, the frequency of blackouts and brownouts is also high**.**
- ***Inefficiencies in Transmission and Distribution:*** Weak transmission and distribution infrastructure is a constrain to the power supply. Electricity access to healthcare facilities stands at 59%.
- ***High growth rate of demand:*** With the burgeoning population (growth rate of ~5%) and high energy intensity of the equipment used in healthcare facilities, demand is growing at a fast pace and is widening the power deficit.

In the year 2013, direct budgetary support was removed and since then, the energy service infrastructure as well as medical supply chain has been in a state of disrepair. Many development partners have provided support through unilateral interventions. This has resulted in energy access programs of piece-meal nature and creation of multiple supply chains by many development partners (often without coordination with the Ministry of Health and Population or Ministry of Finance), each with their own management teams, logistics chains, storage facilities etc. While these isolated interventions have resulted in improvements, the aggregate investment has been much higher than what would have been required with a focused and coordinated effort.

The Government of Malawi has maintained a commitment to provide ***free healthcare at the point of access*** and has been a torchbearer to the other developing countries of Africa and the world. Since 2004, Malawi has implemented an EHP (Essential Health Package) containing cost-effective interventions, which are delivered free of charge at the point of use to Malawians. However, this ***presents financial implications, which would only increase over the next 10 years as the population grows.***

With energy costs forming a significant share of the operating costs of the healthcare facilities, a ***significant amount of monetary savings can be unlocked by addressing issues on the supply as well as demand side***. On the supply side, this would involve the expansion of the present generation capacity and on the demand side, it would require replacement of old inefficient equipment with new energy efficient equipment along with greater focus on energy management.

At present, there is a ***need to define a plan of action and set a clear policy directions to pre-emptively address the challenges*** that the healthcare sector is likely to face over the next 10 years and prioritize its activities. In response to this need, the Ministry of Health and Population and Population has enunciated a three-pronged strategy for the healthcare sector over the next 10 years. The key elements of this strategy as outlined by the Minister of Health and Population are illustrated below:

Figure 1 Key pillars of MoH&P strategy for 10 years

This document details the guiding principles, institutional framework, operating models and implementation roadmap for the first pillar i.e. the 'Power for Health' master plan. The 'power for health' masterplan seeks to establish a specialist function, which would be responsible for delivering the 10 year Master Plan (2018-2028), managing the dedicated staff to include specialist technicians and liaise with development partners to ensure the most optimal utilization of resources. It is proposed that the co-management setup includes representation from ESCOM (National Electricity Utility), MERA (National Electricity Regulator), Department of Energy (a key department of the Ministry of Energy and Mines), District Administration, Ministry of Finance and Ministry of Health and Population. In terms of its scope, the Master Plan would focus on the MoH&P controlled facilities only as they account for a major share (85%) of the healthcare facilities in number terms. The various categories of healthcare facilities included in the Master Plan and the present number of such facilities is provided in the table below:

Table 1 Categories of facilities included in the Master Plan

Type of Healthcare facility	Number of MoH&P controlled facilities
Central Healthcare facilities	5
District and Community Hospitals	42
Health Centers (Rural and Urban)	405
Health Posts	132
Outreach Clinics	3984
Village Clinics	3542
Dispensaries	41
Central Medical Stores Trust facilities	3

Source: UNICEF

It is expected that its recommendations will be used to guide the relevant government and private sector stakeholders regarding the implementation process for renewable energy and energy efficiency implementation over the next 10 years (2018-2028).

1.1. Methodology adopted for preparation of the Master Plan

The preparation of the Master Plan consisted of five phases, as shown below:

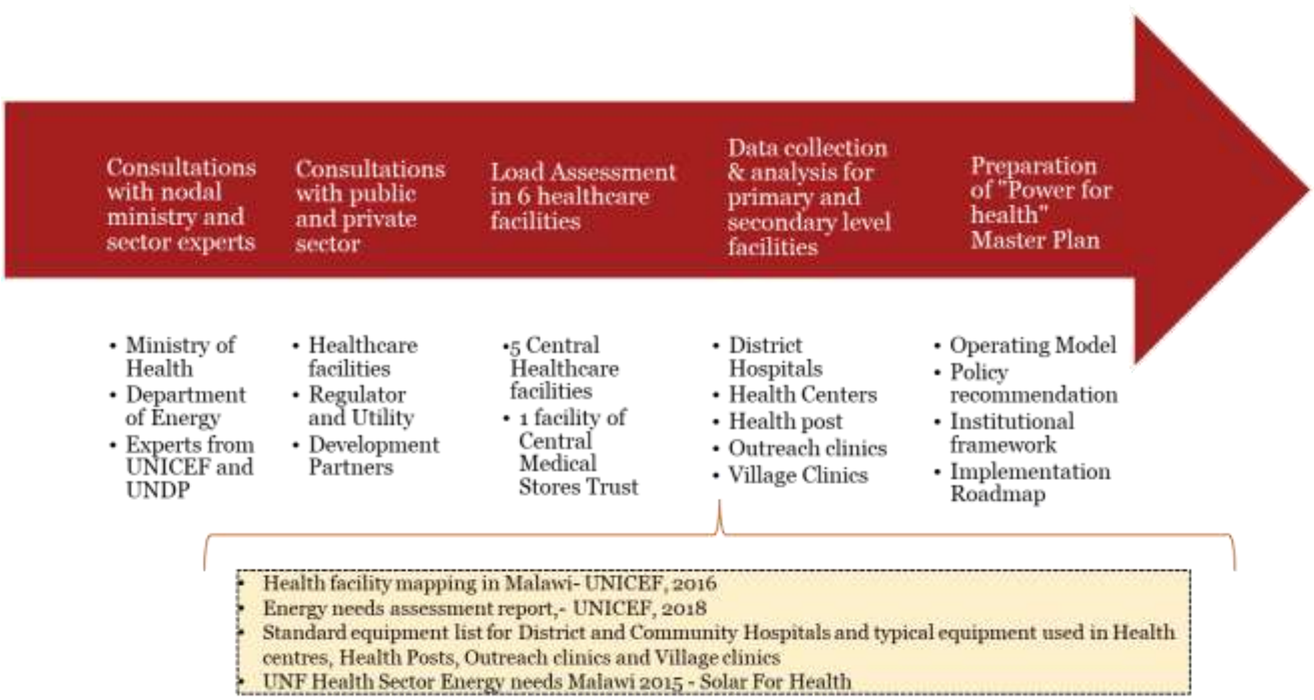


Figure 2 Phases in preparation of Master Plan

The data collection for the master plan has used a mixed-methods approach, which is a combination of primary (stakeholder consultations and load assessment) and secondary research. The recommendations provided in this study are a product of rigorous research, extensive consultations (25 meetings in total) with Ministries, public and private sector bodies and development partners and detailed on-site load assessment studies in 6 healthcare facilities (5 Central healthcare facilities and 1 facility of Central Medical Stores Trust) from September 10th, 2018 to October 23rd, 2018 in Malawi. The project team comprised of International Experts as well as Local experts, whose inputs were crucial in building a clear context of the on-ground realities. The key objectives of the load assessment were as follows:

Figure 3 Objectives of Load assessment

To assess the load of the facility, data related to inventory of energy consuming equipment across various departments of the facilities was gathered and the operating load and efficiencies were measured using portable instruments. Broadly, the equipment covered in the study included medical equipment (mostly laboratory equipment), information communication and telecom equipment (ICT) and utility equipment / building equipment. Utility equipment includes air conditioning, lighting, refrigerators, electric geysers, kitchen, laundry and other electrical and thermal utilities and electrical distribution system.

To understand the present and future energy load/ requirements of the facility, data on inventory of present energy consuming equipment along with future needs was collected through detailed survey of each facility and detailed discussion with facility personnel. While collecting the data, four broad categories of energy consuming equipment were identified at the facilities. The four categories, identified during energy load assessment are mentioned below:

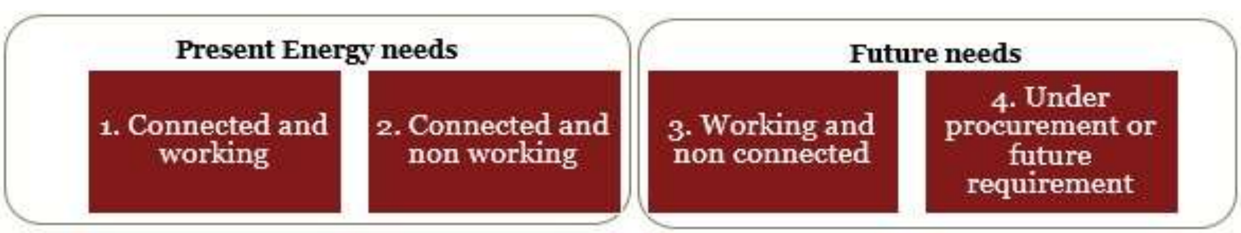


Figure 4 Categories identified during energy load assessment

The first two types of energy consuming equipment were considered for estimating present energy needs of the facilities, whereas type 3 and 4 is considered for estimating increase in future energy needs of the facilities. The steps in the energy load assessment execution included kick off meeting with the facility administration, data collection, performance assessment of energy consuming equipment, data analysis and preparation of energy load assessment report. The observations and recommendations of the load assessments and insights from the review of past interventions in the health/energy sectors in Malawi has been detailed in Chapter 2.

As a part of the secondary research, a review of past interventions in the health/energy sectors in Malawi and their strengths and weaknesses has been carried out. An excel based model has been created to estimate the current energy demand of the healthcare sector using secondary data and data from load assessments. To account for the quantum of demand that is restricted due to reliability issues, 2 scenarios, namely, restricted demand scenario and unrestricted demand scenario have been created. An overview of the key drivers of the energy demand, major energy consuming departments in various facilities, usage patterns and aggregate energy consumption (restricted and un-restricted) at sectoral level has been provided in Chapter 3.

Another excel based model has been used to estimate future energy demand for each year of the master plan's time horizon (2019-2028). The assumptions for modeling the growth of demand and the outcomes of the analysis have been presented in Chapter 4.

The Master Plan has sought to address the existing constraints (identified through literature and consultations) using two levers – namely, Technologies and Business Models. The technologies that would be provided budgetary support through the master plan have been selected for each of the categories of healthcare facilities on the basis of their requirements and scalability considerations. Subsequent to the selection of technologies, the choice of business models has been made to ensure enhanced participation from private sector and accountability from key beneficiaries. The recommendations on technologies and business models have been provided in Chapters 5 and 6 respectively.

Chapter 7 provides an analysis of the challenges and opportunities presented by the current policy and regulatory framework and recommendations on new policies that could be launched. Finally, Chapter 8 draws up the institutional framework, roles and responsibilities of different stakeholders and sets out the funding requirement, financing modes and the timelines for implementation.

While this study has made an earnest endeavor to build estimates of the needs of the entire health sector in Malawi, there are a few limitations, which primarily arise from the pre-defined scope of the assignment:

- This study has used the on-ground observations from the Load Assessments to build estimates of the energy consumption of the Central healthcare facilties and Central Medical Stores Trust Facilities. For the remaining category of healthcare facilities and Cold Rooms, the analysis has relied entirely on the data from previous studies carried out in the health sector in Malawi and fine tuned the same with the information from stakeholder consultations.
- The Master Plan limits its scope to only the Government owned health facilities in Malawi as they constitute a major share (85%) of the overall health sector in number terms. Facilities of CHAM and Private healthcare facilities are not included in the analysis.
- The creation and/or augmentation of the power supply infrastructure of the Electricity Grid in Malawi is not a focus area of the Master Plan and is to be taken up by the Energy Services Management Unit (ESMU) in detail, in coordination with the ESCOM upon commencement of implementation.

A national level workshop was conducted among the key stakeholders on 29th January, 2019 to elicit feedback and the same has been incorporated into the draft Master Plan for finalization. As the champion for this initiative, it is an earnest endeavor of the Ministry of Health and Population to develop the necessary expertise, capacity and resources to ensure that the health facilities are powered up effectively.

2. Background & Situational analysis

The Malawi Government, through the Ministry of Health and Population, has been building up its health service delivery system to address the needs of treatment and care of patients. In Malawi, health services and health outcomes continue to be severely impacted by unreliable energy services. This Chapter present an overview of the institutional structure of the Energy Sector and elaborates the key challenges that plague the energy sector. It then discusses the energy situation in the healthcare sector, strengths and weaknesses of past interventions and the complex challenges necessitating the creation of a Energy Services Management Unit.

2.1.1. Institutional structure in the Energy Sector

In Malawi, the nodal ministry for energy is the Ministry of Natural Resources, Energy and Mining (MNREM) under which the Department of Energy Affairs functions as a key constituent department. The **Department of Energy Affairs (DoE)** was established in 1992 as one of the three departments that constituted the then Ministry of Energy and Mining (MEM) along with the Department of Mines (DoM) and Department of Geological Surveys (DGS). After MEM was abolished in 1998, DoE was reconstituted under the Ministry of Natural Resources and Environmental Affairs (MNREA) in 1999. Currently DoE is one of the constituent departments of the Ministry of Natural Resources, Energy and Mining (MNREM). The Department of Energy Affairs has three core functions and these are as follows;

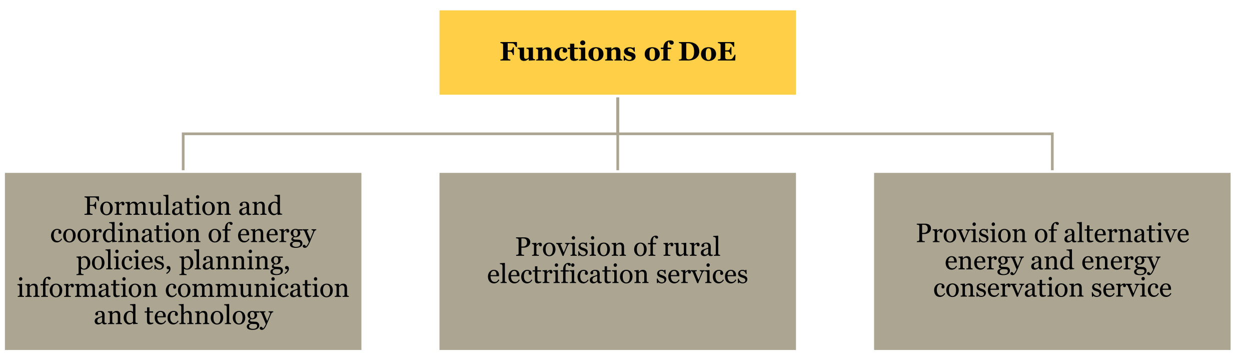


Figure 5 Functions of DoE

The following parastatal agencies function under the guidance of DoE, Ministry of Natural Resources, Energy and Mining:

a) **Electricity Generation Company Limited (EGENCO):** EGENCO is a limited liability company established with the mandate of generating electricity in Malawi. The Company was formed following the unbundling of the Electricity Supply Corporation of Malawi (ESCOM) Limited into two separate institutions; one for generating electricity (thus EGENCO) and another one for transmission and distribution (thus ESCOM). EGENCO started its operations as a separate and independent company on January 1, 2017. It operates 4 hydro power stations and 2 thermal power plants, rest from standby diesel power plants.

b) **Electricity Supply Corporation of Malawi (ESCOM):** The Electricity Supply Corporation of Malawi (ESCOM) is a limited liability company established under the Companies Act of 1984. The mandate of the Corporation is to procure, transmit and distribute electricity in the country and in some border towns for export to Zambia. It also operates the national electricity grid. Presently, ESCOM supplies electricity to customers categorized as domestic, general, commercial and industrial. ESCOM functions as the Single Buyer and System Market Operator. The role of the Single Buyer is to procure power and arrange payment for the power purchased while the role of the System Market Operator is to ensure fair access to the transmission network and to the electricity market.

c) **Malawi Energy Regulatory Authority (MERA):** It is a corporate body established under the Energy Regulatory Act No. 20 of 2004 as the energy sector regulator. The mandate is to regulate the energy sector in Malawi in a fair, transparent, efficient and cost effective manner for the benefit of the consumers and operators. MERA's work is predominantly focused on oversight of generation, transmission and retail of electricity within the national grid. MERA operates in accordance with Energy Regulation Act 2004 and the mandates in act relevant to the master plan include:
- Receive and process license applications for energy undertakings and Grant, revoke or amend licenses granted under the Act and Energy Laws;
- Approve tariffs and prices of energy sales and services;
- Monitor and enforce compliance by licensees with licenses granted under the Act & Energy Laws;
- Develop and enforce performance and safety standards for energy exploitation, production, transportation and distribution;
- Arbitrate commercial disputes under the Act and Energy Laws;
- Promote the interests of consumers of energy with respect to energy prices and charges and the continuity and quality of energy supply;
- Promote energy efficiency, energy saving, consumer awareness and education and promote the exploitation of renewable energy resources.

2.1.2. Overview of challenges faced by the energy sector

The energy-related challenges faced by Malawi are of a multi-dimensional nature with the current energy service infrastructure highly inadequate in terms of energy access, reliability and quality of power. ***Access to modern energy services is very limited in Malawi*** with only ***10% of the country's population connected to the national grid and distribution system almost entirely limited to urban and peri-urban areas.*** With the installed generation capacity (439 MW) significantly less than the demand (598 MW in 2015[2]), Malawi suffers from a ***power supply deficit***. Energy is produced from the Hydro plants as well as the peaking diesel generators[3] which have an installed capacity of 78MW. EGENCO's installed capacity of 16MW also runs 6 hours a day with another 30MW under installation. Power is also imported (10MW) from Zambia and Mozambique through the border towns of Mchinji (Zambia) and Chiponde (Mozambique). There are plans to diversify the energy mix of the country by adding more renewables capacity, however the progress on the same has been slow & mired with procedural delays.

Table 2 Types of Generation and installed capacity

Type of generation	Installed capacity (MW)
Hydro-electric	384

[2] UNF Health Sector assessment in Malawi- 2015
[3] Leased generators run 6 hours a day

Type of generation	Installed capacity (MW)
Diesel Generator	55
Total	439

Source: https://www.usaid.gov/sites/default/files/documents/1860/Malawi_-_November_2018_Country_Fact_Sheet.pdf

The power deficit issue is compounded by ***high transmission and distribution system losses*** (17%) and an ***over-reliance on hydro energy for power generation.*** High system losses and over reliance on hydro-power in turn, lead to seasonal variability in power supply, frequent load shedding and poor quality & reliability of grid power for healthcare facilities. ***The supply-side issues are seen to significantly constrain the energy demand*** with the annual per capita electricity consumption of Malawi recorded at 85 kWh in 2012, as against the African average of 579 kWh and the world average of 2,777 kWh[4]. ***The electricity tariffs in Malawi are not cost-reflective.*** The average existing tariff is 73.23 MK/kWh while Cost of Service is 123.9 MK/kWh, which implies that the national electricity distribution agency, ESCOM, is losing 52.67 MK per unit of electricity sold by it. As per a Cost of Service Study (CoS) conducted by ESCOM, the current average tariff is around 42% lower than the cost reflective tariff. The tariff for the present Maximum Demand Customers is around 38% lower and that of the present domestic consumers is around 68% lower than the cost of service. The prevailing tariff regime not only creates a poor business case for the ESCOM, but also creates barriers for the market entry of renewable energy developers.

Healthcare facilities are a part of the Services sector in Malawi, which contributes to around 17% of the total electricity consumption at the national level[5]. Healthcare facilities are large energy consumers, and a significant share of their energy consumption comes from energy intensive equipment used in various departments. Considering the nature of services provided in healthcare sector, energy is an important operational input, which presents the third largest cost in the healthcare system after staff wages and medicines. The following sections presents an overview of the governance structure for healthcare facilities in Malawi followed by a situation analysis of the challenges being faced at facility level.

2.1.3. Governance structure of Healthcare facilities

Malawi's health system is organized at four levels namely: community, primary, secondary and tertiary. There is an established referral system linking the four levels, however, the capacity of the healthcare facilities to handle the referrals is limited. Improved electricity supply would also give the possibility to set up a radio communication system between peripheral and referral units, which would greatly improve the referral system. A functioning radio communication system would also improve communication between the offices if e-mail is installed. Messages and other information would reach fast and would greatly reduce travel between peripheral units and the Centre.

It is the policy of the Ministry of Health and Population, that every Malawian should reside within 8km from a health facility. The proportion of population living within 8km radius of health facility (health centres and hospitals) stands at 90% in 2016, which is an increase from 80% in 2011[6]. This implies that 10% of the population is still underserved, which is primarily in the rural and hard to reach areas. Community, Primary and Secondary level care falls under district councils. Central healthcare facilities are part of tertiary level. They provide specialist health services at regional level and also provide referral services to district hospitals within their region. Efforts are presently underway to bring greater autonomy to the

[4] International Renewable Energy Agency (IRENA), 2012, Renewable Energy Country Profile: Malawi
[5] Integrated Resource Plan of Malawi
[6] Source: Ministry of Health and Population website

Central Hospitals for transferring operational powers to government owned and operated hospitals with the purpose of improving efficiency and quality of care.

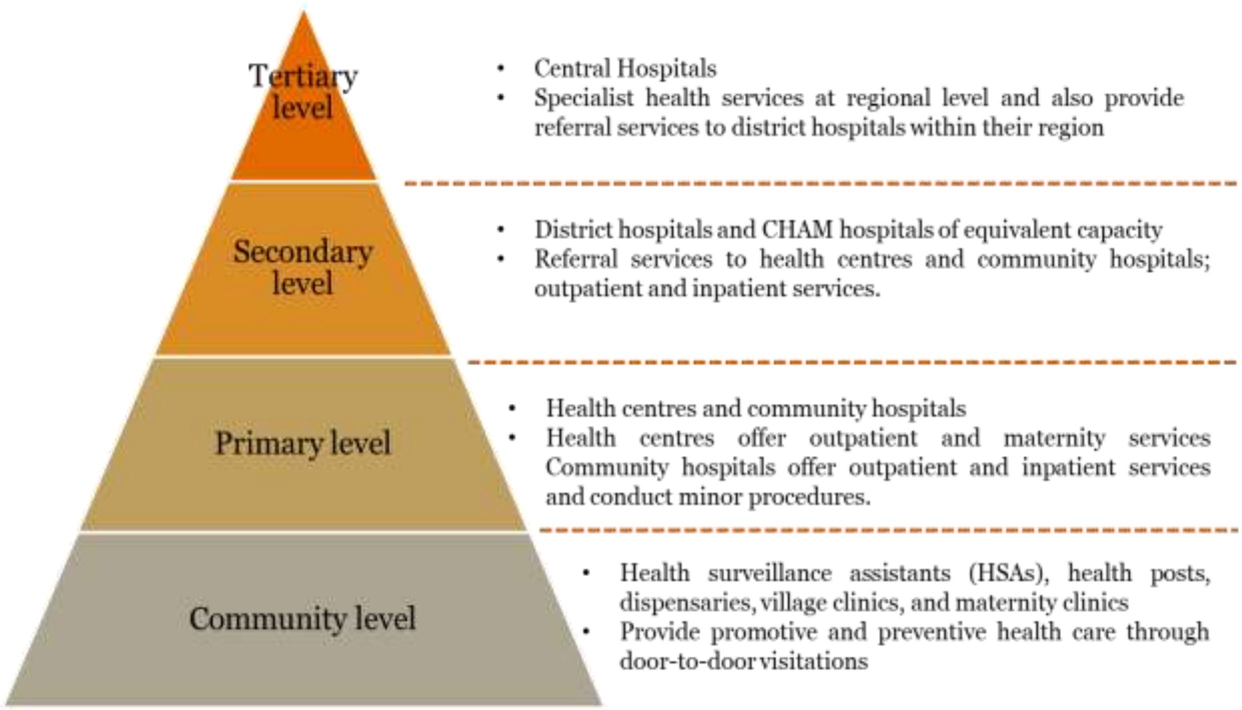


Figure 6 Hierarchy of healthcare facilities

The Physical Assets Management (PAM) is a division under the Health Technical Support Services (HTSS) department in the Ministry of Health and Population. It has four (4) regional offices across the country known as Referral Maintenance Units (RMU) headed by Chief Medical Engineers. The RMUs are situated within the Central hospital premises. It also has maintenance units responsible for the management of infrastructure and utilities in all the central hospitals known as Central Hospital maintenance Units (CHMU) and district health offices known as District Maintenance Units (DMU). The referral maintenance units are attached to the Zonal offices administratively but report to PAM headquarters on technical issues. Its key mandate is to ensure that all physical assets are available and functional in all the government healthcare facilities. All physical assets management activities in Malawi are guided by the Physical Assets Management Policy which is reviewed every five years.

Below the central level, the healthcare facilities fall under 27 districts. Each district has a District Health Officer (DHO) who is accountable to the Principal Secretary. The DHO and his/her team run the District Hospital and the peripheral health units (health centers, dispensaries and mobile clinics). A new government policy on national decentralization has been approved in order to devolve administrative authority to the district level. The DHO will have the responsibility for the management of all health services in the district. District Health Management Teams (DHMTs) are accountable to the District Assemblies for decisions on financial planning and expenditures. The District Health Officer (DHO) reports to the District Commissioner (DC) who is the Controlling Officer of public institutions at district level.

Malawi has developed an infrastructure network for vaccine management at national, Zonal and district and sub-district levels. Cold chain infrastructure is in place in 826 health facilities. The Cold Rooms are governed under the EPI programme, which falls under the Directorate of Preventive Health Services of MoH. At the central level, the programme is managed by the EPI Manager, Deputy Manager and officers dealing with Logistics, Cold Chain, Disease Surveillance, Data Management and Vaccine and Dry Store Management. The Zonal EPI Officers in the North, South East and South West are responsible for coordinating EPI activities in their respective zones and are assisted by the Zonal Cold Chain Officers.

The governance structure for the four categories of healthcare facilities operates at 3 levels as shown in the infographic below:

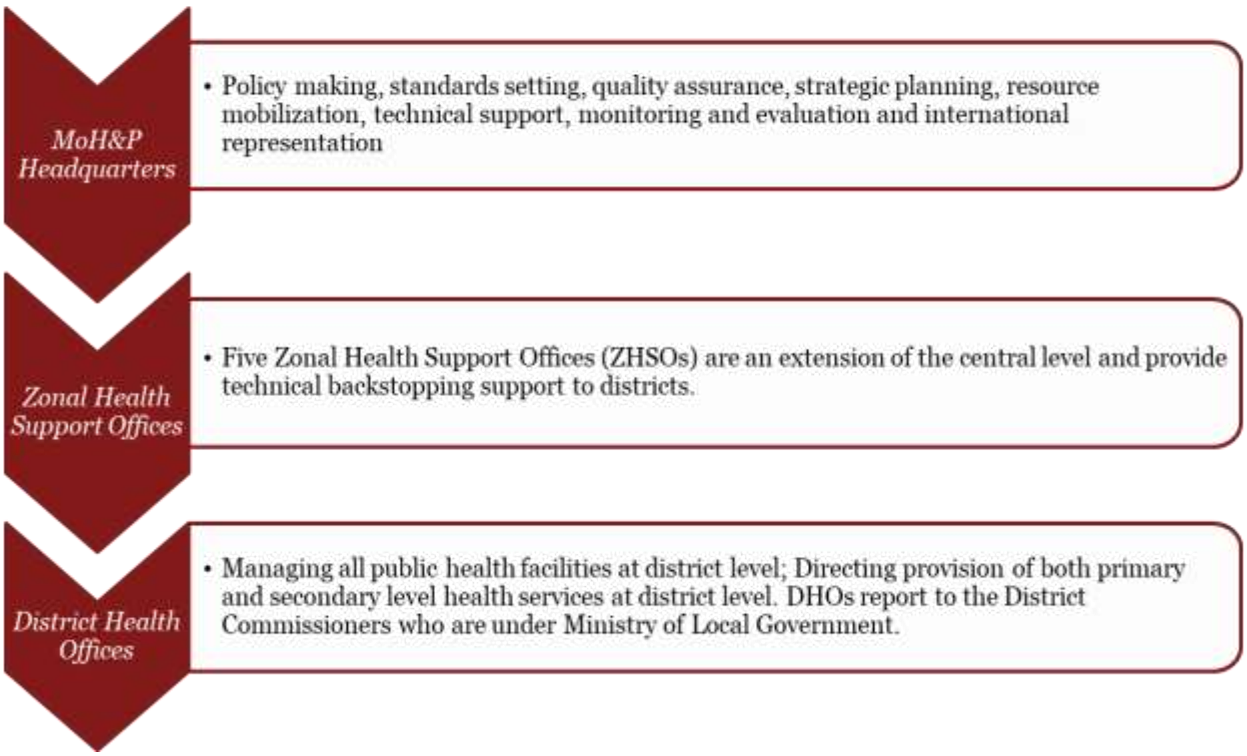


Figure 7 Governance structures of healthcare facilities

MoH&P has signed a Memorandum of Understanding (MOU) with CHAM under which a coordination committee composed of MoH&P and CHAM officials was constituted. As per this MoU at district level, Service Level Agreements (SLA's) have been signed with CHAM facilities for patients to access CHAM facilities at subsidized rates. CHAM compiles invoices monthly for patients' services under the SLA and sends to MoH&P for payment through the CHAM secretariat. Sometimes drugs used in CHAM facilities are procured by MoH&P. MoH&P provides strategic leadership to CHAM operations and also pays salaries for CHAM staff members. The MoH&P is also planning to expand the Service Level Agreements with service partners beyond CHAM.

In Malawi, public, private for profit (PFP) and private not for profit (PNFP) sectors are engaged in the provision of health services. The public sector includes health facilities under the Ministry of Health and Population (MoH&P), district, town and city councils, Ministry of Defense, Ministry of Internal Affairs and Public Security (Police and Prisons) and the Ministry of Natural Resources, Energy and Mining. The PFP sector consists of private hospitals, clinics, laboratories and pharmacies. The PNFP sector is constituted by religious institutions, non-governmental organizations (NGOs), statutory corporations and companies. The major health service provider is the Christian Health Association of Malawi (CHAM) which, along with Ministry of Health and Population provides approximately 95% of all health services in Malawi.

While the public health facilities provide healthcare services free of cost at the point of use, most private and private-not-for-profit providers charge user fees for their services. The physical access to health facilities (proportion of the population living within 8 km radius of health facility) is recorded at 90% in 2016[7]. Therefore, ascertaining affordable and sustainable energy availability options for healthcare sector is of crucial importance.

2.1.4. Role of International Development agencies and lessons learned from their experience

International development agencies and donors are reasonably active in the energy sector of Malawi. Health care financing in Malawi remains a challenge. During the period 2012/13-2014/15, development partners' contributions accounted for an average 61.6% of total health expenditure (THE), followed by the Government (25.5%) and households (12.9%). UNDP has been active since 1998 and continues to play a key role. Japanese International Cooperation Agency (JICA), the World Bank, the Millennium Challenge Corporation (MCC) and European Union (EU) have been providing support through various projects. The United Kingdom (UK) Government's Department for International Development (DfID), Government of Scotland (GofS) and German technical assistance agency Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) all play important roles in clean energy and electrification in Malawi.

A summary of some of the most recent interventions from Malawi's development partners in the Energy and Health Sectors is provided in the table below:

Table 3 Past programmatic interventions of Development Agencies in Malawi related to Healthcare/ Energy sectors[8]

Organisation	Activity	Amount
UNDP	Capacity Development in Health Programme	USD 9.9 million
US Government	Millennium Challenge Corporation Compact Aimed at the most urgent rehabilitation, upgrade and modernization needs of Malawi's power system	USD 350.7 million
World Bank	• Energy Sector Support Programme • Health Sector Support Programme	• USD 84.7 million • USD 35.00 million (2003) USD 15.00 million (2004 – 2007)
GAVI	Cold Chain Equipment Optimisation Platform	>USD 5.6 million
Global Fund	Programs for HIV, Tuberculosis, Malaria, TB and other diseases	USD 1.28 trillion[9]
DFID	Malawi Health SWAp Support	GBP 100.00 million 2004 - 2010
NORD/SIDA	Malawi Health SWAp Support	USD 60 million 2004 - 2010

[7] Capital Investment Plan 2017-2022
[8] List is not exhaustive
[9] https://www.theglobalfund.org/en/portfolio/country/?loc=MWI&k=b2d78cbb-a8d0-45e2-a78c-9e53b907c4a3

UNICEF	Funds programmes such as Water and Sanitation; Family Planning; Safe pregnancy; Expanded Programme of Immunisation; and Communication; and AIDS control	USD 341,500,000 (allocation for 2019-2023)
WHO	Co-ordinates and directs health activities including health systems, human resources	USD 7.34 million (2004 – 07)
USAID	Involved in maternal health, support systems, donor coordination, health information system, capacity building and logistic support	USD 44.00 million (2004 – 07)
GTZ, KFW, CIM	Involved mainly in Central Operations, Policy and Systems Development Programme covering physical assets management and maintenance programme.	USD 4.51 million 2004 - 2007
JICA	• MCH equipment and supplies, training, and long-term technical assistants • Physical Asset Management project	• USD 1.57 million (2004 – 07) • Yen 49 million (2011-2014)

Source: APPRAISAL REPORT SUPPORT TO THE HEALTH SECTOR PROGRAMME REPUBLIC OF MALAWI, AfDB

Across all the Development Partners, funds in excess of USD 800 million have been pumped into the Malawian energy and health sectors, however the impact has not been at a proportionate level. There is a significant scope for optimizing the flow of funds to ensure maximum impact per dollar of investment.

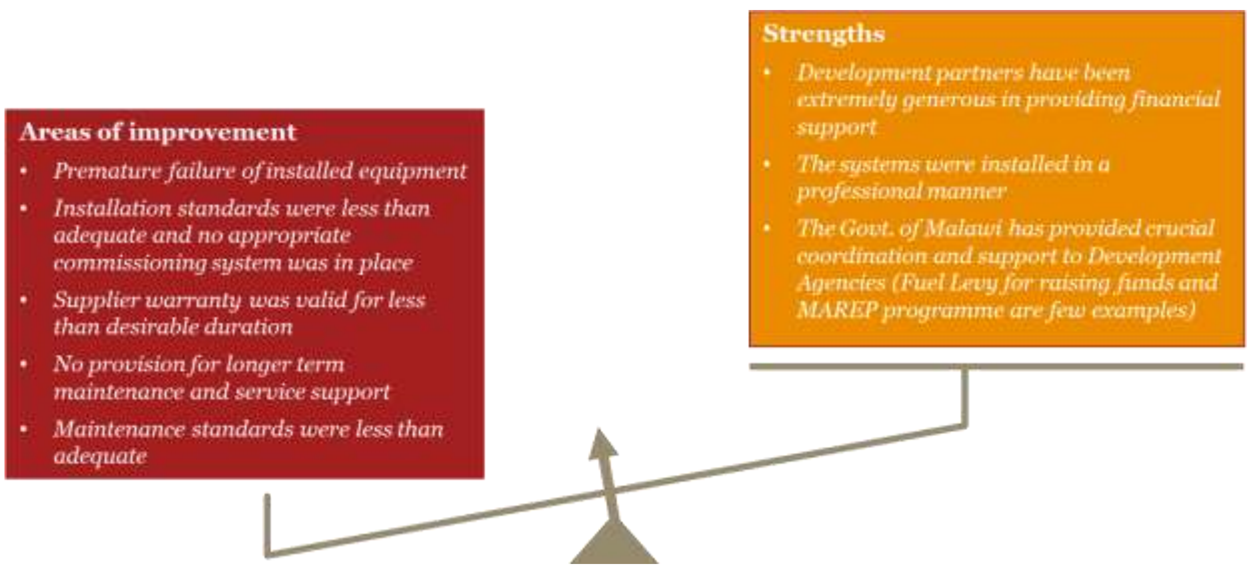


Figure 8 Balance of scale in earlier interventions: Strengths vs Areas of improvement

An analysis of the performance of the earlier programs indicates that while the quantum of financial support provided by development agencies and their hand-holding during the installation phase was commendable, there was little effort to institute the necessary support systems to ensure sustainable operations. Greater co-ordination across key stakeholders could go a long way in creating synergies for the master plan and ensure continuing success across its 10 year time horizon.

2.1.5. Energy situation in healthcare facilities

In the healthcare sector, 59% of the facilities enjoy regular electricity from the Grid as on 2013-1410. Central, District and Community healthcare facilities have a relatively higher share of facilities with regular and uninterrupted electricity. CHAM facilities also perform slightly better than other categories of hospitals.

Network Operators are supposed to prioritize supply of electricity to Health Facilities but in most cases system designers and operators don't know where these are located except for the Central Hospitals. Despite this, the power utility has the mandate to supply power all day and everyday. Due to poor reliability and quality of power, healthcare facilities in Malawi have limited access to energy for basic services such as lighting, heating and the powering of medical equipment. The table below presents the share of facilities across different tiers, which have access to grid electricity.

Table 4 Status of electricity access in Healthcare facilities

Type of Healthcare facility	Share of facilities with electricity from Grid
Central Hospital and Central Medical Stores Trust (CMST)	100% with unreliable power
District and Community Hospital	79% with high likelihood of reliable power
Health center	65% with high likelihood of reliable power
Health post	30% with high likelihood of reliable power
Dispensaries and Clinics	49% with high likelihood of reliable power
CHAM	68% with high likelihood of reliable power
Private healthcare facilities	44% with high likelihood of reliable power
NGO-run healthcare facilities	49% with high likelihood of reliable power
Cold Rooms	100% with unreliable power

Source: Malawi Service Provision Assessment final report 2013-14

The reliability issue limits diagnostic capabilities and treatment services, reduces hours of operation to daytime hours and leads to attrition of healthcare professionals. Further, poor quality of power supply (voltage fluctuation and current surge) often damages sensitive medical equipment, which is mostly uninsured and difficult to replace. Therefore, it is the need of the hour to identify affordable and sustainable energy supply options and manage the internal energy use better within the healthcare facilities. As discussed in the earlier sections, renewable generation systems have been installed in the healthcare facilities as a part of many programs implemented by International Development Agencies. While these programs fared very well on some targeted outcomes, they were not able to hold the gains and demonstrate sustainability. The master plan seeks to borrow on the strengths of the previous programs and address the aspects on which they did not fare very well in the design stage.

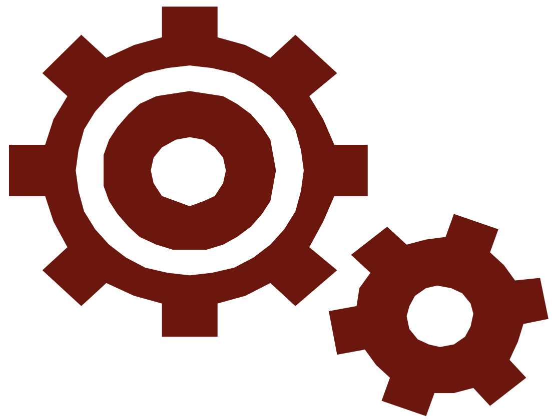
2.1.5.1. Issues in Operation and Maintenance (O&M) of Renewable energy generation systems identified through literature review

Solar PV generation systems typically need to operate for period >20 years, therefore, O&M processes are very critical for sustainable operations. Proper O&M requires certain level of planning, commitment and monitoring. Preventive maintenance includes work that is planned and carried out on a regular basis to

[10] Malawi Service Provision Assessment final report 2013-14

maintain and keep the system in running condition. As the Solar PV systems become older, operation and maintenance (O&M) is critical for maintaining performance levels at desirable levels. The following sections highlight some of the key issues contributing to improper functioning of RE generation equipment installed in healthcare facilities in Malawi as identified through literature review.

Equipment design and performance inadequate due to poorly defined tender specifications, non-compliance with tender and weak quality assurance



- In the past, the tender specifications have not complied with international and domestic norms and standards for efficiency. In many cases, the equipment specifications for Solar PV systems in the tenders have not included max power point tracking (MPPT) devices into the energy management package, have not considered battery storage at all or have taken less than adequate system autonomy considerations (specifications considered single day autonomy).
- No proper safety related safeguards were considered in the tender for medical equipment such as stabilizers, batteries, UPS which are expensive and prone to theft.
- Tender specifications did not consider the prevailing market conditions with regard to access to spare parts, consumables and accessories which was limited, due to:
  - Limited presence of local suppliers and relatively high cost of parts, due to transport and taxes
  - High variety of equipment
- Quality assurance related issues were primarily of the following types:
  - Inferior solar module quality with respect to the tender specifications
  - Substandard battery provided that does not have labels for load rating, type, capacity or manufacturer details and has poor aeration and protection of battery bank.
  - Non-compliance with performance and maintenance standards
  - No consideration to balance connected loads across phases of electrical distribution circuits
  - Unmarked, un-identifiable equipment, non-compliant with the terms of reference for supply.
  - Variation in design, materials and structural stability of PV array support structures

Current processes related to governance, procurement, contract management and budgeting need streamlining

- Absence of single management agent/unit across Multilateral development Agencies has resulted in lack of coordination and engagement with important stakeholders such as DoE, MERA, and private service providers
- Facility-level budgeting for maintenance of infrastructure (including recurrent costs and consumables) is largely missing. The budget for energy access and maintenance of equipment for central hospital is determined by the Chief administrative officer and the Director. They collect and compile the requirements from various levels before sending

the details to Ministry of Health and Population. The ministry allocates the budget as per the availability of funds. Due to lack of predictable budget, the facility teams are unable to carry out the O&M activities on schedule (preventive maintenance).

- Distict Health Offices (DHOs) are not involved in community participation in any form for financing, procurement and installation of Solar PV equipment. Despite that, there is dependence on DHO personnel for solar equipment maintenance, replacement parts.
- The procurement of major medical and electrical equipment is carried out by the Ministry of Health and Population. The ministry compiles the requirements from all healthcare facilities and after prudence check, procure the equipment centrally based on the funds available with them and get it delivered at respective locations. The ministry also allocates the budget for each healthcare facility in the country.
- The procurement of medical equipment is carried out by Ministry of Health and Population. Some medical equipment are directly received by healthcare facilities as donation but their quantity is low.

Facility level management of implementation and post-implementation process needs improvement

- Due to lack of an integrated facility-wide electrification approach, the solar PV systems have been installed on a piecemeal basis, without proper load matching, resulting in poor capacity utilization after installation. To add to this, inadequate attention has been given to the need for facility retrofits to optimize use of solar PV.
- Weak facility-level experience to take responsibility for installed systems has resulted in poor O&M and premature failure of the equipment. The physical asset maintenance (PAM) team is understaffed and overworked. Across central hospitals, the PAM consists of a supervisor and an electrician as against an expected team of 2 supervisors and 5 electricians. A similar situation prevails in district hospitals and health centers. The PAM team is able to take care of equipment on need-to-maintain basis, there is no preventive maintenance schedule available except for DG sets and critical equipment.
- There is no standard O&M process for the installed equipment, which could have been institutionalized through providing O&M manuals and conducting awareness sessions for facility level staff. Although, in case of a few healthcare facilities, there is a provision for remote monitoring and regular maintenance of installed equipment, in most of the healthcare facilities, there is no provision for Annual Maintenance Contracts (AMC) for installed solar systems
- In many cases, due to limited time for for implementation, SPV systems were installed without proper load assessment. Conducting a detailed load assessment to capture seasonality would require facility-level documents such as electricity bills for past 3 years, which are often not maintained in a proper manner by the hospital management.
- Scant attention has been accorded to energy efficiency of electrical loads in facilities and balancing of load distribution.
- On many occasions, the priority setting was not adjusted and Solar PV systems are used as backup systems which led to poor commercial feasibility.

Skill levels for government and management require upgrade for addressing facility level issues

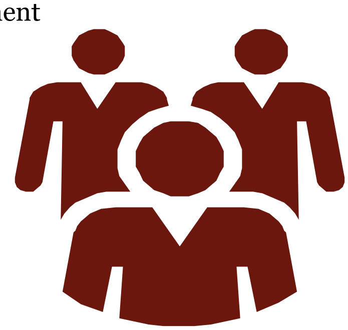
- The lack of information within the Government of Malawi regarding the exact number of healthcare facilities has created a situation in which the planning process underestimates the necessary number of workers and the budget is less than adequate for mobilizing the required manpower. Consequently, there are insufficient qualified technical staff at all levels across all tiers of healthcare facilities. As of June 2016, there were 33% vacant seats against established positions for MoH&P and CHAM[11].

Table 5 Status of staff positions in healthcare facilities in Malawi

Cadre	Establishment	Filled	Vacant	% Vacant
Medical Officer	398	284	114	29%
Clinical Officer	3,135	1,159	1,976	63%
Nursing Officer	3,275	1,098	2,177	66%
Nurse Midwife Technician	8,626	3,475	5,151	60%
Medical Assistant	1,506	1,199	307	20%
Pharmacy Technician	1,063	218	845	79%
Lab Technician	1,053	397	656	62%
Health Surveillance Assistants	6,699	9,468	-2,769	-41%
Total	**25,755**	**17,298**	**8,457**	**33%**

Source: HRH Assessment Report, June 2016

- DHO engineers are responsible for maintenance of various types of solar equipment in the health sector after the warranty period has elapsed. These systems with varying designs and specifications have been procured through communities supplied through DHO offices or DFI's. The medical centers depend upon district hospital maintenance personnel or EPI technicians for guidance since skills are not fully available within MoH&P (PAM), DoE and ESCOM to meet this requirement
- The healthcare facilities have low awareness about routine tasks relating to energy management and storage systems or management and preventive maintenance measures required for solar equipment. User training where conducted does not provide basic information or documentation defining user tasks and responsibilities. No training on diagnostic techniques has been provided. Technicians are not adequately equipped with measuring instruments and tools and there is no system in place for maintenance planning, preventive maintenance visits and defect reporting



- There has been no provision for mandatory reporting of investments in the healthcare sector, which could ensure that the spending on human resources is monitored and tracked.
- Lack of collaboration with other ministries such as Ministry of Labour has meant that any opportunity to introduce internship programmes, which could help bring in the required human resource pool at lower cost has been completely missed.

[11] : HRH Assessment Report, June 2016

Data gathering, management and reporting in need of significant improvement

- There is inadequate information and communication technology (ICT) infrastructure at all levels, especially in remote areas and villages. In general there has been a conspicuous absence of maintenance data management systems to monitor performance and trigger actions. Although there is a provision for the Health Management Information System (HMIS), to aggregate the routine health management information data from health facilities, the data quality is poor due to challenges in recording, extracting and reporting data, with most facilities not able to collect and submit the required data on time. The HMIS has a process of manual data collection and reporting, which makes it difficult to record, extract and use the data. The existence of parallel reporting systems in the Health Management Information systems has weakened the mainstream monitoring and evaluation system.
- The status of medical equipment is not routinely tracked. Information was previously collected in the Planning and Management of Assets in the Health Sector (PLAMAHS) software, which has not been updated since 2007. The expenditure on licensing of the software may continue to be deprioritized over key equipment for healthcare facilities unless cheaper or lower cost alternatives are introduced to deliver on the primary requirements.
- Gaps exist in the management and sharing of research results at the local level, due to lack of a documentation system that supports the sharing of research reports and data in order to inform decision-making.
- Data recorded from remotely monitored systems is not shared with MoH&P (PAM), DoE or ESCOM, which is a lost learning opportunity.

Safety needs are grossly unaddressed in many installations

On the safety front, there are multiple issues with installation standards such as absence of earthing cabling from PV array fixation arrangements, cabling standards, routing and fixation, and inaccessibility of PV arrays directly mounted on roof cladding for maintenance purposes etc. In many cases solar PV arrays are not grounded for protection. Most solar array support structures or mounting arrangements are either unsafe or compromise on performance and maintenance standards. Some of the commonly observed safety issues include:

- No protection provided to safeguard systems from damage by lightning
- Sub-standard ground cabling and grounding
- Poor aeration and protection of battery banks
- Poor quality with inadequate overload protection at most hospital facilities.
- Corrosion on the PV array support structure
- Fire risk from sub-standard electrical distribution panels, circuit breakers, cabling, wall sockets, fixtures and fittings
- Theft of high value appliances is a significant risk
- No consideration is made at any assessed location to provide safe access to roof mounted PV arrays for purposes of cleaning or maintenance and most facilities do not have ladders.
- Lead acid battery banks are not mounted on a support frame and poorly aerated.

2.1.5.2. Key outcomes of load assessment in 6 health facilities

With the objective of triangulating the issues identified through secondary research with on-ground observations, load assessments were carried out in 6 centrally managed health facilities in Malawi which identified energy efficiency and renewable generation options for each healthcare facility and and suitable business models for implementation. The following sections summarize the key takeaways of the load assessments starting from the issues observed and progressing to the recommended measures.

Monthly maximum load fell short of the contracted capacity by a fair margin for 2 central healthcare facilities

Given that the electricity bill has two-part tariff, proper utilization of the contract capacity is also necessary. It was observed for 2 central healthcare facilities that the monthly maximum load was less than 70% of the contracted capacity. This could be an indicator of poor reliability of power, which may restrict the demand of the healthcare facility.

Table 6 Maximum load as a percentage of contracted capacity

Issues with Distribution	Queen Elizabeth Blantyre	Zomba Central	Zomba Psychiatric	Mzuzu	Kamuzu	CMST
Monthly maximum load as a percentage of contracted capacity	76%	65%	82%	94%	66%	80%

Solar PV capacity installed was capable of serving only a small share of the overall contract demand

For all 5 central healthcare facilities, the Solar PV capacity was relatively insignificant compared to the contract demand. More often than not, the Solar capacity was observed to be capable of serving only a few wings of the entire building. Therefore, Solar PV systems could at best play a back-up role when grid supply wouldn't be available, which made the them a commercially less attractive option.

Table 7 Contract demand vs Solar PV capacity installed

Contract Demand/ Solar PV	Queen Elizabeth Blantyre	Zomba Central	Zomba Psychiatric	Mzuzu	Kamuzu	CMST
Total Contract Demand (kVA)	501	303	74	206	2244	120
Solar PV capacity installed (kWp)	96	48	-	96	-	-

Furthermore, for the facilities where Solar PV systems were installed, the annual generation from Solar PV system was not available as there is no process to record and monitor the same. The asset tag number was the only parameter which was recorded in an excel-based format and reported to the PAM department. From the perspective of project management, proper recording and reporting of energy data is crucial and the introduction and use of Energy management information systems can be a key plank for greater process control.

Favorable rooftop area across all 5 healthcare facilities was found to be sufficient to accommodate the required size of the installation

Contrary to the expectation that available roof space with favourable orientation can pose a constraint to the capacity of Solar PV systems that can be installed, it was observed during the load assessments that ample space is available for the required installation.

Table 8 Available roof area with favorable orientation

Roof top area available	Queen Elizabeth Blantyre	Zomba Central	Zomba Psychiatric	Mzuzu	Kamuzu	Average available area
Roof area available (sq.m)	3930	2000	3420	3800	3600	3350

On an average, 27% of the total load was not working in the central healthcare facilities

The average non-working load across the five healthcare facilities (27%), as recorded in the load assessments was almost in alignment with the data gathered through secondary sources (25%). Kitchen and Laundry were the key departments in which the equipment was non-functional, indicating a greater attention to equipment specification and vendors when procurement is done in the future.

Table 9 Non working load- Quantum and type

Category	Queen Elizabeth Blantyre	Zomba Central	Zomba Psychiatric	Mzuzu	Kamuzu	CMST	Avg. of 5 healthcare facilities
Non working load as a % of total load	20%	13%	46%	42%	14%	-	27%
Connected but not working equipment	AC, Refrigeration, Medical Equipment, Heaters, ICT, Kitchen and Laundry	Kitchen and Laundry	Kitchen and Laundry	Kitchen and Laundry	Kitchen and Laundry	-	-

Lack of space for connecting new equipment also observed to present a constraint to the operation of procured equipment for hospitals.

On an average 5% of the load across all 5 central healthcare facilities was not operating because of lack of space. This suggests that space should also be a consideration when designing and building new central healthcare facilities.

Table 10 Working and non connected load due to space constraints

Category	Queen Elizabeth Blantyre	Zomba Central	Zomba Psychiatric	Mzuzu	Kamuzu	Average of 5 healthcare facilities
% of future load that is working but not connected due to lack of space	7%	13%	-	0%	2%	5%

Actual generation observed to be a very small percentage of the available capacity suggesting underutilization of the installed SPV system

Underutilization of installed Solar PV systems is a common issue across all the facilities with Solar systems installed. The key reasons contributing to this issue are as follows:

- **Improper system sizing:** Decentralized SPV system has been installed without any assessment of load and existing distribution system. This led to mismatching of SPV system with actual load.
- **Improper battery sizing:** Sizing of battery has not considered the type of load connected in the building. Due to improper battery sizing, batteries are unable to cater to the transient and in rush power requirement of some of the medical equipment, if connected.
- **Improper priority setting of invertor:** Inverter installed with SPV system has option of automatic switching between ESCOM supply, solar module and battery based on set priority. During performance assessment, it was observed that the ESCOM supply was the first priority, followed by solar and battery. Due to this setting, the invertor was almost always on ESCOM supply mode.

In general, the issues with Solar PV systems were common across all facilities were such installations have been done.

Table 11 Issues with installed Solar PV systems

Issues with performance of existing solar system	Queen Elizabeth Blantyre	Zomba Central	Zomba Psychiatric	Mzuzu	Kamuzu	CMST
Improper system sizing	Yes	Yes	NA	Yes	NA	NA
Improper battery sizing	Yes	Yes	NA	Yes	NA	NA
Improper priority setting of invertor	Yes	Yes	NA	Yes	NA	NA
Improper grounding of the installation and lightning protection	Yes	Yes	NA	Yes	NA	NA
Orientation of the panel, lighting protection, cabling and safety measures in battery and invertor room were not as per standard	Yes	Yes	NA	Yes	NA	NA
No trained personnel at hospital for O&M	Yes	Yes	NA	Yes	NA	NA
Non-availability of actual generation (performance) data to central hospital	Yes	Yes	NA	Yes	NA	NA

Issues with performance of existing solar system	Queen Elizabeth Blantyre	Zomba Central	Zomba Psychiatric	Mzuzu	Kamuzu	CMST
No involvement of central health facility O & M staff during project planning, project execution, O&M	Yes	Yes	NA	Yes	NA	NA
No formal handover of the Solar PV system to central hospitals	Yes	Yes	NA	Yes	NA	NA
Battery provided with Solar PV system are substandard and does not contain any rating or manufacturer details	Yes	Yes	NA	Yes	NA	NA
Poor ventilation of the room used for storing batteries and invertor	Yes	Yes	NA	Yes	NA	NA
Invertor are installed above batteries and in absence of ventilation there is chances of corrosion	Yes	Yes	NA	Yes	NA	NA

Diesel Generator systems observed to be operated sub-optimally with a high Specific Energy Generation Ratio (SEGR)

Diesel Generator systems were found to be used for back up when the ESCOM grid supply was not available. However, they were operating inefficiently with a higher than expected Specific Energy Generation Ratio, i.e. higher than usual quantity of diesel to produce one unit of electricity.

On the power distribution front, healthcare facilities found to perform poorly with regard to maintaining Power Factor and Current balance

Current imbalance, I-THD and Power factor were found be problematic aspects across all the healthcare facilities indicating potential for improvement on load balancing in general

Table 12 Issues with distribution systems in assessed facilities

Issues with Distribution	Acceptable value/ range	Queen Elizabeth Blantyre	Zomba Central	Zomba Psychiatric	Mzuzu	Kamuzu	CMST
Voltage variation	-3% to 3%	Satisfactory	Not satisfactory	Not satisfactory	Satisfactory	Not satisfactory	Satisfactory
V (Total Harmonic Distortion)	3% as per Malawi Grid Code	Satisfactory	Not satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Average current imbalance	<10%	Not satisfactory	Not satisfactory	Not satisfactory	Not satisfactory	Not satisfactory	Not satisfactory
Average Voltage imbalance	<1	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
I (Total Harmonic Distortion)	<10%	Satisfactory	Not satisfactory	Not satisfactory	Not satisfactory	Not satisfactory	Not satisfactory
Frequency	48.5-50.5 hz	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory

Issues with Distribution	Acceptable value/ range	Queen Elizabeth Blantyre	Zomba Central	Zomba Psychiatric	Mzuzu	Kamuzu	CMST
Average Power Factor at the main incomer	>.95	Not satisfactory	Not satisfactory	Not satisfactory	Not satisfactory	Not satisfactory	Not satisfactory

The recommended EE measures were found to be techno-commercially attractive in all 5 hospitals

The recommended measures in all the 6 facilities and the outcomes of their financial analysis are detailed below:

Mzuzu Central

- Improvement of power factor to reduce demand charges
- Optimum loading of Autoclaves in CSSD
- Reduction in cooling load by shifting refrigerators of Laboratories to non-air conditioned area
- Using solar electric hybrid water heaters
- Waste heat recovery from flue gases of incinerator
- Installation of energy efficient air conditioning system with waste heat recovery
- Installation of energy efficient lighting
- Biogas generation from kitchen waste for cooking

Kamuzu Central

- Improvement of power factor to reduce demand charges
- Reduction in cooling load by shifting refrigerators from air conditioned area to non-air conditioned area
- Using solar electric hybrid water heaters
- Waste heat recovery from flue gases of incinerator
- Installation of energy efficient air conditioning system with waste heat recovery
- Avoid idle running of sample heaters

Zomba Central

- Saving in capacity charges by revising contract capacity
- Avoid idle running of sample heater in laboratories
- Reduction in cooling load by shifting refrigerators of Laboratories to non-air conditioned area
- Using solar electric hybrid water heaters
- Improving SEGR of DG by using smaller DG
- Improvement of power factor to reduce demand charges
- Installation of energy efficient air conditioning system
- Installation of EE lighting

Figure 9 Recommended measures in 6 healthcare facilities

Zomba Psychiatric

- Using solar electric hybrid water heaters in place of electric geysers
- Improving SEGR of DG by installing smaller DG
- Improvement of power factor by installing APFC system at main incomer
- Installation of energy efficient air conditioning system
- Installation of energy efficient lighting

Queen Elizabeth Blantyre

- Avoid idle running of lighting and medical equipment
- Reduction in cooling load by shifting refrigerators of Laboratories to non-air conditioned area
- Using solar electric hybrid water heaters
- Improving SEGR of DG by installation of smaller DG
- Improvement of power factor to reduce demand charges
- Installation of energy efficient air conditioning system
- Installation of energy efficient lighting
- Using kitchen waste to generate biogas to reduce electricity consumption of kitchen
- Installation of EE ceiling fan

CMST

- Replace existing ceiling fans with energy efficient ceiling fans
- Improvement of power factor to reduce demand charges
- Installation of energy efficient air conditioning system
- Installation of energy efficient lighting
- Improve insulation of cold room doors to prevent heat ingression

Figure 10 Recommended measures in 6 healthcare facilities- contd

Table 13 Financial parameters at facility level- Energy Efficiency measures

Name of healthcare facility	Total Investment required (MK million)	Total Annual monetary savings (MK million)	Simple payback period for all recommendations combined (months)
Mzuzu Central	39.3	22.4	21
Kamuzu Central	119.1	55.2	26
Zomba Central	25.9	21.3	15
Zomba Psychiatric	15.4	6.8	27
Queen Elizabeth Blantyre	80.4	28.9	33
CMST	24.2	10.1	29

The financial analysis shows that the investments in EE measures have quick paybacks and can save the facility a significant amount on their current energy bills. This cements the case for inclusion of energy efficiency and demand side management measures as a part of the master plan.

Table 14 Financial parameters at facility level- Renewable Energy measures

Name of healthcare facility	Total Investment required for RE (MK million)	Total Annual monetary savings (MK million)	Simple payback period for Solar PV generation systems (Years)
Mzuzu Central	1012	66.4	15
Kamuzu Central	971.6	69.2	14
Zomba Central	532.9	57.9	9.2
Zomba Psychiatric	639.1*	103.8*	6.2*
Queen Elizabeth Blantyre	1047.1	81.8	12.8
CMST	298.4*	39*	7.7*

* refers to Grid connected systems without battery

As with Energy Efficiency measures, the Renewable Energy Measures are also found to be techno-economically feasible in the prevailing market conditions with payback periods ranging between 6 to 15 years. A recent study[12] carried out by UNICEF in 2018-19 for National and Zonal level cold rooms reveals that Solar PV systems have a potential to meet >70% of the electricity demand of the Cold Rooms.

Table 15 Outcomes of UNICEF assessment of Cold Rooms

Type of facility	Size of Solar PV system recomended (kWp)
National Cold Room	87 (75% Solar PV and 25% grid+diesel)
North Zone	44.8 (87% solar 13% grid+diesel)
South Zone	46 (82% solar and 17% grid)
Central	38.4 (72% solar and 28% grid+diesel)

Significant scope for load reduction was identified through implementation of EE measures

As shown in the table below, the load assessments indicated ample scope of reduction in load through implementation of very basic measures. This suggests the need to encourage procurement and installation of energy efficient equipment in addition to the Renewable generation equipment in the Master Plan.

Table 16 Load reduction through EE improvements

Possible Load reduction	Queen Elizabeth Blantyre	Zomba Central	Zomba Psychiatric	Mzuzu	Kamuzu	CMST
Load reduction through EE improvements (kW)	279.5	99.5	30.64	105.4	275.11	69.12

2.2. Need for a Energy Services Management Unit

Currently, the decision-making structure for provision of power to the healthcare sector is complicated by a multiplicity of players that have a role in key decisions. MoH&P urgently needs to enhance its capital project management capacity and donor-aid coordination capacity. The information sharing is relatively good within government ministries, but less so between ministries. Equipment donations, or procurement

[12] Feasibility and costing study to establish the use of renewable energy to run national and sub-national cold rooms/ cold chain system for health sector in Malawi

with donated funds, are not in line with national needs and standards, and rarely include budgets for maintenance, infrastructure needs or training. The capital investment rate has been very low, at only 5.4 % of total health expenditure (THE) and is not in alignment with the level of health spending. There are systems for sharing some forms of information (consumption and generation) but some of these are not fully functioning. In addition, there is lack of a common platform for posting and sharing power sector information leading to lack of transparency and accountability. The table below presents an overview of such barriers and provides guidance on the essential elements of the Master Plan to address them in a comprehensive manner.

Table 17 Barriers and Mitigating actions in Master Plan

S. No	Barriers creating a need for a Co-management set up	Guidance for Master Plan
1.	The grid electricity tariffs are not cost reflective	The master plan should have a provision for addressing the issue of viability gap to ensure a commercially feasible business model for a RESCO
2.	There is no formal mechanism for enabling co-ordination between Government and Donors	For the energy service concerns of the healthcare sector it is recommended to set up a Energy Services Management Unit with representation from Government, which is supported by Donor as well as government funding. The ESMU would be the sole entity which would manage the provision of energy services to the Healthcare sector and all funding for the same would be routed through MoH&P
3.	Energy planning for healthcare needs stronger links with existing policy, plans, and resources. There is a need to dovetail economic and engineering considerations into the creation of policy, planning and priorities	The Master Plan for the healthcare sector should be based on on-ground assessments to clearly identify and cost major investments. It should be aligned with the National Energy Policy and Integrated Resource Plan. The budget planning for the same should be done in consideration of the Capital Investment plan (2017-2022) and the Health Sector Strategic Plan II
4.	There is heavy reliance on ESCOM as the single source of all power sector data. On many occasions, MERA and DoE had different demand projections for power, both of which were prepared using ESCOM data. The format of data collected and frequency of data collection needs improvement to be more useful to decision-makers	A sector-wide strategy should be developed for MERA for collecting, analyzing and disseminating energy/power statistics for the healthcare sector in the next 10 years. This can be initiated by standard Data Quality Assessment of the current format of data collection to ascertain if it is of the right type and quantity to support the intended use
5.	Lack of enforcement mechanisms for standards resulting in a proliferation of poor quality products on the market	A standard process of procurement should be adopted as a part of the Master Plan including creation and publication of Standard Bidding Documents, Minimum requisite specifications and standards and a stringent process of quality control and assurance. The Master Plan would provision for collaborating with Malawi Bureau of

S. No	Barriers creating a need for a Co-management set up	Guidance for Master Plan
		Standards wherever possible in specification setting for tenders

As mentioned in point 3 of the above table, the ESMU will address priority objectives and activities listed under the Health Sector Strategic Plan 2 as shown in the infographic below.

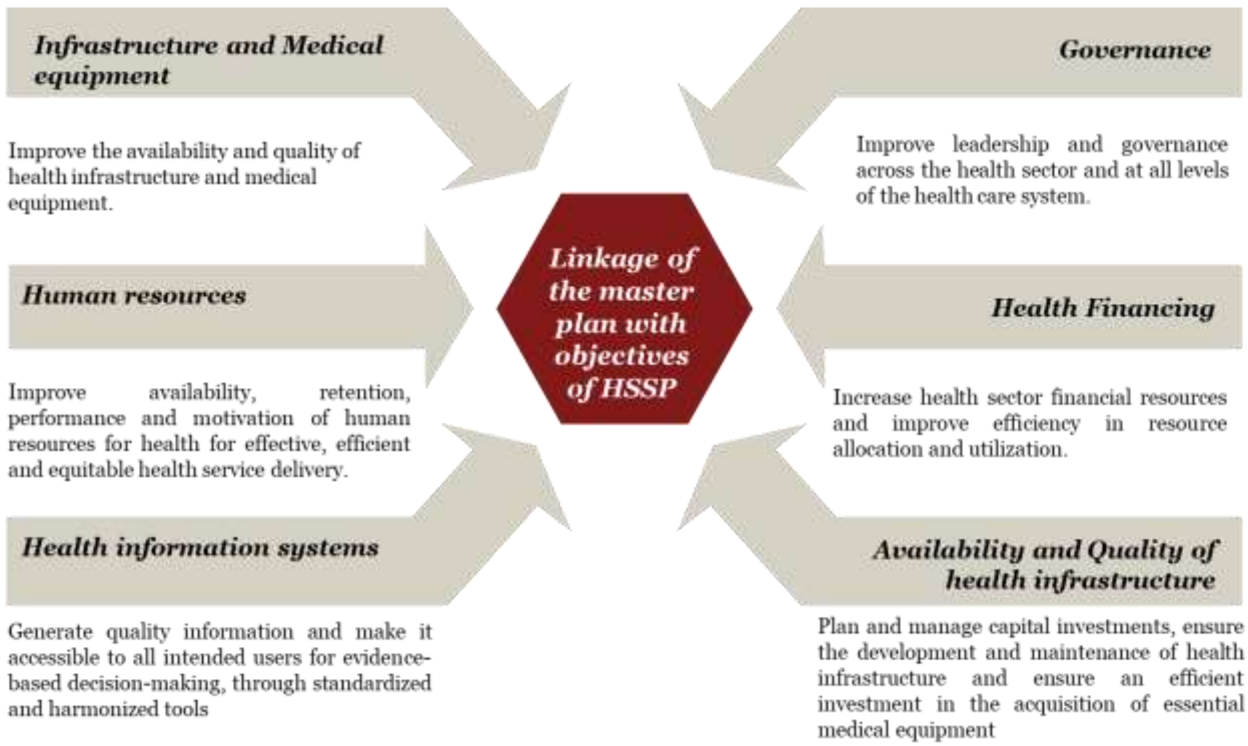


Figure 11 Linkage of master plan with the key objectives of the HSSP

The creation of a Energy Services Management Unit for co-managing the provision of efficient energy service to healthcare facilities is not only well aligned to the national level goals and priorities but also has a high potential for optimizing investment and creating synergies through better collaboration. As the starting point for the analysis that feeds into the master plan, the following chapter presents an overview of the current energy scenario in healthcare facilities along with the key challenges in effective provision of energy services.

3. Current energy consumption of Healthcare facilities

The Energy loads in the healthcare facilities could be classified into ***electrical loads*** and ***thermal loads***. Electrical loads for grid-connected facilities are serviced by ESCOM and those of the off-grid facilities are serviced through standalone renewable energy systems. The following sections present an overview of the options for servicing the thermal and electrical energy demand, their key drivers and the current usage patterns. The current energy demand for the entire healthcare sector has been used as the baseline for creating future projections in the subsequent chapter.

3.1. Current energy options for the healthcare sector

The following sections detail the options for meeting electrical and thermal load for grid-connected and off-grid facilities.

3.1.1. Options for meeting electricity demand & their associated costs

In the healthcare sector, 59% of the facilities enjoy regular electricity from the Grid13. The average existing tariff is 73.23 MK/kWh.

Malawi enjoys solar photovoltaic yields ranging between 3.8 to 4.8 kWh/sq.m/day[14] and *most off-grid healthcare facilities have solar systems installed*. The most common solar PV panel technologies are crystalline silicon modules and thin-film modules. In most of the off-grid facilities, there are multiple solar generation systems installed as a part of different programmatic interventions[15]. However, these installations have been done on a piecemeal basis without any attempt at interconnection of various systems and on an average only 50% of such systems are operational due to poor availability of spares. Furthermore, recent studies have revealed that energy storage capacity of the 25kWp and larger installations is far less than required to provide energy autonomy during periods of ESCOM grid failure[16].

Malawi also offers potential for the use of wind energy converters. There are *sites with limited suitability* (with average annual wind speeds at 80 meters hub height between 4 and 5 m/s) *as well as good suitability* (with average annual wind speeds at 80 meters' hub height are between 5 and 7 m/s)1 2. However, *due to limited site-specific wind resource assessments and poor availability of bankable site data, the scope of its application to healthcare facilities is limited.*

As shown in the table below, the *Central Healthcare facilities are currently utilizing electricity as main source of energy. Diesel is presently used as a fuel for power back up when ESCOM supply is not available*. Details of energy source, its availability and tariff details are presented in the table below.

[13] Malawi Service Provision Assessment final report 2013-14
[14] Based on a map developed by Geo Model Solar, as part of a World Bank Group project which was funded by the Energy Sector Management Assistance Program (ESMAP)
[15] United Nations Foundation (2014)
[16] Energy Needs Assessment Report: UNDP, 2018

Table 18 Energy source, availability and tariff details in Central Healthcare facilities

Name of hospital	Energy Source	Tariff details
Zomba Central	Electricity from ESCOM	**Connection type: Industrial / 11 kV** Capacity charge: MK 4341.60/kVA Demand charge: MK 7025.60/kVA Energy charge: On peak energy charge: MK 103.00/kWh Off peak energy charge: MK 28.20/kWh
	Diesel Generator	MK 932.50
Zomba Psychiatric	Electricity from ESCOM	**Connection type: Industrial / 11 kV** Capacity charge: MK 5200/kVA Demand charge: MK 9000/kVA Energy charge: On peak energy charge: MK 124/kWh Off peak energy charge: MK 42/kWh
	Diesel Generator	MK 932.50
Mzuzu Central	Electricity from ESCOM	**Tariff category: ET10** Connection type: Industrial / 11 kV Fixed charge: MK 36,694.15/month On peak energy charge: MK 91.75/kWh Off peak energy charge: MK 25.40/kWh Capacity charge: MK 3,934.25/kVA Demand charge: MK 6,662.40/kVA Average energy charge(including taxes): MK 85.63/kWh
	Diesel Generator	MK 932.50 per litre
Kamuzu Central	Electricity from ESCOM	**Tariff category: ET10** Fixed charge: MK 36,694.15/month On peak energy charge: MK 91.75/kWh Off peak energy charge: MK 25.40/kWh Capacity charge: MK 3,934.25/kVA Demand charge: MK 6,662.40/kVA **Tariff category: ET9** Fixed charge: MK 36,694.15/month On peak energy charge: MK 103.00/kWh Off peak energy charge: MK 28.20/kWh Capacity charge: MK 4341.60/kVA Demand charge: MK 7025.60/kVA **Tariff category: ET6** Connection type: General post paid Fixed charge: MK 6630.10/month Energy charge: MK 78.05/kWh Average energy charge (including taxes): MK 119.77/kWh
	Diesel Generator	MK 932.50 per litre
Queen Elizabeth Blantyre	Electricity from ESCOM	**ESCOM (ET-6) General postpaid single phase supply** Fixed charge: MK 6630.10 Energy charge: MK 78.05 **ESCOM (ET-08) Postpaid three phase supply** Fixed charge: MK 10001.80 Energy charge: MK 89.15

Name of hospital	Energy Source	Tariff details
		ESCOM (ET-09) Maximum Demand - Low Voltage Supply (Large power for industrial users, supplied at three phase supply and metered at 400 Volts) Capacity charge: MK 4341.60/kVA Demand charge: MK 7025.60/kVA Energy charge: On peak energy charge: MK 103.00/kWh Off peak energy charge: MK 28.20/kWh **ESCOM (ET-10) Maximum Demand - Medium Voltage Supply (Large power for industrial users , supplied at three phase supply and metered at 11 kV or 33 kV)** Capacity charge: MK 3934.25/kVA Demand charge: MK 6662.40/kVA Energy charge: On peak energy charge: MK 91.75/kWh Off peak energy charge: MK 25.40/kWh
	Diesel Generator	MK 932.50 / litre
CMST	Electricity from ESCOM	**Connection type: Industrial / 11 kV** Capacity charge: MK 5200/kVA Demand charge: MK 9000/kVA Energy charge: On peak energy charge: MK 124/kWh Off peak energy charge: MK 42/kWh
	Diesel Generator	MK 932.50

Source: Load assessments in 6 healthcare facilities in Malawi

3.1.2. Options for meeting thermal energy demand and their associated costs

The thermal energy demand in healthcare facilities is majorly from the *kitchen and laundry sections. In these sections, presently, electricity is being used to serve the heating need.* In the Kitchen and laundry the facility specific equipment such as washing machine or cooking pot has in built heater to generate hot water. Hot water is mostly required during day time when all of the hospital facilities are working. *Solar electric hybrid water heaters offer the potential to replace electric geysers* and lower the consumption of electricity in general and partly during the peak hours. Most of the electric geysers are typically installed in ICU, main theatre, and wards to provide hot water to in patients. They are very attractive as a cost-saving and demand-reduction measure.

3.2. Energy consumption of Healthcare sector in present (energy deficit) scenario

3.2.1. Drivers of energy consumption

The energy consumption in the healthcare facilities is influenced by a few key factors such as *hours of equipment usage per day, hours of grid supply, footfall of patients in the facility, number of sections in the healthcare facility, number and wattage of appliances being used and availability of appliances in* *working condition*. Among these factors, hours of grid supply and availability of appliances in working condition present a constraint to the usage under normal conditions and restrict the demand.

Figure 12 Daily Load curve- Zomba Central

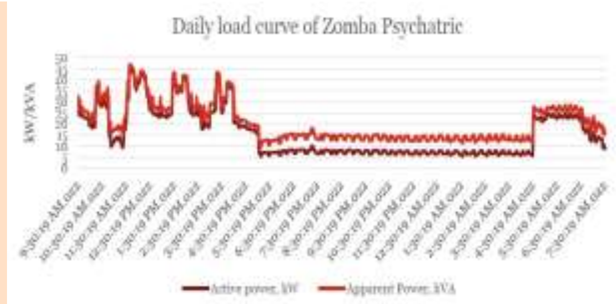


Figure 13 Daily Load curve- Zomba Psychiatric

Figure 14 Daily Load curve-Mzuzu Central

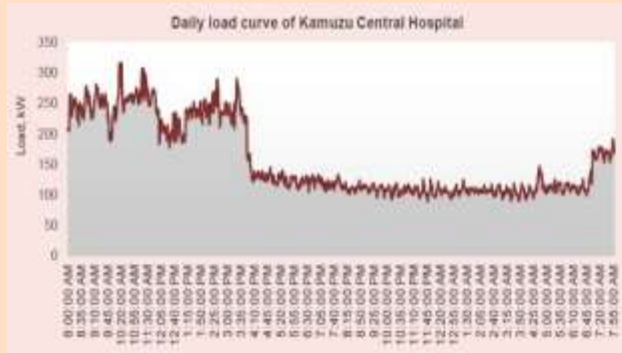


Figure 15 Daily Load curve- Kamuzu Central

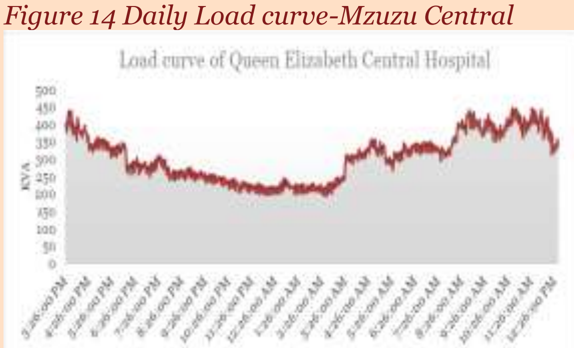


Figure 16 Daily Load curve- Queen Elizabeth Blantyre

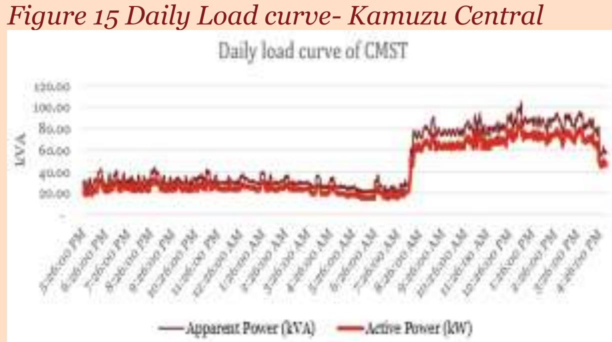


Figure 17 Daily Load curve- CMST

The load curves for the central healthcare facilities where the load assessment was carried out are presented in the figures above. It can be observed that the peak demand electricity at the hospitals typically happens from 8:00 am to 4:30 PM.

3.2.1.1. Major energy consuming equipment used in healthcare facilities

Table 19 presents an overview of the different departments in the healthcare facilities and the energy consuming appliances/equipment used in the departments. Central Hospitals, District Hospitals and Urban Health Centers have more departments and hence higher energy consumption per day.

Table 19 Energy consuming equipment in various departments of hospitals

Type of healthcare facility	Department	Energy consuming equipment[17]
Central Hospital	Laundry	Dryer, Washing machine, Iron, Sewing machine
	Kitchen	Hot plate, Cold room, Deep fryer, Food warmer, Toaster, Oven, Cutter, Blender, Mincer, Refrigerator, Mixer, Deep freezer, Slicer, Chiller, Butcher saw
	Laboratory	FBC Machine, Sterilizer, Distilling unit, Hot plate, Incubator, Water bath, Mixer, UPS, Printer, Stirrer, Centrifuge, Oven, Slide dryer, Computer, Hematology analyzer, Viral load set, Refrigerator, Microscope, Shaker, AVR, Haemoglobinator, Balance/Scale, Chemistry analyzer, Colorimeter, CD4 counter, Keyboard
	Radiology/Imaging	X-ray processor, Auto Processor, X-ray viewer, X-ray machine, Computer, Ultrasound machine, Light
	CSSD	Sterilizer, Hot plate, Disinfector
	Wards	Kettle, Suction machine, Disinfector, Infusion pump, Oxygen concentrator, Nebulizer, Light
	Emergency ward/ Theater	X-ray viewer, Suction machine, Heater, Light, Resuscitaire, Anesthesia machine, Oxygen concentrator, Diathermy machine, Pulse oximeter, Refrigerator, ECG monitor, Pump, NIBP machine, Kettle, Suction machine, Disinfector, Infusion pump, Oxygen concentrator, Nebulizer, Light
	Burns	Kettle, Suction machine, Disinfector, Infusion pump, Oxygen concentrator, Nebulizer, Light
	Lighthouse	Oxygen concentrator and oxygen supplying pump, patient monitor, surgical equipments, autoclaves, ultraviolet air sterilizers, laboratory equipments, air conditioners, lighting, geyer, desktops, laptops, Printers, refrigerators, laundry equipments (washing machine, dryer), kitchen equipment (hot plates, kettle, microwave).
	Eye	Computer, Light, Lensometer
	Pharmacy	Computer, Refrigerator, Mixer, Cell counter, Fan, Balance/Scale, Balance/Scale, UPS
	Orthopedic	X-ray viewer, Resuscitaire, Oxygen concentrator, Cutter, Pulse oximeter, Ventilator, Suction

[17] List of equipment is indicative only and may need to be updated when the standard equipment list is prepared for all categories of hospitals. Presently only the District and Community hospital list is based on the standard equipment manual

Type of healthcare facility	Department	Energy consuming equipment[17]
		machine, ECG monitor, Saw, Light, Auto BP machine
	PAM office	Photocopier, Projector, Computer, Calculator
	Dental	X-ray viewer, Dental unit, Suction machine, X-ray machine, Light, Amalgamator, Ultrasonic scaler
	ICU	Kettle, Suction machine, Disinfector, Infusion pump, Oxygen concentrator, Nebulizer, Light, X-ray viewer, Suction machine, Heater, Light, Resuscitaire, Anesthesia machine, Oxygen concentrator, Diathermy machine, Pulse oximeter, Refrigerator, ECG monitor, Pump, NIBP machine
	OPD	Sterilizer, Kettle, Light, X-ray viewer, Suction machine, Disinfector, Oxygen concentrator, Nebulizer, Haemoglobinator
	Main operating theatre	Boiler, X-ray viewer, Suction machine, Heater, Light, Resuscitaire, Anesthesia machine, Oxygen concentrator, Diathermy machine, Pulse oximeter, Refrigerator, ECG monitor, Pump, NIBP machine
	ENT	Patient Monitor, anesthesia Machine, surgical equipment, ultraviolet air sterilizers, autoclaves, laundry equipment (washing machine, dryer), desktops, laptops, printers, lighting, air conditioners, refrigerators, geyser, kitchen equipment (hot plates, kettle, microwave)
	Administration/Accounts	Photocopier, Projector, Computer, Calculator
		Kettle, Photocopier, Projector, Computer, Refrigerator, Radio, TV, VR, Calculator
	Blood Bank	Refrigerator, Water bath, Microscope, Centrifuge, Deep freezer
	Maternity ward	Heater, Incubator, Sterilizer, Kettle, Suction machine, Infusion pump, Resuscitaire, Oxygen concentrator, Phototherapy unit, Light, Ultrasound machine
	MCH	Sterilizer, Kettle, Light
	Ophthalmology	Computer, Light, Lensometer
	Physiotherapy	Shortwave unit, Ultrasound machine, Wax bath, Chiller, Ergometer
	Incinerator	Incinerator equipment
District/Community Hospital	Administration	Kettle, Photocopier, Projector, Computer, Refrigerator, Radio, TV, VR, Calculator
	Blood Bank	Refrigerator, Water bath, Microscope, Centrifuge, Deep freezer

Type of healthcare facility	Department	Energy consuming equipment[17]
	Central Sterilization Department	Sterilizer, Hot plate, Disinfector
	Dental Department	X-ray viewer, Dental unit, Suction machine, X-ray machine, Light, Amalgamator, Ultrasonic scaler
	Hospital Maintenance Unit	Photocopier, Computer
	Instrument Sets	Otoscope, Ophthalmoscope
	Kitchen	Hot plate, Cold room, Deep fryer, Food warmer, Toaster, Oven, Cutter, Blender, Mincer, Refrigerator, Mixer, Deep freezer, Slicer, Chiller, Butcher saw
	Laboratory	FBC Machine, Sterilizer, Distilling unit, Hot plate, Incubator, Water bath, Mixer, UPS, Printer, Stirrer, Centrifuge, Oven, Slide dryer, Computer, Hematology analyzer, Viral load set, Refrigerator, Microscope, Shaker, AVR, Haemoglobinator, Balance/Scale, Chemistry analyzer, Colorimeter, CD4 counter, Keyboard
	Laundry	Dryer, Washing machine, Iron, Sewing machine
	Maternity	Heater, Incubator, Sterilizer, Kettle, Suction machine, Infusion pump, Resuscitaire, Oxygen concentrator, Phototherapy unit, Light, Ultrasound machine
	MCH	Sterilizer, Kettle, Light
	OPD	Sterilizer, Kettle, Light, X-ray viewer, Suction machine, Disinfector, Oxygen concentrator, Nebulizer, Haemoglobinator
	Operating Theatre	Boiler, X-ray viewer, Suction machine, Heater, Light, Resuscitaire, Anaesthesia machine, Oxygen concentrator, Diathermy machine, Pulse oximeter, Refrigerator, ECG monitor, Pump, NIBP machine
	Ophthalmology	Computer, Light, Lensometer
	Orthopedic	X-ray viewer, Resuscitaire, Oxygen concentrator, Cutter, Pulse oximeter, Ventilator, Suction machine, ECG monitor, Saw, Light, Auto BP machine
	Pharmacy	Computer, Refrigerator, Mixer, Cell counter, Fan, Balance/Scale, Balance/Scale, UPS
	Physiotherapy	Shortwave unit, Ultrasound machine, Wax bath, Chiller, Ergometer
	Supervisor Room	Computer
	Wards	Kettle, Suction machine, Disinfector, Infusion pump, Oxygen concentrator, Nebulizer, Light

Type of healthcare facility	Department	Energy consuming equipment[17]
	X-Ray	X-ray processor, Auto Processor, X-ray viewer, X-ray machine, Computer, Ultrasound machine, Light
Urban Health Centre	Laboratory	FBC Machine, Sterilizer, Distilling unit, Hot plate, Incubator, Water bath, Mixer, UPS, Printer, Stirrer, Centrifuge, Oven, Slide dryer, Computer, Hematology analyzer, Viral load set, Refrigerator, Microscope, Shaker, AVR, Haemoglobinator, Balance/Scale, Chemistry analyzer, Colorimeter, CD4 counter, Keyboard
	OPD	Sterilizer, Light, X-ray viewer, Centrifuge, Refrigerator, Oxygen concentrator, Haemoglobinator
	Operating Theatre	Boiler, X-ray viewer, Suction machine, Heater, Light, Resuscitaire, Anesthesia machine, Oxygen concentrator, Diathermy machine, Pulse oximeter, Refrigerator, ECG monitor, Pump, NIBP machine, Sterilizer, Oxygen regulator, Ultrasound machine, Diagnostic set, Haemoglobinator
	Ward, Maternity	Sterilizer, Autoclave, Vacuum , Light
	X-Ray	X-ray processor, X-ray viewer, X-ray machine, Computer, Light
Rural Health Centre	OPD	Kettle, Centrifuge, Refrigerator, Light
	Ward, Maternity	Light
Health Post	OPD	Light, Refrigerator
	EPI	Light
Outreach Clinic	-	Light
Village Clinic	-	Light
Dispensary	-	Light
Cold Room	-	Freezer, Tube lights, Refrigerator, Exhaust fan, Printer, Air Conditioner, Desktop Computer, Electric Kettle

Source: UNICEF, Standard Equipment list for District and Community Hospitals in Malawi

At present, the energy consumption is restricted due to poor reliability of power as well as non-functioning equipment. Under the restricted use scenario, the energy consumption of different healthcare facilities has been modelled and presented below. As Outreach clinics, village clinics and dispensaries only have lighting as their main load, the graphical representation has not been provided for them.

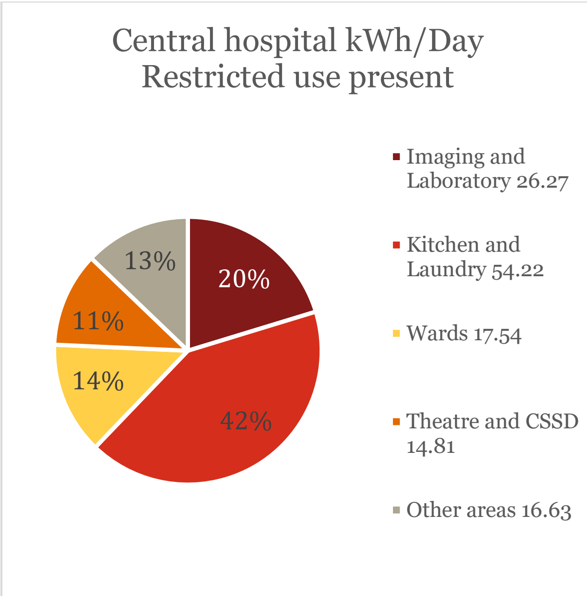


Figure 18 Central Hospital- Restricted usage scenario

Source: PwC analysis on Load assessment data

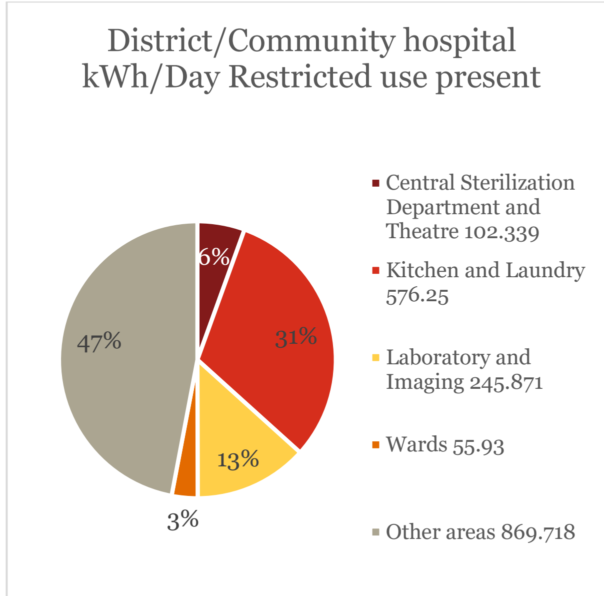


Figure 19 District/Community Hospital- Restricted usage scenario

Source: PwC analysis on UNICEF data

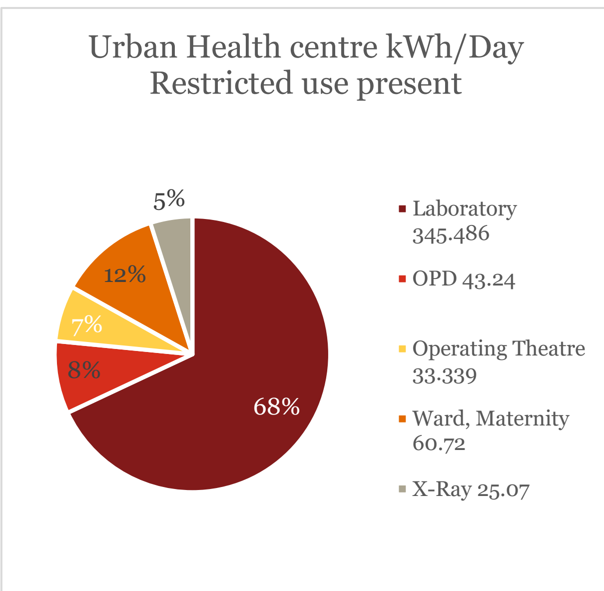


Figure 20 Urban Health Centre- Restricted usage scenario

Source: PwC analysis on UNICEF data

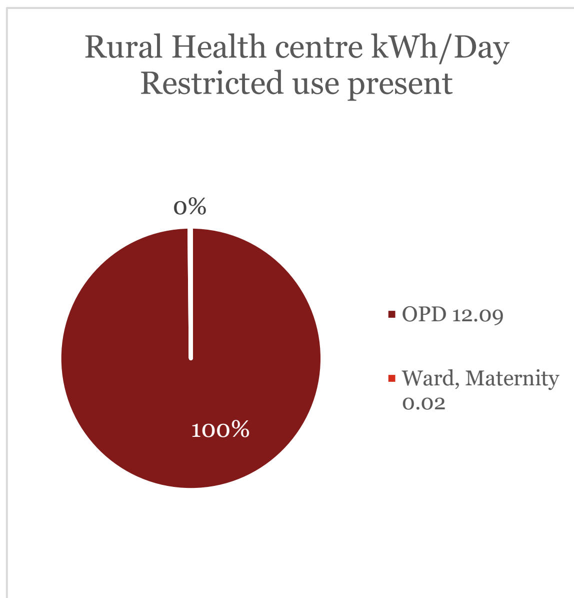


Figure 21 Rural health center kWh/day Restricted Use present

Source: PwC analysis on UNICEF data

In Central Hospitals, the major share of the energy consumption comes from Kitchen and Laundry section (42%) followed by the Imaging and Laboratory departments (20%). In District and Community hospitals, the Kitchen and Laundry (31%) and Laboratory and Imaging (13%) sections form a major portion of the total load under the restricted usage scenario. In the Urban Health Centers, the Laboratory section constitutes a major share (68%) of the energy consumption in the restricted usage scenario, followed by the Maternity Ward and OPD sections. In rural health centers and health posts, the OPD section constitutes a major share (99%) of the total energy consumption under the restricted usage scenario.

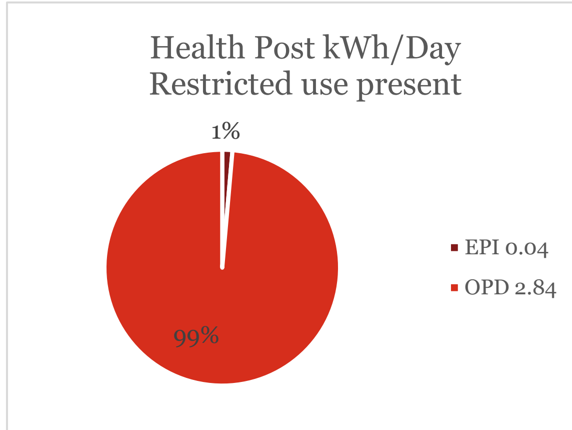


Figure 22 Health Post- Restricted usage scenario

Source: PwC analysis on UNICEF data

As Outreach clinics, Village Clinics, Dispensaries, CMST and Cold rooms don't have separate departments as in other healthcare facilities, a graphical representation for their restricted and unrestricted energy use hasn't been provided.

3.2.2. Usage patterns of energy consuming equipment & extent of unmet energy demand in healthcare facilities

The following sections list out the assumptions for estimation of current energy consumption under the restricted and unrestricted scenarios and provide a comparison of the restricted and unrestricted energy consumption for different types of healthcare facilities in Malawi.

3.2.2.1. Key assumptions for demand estimation

- Modeling of energy needs has been done for MoH&P controlled facilities only as they account for 85% share of the healthcare facilities in number terms[18]. As there are no previous load assessment studies carried out for CHAM facilities, the analysis for CHAM has not been done for this report.
- The number and power rating assumed for various appliances in the different categories of healthcare facilities has been taken from previous UNICEF studies and provided in detail in the Annexures.

3.2.2.2. Energy consumption of healthcare facilities in unrestricted scenario

The energy consumption under the un-restricted scenario has been estimated by considering an increase in the hours of power supply. Healthcare facilities with a diverse range of equipment and large number of equipment using electricity are expected to witness a drastic increase in the energy consumption moving from a restricted use scenario to an unrestricted use scenario. The following graphs illustrate the increase in energy consumption going from a restricted scenario to an unrestricted scenario per facility for different types of healthcare facilities in Malawi.

[18] Health facility mapping in Malawi:UNICEF

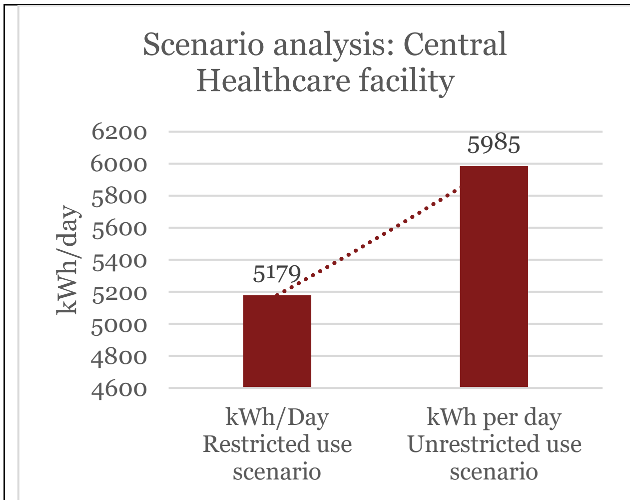


Figure 23 Present Energy consumption in a Typical Central Hospital

Source: PwC analysis on data from load assessment of 5 Central healthcare facilities

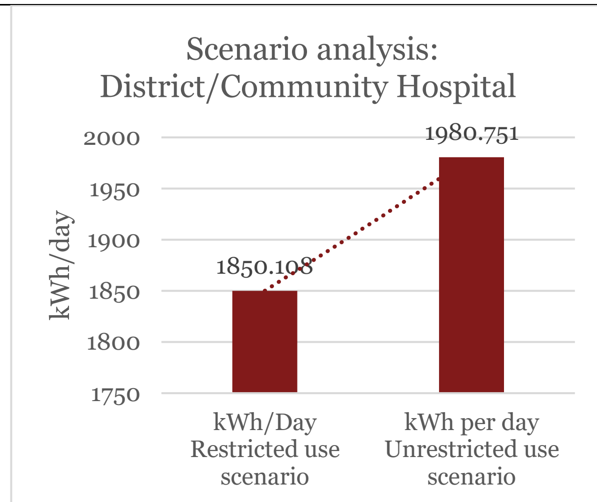


Figure 24 Present Energy consumption in a Typical District/Community Hospital

Source: PwC analysis on UNICEF data

An analysis of the energy use shows a significant jump in the energy consumption when the reliability of power supply is increased from the current levels. The level of increase has been assumed as 9% for the Central District and Community hospitals[19], 10% for Urban Health Centers, 11% for rural health centers and 12% for heath posts (progressively increasing levels moving towards lower tier facilities) to accommodate the high variation in power reliability across different geographies of Malawi. The increase is found to be the most pronounced (16%) for Central healthcare facilities. This shows that the extent of unmet demand due to poor reliability is the highest in Central healthcare facilities.

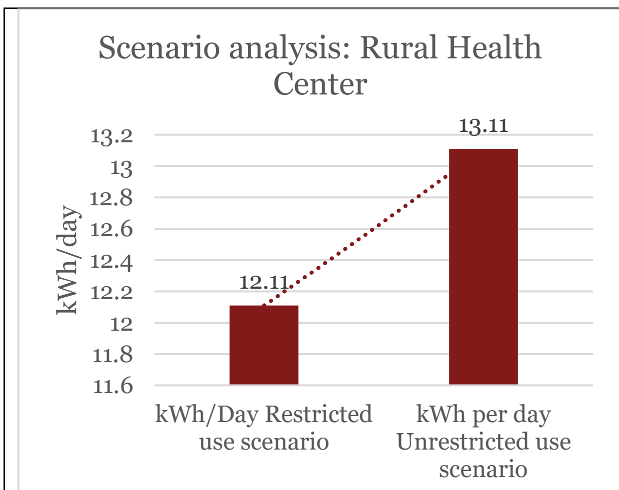


Figure 25 Present Energy consumption in a Typical Rural health center

Source: PwC analysis on UNICEF data

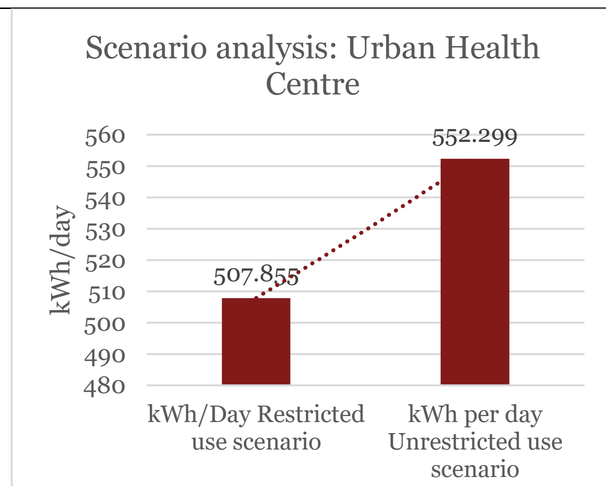


Figure 26 Present Energy consumption in a Typical Urban health center

Source: PwC analysis on UNICEF data

[19] Based on average of current percentage of outage hours during morning shift (7:30 AM to 4:30 PM) for 5 Central healthcare facilities in which Load assessment was carried out.

Urban health centers tend to have a significantly higher energy consumption than rural health centers due to high diversity of appliances. Health posts are situated in far-flung rural areas and most of the consumption of power is from refrigerators used for storing vaccines.

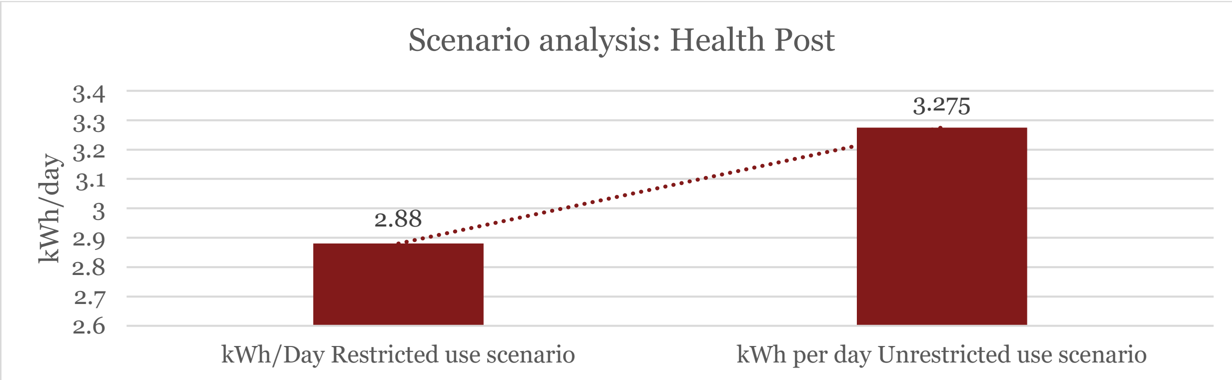


*Figure 27 Present Energy **consumption** in a typical Health post*

Source: PwC analysis on UNICEF data

The other sub-district level facilities such as dispensaries, outreach clinics and village clinics have low electricity loads, mostly contributed by lighting. Therefore, the increase in such loads due to improved reliability is not significant. As regards the Cold Rooms, only the National and Zonal Cold rooms were studied as a part of the UNICEF comissioned "Feasibility and costing study to establish the use of renewable energy to run national and sub-national cold rooms/ cold chain system for health sector in Malawi" for which the available data is not sufficient to model the unrestricted energy consumption. Further, the district and sub-district level cold rooms are already included as a part of the health facilities at the district and sub-district level. Therefore the comparison of kWh/day under restricted and unrestricted scenarios hasn't been provided for the Cold Rooms in Malawi.

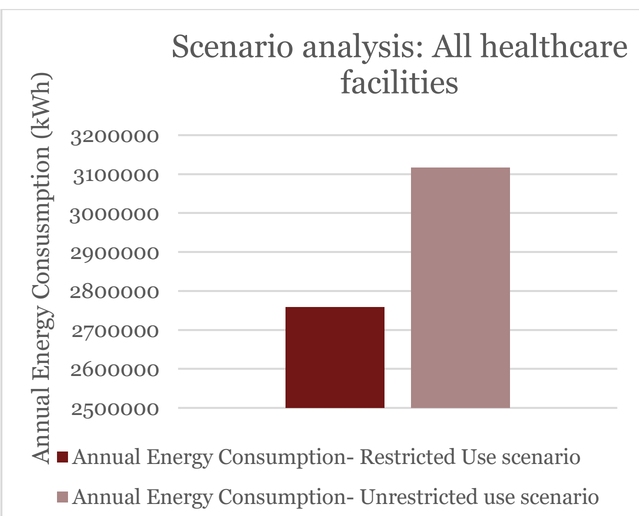


Figure 28 Present Energy Consumption- All healthcare facilities combined

Source: PwC analysis on UNICEF data

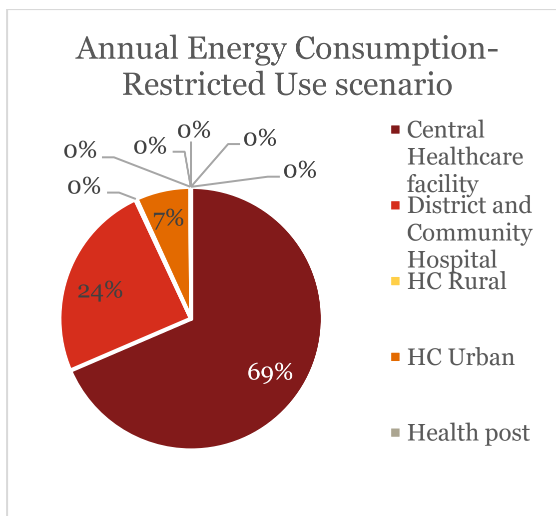


Figure 29 Annual Energy Consumption- Share of different types of healthcare facilities

The figure above shows the energy consumption for the entire healthcare sector under the restricted use and unrestricted use scenario, which has been prepared by aggregating the consumption from all categories of hospitals. It is estimated that 13% of the annual energy consumption of the healthcare sector is not met because of poor reliability.

The outcomes of the analysis presented above and the observations in the load assessments indicates that a significant share of the energy consumption is restricted due too poor reliability in all categories of healthcare facilities. When the reliability of power increases and the existing facilities upgrade themselves in terms of the specialty of services that they offer, the consumption of energy and the corresponding expenditure is also expected to increase, putting a strain on the already meagre resources. Therefore, *it is important to manage the energy demand better and that the equipment used within the healthcare facilities be replaced with their energy efficient versions*.

4. Future energy consumption of Healthcare facilities

Chapter 3 provided an overview of the key drivers of energy consumption and the extent to which they influence the current energy consumption of the healthcare sector in Malawi. As the master plan has a time horizon of 10 years, the design of interventions should be done considering the future energy consumption. The design of RE and EE equipment to service the energy demand of healthcare facilities under the Master Plan and the budgeting of the activities under the master plan has to be done considering the future energy consumption. Three key factors have been considered for the estimation of future consumption.

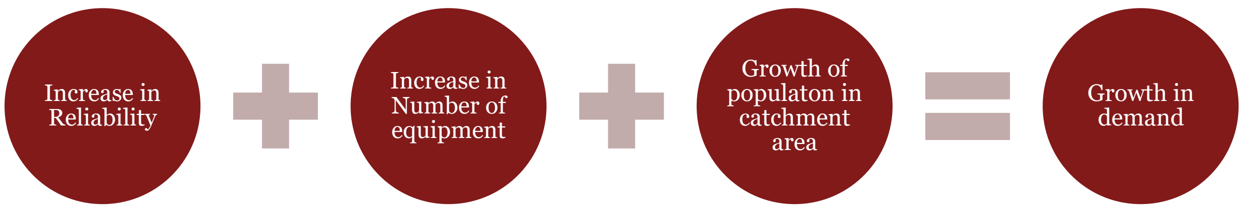


Figure 30 Factors influencing growth in energy consumption

An excel based model has been created to estimate the future consumption for each year of the master plan from 2019 to 2028. *The following section presents the assumptions for modeling of the future energy demand*, which, along with investment related assumptions, forms the basis for the capital budgeting for the Master Plan.

4.1. Assumptions for estimating future energy consumption and methodology for estimation

The assumptions in modeling for each of the three factors are elaborated below:

1. **Assumptions on population growth in Catchment Area:** To estimate the future growth of Healthcare facilities in next 10 years, a Compounded Annual Growth Rate (CAGR) has been applied on the catchment population. As per the Health Sector Strategic Plan-II, Malawi is predicted to experience an average annual population growth rate of 4.2% from 2013 to 2030. Assuming that the future growth rate of population would be higher, the ***growth rate for the catchment of the Central Healthcare facilities has been taken to be 5.5% and that for the remaining healthcare facilities have been tempered down progressively*** as the geography changes to district and sub-district level. The population of the catchment area and the growth rate of the population have been taken to be as shown in the table below:

Table 20 Catchment population size and growth rate for healthcare facilities

Type of healthcare facility	Catchment population	Growth rate of population
Central Healthcare facility	250000	5.5%
District Hospital	50000	5.0%

Type of healthcare facility	Catchment population	Growth rate of population
Health center	25000	4.0%
Health post	9000	3.5%
Outreach clinic	2500	3.0%
Village clinic	1000	2%
Dispensary	1000	2%
CMST	NA	2% applicable on no. of stores

Source: UN Foundation Energy for Women's and Children's health project

In addition to the healthcare facilities mentioned above, the present and the upcoming facilities of the Central Medical Stores Trust (CMST) would also present energy demand. The growth rate of CMST facilities has been taken to be 2%.

The growth rate of population has been used to estimate the increase in the number of healthcare facilities taking the catchment population as the standard figure for each type of healthcare facility. The increase in the number of facilities is estimated as below

Table 21 Number of healthcare facilities projected across time horizon of master plan

Type of healthcare facility	Number of healthcare facilities									
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Central Healthcare facility	5	6	6	6	7	7	7	8	8	9
District and Community Hospital	44	46	49	51	54	56	59	62	65	68
HC Rural	354	368	383	398	414	430	448	465	484	504
HC Urban	67	70	73	76	79	82	85	89	92	96
Health post	137	141	146	151	157	162	168	174	180	186
Outreach clinic	4104	4227	4354	4484	4618	4757	4900	5047	5198	5354
Village clinic	3613	3685	3758	3832	3910	3988	4070	4151	4233	4318
Dispensary	42	43	44	44	45	46	47	48	49	50
CMST	3	3	3	3	3	4	4	4	4	4

2. **Assumptions on increase in the number of equipment due to out of service equipment coming online:** As per the Service Provision Assessment of the Healthcare sector by Ministry of Health and Population in 2014, the quantity of equipment in Government facilities that is out of service is 25%. Based on observations during the load assessment, the failure of equipment was found to be highest in the Kitchen and Laundry sections of the healthcare facility. For a few departments/sections within the healthcare facilities, in which non working equipment were identified during load assessments in 5 Central healthcare facilities, the figure of 25% has been directly used to represent the percentage increase (compounded annual growth rate) over the next 10 years. The percentage increase in the number of equipment at the end of 10 years has been assumed for the identified section/department in all types of healthcare facilities is provided in the table below. ***For the remaining sections/departments within the hospital, equipment growth has been assumed to be nil.***

Table 22 Percentage increase in the number of equipment

Type of equipment	Percentage increase in number of equipment
Laundry	25%
Kitchen	25%
Laboratory	25%
X-Ray	25%
Operation Theater	25%
CSSD	25%
AC/Light/Refrigerator	25%
New Wards	25%

Source: PwC Analysis on data of Service Provision Assessment – MoH&P, 2014

3. **Assumptions on increase in the number of equipment due to load growth:** Based on the load assessment, it has been observed that for departments such as Radiology, X Ray, Kitchen, Laundry, CSSD, Wards and Dental the load growth is ***on an average 38%***. This figure has been used in the model to estimate the increase in the number of equipment due to load growth.
4. **Assumption on increase in reliability of power:** Improvement in power reliability (hours of power supply per day) over the prevailing levels, for all sets of equipment in various departments has been assumed as ***9% for the Central, District and Community hospitals[20], 10% for Urban Health Centers, 11% for rural health centers and 12% for health posts*** for the unrestricted use scenario.

4.2. Energy demand forecasts and their alignment with the Government Plans for healthcare sector

With the objective of scaling up the coverage of high quality Essential Health Package (EHP) at all levels of the healthcare delivery system, the MoH&P has prepared a Capital Investment Plan from 2017-2022. The Capital Investment Plan (CIP) focuses on the following key areas:

- ***New Builds:*** Investment into Buildings and permanent structures for healthcare facilities
- ***Equipment:*** Essential Equipment sets for provision of health services comprising of medical equipment, furniture and hospital plant
- ***Facility Upgrade:*** Adding additional provisions for upgrading the facility to a higher level. For Ex- Upgradation of maternity units to health centers
- ***Facility rehabilitation:*** Increasing the number of healthcare workers

The following table presents an overview of the ***number of facilities, which have been demarcated under the CIP*** under the above mentioned areas:

Based on average of current percentage of outage hours during morning shift (7:30 AM to 4:30 PM) for 5 Central healthcare facilities in which Load assessment was carried out.

Table 23 Expansion envisaged under Capital Investment Plan 2017-2022

Type of healthcare facility	No. of Facilities designated as New Build	No. of Facilities designated for Rehabilitation	No. of facilities designed for new Medical Equipment	No. of facilities designated for upgrade
Central Hospital	1	4	4	-
Community Hospital	13	9	9	2
Dispensary	11	12		-
District Hospital	2	5	22	-
Health center	57	88	98	-
Health Post	904	4	901	-
Maternity Clinic	3	1	-	-

Source: Capital Investment Plan 2017-2022

The following table presents the projections for increase in the number of healthcare facilities over the next 10 years, which have been prepared taking assumptions on catchment growth. In addition to the healthcare facilities, whose growth depends on the population growth of the catchment area, a growth rate has been applied to CMST stores on the basis of which the number of such facilities is estimated to increase to 4 by 2028.

On comparing the projected increase in facilities in the table below with the plan of the Government for New Builds, it is observed that for the *designated number of Central Healthcare facilities, Health centers and Village clinics for New Build are significantly lower than the requirement,* assuming business-as-usual growth. The Capital Investment plan for the years 2022 to 2027 would need greater allocations for new builds to make sure that the national objective of ensuring access to healthcare facilities is met comprehensively.

Table 24 Increase in number of hospitals due to catchment growth

Type of healthcare facility	Projected yearly increase in number of Healthcare facilities										Total no. of new faciliti es
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
Central Healthcare facility	0	1	0	0	1	0	0	1	0	1	4
District/ Community Hospital	2	2	3	2	3	2	3	3	3	3	26
Health Center Rural	14	14	15	15	16	16	18	17	19	20	164
Health Center Urban	2	3	3	3	3	3	3	4	3	4	31
Health post	5	4	5	5	6	5	6	6	6	6	54
Outreach clinic	120	123	127	130	134	139	143	147	151	156	1370
Village clinic	71	72	73	74	78	78	82	81	82	85	776

Type of healthcare facility	Projected yearly increase in number of Healthcare facilities										Total no. of new facilities
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	
Dispensary	1	1	1	0	1	1	1	1	1	1	9
CMST	0	0	0	0	0	1	0	0	0	0	1

Source: PwC Analysis

Based on the Integrated Resource Plan of Malawi (Norconsult version), ***the total electricity demand for the year 2030*** is estimated at 1236 MW, ***1873 MW*** and 2591 MW under the low, base and high demand scenarios respectively.

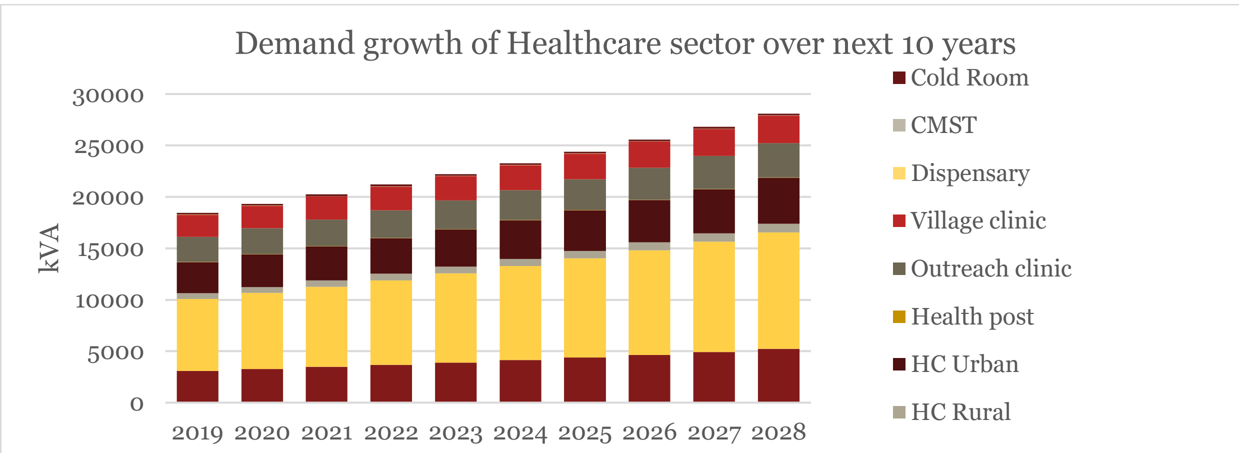


Figure 31 Demand growth estimated in next 10 years

Source: PwC Analysis

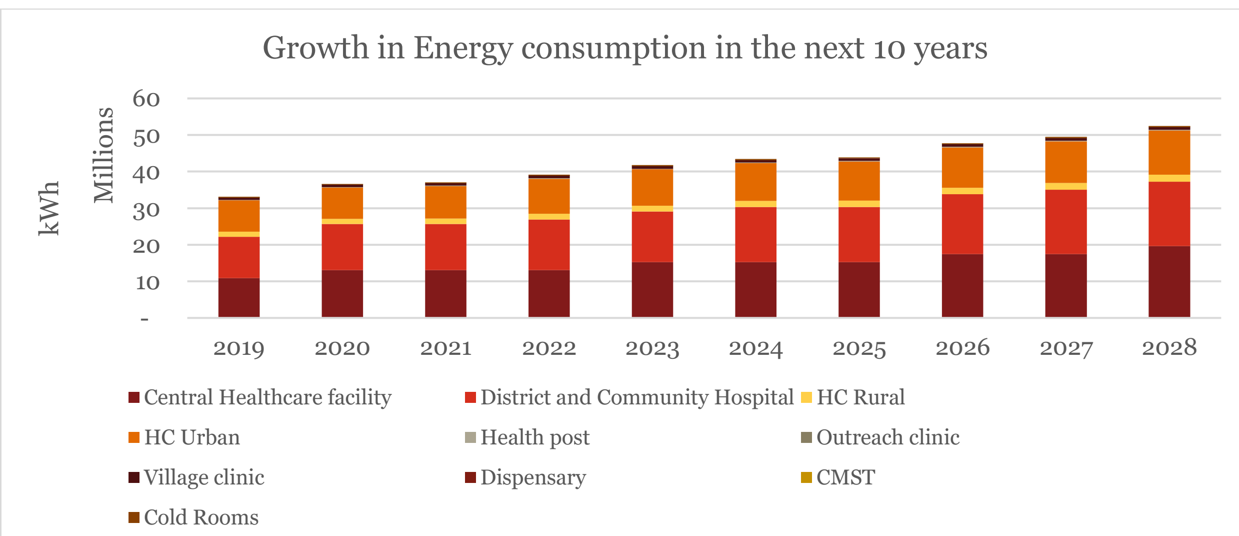


Figure 32 Growth in Energy consumption in the next 10 years

Source: PwC Analysis

As shown in the figures above, the load of the healthcare sector is expected to increase to over ***28.09 MVA by 2028, the final year of the master plan***. The share of District and Community Hospitals is expected to be the highest (40.32%) among all other type of healthcare facilities. For the same duration, the ***energy consumption of the health sector increases to 52.4 MU in 2028 from 33.1 MU in 2019***. The master plan seeks to equip the healthcare sector with the necessary renewable generation systems to meet the future demand comprehensively. The budget allocated for the RE generation systems would be one of the major line items in the overall budget of the master plan.

Given that a significant share of this demand would be met by renewable energy systems, the capability of the Malawian electricity grid to accommodate renewable generation is a real concern. A recent study on grid capacity indicated that ***renewables developments of 15 to 17MW (dependent on location) could be accommodated across the network up to a maximum total capacity of 70MW***[21]. Assuming that the adoption of renewable energy will be at a fast pace in the residential and commercial sectors as well, MERA and ESCOM would need to conduct detailed technical studies to understand the impact of renewable penetration on the electricity grid.

[21] Draft Malawi Renewable Energy Strategy 2015

5. Technology options for the Master Plan

Past programmatic interventions related to energy access in healthcare sector of Malawi have demonstrated that ***cross cutting technical interventions (i.e. technologies that are applicable to most categories of healthcare facilities) can go a long way in ensuring scalability and substantially increase program impact***. Large-scale interventions are attractive to technology vendors and ***the advantage of scale and could be leveraged by the Government to push vendors for price reduction and better quality of product/service***. Therefore, with a proper structure and operating framework, technology related interventions could also help the Government to meet ***broader economic and social objectives of market development and employment generation*** in addition to their primary objectives. The following sections present an overview of the technology options considered for meeting captive energy needs in the healthcare facilities in Malawi. The prospective technology options fall into the following two categories:

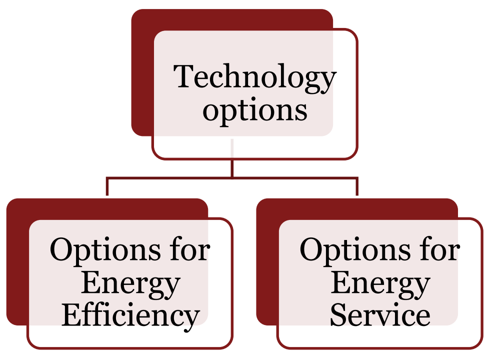


Figure 33 Prospective Technology options for Master Plan

- The ***technology options for energy efficiency*** are those technologies, which are intended to reduce the energy consumption from the current levels in the healthcare facilities, i.e. ***address issues on the demand side.*** These technologies ***would not be provided direct budgetary support.*** However, ***it is proposed that centralized procurement programs be initiated for these technologies*** by the Ministry of Health and Population for achieving price reduction through economies of scale.
- The ***technology options for energy service*** provide electrical energy or thermal energy (as hot water or recovered waste heat), i.e. ***address issues on the supply side***. These options ***would be provided direct budgetary support*** in the Master Plan.

It is recommended that the facilities take initiatives to ***first reduce optimize their energy consumption through energy efficiency, which results in savings that can be ploughed back to invest in renewable energy systems.***

5.1. Technology Options for Energy Efficiency

The following technology options were identified during the load assessments conducted in 5 Central healthcare facilities and 1 CMST facility. The identified options are of a cross cutting nature, i.e. applicable across multiple types of healthcare facilities. This would be a suitable parameter for achieving scale to ensure the success of centralized procurement programs in achieving price reduction.

5.1.1. Option-1: Energy Efficient Ceiling Fans

During energy load assessment, it was observed that the hospitals have ceiling fans, which are installed in various departments (mostly in wards). Energy efficient fans with brush less DC motor and aerodynamic fan design are commercially available, which provide similar air flow (as the existing fan) with a lower power consumption in comparison to the existing fans. The following table presents an illustrative cost benefit analysis of the installation of energy efficient fans in a Central Healthcare facility.

Figure 34 Ceiling fans installed in healthcare facilities

5.1.1.1. Cost Considerations

The following table presents a cost benefit analysis for energy efficient ceiling fans in a healthcare facility audited during load assessment.

Table 25 Illustrative Cost benefit analysis of installation of energy efficient fans in a Central Healthcare facility

Particular	Unit	Existing	Proposed
Quantity	Nos.	58	58
Rated capacity	W	75	28
Total connected load	kW	4.9	1.6
Annual energy consumption	kWh	9,860	3,248
Annual energy savings	kWh	-	6,612
Annual monetary savings	MK million	-	0.5
Investment required	MK million	-	2.0
Simple payback period	Months	-	46

The investment is found to be techno-commercially feasible with payback in <4 years. If the duty cycle increases, the payback can happen much faster.

5.1.2. Option-2: Energy Efficient Air Conditioners

During energy load assessment, it was observed that there are many split-type air conditioner installed in various facilities of the hospital for space conditioning especially in laboratory, X – ray, ICU and Pharmacy.

Figure 35 Air conditioner installed in a Central Healthcare facility

Observed value of Energy Efficiency ratio (EER) was found to be less than the rated value EER, which is due to lower loading of the AC. At most of the departments, the air conditioners were operated with set temperature of 16-18 ^{o}C, which is 6-8 ^{o}C less than the recommended set temperature of 24 ^{o}C. In addition, a number of facilities the AC were found running during lunch hours or after office hours even when the occupants had already left the facility.

5.1.2.1. Cost Considerations

The following table presents a cost benefit analysis for energy efficient air conditioners in a healthcare facility audited during load assessment.

Table 26 Illustrative Cost benefit analysis of installation of energy efficient AC in a Central Healthcare facility

Particular	Unit	Existing	Proposed
Quantity	Nos.	131	131
Rated cooling/heating capacity	kW	810.0	810.0
Energy efficiency ratio	W/W	2.75	4.50
Annual energy consumption	kWh	537,545	328,500
Annual energy savings AC replacement	kWh	-	209,045
Annual energy saving from waste heat recovery	kWh	-	93,936
Total annual energy saving	kWh	-	302,982
Annual monetary savings	MK million	-	24.3
Investment required	MK million	-	91.7
Simple payback period	Months	-	45

The investment is found to be techno-commercially feasible with payback in <4 years. If the duty cycle increases, the payback can happen much faster.

5.1.3. Option-3: Energy Efficient Lighting

Every lighting system provides a particular value of lumen output for consumption of one watt of power, this is known as efficacy of a lighting system. The central healthcare facilities use different type of lights which include fluorescent tube lights (FTL T-12 and T-8), LED, compact fluorescent lamp (CFL) and mercury vapour lamp (MVL). During the energy load assessments, it was observed that the healthcare facilities are mostly using Fluorescent tube light (FTL) for illumination in various departments. The Luminous efficacy of FTL tube light is 70 lumen/watt whereas the LED tube light has 120 lumen/watt. In addition, the illumination level was found to be very low in comparison to standards in most of the departments of the healthcare facilities due to the presence of faulty lights.

5.1.3.1. Cost Considerations

The following table presents a cost benefit analysis for energy efficient lighting in a healthcare facility audited during load assessment.

Table 27 Cost benefit analysis of energy efficient lighting

Particular	Unit	Existing	Proposed
Type of light		FTL	LED
Quantity	Nos.	441	441
Rating	kW	21.17	8.82
Annual energy consumption	kWh	61,811	25,754
Annual energy savings	kWh		36,056
Annual monetary savings	MK million	-	3.09
Investment required	MK million	-	2.20
Simple payback period	Months		9

The investment is found to be techno-commercially feasible with payback in <1 year, which is very attractive.

5.2. Technology options for Energy Service

5.2.1. Option-1: Solar Photovoltaic systems

5.2.1.1. Technology Overview

Malawi receives solar radiation of about 2133 kWh/m2/year. The global solar radiation on a horizontal surface ranges between 4.3 kWh/m2/day minimum and 7 kWh/m2/day maximum. The annual daily mean global solar radiation is about 5.86 kWh/m2/day. Solar energy presents good prospects for diversification beyond hydropower and enhancement in the existing generation capacity in Malawi. Based on their mode of installation, Solar PV systems can be either off-grid systems and Grid-connected systems.

5.2.1.1.1. Off-Grid Systems

As the name implies, off-grid PV systems are not connected to the central electricity grid and make economic sense for healthcare facilities that are located far from the grid (far enough to make the costs of grid extension higher than the cost of installation of the PV systems). These systems require an energy storage system for the energy generated to function effectively beyond daylight hours. A typical off-grid system comprises the following main components:

- Solar PV Modules to convert sunlight directly to electricity.
- Charge Controllers to manage the charging and discharging of the batteries
- Battery Bank to store the energy generated by the PV modules
- Inverter to convert the DC current generated by the solar PV modules to AC current for AC applications.

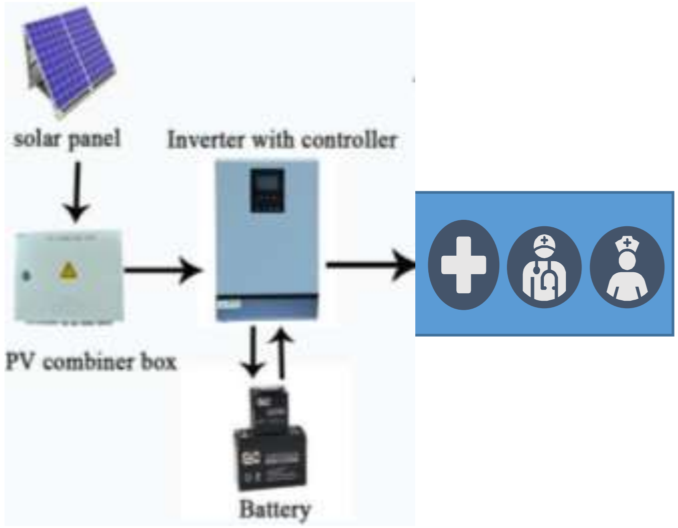


Figure 36 Schematic of Off-grid Photovoltaic system

5.2.1.1.2. Grid-Connected PV Systems

Grid-connected systems are systems connected to the central electricity grid and feed power directly into the grid through a net/gross metering arrangement. These systems are better suited for healthcare facilities that are connected to the grid but experience poor reliability and quality of power. In grid-connected PV applications, the panels are mounted on the rooftops of facilities, assuming the required area of favourable orientation to be available. A typical grid-connected PV system comprises the following components:

- Solar PV Modules to convert sunlight to direct current electricity.
- Inverter to convert the DC current generated by the solar PV modules to AC current for the utility grid.
- Main disconnect/isolator Switch

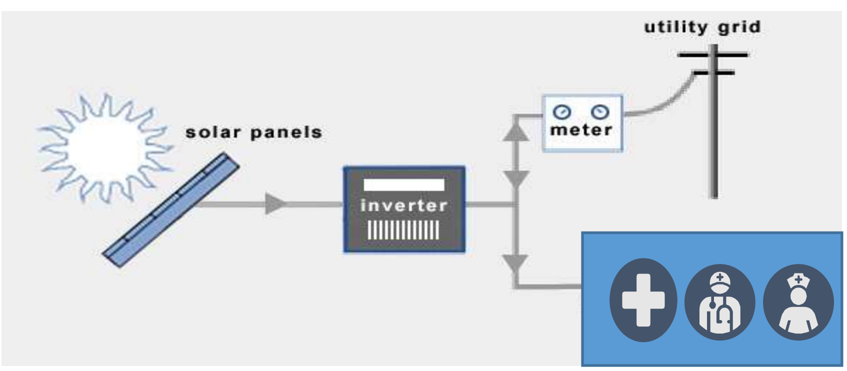


Figure 37 Schematic of Grid connected PV systems

5.2.1.2. Cost Considerations and Financial analysis

Solar PV systems are sized based on the energy demand per day of the facility and considerations around battery autonomy. Based on the energy demand per day calculated for Central healthcare facilities, District/Community hospitals, Urban Health Centers and Rural Health Centers, the size of the Solar generation systems was estimated for each of the categories. The following assumptions were considered for sizing the solar plant for the different categories of hospitals:

Table 28 Assumptions for system sizing

Parameter	Value
Average irradiation	5.35 kWh/sq.m/day[22]
Panel Efficiency	10%
kW/m² of panel area	0.135

For Central healthcare facilities, the sizing was done to be able to meet 50% of the daily demand (as all facilities could be expected to be grid connected) and for the other categories of hospitals, the sizing of the plant was done to meet 100% of the energy demand.

Considering these assumptions, the ***size of solar PV systems was estimated to be 700 kWp for Central healthcare facilities, 690 kWp for District/Community hospitals, 200 kWp for Urban Health centers, 6 kWp for Rural health centers and 1 kWp for Health posts***. Based on the load assessment of the Central Medical Stores Trust facility, the size of the solar PV system with battery was considered as 150 kWp. For the Cold Rooms, the size of the Solar PV systems to be installed was calculated only for the National and Zonal Cold Rooms by adding the recommended sizes under the UNICEF study.

An economic analysis for these capacities of standalone solar PV system with Maximum Power Point Tracking was carried out to assess the cost and intended benefits of the project. The total investment cost comprises the following components; module, inverter, cables, mounting structures, engineering and project management, labor and miscellaneous costs. The module and inverter cost alone makes up about 76% of the total investment cost. Table 11 contains a breakdown of the total investment cost.

Table 29 Cost breakdown for standalone rooftop PV system with battery

Parameter	Unit	Value
Module Cost(including battery cost with 2 day autonomy)	USD Mn/MW	1.97
Mounting structures and trackers	USD Mn/MW	0.09
Inverter	USD Mn/MW	0.08
Transformers, switchyard, cables, transmission	USD Mn/MW	0.15
Installation and Civil Works	USD Mn/MW	0.06
Sub Total- Hard Costs	USD Mn/MW	2.35
Interest during construction (IDC)	USD Mn/MW	0.004
Financing cost	USD Mn/MW	0.016
Working capital margin money	USD Mn/MW	0.012
Contingency, insurance, pre-operative cost, PMC	USD Mn/MW	0.071

[22] As gathered through Load Assessment in 5 Central Healthcare facilities

Total Power Plant Cost	USD Mn/MW	2.45

The key financial assumptions for the analysis are presented below:

Table 30 Key financial assumptions

Parameter	Value
Debt	70%
Equity	30%
Interest Rate	15.0%
Return on equity for first 10 years (per annum)	20%
Return on Equity after 10 years (per annum)	20%
Income Tax rate	30%
Weighted Average Cost of Capital	11.6%

Source: Stakeholder consultations and PwC analysis

The output parameters calculated on the basis of a recovery of MK 83.04/kWh and a Viability Gap Funding of USD 1.5 million/MW (61% of the cost per MW) show that the ***Internal Rate of Return is higher than the Weighted Average Cost of Capital of 11.55%*** (calculated on the basis of a debt-equity ratio of 70:30). The Return on Equity of 15.47% meets the minimum requirement of 15% for Solar projects in Malawi.

Table 31 Output of financial model

Parameter	Value
Project IRR	12.11%
Equity IRR	15.47%
Average annual generation Million Units/MW	1.59
Payback period	8.6 years

Source: PwC analysis

Therefore, Solar PV systems are ***evaluated as a suitable option*** for meeting the electrification need in a sustainable manner as a part of the Master Plan. It is recommended that Lithium Ion battery storage systems be compulsorily installed with proposed solar photovoltaic system even they are grid interactive. Storage system with grid interactive solar photovoltaic systems will ensure uninterrupted power supply during power outage and reduces impact of fluctuating solar power on the grid.

5.2.1.3. Operation and Maintenance

Most PV manufacturers guarantee a power output of 80% for 20 years provided their products are properly installed and maintained, Maintenance of PV modules is relatively easy as the most common technical problems occur due to misplaced or dirty modules which are defects that can be identified visually. Solar modules can be easily cleaned with water and a sponge, but ongoing maintenance is also necessary. This should include checkup of cables and fixation, the opening and control of the junction box and the strain relief of electric cables.

Table 32 O&M of Solar PV system

System Component	Type of maintenance
Solar Panels	• Clean dust on modules regularly (once a month) • Check PV array output current, voltage and connections (once a year)
Batteries (lead-acid type)	• Clean batteries poles regularly (once a month is recommended) • Check the voltage of the battery (twice a month) • Check level of electrolyte of cells (once a month) • Fill distilled water when needed
Charge Controllers	• Inspect connection of wiring to and from charge controllers (once a year) • Check charging current and voltage
Inverters	• Inspect connection of wiring to and from inverters (once a year) • Check output current and voltage
Wiring, connections, etc.	• Check fuse, connections between system components regularly (once a year)

Batteries are the main components in stand-alone PV systems that need to be recycled. Basically, they contain toxic materials which have negative effects on the environment if disposed of inadequately. Therefore, recycling of batteries should be considered mainly when designing maintenance mechanisms. The investment costs of PV systems are high, therefore systems can be stolen in remote areas. Some health facilities lack the safety of fences or other measures that prevent installed systems from being stolen. Anti-theft screws can keep the PV modules secured. Another option to secure the PV modules is through the welding of module frames together, if possible with a fixed foundation.

A detailed work plan to address the design and O&M related issues with Solar PV systems has been provided in the Annexures.

5.2.2. Option-2: Solar water heater with electrical element

5.2.2.1. Technology Overview

Solar water heating systems consist of solar thermal collectors and a hot water storage tank. The solar panels collect and convert the heat from the sun into useable hot water needed in the hospital facility. Besides being environment friendly, they considerably reduce fuel consumption otherwise required for hot water.

In this above system, user has an option to set temperature of required hot water and cold water is first passed through solar exchange tank and gets heated through solar thermal energy. From solar exchange tank the hot water is supplied to electric water heaters to heat the water up to required set temperature. The energy supplied by solar collector in this system makes up the savings over the conventional electric geyser.

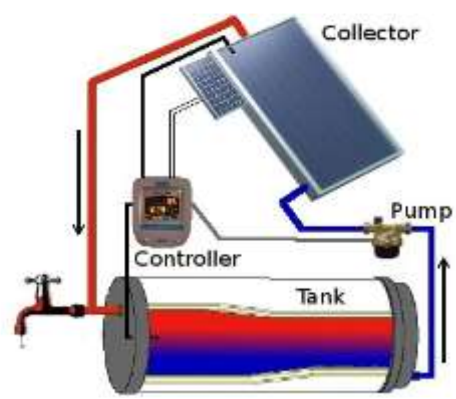


Figure 38 Schematic of Solar water heater

Solar water heaters contribute to a substantial reduction in fuel consumption. Solar water heating was proposed in SE4ALL's Agenda Action (AA), which reports that the Government of Malawi has agreed in its Intended Nationally Determined Contributions submission to UNFCCC that it will replace 20,000 electric geysers with solar alternatives by 2030. Installations are available in different sizes and types and can be fitted on most roofs. Increasingly, they are integrated into the design of new or retrofitted buildings, including (sun-facing) facades.The efficiency of solar water heating systems varies with the desired output water temperature.

5.2.2.2. Cost Considerations and financial analysis

Solar water heating systems operate without fuel. Costs of operation are therefore very low. Only the pump that circulates the water through the system consumes some electricity. The initial investment represents the largest share of the total costs of these systems. Based on an analysis of the techno-commercial feasibility, it has been estimated that for retrofitting a 1575 litre electric geyser system which is of 77 kW installed capacity, the simple payback period is 15 months.

Table 33 Output of financial model

Particular	Unit	Existing	Proposed
Total capacity	Litre	1575	1,575
Rated capacity	kW	77	77
Annual electricity consumption	kWh	56,210	22,484
Annual energy savings	kWh	-	33,726
Annual monetary savings	USD	-	5389
Investment required	USD	-	6720
Simple payback period	months	-	15

The costing and analysis reveals that the payback period is at an acceptable level. Considering central healthcare facilities as the target category, ***Solar Water heaters are observed to have good potential and are recommended as a solution in the master plan.***

5.2.2.3. Operation and Maintenance

Solar water heating systems require almost no maintenance apart from occasional cleaning of the collector surface. The rest of the (central) heating system, pumps, pipes, radiators, etc. have comparable maintenance requirements as those connected to a traditional boiler system. Systems have a long lifetime of up to 25 years.

5.2.3. Option-3: Biogas systems

5.2.3.1. Technology Overview

Biogas is produced by bacteria through the bio-degradation of organic material under anaerobic conditions. This gas is useful as fuel to substitute firewood, petrol, LPG, diesel and electricity depending on the nature of the task and local supply conditions and constraints. Biogas digester systems provide a residue organic waste, after its anaerobic digestion (AD) that can be used as manure. In addition, anaerobic biogas digesters can also be used as waste disposal systems, particularly for human wastes and prevent potential sources of environmental damage and the spread of pathogens. Biogas technology is particularly valuable in residual treatment of animal excreta and kitchen refuse (residuals). For the master plan, Biogas systems have been evaluated as an option for meeting the cooking requirement in the healthcare facilities.

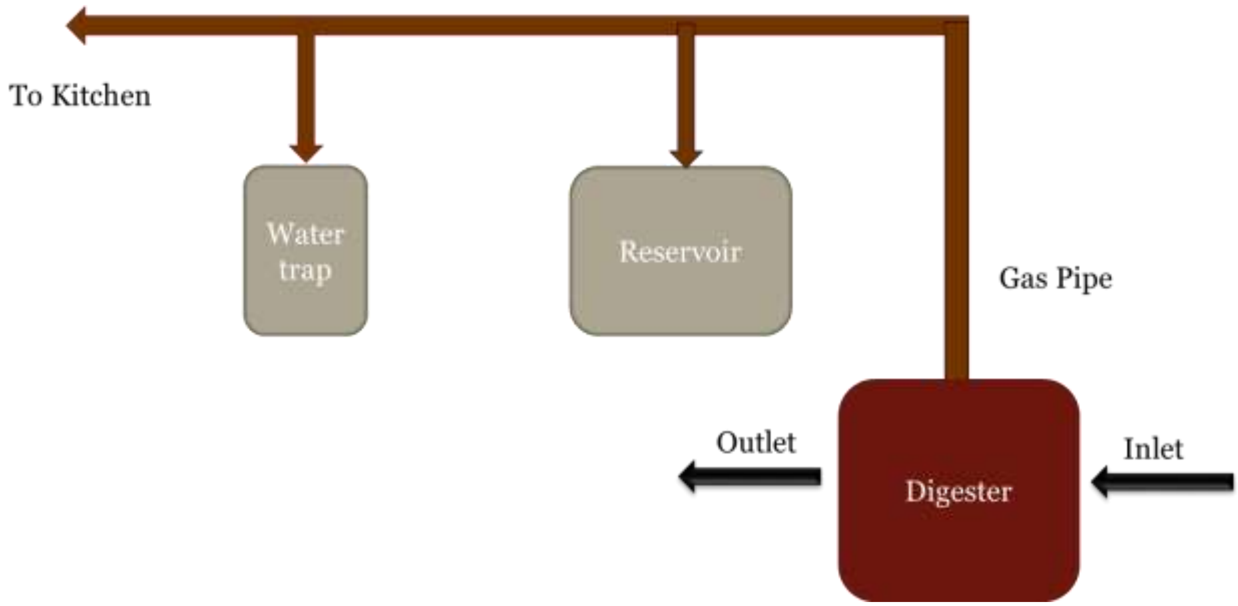


Figure 39 Process flow diagram of Biogas systems for kitchen waste

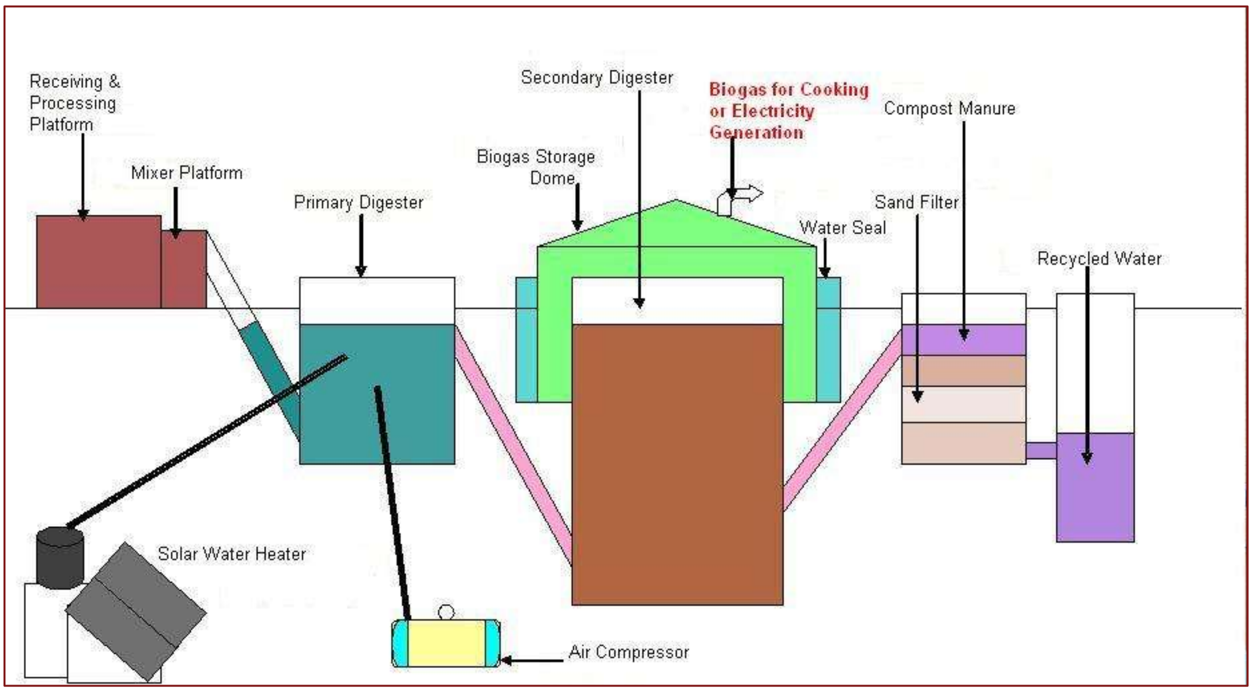


Figure 40 *Schematic of Biogas plant for kitchen waste*

A biogas production system consists of the following components:

a) **Substrate inlet**: This consists of a receptacle for the raw fresh organic waste and pipe of at least 10 cm diameter leading to the digester. The connection between the inlet pipe and the digester must be air tight.

b) **Digester:** This is the reservoir of organic wastes in which the substrate is acted on by anaerobic microorganisms to produce biogas.
c) **Gas Storage /Reservoir**: Depending on the proposed design, this may be simply an empty but enclosed space above the slurry in the digester, an inverted floating drum whose diameter is just slightly smaller than that of the cylindrical digester or an air tight polythene tube with an inlet –outlet outfit.
d) **Gas Burner:** This may be a special lighting lamp or a modified burner for cooking.
e) **Exhaust outlet:** This consists of a pipe of similar size to the inlet pipe connected to the digester at a slightly lower level than the inlet pipe to facilitate outflow of exhausted slurry.

5.2.3.2. Cost Considerations

The cost of biogas systems considered for the analysis is USD 350 for a biogas generation potential of 1 cu. meter per day. The following table presents a financial analysis of a sample biogas system for kitchen waste availability of 50 kg per day[23].

Table 34 Financial analysis of Biogas systems

Particular	Unit	Value
Kitchen waste available per day	kg/day	50
Biogas production from 1 kg kitchen waste	m3/kg	0.3
Total biomass generation potential	m3/day	15
Calorific value of biogas	KJ/m3	20,000
Calorific value of biogas	kCal/m3	4,777
Efficiency of Biomass stove	%	60%
Useful heat available per day	kCal/day	42,992
Quantum of power demand displaced by biogas	kW/day	50
Kitchen Load		
No. of cooking pot	Nos.	3
Power rating of each cooking pot	kW	18
No. of batches per day	batch/day	9
Operating hour per batch	hours/batch	2
Electricity consumption per day	kWh/day	324
Savings		
Monetary savings per day	MK/day	2,964
Annual electricity savings	kWh/year	18,247
Annual monetary savings	MK million/year	1.1
Investment required	MK million	3.8
Simple payback period	months	42

Source: PwC analysis

Therefore, Biogas systems are ***evaluated as a suitable option*** for meeting the cooking need in a sustainable manner as a part of the Master Plan.

[23] As per Load assessment observations in 5 Central Healthcare facilities

5.2.3.3. Operation and Maintenance

Most of the controls may be done continuously by control and monitoring systems (like temperature of the reaction, the amount of substrates, the quantity of gas/electricity/heat produced, etc.) but others might require expert support or can be done by the end-user himself. The end-user has to ensure maintenance and observe the maintenance intervals (important for warranty of plant parts) of the biogas plant and the downstream equipment. Some maintenance can be done by the end-user himself (e.g. scheduled replacement of wear parts as filters, seals and replacing or replenishing supplies or consumables like engine oil or water) or by certain service provider. Measuring is the precondition for process control and optimization.

5.2.4. Option-4: Waste heat recovery from Incinerator

5.2.4.1. Technology Overview

The hospital has installed one incinerator to burn all the medical waste. All solid waste from the hospital facilities is considered infectious. Hence, all the solid wastes will be treated in an incinerator and the ash will be disposed in a well-covered ash pit to be constructed near the incinerator.

Figure 41 Incinerator for waste burning

Some of non-infectious waste are burned in open pit. The waste heat in flue gas which is presently rejected to atmosphere. This waste heat can be utilized to generate hot water. The incinerator operates daily for around 2 hours, during this period the waste heat can be recovered by an economizer arrangement (shell and tube heat exchanger). This heat in turn can be used to produce hot water and supplied to guardian shelter or other areas near the incinerator.

5.2.4.2. Cost Considerations

The following table presents an illustrative cost benefit analysis of the waste heat recovery system for a Central healthcare facility.

Table 35 Cost benefit analysis for a Central healthcare facility

Particular	Unit	Existing	Proposed
Monthly diesel consumption	L	280.00	280.00

Particular	Unit	Existing	Proposed
Average flue temperature	°C	175	75
Annual fuel saving	L	-	336
Annual monetary savings	MK million	-	0.31
Investment required	MK million	-	0.70
Simple payback period	months	-	27

5.2.4.3. Operation and Maintenance

The following points should be considered in the O&M of the Waste heat recovery system.

- At regular intervals and as frequently as experience indicates, an examination should be made of the interior and the exterior of the heat exchanger. Neglect in keeping all tubes clean may result in complete stoppage of flow through some tubes, causing severe thermal strain, leaking tube joints, or structural damage to other components.
- Exchangers subject to fouling or scaling should be cleaned periodically. A light sludge or scale coating on tubes greatly reduces their efficiency. A marked increase in pressure drop and/or reduction in performance usually indicates cleaning is necessary. Because difficulty of cleaning increases rapidly as scale or deposit thickness increases, intervals between cleaning should not be excessive.

In summary, Solar PV generation systems, Solar Water heating systems, Waste Heat recovery from Incinerators and Biogas systems have been evaluated as suitable technology options on the basis of the load assessments in 5 Central Healthcare facilities. In addition, for Outreach clinics, village clinics and dispensaries, standalone small scale technology options such as Solar Direct Drive refrigerators and Solar Lanterns have been considered based on their need. These technology options would be the common technical interventions which the master plan would support by making budgetary provisions.

In addition, energy efficient ceiling fans, energy efficient lighting and energy efficient air conditioning have been identified as techno-commercially feasible options, which could be a part of centralized procurement programs aimed at price reduction.

6. Potential business models & modes of financing

In order to increase access to affordable and reliable electricity, in addition to technology, business models also play a key role. The study of ***existing Renewable Energy Technology (RET) installation has suggested that they have not performed as desired due to lack of oversight arrangements, limited availability of qualified technical assistance and engineering, non-availability of spare parts and good quality components and low feasibility of small scale renewable energy***.

Depending upon the proximity to the central grid and the availability and reliability of power, there may be three ways of powering any healthcare facility, which are listed below:

- By extending the national electricity grid
- By setting up of Renewable energy mini grids, which can generate electricity in a standalone manner
- In case the healthcare facility is already connected to the grid, making it more reliable by also connecting a renewable energy source.

Renewable Energy and Energy Efficient technologies offer a wide range of options to healthcare facilities and project promoters. The following sections present the business models for developing self-sufficient, independent and reliable projects, taking into consideration the involvement of different stakeholders such as the local public, decision makers, potential investors and project promoters.

6.1. Business models to implement the recommended technology options

Cost-plus tariffs are a key to ensuring long-term sustainability of the project and proper O&M. The tariff must also integrate other expenditures in running the system such as spare parts, repairs, battery necessities etc. However, tariffs should always be designed considering the affordability of the end user. The optimal business model for any given project would depend on local conditions, financial and regulatory environment, the institutional framework and the support mechanisms in place. Business models need to be adaptable to the local circumstances to best fit the requirement of the end-user i.e. the healthcare facilities. In broad terms, the suggested business models can be classified into two categories:

- Business Models for Electricity supply
- Business Models for Thermal energy supply

6.1.1. Models for Electricity supply

The models for electricity supply apply to Captive Solar PV generation systems, Solar Lanterns and Solar Direct Drive Refrigerators, which would be installed as a part of the master plan. The models are described in details in the following subsections.

6.1.1.1. Build Own Operate (BOO) model

The BOO model would be ***applicable only to the Solar PV generation systems***, for which a competitive tendering process would be put in place for procuring the services of a suitable private agency (RESCO).

In the BOO model, the ***private party*** (RESCO/IPP) provides a service (e.g., electricity supply) and ***assumes a substantial amount of the financial, technical, and operating risks***. The objective of a RESCO is to provide electricity to the healthcare facility by designing, installing and maintaining renewable energy generation systems. The value proposition of this structure is to allocate the tasks and risks to those parties best able to manage them, namely the RESCO/IPP.

Typically such a model would involve the setting up of a special-purpose vehicle (SPV) to develop, build, maintain, and operate the RE generation system for a contracted period. The SPV would be responsible for hiring local subcontractors to build the facility and then operate and maintain it. The SPV would be a central administrative and operating entity handling all contracts for funding with equity and debt investors. It would also manage the construction, installation and operation and maintenance (O&M) contracts, as well as the billing of the hospital. The asset will be recorded on the balance sheet of the Special Purpose Vehicle. MoH&P would tender out contracts for the selection of suitable parties for implementation of projects. ***While the RESCO would be expected to put in the entire equity, MoH&P would facilitate the provision of low cost debt at predetermined rates through an intermediary bank for the RESCO***. The lowered cost of capital is expected to result in improved cost competitiveness of Solar power with respect to the Grid power.

With the introduction of net metering, this arrangement can also work for the grid-tied Solar PV systems. In such cases interactions with ESCOM and the grid need to be developed upfront and negotiated for all points of interface. Also, the power can be sold to the utility should be calculated and included in the financial model.

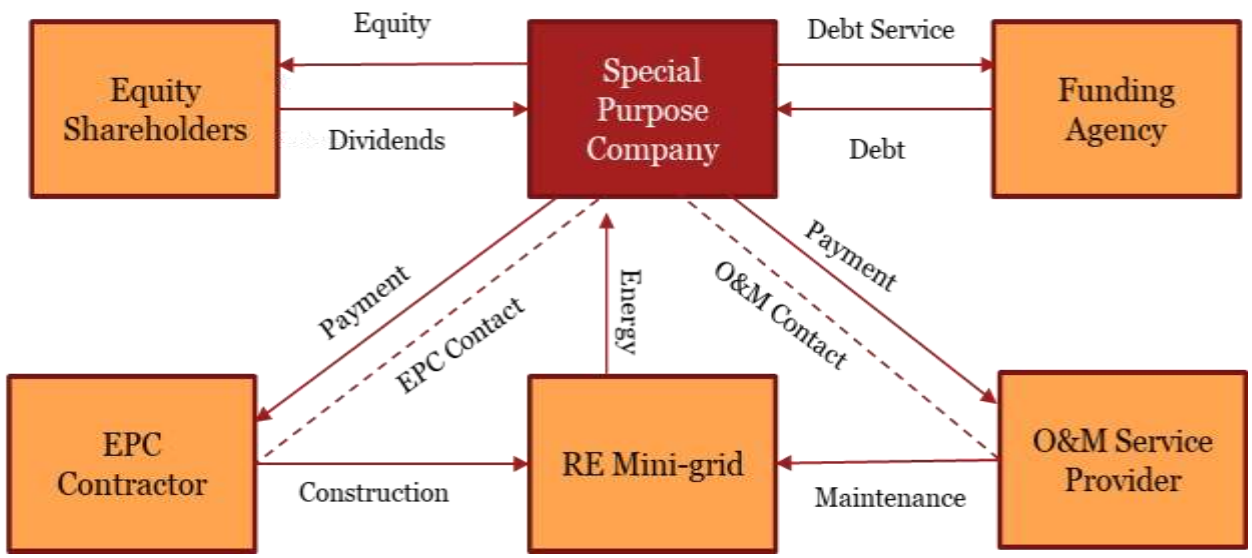


Figure 42 BOO Model

There are several barriers in the existing setup, which the BOO model addresses. The modality by which the challenges are addressed are provided in the table below:

Table 36 Current Challenges and mitigating elements in the BOO model

Challenges associated with present installations	Mitigating elements in the proposed model
Lack of regulatory clarity on need of License for Captive generation	The entity which already has the license will be the owner of the equipment at all times
No formal handover of the Solar PV systems	The ownership and maintenance of the installed solar PV systems vests with the RESCO
Lack of monitoring and oversight of the performance post installation	Operation is performed not by the staff of hospitals but by a private entity
Limited availability of qualified technical assistance and engineering, non-availability of spare parts and good quality components	The BOO contract signed between the RESCO and the healthcare facility would have Service Level agreements to ensure that faults in the operation are rectified on time, failing which a penalty could be imposed on the RESCO. The contract could also provide for extended on-site warranties to ensure performance. Vendor could be mandated to set up service centers in designated locations for quickly addressing faults
Low feasibility of small scale renewable energy	Bundling of projects for the Special Purpose Vehicle will reduce the transaction costs
Cost of debt may make project finance infeasible	Debt to the RESCO will be provided at concessional (less than market rate) through the pooled fund of MoH&P

The cost of using the service can be borne either exclusively by the users of the service, i.e. hospital, or jointly by the hospital and the pooled fund of Ministry of Health and Population (MoH&P) housed at the intermediary bank. In the former case, the government may further support the project by providing revenue subsidies, through favorable taxes or other means.

6.1.1.2. Conditional Grant model

The conditional grant model would be targeted towards enabling the ***installation and O&M of Solar Direct Drive refrigerators and Solar Lanterns through grant funding*** in the designated healthcare facilities ***subject to the facilities adhering to conditions stipulated by the ESMU***. This will differ from traditional grant based installations in the sense that the grant will be used to provide a service (equipment+ O&M) rather than the equipment only. A contract would be signed between the Vendor and the facilities stipulating the service levels for the vendor and the conditions for the facilities. The conditions may include commitment from the beneficiary facilities to:

- Record and report information and other aspects on which accountability is required at the facility level.
- Restructure staff according to the norms laid out by the ESMU
- All relevant services rendered in order to implement the EHP package.
- Energy systems maintained according to plan.
- Appropriate medical equipment put in place

The following table presents an overview of the pitfalls of the past grant based models and the mitigating elements in the proposed arrangement.

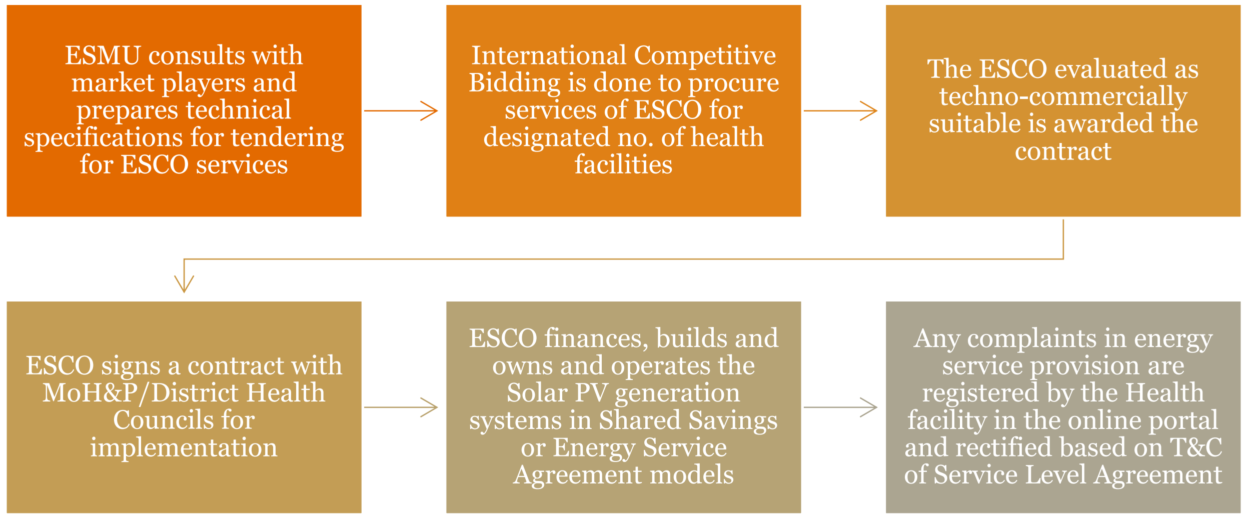
Table 37 Current Challenges and mitigating elements in the Conditional Grants model

Barriers in present set up	Mitigating elements in the proposed model
There has been no provision for O&M of the installed equipment	O&M service will be a part of the vendor's scope of work in the form of an Annual Maintenance Contract
Lack of availability of service stations/spares/trained technicians	The Vendor will be mandated to set up service stations on a cluster basis. The vendor would provide on-call maintenance services to ensure sustainable operations.
Facilities had no accountability in grant based model in past interventions	The grant will be conditional which would require the facilities to comply with the stipulated conditions

Overall, this model is a win-win for both the ESMU and the facilities as the imposed conditions are expected to lead to improvement in staffing, planning and data management within the facilities.

6.1.2. Models for Thermal energy supply

The models for thermal energy supply apply to the identified thermal energy technologies such as solar water heating systems, waste heat recovery from Incinerators and biogas generation systems to provide thermal energy as a solution or as a service. While the ***shared savings model is suitable for Solar water heating systems, Waste heat recovery from Incinerators and Biogas generation systems, the Energy Supply contracting model is more suited to the Solar Water heating systems.*** The models are described in details in the following subsections.



6.1.2.1. Supplier's Credit/Shared savings model

The Shared savings model is a type of Energy Service Performance Contracting model. In Energy Service Performance Contracting, an entity called Energy Service Company (ESCO) carries out design, implementation and O&M of the installed equipment for a pre-determined duration. After the ESCO recovers its initial investment, the possession of the asset would be transferred to the healthcare facility. Shared savings projects are funded on the ESCO balance sheet, The ESCO gets paid out of the savings/additional generation. ***The sharing of savings with the ESCO can be structured in such a way that the monthly payout to the ESCO is less than the current expenditure of the facility in getting similar level of energy service.*** The ESCO would have the option to avail concessional financing from the pooled fund of MoH&P hosted by an intermediary bank. There are two modalities in which the supplier's credit model may function:

(a) ***Deemed savings***: in which the future savings (based on operating conditions that are specified in the contract) are calculated by the ESCO ex-ante and contractually agreed to by the healthcare facility.
(b) ***One time measurement post installation***: The operating conditions (such as duty cycle) during the one-time savings demonstration are the benchmark conditions and the onus is on the healthcare facility to maintain them near those levels to continually achieve savings. Therefore, in this model the ESCO puts the onus of maintaining the operating parameters on the healthcare facility and transfers part of the performance risk to the healthcare facility.

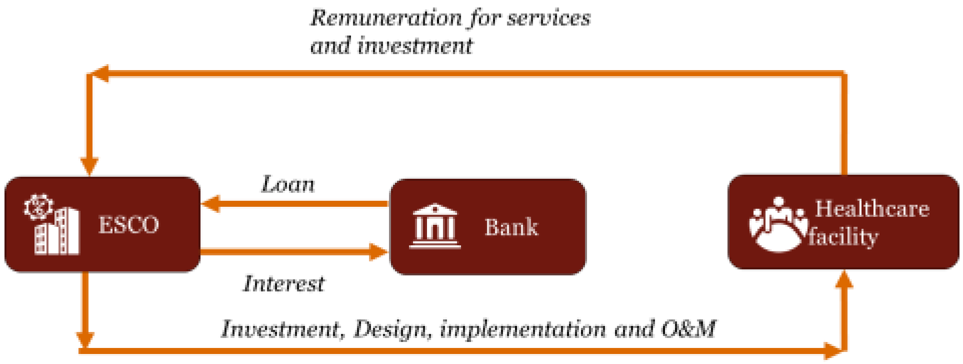


Figure 43 Supplier's credit model

Presently the ***Energy Service Performance Contracting market in Malawi is non-existent. However, the introduction of this concept can create an entirely new market for Energy Efficiency and result in spillover benefits such as faster technology diffusion and employment creation***. It is recommended that the procurement of ESCO services be carried out by the ESMU through international competitive bidding to bring in ESCOs from neighbouring countries of Africa such as South Africa which have a relatively evolved ESCO market. The ESCO can avail loan at concessional rate through the intermediary bank which would be managing the pooled fund of MoH&P, which would enable it to offer the overall service at a rate which is agreeable for the healthcare facility.

Table 38 Current Challenges and mitigating elements in the Shared Savings model

Barriers in present set up	Mitigating elements in the proposed model
The Healthcare facility may not be able to finance the project itself	The ESCO finances the project on its balance sheet and recovers the cost through monthly savings.
In the past, there hasn't been sufficient focus on thermal energy interventions as the share in terms of overall consumption in a facility is low	By considering the entire healthcare sector, the demand for thermal EE interventions is aggregated, which will build scale for attracting vendors through competitive bidding
No technical know how to operate and maintain EE systems among the facility staff	In the shared savings model, the ESCO will use its technical expertise to operate and maintain the installed systems
In the existing system based on procurement and installation, there is no way to bring about a greater accountability on the part of the healthcare facilities	In the shared savings model, the ESCO and Healthcare facility will have a share in the savings achieved over the baseline energy consumption levels. The onus is also on the healthcare facility to ensure that the parameters are maintained at the levels stipulated in the Energy Service Performance Contract.

6.1.2.2. Energy supply Agreement (ESA) model

In such a business model, the ESCO provides a service for a cost per unit (MK per litre of hot water) to the healthcare facility. ESCO has the total ownership of the equipment during the contract and uses its own resources to perform O&M and repair, when required through the duration of the contract. At the end of the contract, the ownership of the equipment may be transferred to the Healthcare facility. The ESCO would have the option to avail concessional financing from the pooled fund of MoH&P hosted by an intermediary bank.

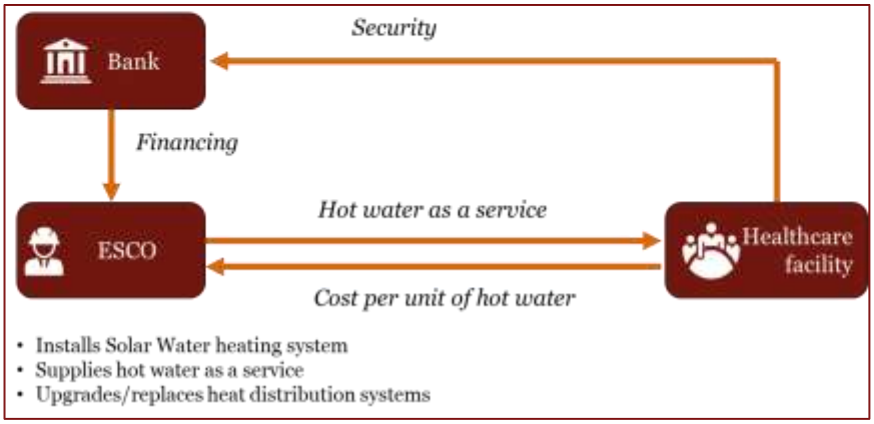


Figure 44 Energy as a service

This model would eliminate the need for the facility personnel to be involved in the O&M or repair of the installed equipment and would give greater control to the ESCO as it would have its own specialist manpower to attend to the installed equipment for O&M/repair. Money from the MoH&P pooled fund would be used deposit a security amount with the bank on behalf of the healthcare facilities to mitigate the risk of non-payment or delayed payment.

Table 39 Current Challenges and mitigating elements in the Energy as a Service model

Barriers in present set up	Mitigating elements in the proposed model
The Healthcare facility may not be able to finance the project itself	The ESCO finances the project on its balance sheet and recovers the cost through monthly savings
In the past, there hasn't been sufficient focus on thermal energy interventions as the share in terms of overall consumption in a facility is low	By considering the entire healthcare sector, the demand for thermal EE interventions is aggregated, which will build scale for attracting vendors through competitive bidding
No technical know how to operate and maintain EE systems among the facility staff	In the shared savings model, the ESCO will use its technical expertise to operate and maintain the installed systems
In the existing system based on procurement and installation, there is no way to bring about a greater accountability on the part of the healthcare facilities	In the shared savings model, the ESCO and Healthcare facility will have a share in the savings achieved over the baseline energy consumption levels. The onus is also on the healthcare facility to ensure that the parameters are maintained at the levels stipulated in the Energy Service Performance Contract

The business models recommended as a part of the master plan attempt to provide energy efficiency and renewable energy as a service rather than in the form of only equipment, which has been an important reason why previous programs for energy access have not been able to create lasting impact. A conscious effort has also been made in the design of business models to bring about greater participation of the private sector in the development agenda of the Government of Malawi, which would bring in skills as well as efficiency that is greatly missing in the present set-up. In addition, ***for the new healthcare facilities, it is recommended for the building design to follow the 'green building' concept so that energy efficiency considerations are incorporated for the facilities right from the outset.***

7. Review of policy regime and key recommendations

The Master Plan is targeted towards comprehensively addressing the twin issues of increasing power supply and reducing the power demand. Owing to its broad mandate, the activities of the Master Plan would need to operate under the framework of many policies, regulations and plans which are and will be in effect in the next 10 years. In Malawi, Electricity Act, Energy Policy, Malawi Grid Code, Integrated Resource Plan and IPP framework are the key legislations/guiding documents related to the provision of energy services. A brief description of the relevant policies, regulations and plans has been provided below:

Key policies, plans & legislations

Electricity Act, 2004 (amended 2016): It is a key act promulgated by MERA that makes provisions for the regulation of the generation, transmission, wheeling, distribution, sale, importation and exportation, use and safety of electricity and for matters connected therewith.	**Energy policy, 2003 (revised 2018):** It provides a guiding framework for affordable,reliable, sustainable and efficient energy access. It emphasizes the importance of private participation in energy sector and recognizes energy efficiency as a priority area.	**Malawi Grid Code, 2016:** It is a document that legally establishes technical and other requirements for the connection to and use of an electrical system by parties other than the owning electric utility in a manner that will ensure reliable, efficient, and safe operation. Malawi Energy Regulatory Authority Board (MERA) is the administrative authority for the Grid Code	**Integrated Resource Plan, 2017:** It is a least-cost investment plan in generation, transmission and demand-side measures prepared by the Ministry of Natural Resources, Enegy and Mining covering the 20 year period 2017 to 2037 to help make decisions concerning investments that should be initiated over the coming 3-5 years.	**IPP framework,2017:** The IPP Framework is a commitment of the Government and other stakeholders to establish a clear, robust process for securing investment in the power sector that balances the interests of consumers for cost-effective, reliable power supply with the commercial interests of private investors. Ministry of Natural Resources, Energy and Mining is the nodal ministry for IPP framework

Figure 45 Key policies/plans and regulations for energy sector in Malawi

The policy and regulatory regime may present opportunities or constraints from a program planner's perspective. The analysis of such aspects is provided in the following section.

7.1. Present policy and regulatory framework: Analysis of opportunities and constraints

Some of the key terms relevant to Captive Renewable energy generation and their implications for on the institutional framework are presented below. If the terms elaborated from the policy/regulation/plan present a constraint, it has been indicated with a negative sign and if it presents an opportunity, it has been indicated with a positive sign.

Table 40 Analysis of key legislations

Legislation /Policy /Plan	Relevant Extract	Alignment with "Power for Health" Master plan
Energy Policy, 2003 (amended 2018)	The following strategy has been defined for Renewable Energy sector: "Promulgating and regularly reviewing standards for RET products, especially Solar PV and Pico Solar Products"	Clear outputs, performance indicators, responsible entities, targets and timelines are defined for the strategy. This aligns well with the ***Master plan recommendation for reviewing standards of Solar PV systems and harmonizing them with international standards***. ESMU can collaborate with the responsible entities for optimal resource utilization.
	The following strategy has been defined for Renewable Energy sector: "Establishing fiscal incentives for renewable energy using existing funds such as the Rural Electrification Fund"	Clear outputs, performance indicators, responsible entities, targets and timelines are defined for the strategy. This aligns well with the ***Master plan recommendation for using pooled fund of MoH&P for providing capital support.*** ESMU can collaborate with the responsible entities for optimal resource utilization.
	The following strategy has been defined for Renewable Energy sector: "Developing appropriate regulations for specific small-scale technologies under the Renewable Energy Act"	Clear outputs, performance indicators, responsible entities, targets and timelines are defined for the strategy. This aligns well with the ***Master plan recommendation for introduction of new regulations.***
	The following strategy has been defined for Renewable Energy sector: "Promoting competitive bidding for mini-grid concessions in order to achieve the best value for money"	Clear outputs, performance indicators, responsible entities, targets and timelines are defined for the strategy. This aligns well with the ***Master plan recommendation for competitive bidding for availing RESCO and ESCO services***

Legislation /Policy /Plan	Relevant Extract	Alignment with "Power for Health" Master plan
	The following strategy has been defined for Energy Efficiency "Providing duty and VAT waivers for solar water heaters"	Clear outputs, performance indicators, responsible entities, targets and timelines are defined for the strategy. This aligns well with the ***Master plan recommendation for promoting Solar Water heaters in healthcare facilities***. ESMU can collaborate with the responsible entities for optimal resource utilization.
	The following strategy has been defined for Energy Efficiency "Promulgating regulations and standards for building designs and energy efficient devices"	Clear outputs, performance indicators, responsible entities, targets and timelines are defined for the strategy. This aligns well with the ***Master plan recommendation for promotion of Green Building concept in Healthcare facilities***. ESMU can collaborate with the responsible entities for optimal resource utilization.
Electricity Act, 2004 **(Amended in 2016)**	"The activities in the electricity supply industry for which a license is required are— (a) generation of electricity for sale; (b) operation of a transmission network; (c) operation of a distribution network for the supply of electricity; (d) importation of electricity into Malawi; and (e) Export of electricity out of Malawi"	Licenses are required for mini-grid systems. For RESCOs from outside Malawi that want to participate in international competitive bidding, the process of acquiring a license may be time taking. However, if the systems are installed as a DSM solution in part connected to ESCOM's grid, then it would not require a license.
	"Licensees to hold only one type of license."	Any wheeling of power by a Captive RE generation system installed inside a healthcare facility to staff houses or neighboring communities would require an agreement with ESCOM, since Transmission and Distribution Licenses can only be issued to the utility. The use of ESCOM's grid to supply other hospital premises would not guarantee that the power will actually be supplied to the intended users.
	"If an application for the issue of a license is granted, the Authority shall issue the license in the prescribed manner and the license shall— (b) define the area in respect of which the license is issued"	The distribution license for the Captive RE generation system for a healthcare facility should include the neighboring communities also. In case selling back of power to the grid is not allowed, this shall ensure that the surplus electricity can be used to power households, pumps etc. in the periphery of the healthcare facility.

Legislation /Policy /Plan	Relevant Extract	Alignment with "Power for Health" Master plan
		If ESCOM Infrastructure is utilized, an agreement need to be made between the RESCO and the ESCOM. The operator will still need a License to operate the system
	"(8) If an application for the issue of a license is granted, the Authority shall issue the license in the prescribed manner and the license shall— (d) contain a schedule specifying the approved tariffs that may be charged by the licensee to its customers. (1) Subject to the provisions of this Part, a licensee shall not charge any customer any tariffs higher than those specified in the schedule of approved tariffs for his or her license."	If Captive RE generation also requires a license, then the tariffs cannot be market determined; It will be mutually agreed between the RESCO and the Healthcare facility. Mutually agreed tariffs for a Captive RE generator with license cannot be higher than that which has been approved by the energy regulator under the proposed contractual arrangement set between the two parties.
	"All generators shall sign power sale agreements with the transmission licensee for sale of their power at a price to be agreed between the parties but approved by the Authority."	As the power generated by the RESCO would be directly distributed, such an arrangement cannot be mandated for captive power plants, unless a provision is made for net metering.
Malawi Grid Code, 2016	"The Energy Laws have allowed third party access where Independent privately owned generating plants are built, initially selling to the central organization, the Single Buyer, which will be a separated section of ESCOM. The Single Buyer is the only authorized buyer of all power and energy within Malawi."	Depending on the amount of power generated by the RESCO and if there is significant excess, which will need to be sold to ESCOM to ensure project viability, the RESCO would need to register as an IPP following the procedures described in the IPP Framework.
IPP Framework, 2017	"The SB, ESCOM Transmission and MERA shall set maximum response target times for stages of IPP evaluation, generation license applications and transmission connections and agree to sign a charter codifying these response times."	Considering the urgency of providing sustainable energy access to the Healthcare facility in Malawi, the bidding and award process can benefit greatly if the maximum response target times are quantified in the proposed C aptive RE regulations for all essential services

7.2. Recommendations on new policies and regulations

At present, there is lack of regulatory clarity on captive use of power by healthcare facilities in Malawi. Therefore, it is recommended to introduce separate regulations governing captive Renewable energy for Healthcare sector. This section proposes two new policies for Malawi for meeting the objectives of the Master Plan. The policies and their indicative table of contents have been provided below. In addition to these policies, it is also proposed to develop Technical Standards for connectivity of the Distributed Generation Resources to establish requirements for any generation resource connecting to the grid at voltage levels below 33kV and amend the relevant tariff policies to develop regulatory framework for "compulsory purchase of power into the grid from such mini grids. In such cases, ESCOM would need to indicate the maximum quantity of renewable energy that the grid can absorb at specific points, where the installed RE generation systems would have inter-connectivity with the grid.

7.2.1. National Mini-grid Policy

The objective of the proposed policy would be to promote the deployment of micro and mini grids powered by RE sources such as solar, biomass, Pico-hydro, wind etc. in un-served and under-served parts of the country by encouraging the development of policies and regulations that enable participation of RESCOs. As the master plan aims for a demarcation of facilities that would be electrified through grid and those that would be electrified using standalone Solar PV systems with battery back-up (essentially Mini-grids), clarity on regulations for mini-grids would be required. Therefore ***it is recommended that the Government of Malawi draft and launch a National Mini-grid policy in the near term (by end of 2019).*** The indicative contents of the policy would be as follows:

Definition of Mini and Micro Grids
Type of system configuration, customer categories, tariff and revenues
Policy regulatory and implementation level interventions
Implementing partner
Project Site Identification and development
Single Window Support Channel
Project Information System (planning & development, clustering and size of projects, role of nodal agencies)
Service Performance Norms
Components and Sub-systems
Public Distribution Network (PDN)
Interconnection with ESCOM grid
Exit Options
Grievance Redressal
Financial assistance and other incentives
Empanelment of RESCO
Add-on services
Programmes- Innovation, Pilot and Capacity Building
Role of Stakeholders such as Energy Service Company, Consumers, Nodal Agency and Electricity Regulators

Figure 46 Indicative contents of National Mini-grid Policy

7.2.2. Net Metering Regulations

The recommendations of the load assessment present 2 options for Solar PV installation, namely Decentralized systems with battery and Grid connected systems without battery. For enablement of the second category of recommendations, net metering regulations are required to be instituted.

Net metering regulations would apply to the Distribution Licensees, eligible consumers of the Distribution Licensees and third party owners of net metering arrangement of rooftop solar PV system in Malawi. The objective of such regulations is to ensure that the ***surplus power that is produced by captive generation systems in healthcare facilities can be sold back to the grid to earn revenue***. To enable a transition towards renewables based on a sound business case, net metering is very important. Therefore, ***it is recommended that the Government of Malawi conduct detailed techno-commercial studies to enable the launch of net metering regulations in the medium term (by end of 2020)***. The indicative table of contents of the net metering regulations is as follows:

Scope and application
General Principles
Capacity of Rooftop PV System.
Procedure for Application and Registration
Interconnection with the distribution system
Metering arrangement
Energy Accounting and Settlement
Applicability of other charges
Solar Renewable Purchase Obligation
Penalty or Compensation

Figure 47 Indicative contents of Net Metering regulation

Considering the criticality of the energy needs for Central hospitals, it is recommended that each Central Hospital be connected with a dedicated ESCOM feeder. This would be accompanied by changes in the Malawi Grid Code to incorporate guaranteed power supply for such dedicated feeders to ensure round the clock power supply to such facilities.

In summary, the existing policy regime presents both opportunities and constraints. The Energy Policy and IPP framework are very well aligned to the suggestions and recommendations of the master plan. The ESMU should look to collaborate with the designated responsible entities for achieving synergies in terms of the effort as well as the resource expenditure. In contrast, the Electricty Act and Grid code present a few constraints from a tariff setting and procedural perspective. To address these constraints the launch of a National Mini-grid policy and promulgation of National Mini-Grid regulations is recommended.

8. Implementation roadmap

As identified in 0, multiplicity of players in the provision of energy services to health sector, limited development of project management and donor-aid coordination capabilities, lack of proper information management and lack of training at health facility level are acute issues plaguing the health sector.

The Master Plan envisages several operational activities for the Energy Services Management Unit including but not limited to ***data management and reporting, monitoring, supervision, procurement and contract management and general project management***. It also sets out activities such as ***maintaining monitoring systems and database of the status of energy service to healthcare facilities and help-desk services for troubleshooting of malfunctioning equipment***.

8.1. Recommended Institutional Framework

The following sections present the operating boundaries, decision points and recommended scope of work for all the key stakeholders.

8.1.1. Energy Services Management Unit (ESMU)

The ESMU is ***envisaged as a Project Management Unit***, which is entrusted with the responsibility of implementation of the Master Plan. The ESMU will be tasked with co-management of energy services in the health facilities with the guidance and oversight provided by Ministry of Health and Population, Department of Energy, MERA and ESCOM. ***The ESMU shall be hosted by the Project Implementation Unit of Ministry of Health and Population***. The Project Implementation Unit has been created to enable greater coordination across the Fiscal Assets Management division and the Planning Division. Although decentralization of the government functions may require reduced role of MoH&P in management of capital intervention projects, ***due to the limited experience and capacity of district health offices to manage large-scale capital investment projects, MoH&P is the best suited ministry for spearheading the activities under the master plan***. The ESMU shall operate under the boundaries set by the existing Government policies at all times.

8.1.2. Key functions and responsibilities of ESMU

As the key implementing arm for energy service in healthcare facilities, the key functions of the ESMU would include but not be limited to the following activities:

- To ***liaison between key ministries*** **and** ***entities*** which would be involved in the provision of energy services to the healthcare sector in Malawi.
- To ***coordinate the implementation activities*** related to renewable energy in the government healthcare facilities in Malawi.
- To ***prepare short, medium and long term development projects*** to extend the use of renewable energy with specific targets and take steps to implement them in government healthcare facilities;
- The ESMU shall function as the ***single point of contact for data management*** of energy services for healthcare facilities. It shall be empowered to have access to all relevant data from MoH&P, MERA, DOE and ESCOM approved by the steering committee for the performance of its functions effectively.
- To ***demarcate facilities to be electrified through RE interventions*** as a part of the master plan.

- To provide ***technical and financial assistance in research, development, demonstration and training on renewable energy***. The ESMU shall utilize the Capacity Building Budget of the MoH&P HR department as the first option for meeting its training and capacity building mandate.
- To ***identify sources of financing and make necessary arrangement (such as concessional credit lines) encourage private investment in renewable energy sector***.
- To conduct, or otherwise subsidize experimental workshops for scientific and technical research.
- ***Demarcation of sub-district healthcare facilities to be included in the master plan***: The ESMU shall request the District Assemblies/District Health Management teams to provide a list of District and Sub-district level facilities without access to electricity and perform an assessment of the techno economic feasibility of implementing renewable generation systems.
- ***Institutionalize Energy service performance contracts across the health sector***.
- Establish mechanisms for health facility management committees to report data to District HECs, and for community issues to be raised to national level.
- To perform such other functions as may be prescribed by the Ministry of Health and Population, from time to time.

Details of the skillset and capabilities of the proposed ESMU members are provided in the Annexures.

8.1.2.1. Matters relating to Management

The general direction and management of the ESMU shall vest with the Project Implementation Unit of the Ministry of Health. ***It is recommended that the Director of the Physical Assets Management Department be the ex-officio Chairperson of the ESMU also.*** The members constituting the Stakeholder Committee are described below:

Table 41 Composition of the Stakeholder Committee

Members[24]	Number of members	Type of member
Representative from Physical Asset management Department, Ministry of Health and Population	1	Ex-officio member
Representative from the Health Sector Task Team	1	Ex-officio member
Representative from Malawi Energy Regulatory Authority	1	Ex-officio member
Representative from Electricity Supply Corporation of Malawi	1	Ex-officio member
Representative from Department of Energy Affairs(Designation to be determined by DOE)	1	Ex-officio member
Representative from Ministry of Finance	1	Ex-officio member
Representative from Technical Working group for identification of financing options for healthcare sector	1	Ex-officio member
Representative from Ministry of local Government for 27 Districts	1	Ex-officio member
Representative from the Buildings Department	1	Ex-officio member
Representative from Health Services Joint Fund	1	Ex-officio member

The members of the STAKEHOLDER COMMITTEE shall be appointed by the Government of Malawi and the terms and conditions of their service shall be determined by the Government of Malawi.

[24] The designations of the representatives would be determined by the respective organizations

The success of the implementation of Capital Investment Plan (CIP) interventions at the district level depends on the prioritization of these by the Districts Councils. It is important that councils during the development of district implementation plan (annual planning exercise), districts should consider these priorities. Therefore, the Representative from Ministry of local Government has been made a member of the stakeholder committee. An officer from the Ministry of Finance is also proposed to be a member of the stakeholder committee to leverage relationships with financing entities for fund-raising and to make sure that proposals are in line with the approved budgets. The Government of Malawi has recently established a Technical Working Group to identify options for financing the health sector. It is therefore proposed that the stakeholder committee also have a representative from the TWG as a member.

8.1.2.2. Meeting of the Stakeholder Committee

The following terms lay out the procedures for the conduct of meetings of the Project Steering Committee:

1) The stakeholder committee shall determine the procedures of its meetings.
2) The meeting of the stakeholder committee shall be held at as such times and places as may be determined by the Chairman, provided that the stakeholder committee shall hold its ***meeting at least once every quarter***. The minutes of these meetings shall be published online for ensuring transparency.
3) All the meetings of the stakeholder committee shall be presided over by the Chairman, and, in his absence, any member empowered by him shall preside over the meeting.
4) To constitute a quorum at a meeting of the stakeholder committee, not less than half of the total members including its chairman shall be present.
5) ***The matters placed at the meetings of the stakeholder committee, shall be resolved on the basis of the majority of votes***.
6) Each member present at the meeting of the stakeholder committee shall have one vote, and in the event of equality of votes, the person presiding over the meeting shall have a second or a casting vote.

8.1.2.3. Constitution of Committees

The following terms lay out the procedures for the constitution of the committees by the STAKEHOLDER COMMITTEE:

1) The stakeholder committee may, for giving assistance to discharge its duties, constitute one or more committees as and when required and the duties and functions of such committees shall be determined by the stakeholder committee .
2) The ***opinions of the expert committee may be of recommendatory rather than binding nature for the STAKEHOLDER COMMITTEE.***

8.1.2.4. Advisory/Consultancy services

1) The ESMU may avail consultancy services from any person or firm to carry out any of its special task.

8.1.2.5. Contract, Report, Borrowing etc

1) The ESMU shall ***facilitate contracts between RESCO/ESCO and healthcare facilities***.
2) Reports - The ESMU shall, at the end of every financial year, submit to the Government a report containing the functions taken and performed by it for that year.

3) The Government of Malawi may, at any time, if it considers necessary, require the ESMU to furnish any report, statement, accounts, statistics or other information regarding any matter of the ESMU and the ESMU shall furnish such report to the Government.

8.1.2.6. Budget, and accounts and audit

1) All selected projects must pass the lowest MCC calculated hurdle rate for Malawi, currently estimated at 12.5%. The viable financial internal rate of return should not be less than the base lending rate for Malawi, which is currently at 15%. In case the bidder found to be techno-commercially suitable doesn't meet the return criteria, the pooled fund of the MoH&P can also be used to cover for the Viability Gap between the Levelized cost of Captive renewable energy and the cost of grid power. The STAKEHOLDER COMMITTEE, in consultation with the technical committee shall determine the trigger point for application of viability gap funding (VGF). The amount of VGF would vary on a case to case basis.

2) The ESMU shall utilize an ***Operational Planning Tool to be developed by MoH&P to track funding commitments towards implementation of the Master Plan***. This tool will map amount and source of funding committed to Master plan activities against the cost of implementation. Disbursement of funds will be tracked on an annual basis throughout Master Plan implementation, to help identify funding gaps in specific areas of the plan. The tool will increase Government, donor and recipient accountability for their commitments, behavior and results. Additionally, the Tool will increase financing predictability and improve harmonization.
3) The ESMU shall, wherever possible, ***design options for pooling health financial resources to minimize risks and explore options for community savings for health financing***. The pooled resources may be managed by an intermediary bank/Fund Manager in Malawi.
4) The ESMU shall have necessary reporting and tracking mechanisms to track the use of funds. Moneys received from the following sources shall be credited to the fund, namely:
    1) Health Services Joint Fund of the Ministry of Health
    2) Grants or loans made by Government agencies/ministries
    3) Grants or loans made by the Multi-lateral/Bilateral agencies
    4) grants or loans obtained from any other source;
    5) sums received from the fee imposed for any act done by ESMU
5) The surplus fund, if any, after meeting up the expenses of the ESMU for a financial year, the whole or any part thereof, shall be transferred to the budget of the following year.
6) The ESMU shall, in such time as may be specified by the donors/Government of Malawi, submit to its donors/Government of Malawi an annual budget statement for every financial year showing the estimated receipt and expenditure and the sums, which are likely to be required from the donor agencies during that financial year.
7) The ESMU shall, if required, request MoH&P to allocate money for the payment of bills to RESCO/ESCO for healthcare facilities at the sub-district level from the Health Services Joint Fund. In exceptional cases, with approval from the Steering Committee, the ESMU can also provide funds for supporting the Central and District Hospitals in payment of energy bills to the RESCO.

8.1.2.7. Training and capacity Building

1) Empanelment of organizations for providing training, maintaining register of affiliated/empaneled organizations and cancelling of such empanelment if the performance is not found to be satisfactory. In addition to O&M, training shall also be provided on procedures and practices which may vary across the different tiers (national, district and regional hospitals). The training would be carried out in the form of classroom programs comprising of 2 modules, i.e. Energy Efficiency and Renewable Energy Technologies and Basics of Facility Level energy management. The indicative contents of the 2 modules

are provided below. ***The targeted recipients of the training are the facility level staff, tasked with the planning and O&M of the energy service infrastructure***.

Energy efficiency and renewable energy technologies	Basics of facility level energy management
• Basics of Electricity supply/Service technologies (including Solar PV, EE Fan, EE Refrigerator, EE AC, Solar Lantern and Solar Direct Drive refrigerator), thermal energy technologies (such as Biogas systems, Solar-Electric Hybrid Water heaters, Waste Heat recovery from incinerators and how to use them. • Supervision of installation by vendors and using checklists for pre-dispatch inspection • Integration of technologies into the existing facility level systems • Best practices for Operation and Maintenance • Standards, codes and specifications • Preventive maintenance schedule and condition monitoring of equipment	• Instituting a facility level energy management policy and plan (including budgeting) and incentivizing energy efficiency at facility level • Data Management and reporting of facility level data to ESMU using dashboard • Need and importance of energy efficiency and using renewable energy at facility level • Inventory management of health equipment in various departments using PLAHMS • Manpower norms for facility O&M team • Self-Assessment of energy performance including Analyses of energy bills and energy use pattern. • Complaint Management systems for reporting faults in equipment and managing fault rectification

2) The selection of training and certification organization shall be done in consideration of
    a. institutional capacity in conducting such training;
    b. logistic and infrastructure facility for conducting training;
    c. capacity and track record for providing standard quality of training for the candidates
3) Facilitating the administration of training and certification of the facility level staff and issue of certificate to O&M staff and facility level energy managers. The ESMU shall also identify topics of training and suitable regional facilities for providing training. Presently, Undergraduate and specialized courses are offered by the University of Malawi and the Malawi University of Science and Technology (MUST) and MoH&P provides scholarships to its staff for the same. In collaboration with the Ministry of Education, the ESMU shall refine and enhance the existing courses to align them to the requirements of the master plan.

8.1.2.8. Bid Process Management, Project Management & Quality Control

The ESMU shall be responsible for the following activities in the procurement and management of project performance:

1) ***Establishing/Updating of Guidelines for procurement of RE generation equipment***. The facilities are presently guided by the Capital Investment Plan and the Standard Equipment list for

procurement. The ESMU shall provide ***support in updating the Standard equipment list to include the renewable generation equipment along with their specifications and vendor details***. It shall be allowed for the healthcare facilities to request the ESMU for procurement on as needed basis.

2) The procurement guidelines shall ensure ***100% adherence to the standards and protocols of ESCOM, DoE and MERA.***

3) Service Level agreement should incorporate the transfer of information on equipment operation post installation with the local facility management (real time monitoring).

4) In the procurement process the ESMU shall ensure adherence and compliance to Public Procurement Act, health sector procurement plans and anti-corruption policy at all times.

5) The procurement would be done at the central level. However, the ESMU shall coordinate with the MoH&P only for the Central Healthcare facilities and the coordination for the district and sub-district level facilities shall be done with the District Assemblies and District councils.

6) Empanelment of developers and Vendors by Energy Services Management Unit for Renewable energy generation equipment and blacklisting of Developers/Vendors who have had a poor track record of providing services/equipment in the past. Given that there are limited number of IPP's/RESCOs/ESCOs operating in Malawi presently, the ESMU can organize ***international competitive bidding to invite proposals from the eligible bidders.***

7) Development of ***framework for assessing RESCOs*** (Renewable Energy Service Companies), who would be tasked with setting up the Captive RE generation project and then monetize the energy produced. In doing this assessment, the framework shall consider the Performance Capability (promoter track record, project management capability and demand side risks) and financial strength of the RESCO.

8) ***Creation of Standard Bidding Documents for procurement of RESCO/ESCO services or RE Generation equipment*** for healthcare facilities with detailed scope of work (including extended on-site warranty and O&M services), minimum required technical specification, Service Level agreements, Quality control (including pre-dispatch inspection), exclusions, Terms of Payment, Delivery/Service schedule, method of evaluation of bid, technical eligibility criteria, financial eligibility criteria, price bid format and general conditions of contract. The solicitation process for RESCOs shall be in line with the Integrated Resource Plan as well as the Generation Procurement Plan.

9) In case of solar generation systems, if the roof area is not available, the Hospital Management shall provide land for the installation to the RESCO free of cost.

10) In case the Healthcare facility prefers to use in-house manpower for planning and installation, it shall be ensured that a proper load assessment is carried out and the reports of the same are approved by the ESMU prior to commencement of installation activities.

11) ***Facilitation of signing of agreement between RESCO and the District Assembly/District Health Management committee*** for implementation of RE generation project.

12) Subsequent to the completion of installation and commissioning works, the ESMU shall carry out a ***formal handover of the asset to the staff designated by the healthcare facility***.

13) During ***random or stringent quality check***, ask RESCOs to furnish information—
    a. Relating to the details of the installed equipment to ensure quality of materials procured and workmanship of executed works.
    b. Relating to details the performance of the installed RE equipment
    c. Additional information as considered necessary.

14) ESMU shall handle complaints from the healthcare facilities and ***issue orders to the Developers/RESCOs/IPPs to rectify the situation based on the Service Level Agreements failing which they have the power to enforce penalties.***

8.1.2.9. Quality Assurance

The ESMU shall ***appoint a Third Party Inspection Agency (TPIA) for test inspections & checks to ensure conformity with procedures established in the Contract***. This shall exclude the level zero pre-dispatch inspection to be carried out before procurement. The elements of the quality assurance process are presented below:

1) Material Inspection:

- Inspection of the installed material as per Material Quality Plan (MQP)/ Drawings/ Technical Specifications shall be carried out in 50% of Central Healthcare facilities, 25% of District Hospitals, 10% of Health centers, 5% of health posts and 1% of the remaining health facilities.
- Inspection of the installed material as per Material Quality Plan (MQP)/ Drawings/ Technical Specifications in 50% of Health facilities where RE generation capacity has been installed.

2) Performance of equipment

- In 50% of the health care facilities, where RE installation has been carried out, verification of energization of healthcare facilities, hours of supply in the healthcare facility every quarter shall be performed.

3) Contract Management

- The TPIA shall oversee and inform the ESMU about the process of identifying defects and their communication to working agencies, timely rectification of defects, time line Assurance mechanism of ESMU for rectification of defects, resolution of project related issues and action on delayed projects
- The TPIA shall ensure availability and awareness of project specific drawings, documents, and quality assurance plans with the ESMU management and board. TPIA shall also see the progress of up-loading of monitoring observations and its compliance details including site photographs in ESMU web portal.

8.1.2.10. Information management and dissemination

1) To improve accessibility of information and better project management, the ESMU may develop a ***dedicated web-portal for registering queries and complaints, faster referrals of patients, information dissemination and providing the status of grievances etc.*** The website may be used for information sharing and updating project information (in Project Information System) etc. ***A toll free number can be created for filing of grievances*** by Healthcare facilities and their redressal. In due course, this portal may be dovetailed with the e-health concept of the Ministry of Health and Population.
2) All the information dissemination to be done as a part of the Master Plan will also be a key responsibility of the ESMU. The website of ESMU shall be used for the purpose of stakeholder consultations and inviting public comments as well as monitoring the progress against the plan targets using dashboards.

8.1.2.11. Monitoring and Evaluation (combination of national level indicators and program level indicators)

1) The ESMU shall use the following sources to develop its own indicators for monitoring and evaluation of the Master Plan:
    a. Core indicators in the HSSP I and II
    b. Malawi Handbook of Health (2003)

c. WHO list of 100 global health indicators
d. Sustainable development goals (SDG)

The indicators so developed shall account for programmatic preferences and national and global reporting requirements to ensure alignment with other reporting obligations. The indicators for routine project management shall use existing tools of MoH&P such as Health management information system and Human resource information system.

2) The ESMU shall apply WHO's Service Availability and Readiness Assessment (SARA), which is a health facility assessment tool designed to assess and monitor the service availability and readiness of the health sector and to generate evidence to support the planning and managing of a health system.
3) The ESMU shall engage the services of M&E agencies during the 5th year and 10th year of the master plan for Independent Evaluation of the work carried out with the aim of providing an objective consideration of the impact and usefulness of the master plan.
4) The following metrics are proposed for monitoring and evaluating the performance respectively:
   a. ***Monitoring indicator:*** Multi-tier energy access indicator framework developed by World Health Organization[25] also known as Service Availability and Readiness Assessment (SARA) framework shall be used. It is a health facility assessment tool designed to monitor service availability and health sector readiness, and to build capacity in healthcare facilities to conduct their own assessments as well as to analyze data and generate evidence to support health system planning and management. Carrying out evaluation is to take stock of how well the master plan is progressing and the goals which have been achieved.
   b. ***Evaluation indicator:*** Goals defined in terms of ***fund expenditure required per MW enabled*** may be used for benchmarking and optimizing expenditure in the master plan. The cost-efficiency of the invested money increases with the length of the programme. The annual targets for cost efficiency should be framed in such a way that they progressively reduce every year.

8.1.3. Key decision points

The Table below presents the key decision points for the establishment/operation of the Energy Services Management Unit, which are supposed to be used as guidance for MoH&P.

Table 42 Key decision points

Decision point	Guidance framework
Type of responsibilities which can be sub-contracted	➢ The responsibilities of the ESMU can be divided into sensitive and non-sensitive tasks. Sensitive tasks such as budgeting, procurement etc shouldn't be allowed to be outsourced. Non-sensitive tasks may include provision of training, post installation audits of healthcare facilities for quality control etc. ➢ If the additional resources required for fulfilling responsibilities can be quickly mobilized, then outsourcing is not required. However, if outsourcing is carried out, there should be checks and balances to ensure that there is no conflict of interest or anti-competitive behavior.
Quality control of RE systems installed as a part of the Master Plan	➢ **Non-stringent:** This approach involves Random checks for quality of installed equipment which are triggered by an internal or external impulse, such as complaint by a healthcare facility to ESMU. ➢ **Stringent:** Quality control may be based on the submitted reports or site visits. In case such reports lead to adverse findings, the developer may be blacklisted and barred from participating in any competitive bidding done by ESMU in the future.

[25] Access to Modern Energy Services for Health Facilities in Resource-Constrained Settings- WHO, 2014

	The following guiding principles should also be used to determine the level of rigor for quality control audits: ➢ Non-professional RE developers/IPPs should be kept out of the business; ➢ All developers/IPPs should do work in a similar way and produce equal quality of work for healthcare facilities; ➢ The quality and public image of the installed RE generation equipment is appreciated
Trigger for administrator to provide subsidy	➢ Subsidies/viability gap funding may be used as a supporting instrument for encouraging buy-in from the management of the healthcare facilities. If, for a year, the RE installations are significantly less than desired (with reference to the projections of Master Plan), subsidies/viability gap funding could be considered by ESMU. ➢ The subsidies can take the form of increased budget allocation in the succeeding year for training of facility staff. ➢ The trigger point for application of VGF and the amount of VGF for a project would be determined on a case-to-case basis by the technical advisory committee constituted by ESMU

8.1.4. Healthcare facilities

It is the responsibility of the Healthcare facilities to report to the ESMU via the Third Party Inspection Agency, as and when such as requirement is specified by the ESMU.
The figures below present the proposed restructuring of the departments in Central Healthcare facilities.

Before

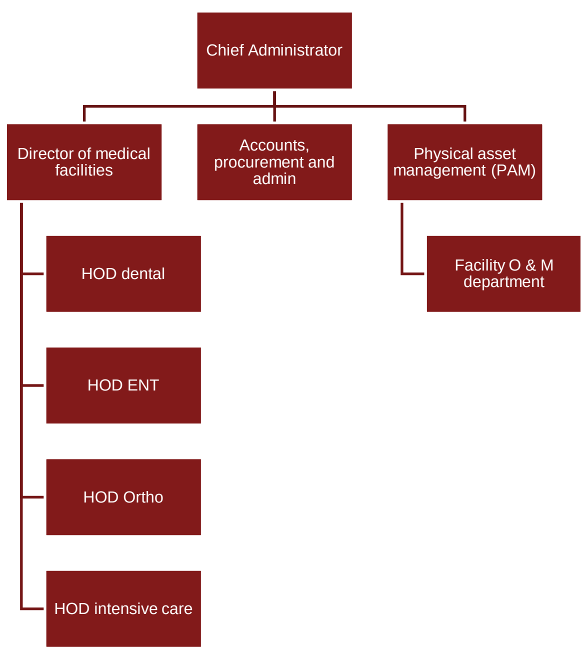


Figure 48 Present Organizational structure at Central Hospitals

After

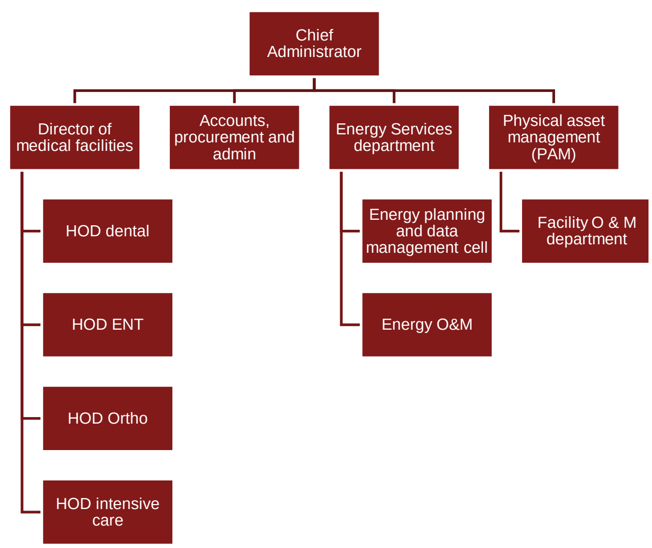


Figure 49 Proposed Organizational structure at Central Hospitals

It is proposed to create a ***new department called the Energy Services Department, which would report to the ESMU***. The Energy Services Department would have the following capabilities:

1) **Energy Planning and Data management cell:** This team shall comprise of supervisory staff to maintain the inventory of working and non-working energy generation equipment including Renewable Energy generation equipment and back-up power assets. In case of in-house installation of Captive renewable generation systems, the Energy planning cell shall assume a stronger role in coordinating with the ESMU for the procurement of the equipment and shall follow all requisite protocol and guidelines provided by the ESMU in such installation. The scope of the Energy planning and data management cell shall be distinct from the Physical Asset Management department which shall be responsible for maintaining record of available medical equipment of healthcare facilities. However, co-ordination between both PAM and the Energy planning cell may be required.

2) **Energy O&M:** This team shall comprise of workers trained and certified by the Energy Services Management Unit who shall report to the Lead supervisor of the Energy Planning and Data management cell. ***The exact number of workers in the O&M team shall be determined by the facility management on a case-to-case basis***. MoH&P has already introduced the position of **Medical Engineering Technician** in the Central Hospitals and District Hospitals to this effect. It is recommended to have the structure as shown in Figure 49 established through an executive order in urban and rural health centers also. ***For the sub-district level healthcare facilities, the terms of procurement of equipment such as Solar Panels, Refrigerators and Solar Lanterns would require the vendor to provide extended on-site warranty and maintenance services on call***. ***It is recommended that the tender also stipulate the technology vendors to establish regional or cluster level repair centres for quick redressal of maintenance issues.*** The complaints by such facilities related to O&M would be registered on the ESMU website and the vendor would be mandated to set up service stations in proximity to the facility locations and respond to such complaints within a specified time period as per the contract. The scope of the Energy O&M team shall be distinct from the Facility O&M department, which undertakes preventive and breakdown maintenance of medical, ICT and utility equipment of the healthcare facilities. The Energy O&M team shall work in close coordination with the RESCO team in case of RESCO based implementation. ***In RESCO based implementation, the O&M team shall also closely monitor the performance of the RESCO with respect to the terms of the Service Level Agreement*** laid out in the contract and report any instances of non-compliance promptly through the channels made available to them (including ESMU website/mobile app etc). ***In case the RE installation is done in-house, the O&M team shall assume a stronger role and shall ensure the availability of critical spares and consumables at all times***. In case of in-house implementation also, the O&M team would prepare monthly reports of inventory to be sent to ESMU.

8.1.5. MERA

Key functions and responsibilities of MERA as a part of the ESMU

1) Nominate relevant staff to be a part of the STAKEHOLDER COMMITTEE within ESMU.
2) Provide expert inputs on and approve/ratify all official documents created by ESMU after technical due-diligence and publish the same on their website for ensuring transparency.
3) Arbitrate on disputes between end-customers/healthcare facilities and RESCOs/ESCOs.
4) Recommend reforms to the Energy Laws and the Act etc.

5) Carry out a technical study to assess the feasibility of amending the Grid Code to provide preferential electricity supply to Healthcare facilities. The outcomes of the study shall be taken up for discussion with the Stakeholder Committee to take the decision on amendment of the Grid Code.
6) In consultation with the ESMU stakeholder committee, MERA shall create regulations for Net Metering and Grid Interconnectivity of Mini-grids and a National Mini-grid policy framework for Malawi, which would act as enabler for setting up Captive RE facilities in Healthcare facilities. The setting of the price for the electricity sold back to the ESCOM shall be done on a cost plus basis after due consultation with the ESCOM.
7) As the ESCO market evolves, MERA shall take up the role of regulation for ESCOs.
8) Define the minimum technical norms for the construction of RE mini-grids for captive power generation, which will eventually help in standardizing the safety conditions for mini-grids.
9) Strive to create regulations to make electricity (Grid or Off-Grid) a Universal Service Obligation for healthcare facilities by the end of 2025 (end of 2nd phase of the Master Plan)
10) Set up a fast track approval window for receiving and processing the license applications from RESCOs to function as the Captive Generation units. If the performance of the RESCO during the contract is not found to be up to standard, MERA shall have the power to revoke licenses under the Energy Act or other applicable laws.
11) Based on the discovered price per kWh of RE electricity through competitive bidding and extent of Viability Gap Funding agreed to by the STAKEHOLDER COMMITTEE, MERA shall, in exceptional cases, establish a system of preferential tariffs for Grid Connected healthcare facilities through cross subsidization.
12) Carry out financial analysis to advise the ESMU for setting of ceiling tariffs for electricity produced by the RESCO in a standalone or Grid + Mini-grid setting.
13) Ensure that RESCOs, whilst providing energy service, are able to finance the carrying on of the activities which they are licensed or authorized to carry on;
14) Develop and enforce performance and safety standards for energy exploitation, production, transportation and distribution through stand-alone and grid connected Mini-grids.
15) Revision of feed-in-tariff, which was developed in 2012 and in need of further revision if it will be applied in Malawi's energy market.
16) To ensure that importers of RE equipment are reputable, they must be required to be licensed by MERA. A requirement of the license will be to offer a 12 month guarantee for products should they prove to be faulty. At the same time, MERA must work to ensure that those who are seeking the license can do so in a timely manner and will work to streamline the process.

8.1.6. Department of Economic Affairs (DOE)

Key functions and responsibilities of DEA as a part of the ESMU

1) Nominate relevant staff to be a part of the STAKEHOLDER COMMITTEE within ESMU.
2) Support ESMU in selecting candidate sites in close cooperation with all the 27 District Councils across Malawi.
3) Provide expert inputs to the ESMU on the technologies to be adopted for the implementation of RE based mini-grids for captive generation in healthcare facilities.
4) DOE shall use its past experience in advising the ESMU in the tailoring of training programmes for the facility level staff, in cooperation with academic insitutions such as University of Malawi and Mzuzu University.
5) DOE shall use the lessons learned from the on-ground implementation under the master plan to tailor policy recommendations for the Government of Malawi.

8.1.7. ESCOM

Key functions and responsibilities of ESCOM as a part of the ESMU

1) Nominate relevant staff to be a part of the STAKEHOLDER COMMITTEE within ESMU.
2) Support the Energy assessment survey of district and sub-district facilities by employing its field staff to ascertain the feasibility of the technology installations
3) Involving the healthcare facilities in Demand side management programs
4) Using its regional offices as the warehousing and distribution points for energy efficient equipment procured by ESMU
5) Provide expert input to MERA in the preparation of the draft regulations for Grid- interconnectivity of Mini-grids, net-metering and the national mini-grid policy.
6) Conduct grid related studies at the proposed point of connection and give recommendations on maximum allowable RE capacity
7) Provide Specifications of equipment that complies with grid requirements at the point of connection

8.1.8. Ministry of Health and Population (MoH&P)

Key functions and responsibilities of MoH&P as a part of the ESMU

- MoH&P shall resolve to have a dedicated budget line on energy infrastructure in the Capital Investment Plan within 6 months from the constitution of the ESMU.
- MoH&P shall provide the ESMU with the list of healthcare facilities along with their status of energy access, existing power supply situation and capacity utilization. This shall serve as the starting point for the ESMU in understanding the quantum of work to be accomplished as a part of the master plan.
- The MoH&P shall introduce an Project Implementation Unit within the Infrastructure Unit of MoH&P for coordination between the Planning division and Physical Assets Management division.

1) Currently, PAM is under the Health Technical Support Services (HTSS) Department. The ESMU is proposed to be hosted by the Infrastructure unit under PAM. It will administratively report to the Project Implementation Unit and functionally report to the Stakeholder Committee. The proposed reporting structure is shown below:

Figure 50 Proposed reporting structure of ESMU

8.2. Goals and Timelines

In addition to being a co-management set up, ESMU is envisaged to have implementation and fund management capability. Therefore, target setting would also form the basis for estimating the required size of the fund and operating budget of the ESMU. The ESMU shall have a mid-term review at the end of each phase and end of term review on the conclusion of the master plan.

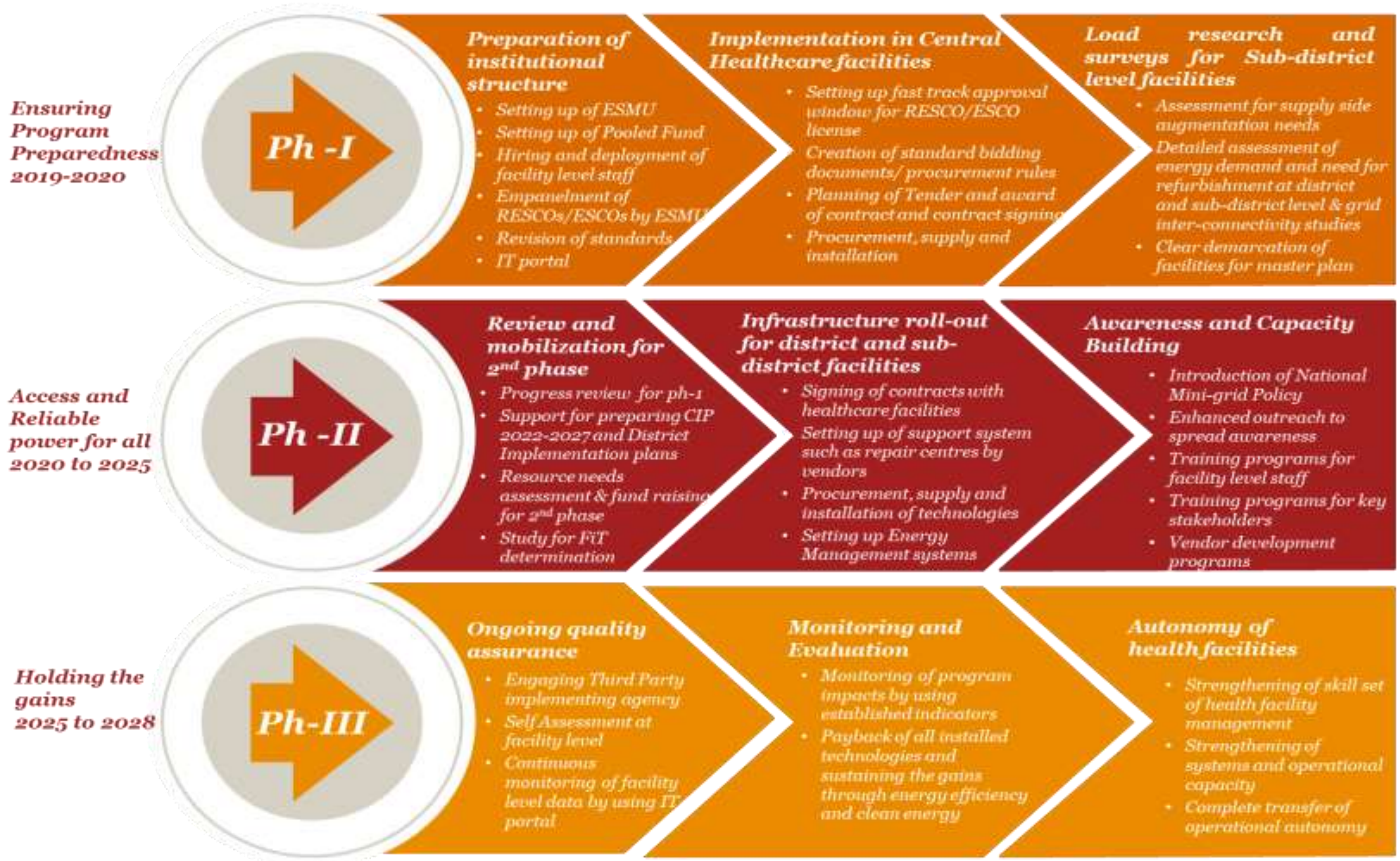


Table 43 Work plan with indicative timelines

Timeline	Activity	Responsible organization	Key Partners
Phase-I			
March 2019-May 2019	• Constitution of Energy Services Management Unit and Stakeholder Committee under the Project Implementation Unit	MoH&P	MERA, ESCOM, DOE, Buildings Dept, Ministry of Local Government Health Sector Task Team, Ministry of Finance
May 2019-December 2019	• Setting up of Pooled Fund	ESMU	Health Service Task Team, Development partners
May 2019-August 2019	• Detailed assessment of energy demand and grid inter-connectivity studies in district and sub-district level facilities • Revision of Standards • Assessment of supply side augmentation needs • Creation of Centralized IT portal	Technical Consultant engaged by ESMU	MERA and ESCOM, Malawi Bureau of Standards
September 2019-October 2019	• Clear demarcation of the facilities for grid electrification/augmentation and RE-based electrification has to be carried out. This would entail a technical study for comparing the costs of grid extension vs the cost of setting up and operating an RE mini-grid	ESMU	ESCOM, District Assembly, MoH&P
November 2019-December 2019	• ***Demarcation of sub-district healthcare facilities*** to be included in the master plan: Engaging technical agencies to provide technical guidance on New Build (Capex) projects being implemented at district level • ***Developing a power/responsibility devolution plan*** explicitly outlining the various functions (including allocation of funds and recruitment of human resources for health) to be devolved to the District Assemblies/Local	ESMU	ESCOM, District Assembly, MoH&P

Timeline	Activity	Responsible organization	Key Partners
	Authorities and corresponding roles and responsibilities. • ***Planning and advisory Support to Districts in the development of District Implementation Plans (DIP)*** specifically pertaining to the Healthcare sector and ensuring that the DIPs align with the future Capital Investment Plans (CIPs) developed at national level		
Jan 2020-March 2020	• Empanelment of developers and Vendors by Energy Services Management Unit • Setting up fast track approval window for RESCO/ESCO license • Creation of Standard Bidding Documents	ESMU	MERA, ESCOM, Malawian Bureau of Standards
April 2020	• ***Upgradation of standard equipment list*** to include solar generation equipment also. ***Expanding the scope of the standard equipment list to include Central healthcare facilities, Health centers, Health posts, Outreach Clinics and Dispensaries*** • ***Development of framework for assessing RESCOs*** (Renewable Energy Service Companies)	ESMU	MoH&P, District Assemblies and Local Governments
May 2020-August 2020	• Invitation for bids for RESCO/ESCO and award of contract • Signing of Agreement between RESCO/ESCO and Central Hospitals • Supply and Installation of RE/EE equipment in Central Hospitals and Cold Rooms	ESMU	Facility Management, Stakeholder Committee
August 2020 December 2020	• Hiring and deployment of Facility Level staff • Commencement of Training programs for staff	ESMU	MoH&P

Timeline	Activity	Responsible organization	Key Partners
January 2021- March 2021	• Restructuring of O&M departments in the hospitals	MoH&P and District Assemblies/District Health management teams	ESMU
	Phase-II		
April 2021	• Progress Review		
April 2021	• ***Preparation of Capital Investment Plan for 2022-2027.*** Detailed cost benefit analysis will need to be carried out for the same.	ESMU	MoH&P
May 2021- June 2021	• Fund raising for Second Phase	ESMU	Development Partners
July 2021- August 2021	• ***Study for feed-in-tariff determination***: To ensure it is reflective of current prices • ***Introduction of Net metering policy*** and other policies and roll-out of the scheme by developing of a fully-updated and cost-reflective framework	MERA	DOE
September 2021- December 2025	• Invitation for Bids and award of contract to RESCOs/ESCOs for district and sub-district facilities • Implementation of projects in District and Sub-district facilities • Facilitation of ***signing of agreement between RESCO and the District Assembly/District Health Management committee*** for implementation of RE generation project	ESMU	Stakeholder Committee
September 2021- December 2028	• Training and capacity building • Vendor Development	ESMU	MoH&P
2023-2025	• Information management and dissemination	ESMU	-
2025-2028	• Engagement of Third Party Inspection Agency (TPIA)	ESMU	-
2025-2028	• Monitoring and Evaluation	ESMU	-
2025-2028	• Strengthening of systems and skill sets at facility level for operational autonomy	ESMU	Facility Management

8.3. Funding requirement and Financing Options

In the past, donors have shown greater interest in financing primary healthcare given that primary health interventions are in general more cost effective. However, consequently, tertiary spending has been left to Government. The Master Plan would use different strategies for different categories of hospitals as illustrated in the figure below. The idea of adopting different strategies for different types of institutions is to shift the focus to tertiary healthcare units and ensure a balanced approach in implementation.

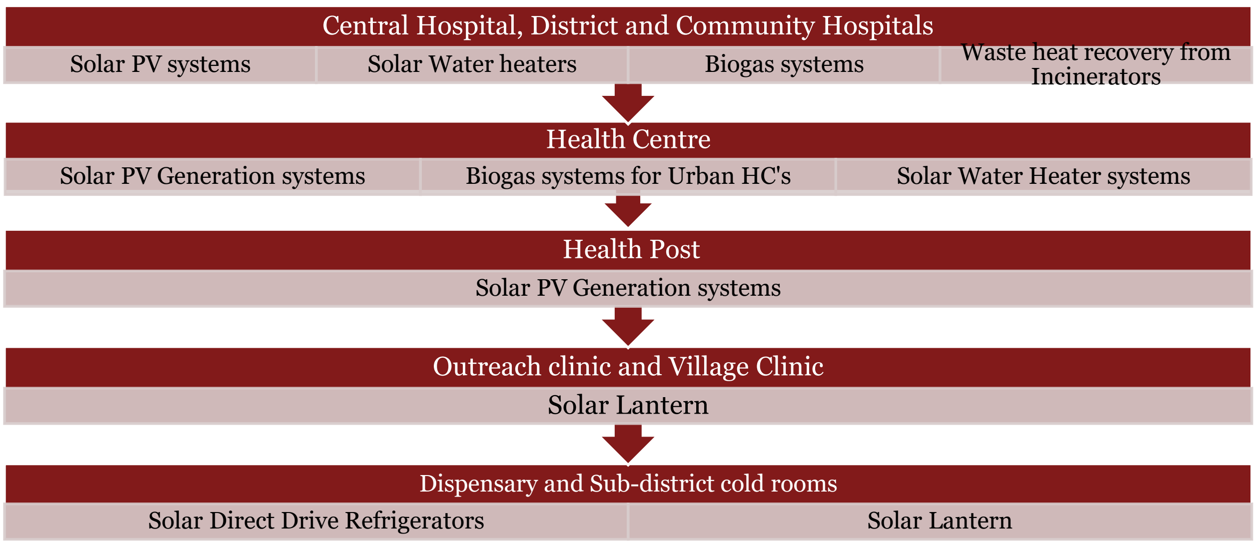


Figure 51 Implementation strategy for different types of healthcare facilities

For calculating the investment potential, the capacity of the solar generation system has been considered for different types of healthcare facilities based on calculations in section 5.2.1.2.

Table 44 Standard capacity and cost details for investment potential

Type of facility	kW	Cost (USD)
Central	700	USD 1,715,000
	Solar Water Heater	USD 6720 per SWH
	Biogas systems	USD 6181 per facility
	Waste Heat recovery from Incinerator	USD 2000 per WHRS
District and Community hospitals	690	USD 1,690,500
	Solar Water Heater	USD 6720 per SWH
	Biogas systems	USD 2,664 per facility
	Waste Heat recovery from Incinerator	USD 2000 per WHRS
Urban health center	200	USD 490,000
Rural Health center	6	USD 14,700
Health post	1	USD 2,450
	Solar Direct Drive Refrigerator	USD 3500 per Refrigerator
CMST	150	USD 367,500
Outreach clinic	Solar Lantern	USD 8/lantern
Village clinic	Solar Lantern	USD 8/lantern
Dispensary	Solar Lantern	USD 8/lantern

Source: PwC Analysis. Cost data from load assessment and financial model for Malawi

For estimation of the budget of the Master Plan, the following key line items have been considered:

1. Capital Expenditure (on Solar Generation system, Solar Water heater, Biogas systems, Solar Lanterns and Solar Direct Drive Refrigerator)
2. Operational expenditure of Energy Services Management Unit
3. Data monitoring system and development of Dashboard/App
4. O&M of equipment
5. Awareness and Dissemination
6. Quality Assurance
7. Training and capacity building
8. Manpower Cost of facility O&M dept.

For calculation of the Capital Expenditure, only the facilities without access to regular electricity have been considered as the target segment. ***An exception to this rule, are the Central Hospitals, where the option of grid plus solar has been considered with both sources having a 50% share in the energy supply***. The installations of Solar PV generation systems and distribution of Solar Direct Drive refrigerators and Solar Lanterns has been phased across the next 10 years based on the increase in the number of healthcare facilities. ***Solar Water heaters are assumed to be applicable to Central Healthcare facilities (25 nos. per facility[26]), District and Community Healthcare facilty (20 nos. per facility), Rural Health Center (5 nos per facility) and Urban health Centers (10 nos per facility). Solar Direct Drive refrigerator is assumed to be applicable to Dispensaries (1 no. per facility) and Sub-district level Cold Rooms (1 no. per facility). For Outreach clinic, Village Clinic and Dispensaries, Solar Lantern has been considered as a potential solution.***

On the human resource front, the ESMU would comprise of skilled professionals with Contracts and legal, Public Relations, IT and Technical expertise. ***The manpower costs of the ESMU for the 10 year duration of the master plan*** have been calculated considering the following assumptions:

Table 45 ESMU cost calculation for 10 year duration of master plan

Project Management Department	General Manager	Senior Manager	Manager	Assistant Manager	Engineer /Officer
Team lead (Nos.)	1	-	-	-	-
Contracts and legal (Nos.)	-	-	1	1	2
Public Relations (Nos.))	-	-	1	1	1
IT (Nos.)	-	-	1	-	1
Technical (Nos.)	-	1	1	1	2
Finance (Nos.)	-	-	1	1	1
Accounts and Admin (Nos)	-	-	-	-	1
Total persons (Nos.)	1	1	5	4	8
Assumed Monthly salaries (USD)	7500	6000	5000	4000	3000
Total Monthly Remuneration costs	7500	6000	25000	16000	24000

[26] Based on average of the recommended number of installations as per the Load assessment in 5 Central Healthcare facilities

Project Management Department	General Manager	Senior Manager	Manager	Assistant Manager	Engineer /Officer
Effort (person-months) in Master Plan	60	120	120	120	120
Total for 10 years (Considering 5% escalation in salary)	566,005	905,608	3,773,368	2,414,955	3,622,433
Misc. administrative expenses including travel for ESMU members- 10% of Total for 10 years (USD)					1,020,000
Programme support costs (including setting up of Pooled Fund)- 7% of Total cost					789,766
Total (USD)					**13,200,372**

Source: PwC analysis

O&M costs have been assumed to be 10% of the total capital expenditure for Lanterns, Refrigerators, Biogas generation systems and Solar Water heaters. Quality Assurance costs have been taken to be 10% of the ESMU costs.

Training and capacity building costs, i.e. costs to be incurred in conducting training programs for facility-level manpower have been estimated by considering the following assumptions:

Table 46 Training costs in master plan

Category	No. of Programs per district (1)	Total No. of districts in Malawi (2)	No. of training Programs (3)= (1)X (2)	Cost per program (USD) (4)	No. of (training + Refresher) programs in 10 years (5)	Total Cost (USD) (6)=(2)X(4)X(5)
Category-1: Central, District, Community hospitals and Urban Health Centers	1	28	28	3000	10 nos. (1 per year)	840,000
Category-II Rural health centers, Health Posts Outreach clinics and Village clinics	10	28	280	1500	10 nos. (1 per year)	4,200,000
Total			308			**5,040,000**

In Malawi, there are 28 districts in total. Two categories were created for healthcare facilities, based on their training need. Category I consists of Central, District, Community hospitals and Urban Health Centers and Category-II consists of Rural health centers, Health Posts Outreach clinics and Village clinics. It has been assumed that for Category-I, one training program would be conducted per district per year for all 10 years of the master plan. For Category-II, it has been assumed that 10 training programs would be conducted per district per year for all 10 years. The training to be conducted for Category-1 would be of 2 days duration and that of Category-II would be of 1-day duration. ***Adding the total expenditure for all 10 years for both categories, the total training cost has been estimated at USD 5,040,000.***

The healthcare provision in Malawi is highly dependent on external financing. Development aid plays a key role in the economy and in the health sector it accounts for on average 62% of total funding. ***While the funding for the master plan is primarily intended to come from donor agencies, it has also considered domestic financing mechanisms to sustain the gains.*** Considering the above mentioned assumptions and calculations, the total expenditure for the ESMU has been estimated as shown in the table below:

Table 47 Key line items in costing of Master Plan

Cost head	Modality of Investment	Total budget (USD)	Budget implication for ESMU (USD)	Budget implication for other partners (USD)
Capex- Solar Generation system *(Renewable Energy Measure)*	80% as concessional debt from pooled fund of MoH&P 20% from RESCO equity	61,384,869	49,107,895	12,276,974 (for RESCO that participates in competitive bidding)
Capex- Solar Water Heater *(Energy Efficiency Measure)*	80% as concessional debt from pooled fund of MoH&P 20% from ESCO equity	11,592,000	9,273,600	2,318,400 (for ESCO that participates in competitive bidding)
Capex- Solar Lanterns *(Renewable Energy Measure)*	100% Grant (conditional) from pooled fund of MoH&P	39,864	39,864	-
Capex- Solar Direct Drive Refrigerator *(Renewable Energy Measure)*	100% Grant (conditional) from pooled fund of MoH&P	3,633,000	3,633,000	-
Capex- Biogas generation systems *(Renewable Energy Measure)*	80% as concessional debt from pooled fund of MoH&P 20% from ESCO equity	147,287	117,829	29,457 (for ESCO that participates in competitive bidding)
Capex- Waste Heat Recovery from Incinerator *(Energy Efficiency Measure)*	80% as concessional debt from pooled fund of MoH&P 20% from ESCO equity	46000	36,800	9,200 (for ESCO that participates in Competitive bidding)
ESMU manpower cost	Entirely met from ESMU operating budget	13,200,372	13,200,372	-
IT based Monitoring system & Dashboard/App	Entirely met from ESMU operating budget	100,000	100,000	-
O&M charges	Entirely met from ESMU operating budget	1,541,215	1,541,215	-

Cost head	Modality of Investment	Total budget (USD)	Budget implication for ESMU (USD)	Budget implication for other partners (USD)
Dissemination charges	Entirely met from ESMU operating budget	50,000	50,000	-
Quality Assurance	Entirely met from ESMU operating budget	1,320,037	1,320,037	-
Training and capacity building	Entirely met from ESMU operating budget	5,040,000	5,040,000	-
Manpower Cost of facility O&M dept	70% from ESMU operating budget and 30% by Human Resource Division of MoH&P	186,840,000	130,788,000	56,052,000 (For Human resource Division of MoH&P)
Total		**284,934,644**	**214,248,613**	**70,686,031**

Source: PwC analysis

From the above analysis, the ***total ESMU budget for 10 years is estimated at USD 214.24 million***. It is further estimated that the ***equity required to be contributed by the RESCOs that participate in the competitive bidding would be USD 12.27 million for works to be executed in the entire 10 year duration***. Similarly, the ***equity contribution from ESCOs that participate in competitive bidding for implementing Biogas, Waste heat recovery systems and Solar Water heating technologies is estimated at USD 2.3 million***. The above mentioned budget shall be used for preparation of the District Implementation Plan, which would govern the budget for various districts under the master plan.

In addition to the line items mentioned in the table above there are certain items for which the ESMU would need to determine the cost in discussion with the relevant stakeholders:

- Cost of carrying out Load assessment in District and Sub-district level facilities
- Cost of refurbishments in the distribution systems in District and Sub-district level facilities
- Cost of Fund administration of Pooled Fund
- Cost of augmentation of grid on supply side for the healthcare facilities

It is expected that the purchasing power be weakened by inflation. The real costs will depend on both the denomination and date of contracts. Therefore the denomination of the currency to be considered for the Master Plan is proposed to be USD. Presently the funding needs of the health sector in Malawi for infrastructure as well as payment of energy bills are being met through the Health Services Joint Fund, which has a trust fund structure. Given that the proposed pooled fund would also need to have capability and mandate to disburse debt, the pooled fund is proposed as a separate entity, for which UN Agencies can act as interim trustees until the Fund Manager is appointed.

The operationalization of the pooled fund would involve the following steps:

- Development of Concept Note stating scope and purpose of the Pooled Fund, Theory of Change, financial and governance arrangements and demonstration of the financial viability (expressed or anticipated donor interest)
- Formal decision on the selection of Administrative Agent

- Development and Finalization of the Terms of Reference of the Pooled fund
- Signing of Memorandum of Understanding between MoH&P and Administrative Agent
- Standard Administrative Arrangements with the donors to receive contributions which they wish to provide.

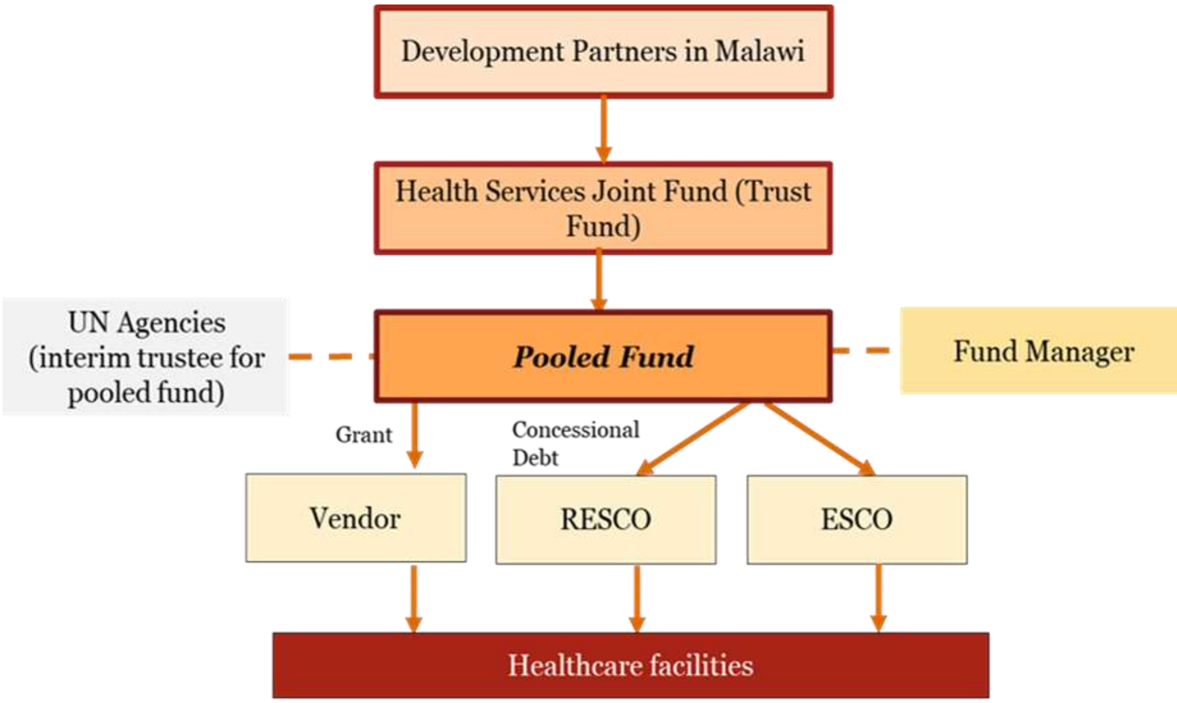


Figure 52 Concept of Pooled Fund

MoH&P shall utilize resource pooling from multiple donor agencies and the Health Services Joint Fund for fund raising for the pooled fund. The budget amount allocated to the master plan implementation may be increased or decreased to reflect the actual on-ground conditions after the midterm review. The implementing entity i.e. ESMU would be required to develop a risk management plan to mitigate against the different risks including financing and inflation

8.3.1. Inputs from analysis for upcoming Capital Investment Plan

The ***Capital Investment Plan 2017- 2022 has allocated an amount of USD 248 million to be spent on Rehabilitation, New Builds, Equipment and Upgrades in the healthcare facilities***.

- Out of USD 248 million, the ***equipment related budget of USD 28.28 million*** can incorporate investments in Captive renewable energy generation. The upcoming Capital Investment Plan should ***include the budget for Capital Renewable Energy systems, Information and Communication Technology (ICT) equipment for telemedicine and Energy Management systems as a part of budget head related to 'Equipment'***.

- The ***manpower cost of facility O&M department for which USD 56 million is supposed to be provided by the Human Resource division of MoH&P could included under the head of 'Rehabilitation costs'*** in the upcoming Capital Investment Plan.

9. Annexures

9.1. Key departments and Job Description for the key positions

The aim of this section is to define the competency levels required by the different departments/ groups of ESMU for appropriate discharge of duties. The overall objectives of the company have been taken into account while designing the competence requirements for different departments. This section identifies the roles that the concerned departmental Executives play and the responsibilities vested upon them towards achievement of the organizational goals. The purpose of Competence Requirement is to be used as reference to identify the competencies required for effective discharge of various roles and functions within the organization. However, the roles/ responsibilities and functions may vary from time to time depending upon changes in the corporate policies.

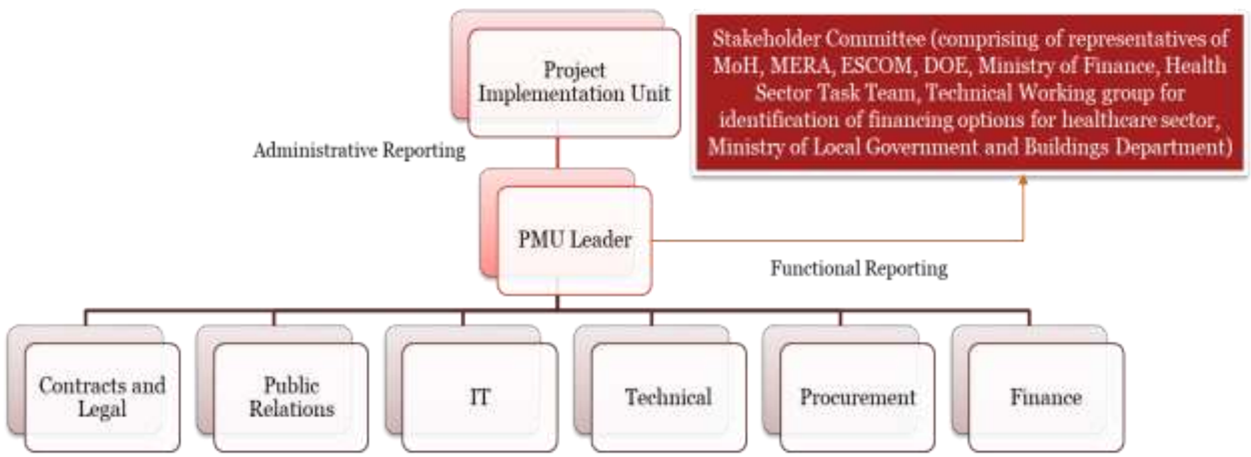


Figure 53 Organogram of ESMU

The number of staff for Contracts & Legal and Technical would be indexed to the number of healthcare facilities to be covered in the Master Plan using manpower norms (e.g. 1 Technical staff per x healthcare facilities) which would be determined by the Human Resources department from time to time with the approval of the STAKEHOLDER COMMITTEE. The norms would vary for different levels of hierarchy in the organogram.

COMPETENCE REQUIREMENT: Technical
ROLE

- Coordinating with the RESCO/Healthcare facility in design, development, construction and installation of Captive renewable energy plants and marketing them to Healthcare facilities.
- Studying project viability and evaluating detailed plan for installation of captive RE plants.
- Analysis of other areas where Captive RE can be used like solar water heating, solar air heating, solar water distillation etc.

- Liaison with the Government agencies/ healthcare facility owners regarding the detailed project plan for Captive RE projects and discussion and finalization of the terms of agreement for execution of the project.
- Facilitating the signing of Power Purchase Agreement between the healthcare facility and the ESCOM with a net metering arrangement.
- Award of bid to a RESCO by considering the techno commercial criteria.
- Monitoring the work of the third party inspection agency.
- Monitoring the Operation and maintenance of the equipment as per the terms of the contract.
- Undertaking extensive tours for discussion with Government and other agencies.

FUNCTIONAL COMPETENCE REQUIREMENT

- Knowledge of Govt. policies, procedure and guidelines for RE generation systems, especially captive RE systems.
- Knowledge of relevant Ministry guidelines, specifications and subsidy rules and procedure and understanding requirements for application for subsidy.
- Complete knowledge of RE generation systems, technical specifications and financial details of solar projects.
- Knowledge of state policies/notifications regarding implementation of renewable energy schemes.
- Knowledge of world scenario of solar power and business expectation.
- Knowledge of financial appraisal of project based on Detailed Project Report.

CROSS-FUNCTIONAL COMPETENCE REQUIREMENT

- Knowledge of RE equipment and project management.
- Knowledge of Finance, HR BD and Contracts.

COMPETENCE REQUIREMENT: CONTRACTS
ROLE

- Formulate and review policies related to procurement of equipment, material, works and services.
- Manage timely resolution of contractual issues including settlement of post award scope variations in co-ordination with Technical/Finance.
- Frame and Implement policies related to procurement and materials.
- Oversee finalization of standard bidding documents as well as qualifying requirements.
- Issuance of bid documents to interested and qualified vendors.
- Opening and evaluation of bids submitted by vendors, as well as the detailed negotiations with vendors
- Participate in tender committee for evaluating and awarding the contract.
- Expediting the process of supply of materials.
- Frame policy guidelines and system circulars for contracts, material management and export/import.
- Understand government policies/guidelines, frame policy guidelines and issue system circulars in the related areas.
- Coordinate and compile inventory related data and carry out inventory analysis and MIS generation.
- Manage all customs clearance activities for imported materials at lowest cost (demurrage, etc.).
- Oversee inputs provided to Ministry of Health and Population, Department of Energy Affairs, vigilance auditors, etc. regarding contracts data.
- Coordination with Technical, Finance and other departments and project sites to successfully complete above mentioned activities.

FUNCTIONAL COMPETENCE REQUIREMENT

- Knowledge of company policies, procedures and guidelines for contracts, materials and procurement.
- Knowledge of government policy on taxation, duties, export and import policies.
- Knowledge of delegation of power and vigilance related guidelines.
- Knowledge of national and international sources of markets and vendors.
- Knowledge of materials management systems.
- Knowledge of quality systems such as ISO 9001 and 14000 standards.
- Knowledge of insurance and risk management.
- Knowledge of customs procedures and regulations and steps/activities involved in customs clearance.
- Knowledge of inventory management, material codification and accounting systems.
- Contract negotiation skills.

CROSS-FUNCTIONAL COMPETENCE REQUIREMENT

- Knowledge of Energy Efficient equipment and project management.
- Knowledge of Finance, HR and IT.

COMPETENCE REQUIREMENT: PUBLIC RELATIONS
ROLE

- Manage all corporate advertising and publicity jobs of ESMU.
- Manage press and media relations.
- Ensure image building and company branding.
- Develop outreach policy of ESMU for appropriate publicity.
- Manage and coordinate PR events of ESMU.
- Manage collection, compilation and dissemination of relevant news.
- Coordinate VIP visit as and when required.

FUNCTIONAL COMPETENCE REQUIREMENT

- Knowledge of corporate communication, mass communication and journalism.
- Communication skill both verbal and written.
- Creative skills in writing and visuals.
- Knowledge of the functional areas of ESMU.

CROSS-FUNCTIONAL COMPETENCE REQUIREMENT

- Knowledge of Finance, HR and IT.

COMPETENCE REQUIREMENT: INFORMATION TECHNOLOGY
ROLE

- Plan, deploy and manage the IT infrastructure such as dashboards for project management of the ESMU. The dashboard would be accessible to the general public for greater transparency.
- Manage software application design, development and implementation within the scheduled timeframe
- Manage the maintenance of the various IT applications used in ESMU.
- Facilitate IT support services to the user departments.
- Troubleshooting of desktops, laptops, peripherals, servers, UPS and server related problems.
- Coordinate with user departments to ensure maximum uptime and utilization of IT systems.
- Manage user trainings for IT products and applications.

- Coordinate with external agencies for Annual Maintenance Contract (AMC) and preventive maintenance and supervise the work of the contractor for outsourced IT jobs.
- Development, maintenance and updating of the ESMU website.
- Annual planning and budgeting for the IT department.

FUNCTIONAL COMPETENCE REQUIREMENT

- Knowledge of latest technology trends and practices in hardware and software
- Knowledge of software development and database management
- Knowledge of database administration, network administration and server administration.
- Knowledge of the best IT practices adopted in other companies.
- Knowledge of ESMU's business processes.

CROSS-FUNCTIONAL COMPETENCE REQUIREMENT

- Knowledge of Contracts, Finance and HR.

COMPETENCE REQUIREMENT:FINANCE
ROLE

- Preparation of annual capital and revenue budgets
- Financial appraisal of projects, studying project viability, preparing financial statements for projects
- Development of financial business models
- Funds management and liaison with financial institutions for external source of fund
- Oversee activities related to audits, collection and sharing of information, monitoring activities and resolution of issues
- Facilitate coordination with statutory auditors/government auditors with regard to the accounting and audits for CMU
- Oversee activities related to financial vetting of cost estimates and procurement proposals
- Perform role as representative of finance function on tender committees for procurement evaluation decisions and award facilitation
- Oversee the processing and release of payments to employees and external parties
- Oversee remittance of deductions to concerned agencies, such as EPF
- Oversee activities related to payment reconciliation under the contracts, including issue of interim/final payment certificates for contract closing and for custom reconciliation
- Manage preparation of financial reports presented to management, creditors, governmental agencies and other users, and ensure accuracy of the information
- Manage PF and gratuity of the ESMU team member, in association with the Accounts and Admin personnel
- Statutory compliance

FUNCTIONAL COMPETENCE REQUIREMENT

- Knowledge of finance, accounts, contracts and legal
- Knowledge of PF rules, Employees PF and other relevant acts
- Knowledge of Income tax act, sales tax, service tax and other indirect taxes
- Knowledge of domestic and international capital markets
- Knowledge of the budgeting process in Ministry of Health and Population
- Knowledge of delegation of powers, procurement policy and vigilance related guidelines
- Experience in preparation of profitability statements and statement of accounts
- Understanding of functioning of financial institutions and banks
- Knowledge of regulatory norms on taxation, duties, exim policies
- Knowledge of internal audit and accounting principles

- Experience in preparation of profitability statements and statement of accounts
- Knowledge of IT systems and applications in finance and accounting

CROSS-FUNCTIONAL COMPETENCE REQUIREMENT
Knowledge of HR, Contracts and IT

COMPETENCE REQUIREMENT:ACCOUNTS AND ADMININSTRATION ROLE

- Manage manpower planning and recruitment process for all members of the ESMU
- Manage the Establishment Section, Time Office – attendance and leave management
- Oversee the employee welfare facilities
- Plan manpower resource requirement for the ESMU
- Manage all communication channels in the organization like newsletters and public address by top management
- Manage wage and salary negotiations and implementation in the organization
- Ensure statutory compliance, compliance with labour laws
- Event management
- Handling general administration – office space, furniture, hospitality arrangements, courier, photocopy services
- Management of office vehicles and coordinate all protocol related activities
- Manage the reimbursement of various benefits and facilities to the employees
- Handling employees grievances
- Management of statutory compliance with the applicable labour laws
- Manage the process of salary and wage revision for all levels in the organization
- Manage documentation and record keeping for all HR policy documents

FUNCTIONAL COMPETENCE REQUIREMENT

- Awareness of ESMU's strategy, HR strategy, systems and policies
- Knowledge of labor laws and working of local administration
- Counseling, coaching and communication skills
- Awareness of HR-IT systems
- Knowledge of grievance handling procedures

CROSS-FUNCTIONAL COMPETENCE REQUIREMENT

- Understanding of line functions and affiliate operations of ESMU
- Knowledge of Finance, Contracts and IT

9.2. Work Plan to address the deficiencies in O&M of existing RE system

The table below illustrates the steps to be taken to mitigate the O&M issues of the existing SPV system at the facility level, which includes measures during the implementation and post implementation stage.

Table 48 Plan for O&M of RE system

Issues in O&M of existing SPV system	Mitigation Plan	Responsible Entity
No proper O&M schedule	Instituting a system of Daily/Monthly/Quarterly Maintenance checks • Monitor power generation and export • Monitor load centre wise power generation values to detect any abnormality • Cleaning and checking shading of modules • Checking and tightening of foundation bolts of all equipment • Thermo-vision scanning of all the equipment and removal of hot spots • Calibration of weather monitoring station • Review of emergency response systems • Preparation of a user manual of the PV system for the health facility staff. The manual should illustrate operation, monitoring and energy management of the system.	MoH&P for Central Hospital District Assembly/District Health management team for District and Sub-district level
Inappropriate sizing	• Based on this study a corrective action to be taken by aligning the size the existing SPV system with demand onsite • Site selection and Load assessment to be made mandatory before installing a SPV system	• RESCO • ESMU through procurement guidelines
Shortcomings in grounding	• An agency to be identified via tendering process to correct grounding (earthing) of existing SPV system • Guidelines and Protocols to be established and enforced for on ground procedures to assure installed solar equipment meets the expected outcome	• Awarded agency for electrical refurbishment works • ESMU through procurement guidelines
Inadequacy of hospital staff for carrying out maintenance activities	• Identify and impart training to hospital staff for carrying out maintenance activities • Ensuring availability of engineers and technicians to service and maintain solar systems correctly • All engineers and technicians to undergo a refresher course every 3 years on O&M of a SPV system	• ESMU • MoH&P for CH and District Assembly/DHMT for district and sub-district level facilities • ESMU
Unavailability of data management system	• Implementation of data management system to monitor performance and trigger actions • Protocol for formal reception of materials and inspection practice to be developed • An single O&M manual to be developed for all types of SPV plants in Malawi • Real time monitoring of installed solar equipment must be a mandatory component of supply of power packs/power plants	• ESMU • ESMU through procurement guidelines • ESMU • ESMU through procurement guidelines

Issues in O&M of existing SPV system	Mitigation Plan	Responsible Entity
Budget of O&M activities not prepared	• Healthcare facility wise budget approved to carrying out O&M activities is to captured • 'Approved budget v/s monthly utilization of budget' report facility wise is to be recorded	PAM department within MoH&P for Central Hospitals; • District Assembly/DHMT for district and sub-district level facilities

9.3. Data gaps and corrective actions

The table below shows the data gaps identified on the basis of literature review as well as load assessment and stakeholder consultations and the entity which would be made responsible for addressing those gaps in course of the master plan.

Table 49 Data gaps and corrective actions

Data Gap	Data to be gathered	Responsible entity
Degree of energy access of healthcare facilities	• Grid connectivity and reliability of power • Usage patterns of Grid and RE	ESMU supported by survey agency and Facility O&M team
Equipment inventory and design specifications	• List of equipment available at each District Hospital, Health Centre and Health Post along with their specification to be prepared • Equipment to classified as Electrical and Medical also further classified into Working, Not-working (Repairable) and Unrepairable • Usage patterns of key equipment (hours and time of use)	ESMU supported by Facility O&M team
Responsible staff for O&M activities	• Staffing norms and Number of staff responsible for O&M activities at facility level for Central, District and Community hospitals and health centers	Facility level management
Standard equipment list and Standard Maintenance Procedure (SMP)	• Equipment list including solar generation systems needs to be prepared and standardized for the different categories of healthcare facilities in Malawi. • Standard Maintenance Procedure for all installed RE system and Major/Critical equipment to be prepared/updated as per instructions of OEM • Standards of performance, technical specifications and procurement protocols for RE systems needs to be defined and implemented	ESMU
Annual Maintenance Plan and record keeping for maintenance	• Annual maintenance plan for all installed RE system and Major/Critical equipment to be prepared and reported to the line ministry • Single Line diagram of electricity distribution system for traceability in case of faults. • List of relevant Preventive maintenance activities to be shared with all healthcare facilities • Key energy consuming sections of the facility and monitoring of energy use	ESMU supported by Facility O&M team

	• Log-book for monitoring and recording equipment run hours, date of last service and other energy related data • Updating of excel based templates prepared by PAM for analyzing the recorded data. • Maintenance activity carried out on any equipment to be recorded at all healthcare facilities • Breakdown history with analysis like Mean Time To Repair (MTTR) and Mean Time Between Failure (MTBF) also to be recorded for Major/Critical equipment at all healthcare facilities • List of mandatory spares for major/critical equipment to prepared as per instructions of OEM • Tools, tackles and consumables for carrying out maintenance activities along with defined minimum-maximum level of spares to be provided to all healthcare facilities	
Database of Visitors	• All healthcare facilities to maintain a profile of visitors, like number of visitors offered treatment and referred to next level in healthcare hierarchy	ESMU supported by Facility O&M team
Planning and Management of Assets in the Health Sector (PLAMAHS)	• Planning and Management of Assets in the Health Sector (PLAMAHS) software has not been updated since 2007. PLAMAHS to be updated and latest data to be uploaded	ESMU supported by Facility O&M team
Data required for all future procurement of equipment	Two sets of Engineering, electrical drawings and Installation and O&M manuals are to be supplied for all equipment procured. The following information must be mentioned in the RFID used on all procured equipment in the future (This can be inside or outside the laminate, but must be able to withstand harsh environmental conditions). • Name of the manufacturer • Month & year of the manufacture • Country of origin • Unique Serial No and Model No • Date and year of obtaining IEC certificate. • Name of the test lab issuing IEC certificate. • Other relevant information on traceability as per ISO 9001 and ISO 14001 In addition the following equipment should be procured: • Data Acquisition System shall be provided for each of the solar PV plant. • Data Logging Provision for plant control and monitoring, time and date stamped system data logs for analysis with the high quality, suitable PC. Metering and Instrumentation for display of systems parameters and status indication to be provided. • All major parameters available on the digital bus and logging facility for energy auditing through the internal microprocessor and read on the digital front panel at any time) and logging facility (the current values, previous values for up to a month and the average values) should be made available for energy auditing through the internal microprocessor and should be read on the digital front panel. • Provision for Internet monitoring and download of data shall be also incorporated.	ESMU through procurement guidelines

	• Remote Server and Software for centralized Internet monitoring system shall be also provided for download and analysis of cumulative data of all the plants and the data of the solar radiation and temperature monitoring system. • Remote Monitoring and data acquisition through Remote Monitoring System software at the owner location with latest software/hardware configuration and service connectivity for online / real time data monitoring/control complete to be supplied and operation and maintenance/control to be ensured by the supplier. Provision for interfacing these data on server and portal in future shall be kept.	

9.4. List of standards

The table below presents the existing standards in Malawi for electricity and renewable energy. These have been adopted from International Electro-technical Commission (IEC) Standards, Covering Safety and Quality Requirements for Design, Installation Practice, Materials, Appliances and Fixtures for: Buildings, Electricity and Renewable Energy Delivery Systems. Consultations have revealed that some of these standards may need to be better aligned with international standards for ensuring the desired performance from the projects, especially when engaging in International Competitive bidding for RESCOs. A detailed list of international standards pertaining to Solar PV systems is provided in Table 51.

9.4.1. Malawian Standards

Table 50 Malawian standards for RE

Name of Malawian standard	Description
Electrical Installations of Buildings MS-IEC 60364	❖ Selection and erection of electrical equipment - Common rules, Wiring systems, Isolation,. Switching and control ❖ Selection and erection of electrical equipment - Earthing arrangements, protective conductors and protective bonding conductors ❖ Fundamental principles, assessment of general characteristics, definitions ❖ Protection against electric shock, overcurrent & thermal effects ❖ Requirements for special installations or locations.
Electric Cables MS-IEC 60287	❖ Calculation of the current rating ❖ Thermal Resistance under different Operating Conditions ❖ Losses and Reduction Factors
Electric Cables MS-IEC 60227:	PVC Insulated Cables of Rated Voltages Up To 450/750 V ❖ General requirements ❖ Test methods ❖ Non-sheathed cables for fixed wiring ❖ Sheathed cables for fixed wiring ❖ Flexible cables (cords)
Plugs Socket Outlets and Switches MS-IEC 60884:	Plugs, socket-outlets and couples for household and similar purposes ❖ General requirements ❖ Particular requirements for fused plugs ❖ Particular requirements for socket-outlets for appliances
Plugs Socket Outlets and Switches MS-IEC 60669:	Switches for household and similar fixed-electrical installations
Low Voltage Fuses MS-IEC 60269:	❖ General Requirements ❖ Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial applications)

	❖ Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications)
Specification for Conduits for Electrical Installations MS-IEC 60614	❖ General Requirements ❖ Particular specifications for conduits: ❖ Particular specifications for rigid plain conduits of insulating materials ❖ Flexible Conduits ❖ Pliable conduits of metal or composite materials
Household and Similar Electrical Appliances - Safety MS-IEC 60335	❖ General requirements ❖ Particular requirements for appliances for heating liquids ❖ Particular requirements for storage water heaters ❖ Particular requirements for battery chargers
Overhead Lines MS-IEC 60652:	❖ Loading tests on overhead line structures ❖ Definitions and classification ❖ Methods of test ❖ Specifications for individual materials
Overhead Lines MS-IEC 60672: Ceramic and Glass Insulating Materials	❖ Definitions and classification ❖ Methods of test ❖ Specifications for individual materials
Power & Instrument Transformers MS-IEC 60044	❖ Current transformers ❖ Inductive voltage transformers ❖ Electronic voltage transformers
Power & Instrument Transformers MS-IEC 60076	Power Transformers (All Parts)
Battery Based Photovoltaic Solar Home System – Specification MS 695 : 2004	❖ Practical minimum requirements
Battery Based Photovoltaic Solar Home System – Specification MS 696 : 2004 –	❖ Design Guidelines
Fluorescent lights for use in photovoltaic systems - Specification MS 709 : 2005	Specifies the minimum requirements for the fluorescent tube lights powered with direct current inverter ballast for use in photovoltaic systems
Secondary cells and batteries for solar photovoltaic energy systems, MS 710 : 2005	❖ General requirements and methods of test
Crystalline Silicon Terrestrial Photovoltaic Modules, MS 711 : 2005	❖ Lays down requirements for the design qualification and type approval of terrestrial photovoltaic modules suitable for long term operation
Domestic Solar Water Heater Specification Specifies the characteristics of domestic solar water heaters. MS 759 : 2009	❖ Code of practice for the construction and installation of solar water heater systems
Domestic Solar Water Heater Specification Specifies the characteristics of domestic solar water heaters. MS 779 : 2007	❖ Covers minimum requirements for domestic stand alone solar photovoltaic wind hybrid systems
Solar Photovoltaic Water Pumping systems – Specification MS 780 : 2007	❖ Covers specifications for solar photovoltaic water pumping systems for domestic use

Recommendations for small RE and hybrid systems for rural electrification MS 889 – 5 – 2011	❖ General requirements for the protection of persons and equipment against electrical hazards to be applied in decentralised rural electrification systems
Recommendations for small RE and hybrid systems for rural electrification MS 889 – 7-1 2011	❖ Specifies the general requirements for erection and operation of PV arrays in decentralised rural electrification systems
Recommendations for small RE and hybrid systems for rural electrification MS 889-9- : 2011	❖ Provides general requirements for the design, erection and operation of micro-power plants and general requirements to ensure the safety of persons and property
Recommendations for small RE and hybrid systems for rural electrification MS 889 – 9- 2 : 2011	❖ General requirements for the design and implementation of micro grids used in decentralised rural electrification to ensure the safety of persons and property
Recommendations for small RE and hybrid systems for rural electrification MS 889 – 9- 3 : 2011	❖ Specifies the general requirements for the design and the implementation of the interface equipment within the user's installation which connects to the grid or the generating part of a stand alone system
Recommendations for small RE and hybrid systems for rural electrification MS 889-9-5: 2012	❖ Applies to portable solar photovoltaic lanterns and is independent of the technology used to provide the light
Recommendations for small RE and hybrid systems for rural electrification MS 889 – 7-1 2011	❖ Specifies the general requirements for erection and operation of PV arrays in decentralised rural electrification systems
Recommendations for small RE and hybrid systems for rural electrification MS 889-9- : 2011	❖ Provides general requirements for the design, erection and operation of micro-power plants and general requirements to ensure the safety of persons and property
Recommendations for small RE and hybrid systems for rural electrification MS 889 – 9- 2 : 2011	❖ General requirements for the design and implementation of micro grids used in decentralised rural electrification to ensure the safety of persons and property
Recommendations for small RE and hybrid systems for rural electrification MS 889 – 9- 3 : 2011	❖ Specifies the general requirements for the design and the implementation of the interface equipment within the user's installation which connects to the grid or the generating part of a stand alone system
Recommendations for small RE and hybrid systems for rural electrification MS 889-9-5: 2012	❖ Applies to portable solar photovoltaic lanterns and is independent of the technology used to provide the light
Over Voltage Protection for Photovoltaic Power Generation MS –IEC 61173 : 1992	❖ Gives guidance on the protection of over voltage issues for both stand alone and grid-connected photovoltaic power generating systems
Characteristic Parameters of Stand Alone Photovoltaic Systems MS –IEC 61194:1992	❖ Defines the major Electrical, Mechanical and Environmental parameters for the description and performance analysis of stand alone photovoltaic systems
Crystalline Silicone Terrestrial Photovoltaic Modules MS-IEC 61215:2005	❖ Lays down requirements for the design qualification and type approval of terrestrial photovoltaic modules suitable for long term operation in general

Wind Turbine Generator Systems MS-IEC 61400-SER-1:2005	❖ Safety and Quality requirements for design, installation and operation of wind turbine generator system
Wind Turbine Generator Systems MS-IEC 61400-SER-2-2006	❖ Turbines having a swept area smaller 40 sq metres and generating at a voltage below 1000 VAC or 1500VDC

Source: MERA

9.4.2. Internationally accepted Standards

The following standards are internationally accepted for installation of Solar PV systems and are expected to act as guidance for Bureau of Malawian standards for harmonization of Malawian standards with world class standards.

Table 51 International accepted standards for Solar PV

Name of Part	Description

PV Modules	❖ The PV modules used must qualify to the latest edition of IEC PV module qualification test Crystalline Silicon Solar Cell Modules **IEC 61215** or qualification test for thin film terrestrial modules **IEC 61646**
	❖ Modules must conform to **IEC 61730** Part-2- requirements for construction & Part 2 – requirements for testing, for safety qualification
	❖ For the PV modules to be used in a highly corrosive atmosphere throughout their lifetime, they must qualify to **IEC 61701**
	❖ PV modules must be tested and approved by one of the IEC authorized test centers.
	❖ For field test **IEC 60904-1 Part 1**: Measurement of photovoltaic current-voltage characteristics should be used.
	❖ The module shall be provided with a junction box. The box shall have hinged, weather proof lid with captive screws and cable gland entry points or may be of sealed type and **IP-65** rated.
	❖ Modules deployed must use a RF identification tag. The following information must be mentioned in the RFID used on each modules (This can be inside or outside the laminate, but must be able to withstand harsh environmental conditions).
	    ❖ Date and year of obtaining IEC PV module qualification certificate.
	    ❖ Name of the test lab issuing IEC certificate.
	    ❖ Other relevant information on traceability of solar cells and module as per **ISO 9001** and **ISO 14001**
	❖ **Mono/Multi C-Si Technology Modules:** Individual Solar PV Module conforming to **IEC: 61215 Ed 2** or latest – Edition II, **IEC: 61730 – I: 2007**, **IEC: 61730 – II: 2007**, and also type tested by any of the accredited test laboratories.
	❖ **For CIGS Technology Module:** Module certificate should comply with Certified for harsh environments: Blowing sand/ resistant (**DIN EN 60068-2-68**)

Batteries	❖ **IEC 60896-11** for procurement of Stationary lead-acid batteries:
	    ❖ Part 11: Vented types – General requirements and
	    ❖ method tests;
	    ❖ Part 21: Valve regulated types – Methods of tests;
	    ❖ Part 22: Valve regulated types – Requirements
	❖ **IEC 61427** Secondary cells and batteries for photovoltaic energy systems (PVES) – General Requirements and Methods of Test
	❖ **IEC 62485-2 Part 2:** Safety requirements for secondary batteries and battery installations: Stationary Batteries should be used for electrical and structural safety
	❖ **IEEE 1361** for field test Practice for determining performance characteristics and suitability of batteries in photovoltaic Systems- Field test

Name of Part	Description
Array Structure	❖ The mounting structure steel shall be as per latest **IS 2062: 1992** and galvanization of the mounting structure shall be in compliance of latest **IS 4759.**
Junction Boxes	❖ Copper bus bars/terminal blocks housed in the junction box with suitable termination threads Conforming to **IP65** standard and **IEC 62208**
DC Distribution Board	❖ DC DPBs shall have sheet from enclosure of dust & vermin proof conform to **IP 65** protection.
AC Distribution Panel board	❖ All switches and the circuit breakers, connectors should conform to **IEC 60947, part I, II and III/ IS60947 part I, II and III.** ❖ All indoor panels will have protection of **IP54** or better. All outdoor panels will have protection of **IP65** or better. ❖ Should conform to Malawian Electricity Act and rules (till last amendment). ❖ Protection of Enclosure : **IP-20**(Minimum) for indoor and **IP-65**(Minimum) for outdoor
Power Conditioning Units (PCUs)	❖ The power conditioning units / inverters should comply with applicable IEC standard for efficiency measurements and environmental tests as per standard codes **IEC 61683/IS 61683** and **IEC 60068- 2(1,2,14,30)**/Equivalent Malawian Std. ❖ **IEC 62109**: Safety of power converters for use in photovoltaic power systems: ❖ Part 1: General requirements; ❖ Part 2: Particular requirements for inverters; ❖ Part 3: Particular requirements for electronic devices in combination with photovoltaic element
Charge Controller	❖ The charge controller (if any) / MPPT units environmental testing should qualify **IEC 60068-2(1, 2, 14, 30)**/Equivalent Malawian std. The junction boxes/ enclosures should be **IP 65**(for outdoor)/ IP 54 (indoor) and as per **IEC 529** specifications. The PCU/ inverters should be tested from the GoM approved test centres / NABL /IEC accredited testing- calibration laboratories. In case of imported power conditioning units, these should be approved by international test houses. ❖ The performance and functioning of charge controllers is governed by **IEC 62509** ❖ The safety of the power converters for use in photovoltaic power systems is governed by **IEC 62109-1:** General requirements.
Lighting Protection	❖ Lightning protection should be provided as per **IEC 62305** standard
Earthing Protection	❖ Each array structure of the PV yard should be grounded/ earthed properly as per **IS:3043-1987.**
Cables	Cables of appropriate size to be used in the system shall have the following characteristics: ❖ Shall meet **IEC 60227, IEC 60502** standards ❖ Description Standard Number Cables General Test and Measuring Methods, UV resistant for outdoor installation **IS /IEC 69947.**
Fire extinguishers	The installation of Fire Extinguishers should confirm to TAC regulations
Data Monitoring	The plant parameters shall be measured by using SCADA or Equivalent system to monitor, maintain, and control the plant, and also to study the plant performance. The system should meet **IEC 61724** standard for this provision
Cables for carrying Power and Control	❖ The power cable shall, in general conform to **IS-1554 Part-I** & other relevant standards. ❖ Control Cables: The cables shall, in general conform to **IS-1554 Part-I** & other relevant standards.
Installation, Testing, Commissioning and Safety	The installation of the PV arrays, Inverters and other components should be as per the **IEC 61173, IEC 62548, IEC 61140 and IEC 62109-1 & 2** standard.

9.5. Number and type of appliances in different types of healthcare facilities

Table 52 No. and type of ICT equipment across various facilities of Central Healthcare facillities

Sr. No	Area	PC/TV		Printer/photocopy	
		(No.)	(kW)	(No.)	(kW)
1	Laboratory	16	3.2	6	0.48
2	X - ray	1	0.2	1	0.08
3	CSSD	-	-	-	-
4	Ward 2 & 3	-	-	-	-
5	Eye	-	-	-	-
6	Pharmacy	-	-	-	-
7	Orthopedic	-	-	-	-
8	Prefab	-	-	-	-
9	Under - 5	-	-	-	-
10	Project office	5	1	2	0.16
11	PAM	2	0.4	-	-
12	Ward - 9	2	0.4	-	-
13	Ward - 7 & 8	2	0.4	-	-
14	Ward - 5 & 6	3	0.6	-	-
15	Private/paying ward	1	0.2	-	-
16	TB Ward	-	-	-	-
17	Surgical	-	-	1	0.08
18	Dental	-	-	-	-
19	Ward 12 & 13	2	0.4	-	-
20	Ward 10	1	0.2	1	0.08
21	ICU	1	0.2	-	-
22	Labour ward	-	-	-	-
23	Post Natal	3	0.6	-	-
24	Nursery	-	-	-	-
25	OPD	-	-	-	-
26	Main operating theatre	10	1	-	-
27	Accounts	7	1.4	4	0.32

Source: Load assessment of 5 Central healthcare facilities by PwC

Table 53 Distribution of medical technical equipment across various facilities of Zomba Central

Area	Lighting Load (kW)	Air conditioner load (kW)	Refrigerator load (kW)	Geyser load (kW)	Kitchen equipment (kW)	Laundry equipment (kW)
Laboratory	1.5	21.2	11.6	-	-	-
X - ray	0.5	7.4	-	-	-	-
CSSD	0.3	-	-	-	-	-
Ward 2 & 3	1.4	-	-	18.0	-	-
Eye	2.6	3.7	-	-	-	-
Pharmacy	0.5	14.4	1.0	-	-	-
Orthopedic	0.6	5.8	0.3	-	-	-
Prefab	0.2	5.8	-	-	-	-
Under - 5	1.0	-	0.5	-	-	-
Project office	0.2	-	0.2	-	-	-
PAM	2.1	-	-	-	-	-
Ward - 9	2.5	-	-	9.0	-	-
Ward - 7 & 8	1.4	-	0.3	-	-	-

Ward - 5 & 6	1.9	-	0.3	-	-	-
Private/paying ward	1.8	-	0.3	-	-	-
TB Ward	2.9	-		-	-	-
Surgical	0.8	-	0.3	-	-	-
Dental	0.4	-		-	-	-
Ward 12 & 13	1.9	-	0.3	-	-	-
Ward 10	0.9	-	0.3	-	-	-
ICU	1.5	7.8		-	-	-
Labour ward	1.2	1.3	0.3	-	-	-
Post Natal	0.9	-	0.3	-	-	-
Nursery	1.6	-	0.3	25.0	-	-
OPD	1.3	-	0.8		-	-
Main operating theatre	5.5	5.8	1.3	15.0	-	-
Accounts	1.5	-	0.2	10.0		-
Kitchen	-	-	-	-	73.1	-
Laundry	-	-	-	-	-	104.0

Source: Load assessment of 5 Central healthcare facilities by PwC

Table 54 Inventory of lighting system at Zomba Central

Area	T-12		T-8		LED		T-8 (5 feet)		CFL	
	Nos.	W	Nos.	W	Nos.	W	Nos.	W	Nos.	W
Laboratory	1	52	10	48	-	-	14	66	-	-
X - ray	-	-	2	48	8	20	3	66	-	-
CSSD	-	-	6	48	-	-			-	-
Ward 2 & 3	-	-	20	48	-	-	6	66	-	-
Eye	19	52	33	48	-	-	-	-	-	-
Pharmacy	-	-	10	48	-		-	-	-	-
Orthopedic	-	-	10	48	10	9	-	-	-	-
Prefab	-	-	4	48	-	-	-	-	-	-
Under - 5	-	-	21	48	-	-	-	-	-	-
Project office	-	-	4	48	-	-	-	-	-	-
PAM	-	-	43	48	-	-	-	-	-	-
Ward - 9	-	-	43	48	-	-	-	-	-	-
Ward - 7 & 8	-	-	29	48	-	-	-	-	-	-
Ward - 5 & 6	-	-	40	48	-	-	-	-	-	-
Private/paying ward	-	-	37	48	-	-	-	-	-	-
TB Ward	-	-	33	48	-	-	-	-	80	11
Surgical	-	-	16	48	-	-	-	-	2	11
Dental	-	-	9	48	-	-	-	-		
Ward 12 & 13	-	-	35	48	-	-	-	-	17	11
Ward 10	-	-	17	48	-	-	-	-	11	11
ICU	-	-	21	48	22	20	-	-	1	11
Labour ward	-	-	24	48	3	20	-	-	2	11
Post Natal	-	-	16	48	-		-	-	15	11
Nursery	-	-	32	48	-		-	-	2	11
OPD	4	52	19	48	7	20	-	-	2	11
Main operating theatre	21	52	75	48	-	-	-	-	4	11
Accounts	-	-	29	48	-	-	-	-	6	11
Kitchen	-	-	20	48	-	-	-	-	-	-
Laundry	-	-	15	48	-	-	-	-	-	-

Source: Load assessment of 5 Central healthcare facilities by PwC

Table 55 Inventory of ACs, Refrigerators and Electric Geysers

Area	Air conditioners			Refrigerators		Geysers		
	Quantity (Nos.)	Total CC (kW)	Total load (kW)	Quantity (Nos.)	Total Load (kW)	Quantity (Nos.)	Capacity (Litre)	Total load (kW)
Laboratory	8	51.6	21.2	14	11.60	-	-	-
X - ray	4	21.1	7.4	-	-	-	-	-
CSSD	-	-	-	-	-	-	-	-
Ward 2 & 3	-	-	-	-	-	2	500	18
Eye	2	10.5	3.7	-	-	-	-	-
Pharmacy	5	35.1	14.4	4	1.03	-	-	-
Orthopedic	2	14.0	5.8	1	0.265	-	-	-
Prefab	4	14.0	5.8	-	-	-	-	-
Under - 5	-	-	-	2	0.53	-	-	-
Project office	-	-	-	1	0.15	-	-	-
PAM	-	-	-	-	-	-	-	-
Ward - 9	-	-	-	-	-	2	175	9
Ward - 7 & 8	-	-	-	1	0.25	-	-	-
Ward - 5 & 6	-	-	-	1	0.25	-	-	-
Private/paying ward	-	-	-	1	0.25	-	-	-
TB Ward	-	-	-			-	-	-
Surgical	-	-	-	1	0.25	-	-	-
Dental	-	-	-			-	-	-
Ward 12 & 13	-	-	-	1	0.25	-	-	-
Ward 10	-	-	-	1	0.25	-	-	-
ICU	3	19.0	7.8			-	-	-
Labour ward	1	3.0	1.3	1	0.25	-	-	-
Post Natal	-	-	-	1	0.25	-	-	-
Nursery	-	-	-	1	0.25	5	500	25
OPD	-	-	-	2	0.75			
Main operating theatre	4	14.0	5.8	5	1.25	5	200	15
Accounts	-	-	-	1	0.15	2	200	10
Kitchen	-	-	-	-	-	-	-	-
Laundry	-	-	-	-	-	-	-	-

Source: Load assessment of 5 Central healthcare facilities by PwC

Table 56 No. and type of appliances in District/Community healthcare facilities

Type of Department in Facility	Type/Description of Electrically Powered Item	Power rating	Items of this type at location
Laundry	Dryer	40000	1
Laundry	Washing machine	8000	2
Laundry	Iron	3000	2
Laundry	Iron	1500	1
Laundry	Sewing machine	370	1
Administration	Kettle	1600	1
Administration	Photocopier	924	1
Administration	Projector	300	1
Administration	Computer	250	1
Administration	Refrigerator	140	1

Type of Department in Facility	Type/Description of Electrically Powered Item	Power rating	Items of this type at location
Administration	Radio	100	1
Administration	TV	75	1
Administration	VR	21	1
Administration	Calculator	10	1
Blood Bank	Refrigerator	2500	1
Blood Bank	Refrigerator	1000	2
Blood Bank	Water bath	1000	1
Blood Bank	Microscope	500	1
Blood Bank	Centrifuge	400	1
Blood Bank	Deep freezer	360	1
Central Sterilization Department	Sterilizer	24000	1
Central Sterilization Department	Sterilizer	3000	1
Central Sterilization Department	Hot plate	2000	1
Central Sterilization Department	Disinfector	1000	1
Dental Department	Sterilizer	3000	1
Dental Department	X-ray viewer	1500	1
Dental Department	Dental unit	1400	1
Dental Department	Suction machine	1100	1
Dental Department	X-ray machine	1000	1
Dental Department	Light	555	1
Dental Department	Light	100	2
Dental Department	X-ray viewer	100	1
Dental Department	Amalgamator	60	1
Dental Department	Light	60	1
Dental Department	Ultrasonic scaler	39	1
Hospital Maintenance Unit	Photocopier	1000	1
Hospital Maintenance Unit	Computer	250	2
Instrument Sets	Otoscope	20	1
Instrument Sets	Otoscope	20	1
Instrument Sets	Opthalmoscope	10	2
Kitchen	Hot plate	4000	
Kitchen	Cold room	2000	1
Kitchen	Deep fryer	2000	1
Kitchen	Food warmer	2000	1
Kitchen	Hot plate	2000	2
Kitchen	Toaster	1800	1
Kitchen	Oven	1800	1
Kitchen	Cutter	1500	1
Kitchen	Blender	1200	1
Kitchen	Mincer	1200	1
Kitchen	Food warmer	850	2
Kitchen	Food warmer	500	
Kitchen	Refrigerator	480	1
Kitchen	Mixer	370	1
Kitchen	Deep freezer	360	2

Type of Department in Facility	Type/Description of Electrically Powered Item	Power rating	Items of this type at location
Kitchen	Slicer	260	1
Kitchen	Chiller	200	1
Kitchen	Butcher saw	10	1
Laboratory	FBC Machine	4000	1
Laboratory	Sterilizer	3000	1
Laboratory	Distilling unit	2500	1
Laboratory	Hot plate	2000	1
Laboratory	Incubator	2000	
Laboratory	Water bath	1000	2
Laboratory	Mixer	800	1
Laboratory	Sterilizer	700	1
Laboratory	UPS	700	4
Laboratory	Printer	660	1
Laboratory	Stirrer	500	1
Laboratory	Centrifuge	450	1
Laboratory	Oven	410	1
Laboratory	Slide dryer	410	1
Laboratory	Computer	250	1
Laboratory	Haematology analyzer	250	1
Laboratory	Viral load set	250	1
Laboratory	Refrigerator	140	2
Laboratory	Microscope	100	1
Laboratory	Centrifuge	80	1
Laboratory	Shaker	80	1
Laboratory	Mixer	70	1
Laboratory	AVR	60	4
Laboratory	Haemoglobinator	50	2
Laboratory	Balance/Scale	30	1
Laboratory	Chemistry analyzer	20	1
Laboratory	Colorimeter	6	1
Laboratory	CD4 counter	5	1
Laboratory	Keyboard	2	1
Laboratory	Thermometer	0	1
Maternity	Heater	5000	3
Maternity	Incubator	4000	2
Maternity	Sterilizer	3000	1
Maternity	Kettle	1600	3
Maternity	Suction machine	1100	1
Maternity	Infusion pump	1000	2
Maternity	Resuscitaire	1000	3
Maternity	Oxygen concentrator	530	3
Maternity	Phototherapy unit	300	1
Maternity	Light	150	1

Type of Department in Facility	Type/Description of Electrically Powered Item	Power rating	Items of this type at location
Maternity	Ultrasound machine	120	2
Maternity	Stethoscope	0	2
MCH	Sterilizer	3000	1
MCH	Kettle	1600	1
MCH	Light	25	2
OPD	Sterilizer	3000	2
OPD	Kettle	1600	2
OPD	X-ray viewer	1500	1
OPD	Suction machine	1100	2
OPD	Disinfector	1000	2
OPD	Oxygen concentrator	530	1
OPD	Nebulizer	430	1
OPD	Light	350	1
OPD	Light	60	1
OPD	Haemoglobinator	50	1
OPD	Light	25	2
Operating Theatre	Boiler	2500	1
Operating Theatre	X-ray viewer	1500	1
Operating Theatre	Suction machine	1100	2
Operating Theatre	Heater	1000	2
Operating Theatre	Light	1000	1
Operating Theatre	Resuscitaire	1000	1
Operating Theatre	Anaesthesia machine	700	1
Operating Theatre	Oxygen concentrator	530	2
Operating Theatre	Diathermy machine	400	1
Operating Theatre	Light	350	1
Operating Theatre	Pulse oximeter	345	1
Operating Theatre	Pulse oximeter	345	1
Operating Theatre	Refrigerator	140	1
Operating Theatre	ECG monitor	129	1
Operating Theatre	Pump	50	1
Operating Theatre	NIBP machine	20	1
Ophthalmology	Computer	250	1
Ophthalmology	Light	50	1
Ophthalmology	Light	40	1
Ophthalmology	Lensometer	15	1
Orthopaedic	X-ray viewer	1500	2
Orthopaedic	Resuscitaire	1000	1
Orthopaedic	Oxygen concentrator	530	4
Orthopaedic	Cutter	500	1
Orthopaedic	Cutter	500	1
Orthopaedic	Pulse oximeter	345	4
Orthopaedic	Ventilator	200	2

Type of Department in Facility	Type/Description of Electrically Powered Item	Power rating	Items of this type at location
Orthopaedic	Suction machine	150	2
Orthopaedic	ECG monitor	129	4
Orthopaedic	Saw	100	1
Orthopaedic	Light	90	1
Orthopaedic	Auto BP machine	20	4
Orthopaedic	Tourniquet	0	1
Pharmacy	Computer	250	1
Pharmacy	Refrigerator	140	7
Pharmacy	Mixer	100	1
Pharmacy	Cell counter	100	2
Pharmacy	Fan	40	8
Pharmacy	Balance/Scale	30	2
Pharmacy	Balance/Scale	30	2
Pharmacy	UPS	25	3
Physiotherapy	Shortwave unit	400	1
Physiotherapy	Ultrasound machine	400	1
Physiotherapy	Wax bath	150	1
Physiotherapy	Chiller	140	1
Physiotherapy	Ergometer	100	1
Supervisor Room	Computer	250	2
Wards	Kettle	1600	1
Wards	Suction machine	1100	1
Wards	Disinfector	1000	2
Wards	Infusion pump	1000	8
Wards	Oxygen concentrator	530	1
Wards	Nebulizer	430	1
Wards	Light	25	1
X-Ray	X-ray processor	2000	1
X-Ray	Auto Processor	1900	1
X-Ray	X-ray viewer	1500	2
X-Ray	X-ray machine	1000	1
X-Ray	Computer	250	1
X-Ray	Ultrasound machine	160	1
X-Ray	Light	25	1
X-Ray	Light	18	1

Source: UNICEF

Table 57 No. and type of appliances in Rural Health centres

Type of Department in Facility	Type/Description of Electrically Powered Item	Power rating	Items of this type at location
OPD	Kettle	1600	1
OPD	Centrifuge	350	1
OPD	Refrigerator	325	2
OPD	Light	60	1
Ward, Maternity	Light	10	1

Source: UNICEF

Table 58 No. and type of appliances in Urban Health Centers

Type of Department in Facility	Type/Description of Electrically Powered Item	Power rating (W)	Items of this type at location
Laboratory	FBC Machine	4000	1
Laboratory	Sterilizer	3600	2
Laboratory	Sterilizer	3000	1
Laboratory	Distilling unit	2500	1
Laboratory	Hot plate	2000	1
Laboratory	Incubator	2000	1
Laboratory	Water bath	1000	3
Laboratory	Mixer	800	1
Laboratory	Sterilizer	700	1
Laboratory	UPS	700	4
Laboratory	Printer	660	1
Laboratory	Stirrer	500	1
Laboratory	Centrifuge	450	1
Laboratory	Oven	410	1
Laboratory	Slide dryer	410	1
Laboratory	Computer	250	1
Laboratory	Haematology analyzer	250	1
Laboratory	Viral load set	250	1
Laboratory	Refrigerator	140	2
Laboratory	Microscope	100	1
Laboratory	Centrifuge	80	1
Laboratory	Shaker	80	1
Laboratory	Mixer	70	1
Laboratory	AVR	60	4
Laboratory	Haemoglobinator	50	2
Laboratory	Chemistry analyzer	20	1
Laboratory	Colorimeter	6	1
Laboratory	Keyboard	2	1
Laboratory	Thermometer	0	1
OPD	Sterilizer	3000	2
OPD	Infusion pump	1000	1
OPD	Oxygen concentrator	530	1
OPD	Centrifuge	350	1
OPD	Refrigerator	325	2
OPD	Light	60	1
OPD	Haemoglobinator	50	1
Operating Theatre	Heater	5000	1
Operating Theatre	Sterilizer	3000	1
Operating Theatre	X-ray viewer	1500	1
Operating Theatre	Suction machine	1100	2
Operating Theatre	Light	1000	1
Operating Theatre	Resuscitaire	1000	1

Type of Department in Facility	Type/Description of Electrically Powered Item	Power rating (W)	Items of this type at location
Operating Theatre	Anaesthesia machine	700	1
Operating Theatre	Oxygen regulator	530	2
Operating Theatre	Oxygen concentrator	530	1
Operating Theatre	Diathermy machine	400	1
Operating Theatre	Light	350	1
Operating Theatre	Pulse oximeter	345	1
Operating Theatre	Light	150	1
Operating Theatre	ECG monitor	129	1
Operating Theatre	Ultrasound machine	120	1
Operating Theatre	Diagnostic set	100	1
Operating Theatre	Light	60	1
Operating Theatre	Haemoglobinator	50	1
Operating Theatre	Light	25	4
Ward, Maternity	Sterilizer	3000	2
Ward, Maternity	Autoclave	2500	1
Ward, Maternity	Vacuum	1600	1
Ward, Maternity	Light	10	1
X-Ray	X-ray processor	2000	1
X-Ray	X-ray processor	1900	1
X-Ray	X-ray viewer	1500	1
X-Ray	X-ray machine	1000	1
X-Ray	Computer	250	1
X-Ray	Light	25	1
X-Ray	Light	18	2

Source: UNICEF

Table 59 No. and type of appliances in Health posts

Type of Department in Facility	Type/Description of Electrically Powered Item	Power rating	Items of this type at location
OPD	Light	60	1
OPD	Refrigerator	325	1
EPI	Light	10	1

9.6. Number of healthcare facilities of different types based on ownership

Table 60 Distribution of healthcare facilities based on ownership

	Central Hospital	District & Community Hospital	Health Centre	Health Post	Outreach clinic	Village Clinic	Dispensary
MoH&P	4	42	405	132	3984	3542	41
CHAM		37	107	18	967		4
Aquaid Lifeline							1
Bilal Trust			1		5		
ESCOM					6		4
Child Legacy		1			5		
Daeyang Luke		1	1		12		

	Central Hospital	District & Community Hospital	Health Centre	Health Post	Outreach clinic	Village Clinic	Dispensary
Dwangwa Cane Growers			1		3		
Estate			1				
Hope Village							1
Illovo Dwangwa			1		4		
Illovo Sugar Estate			5				1
Kavuzi Tea Estate			1		12		1
KINDLE					2		1
Life Line			1		4		
LUANAR					3		1
Mchenga Coal Mine							1
MDF			6		18		3
Millenium Village Project				1			
Al Baraka Charity Trust (ACT)			1		4		
Mulungu Alinafe					4		1
Orant Charities Africa			1	1	12		
Phwezi School					3		1
Police			2		3		4
Raiply					4		1
Seven Day Adventist			1		4		
Tea Estate			6		19		21
UNHCR			1		11		
Grand Total		**81**	**542**	**152**	**5089**	**3542**	**87**

Source: Health facility mapping in Malawi: Ward Jacobs