MALAWI

Integrated Energy Plan

MEDICAL COLD CHAIN & COVID-19 VACCINE DISTRIBUTION

IN PARTNERSHIP WITH:

Global Energy Alliance for People and Planet

10 AUGUST 2022

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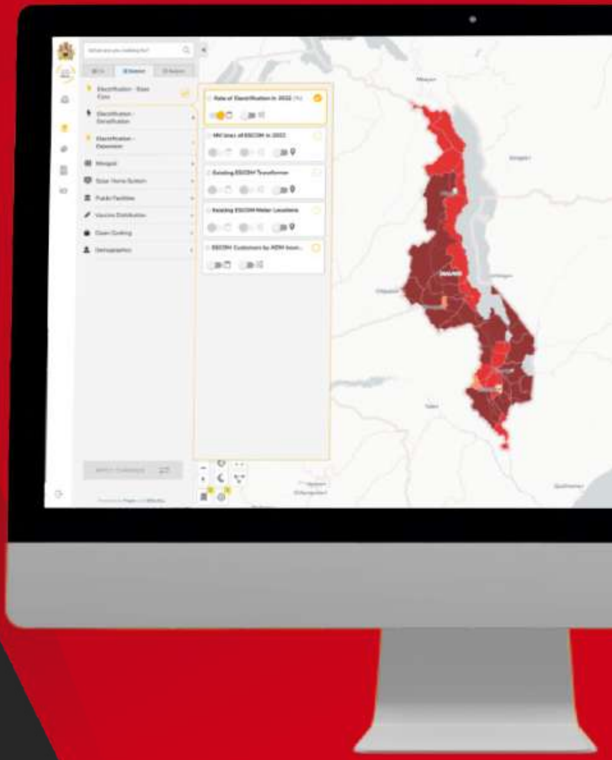

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Acronym List

EPI	Expanded Program on Immunization
CCE	Cold Chain Equipment
DVS	District Vaccine Store
HF	Health Facility
MOH	Ministry of Health
PQS	Performance, Quality and Safety
NVS	National Vaccine Store
RVS	Regional Vaccine Store
UCC	Ultra Cold Chain
WHO	World Health Organization
WICR	Walk-in Cold Room
WICF	Walk-in Cold Freezer

MALAWI IEP – COLD CHAIN

Executive Summary

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Executive Summary

The Ministry of Health in Malawi has had to pivot and quickly adjusted to the COVID-19 pandemic and rapidly scaled up introducing of this new vaccine, using leveraging the vaccine supply chain and a health system that were already constrained. This Vaccine Distribution Plan analysis included an overview of the vaccine introduction to date in the country, a cold chain capacity assessment, and an assessment of the energy needs of health facilities. Final recommendations build on best practices for cold chain planning and COVID campaign planning.

COVID Vaccine Activities to Date. The country has received about 6 million doses of the COVID vaccine since March 2021. 14% of the target population (of 12 year olds and older) are fully vaccinated (either with two doses of AstraZeneca or Pfizer, or one dose of J&J), with coverage a bit lower in the southern region of the country due to vaccine hesitancy. The COVID vaccine is distributed through the routine immunization supply chain using the same cold chain equipment and vehicles for transportation. The COVID vaccines are delivered from the National Vaccine Store to the District Vaccine Stores for campaign activities and to facilities to administer during routine services. The "Vaccinate My Village" approach is implementing community outreach campaigns two weeks of every month to increase access directly to the vaccines in the community.

Methodology. We worked closely with the MOH, EPI, UNDP and UNICEF provided to obtain data sources, while JSI cross-checked sources, validated assumptions, and clarifiy remaining questions with MOH counterparts. Limitations include multiple data sets with conflicting or missing information, particularly related to the master health facility list and population data. Assumptions have been documented and validated by MOH counterparts.

Cold chain assessment

The country has about 2,000 pieces of cold chain equipment (CCE) across the four layers of the supply chain, the majority of which (92%) are reported as functioning. The majority (76%) also have the status of are classified as WHO's Performance, Quality and Safety (PQS) prequalification, which assures their suitability for use in an immunization program. The 24% that are non-PQS may still function yet are appropriately being phased out of the system for newer, more reliable equipment. Fifty-three percent of the equipment is 10 years old or less; the industry life expectancy is 10 years. This presents an opportunity replace older equipment and have a medium- and long-term plan as CCE ages out of utility. There are more than 50 different models of CCE in the system, which complicates maintenance and spare parts management. Investment should be prioritized to replace ~350 CCE that are not working; increase freezer capacity at the district level; and consider expanding to health facilities that do not currently have CCE (considering the additional health worker cost to provide vaccines, supply chaind and vaccine distribution costs, and CCE maintenance costs); CCE costs are between $3,000 and $6,000 per unit.

Cold chain capacity utilization

To determine the capacity utilization for PQS cold chain, we used the vaccine quantity required based on the EPI schedule (e.g., vaccines approved for which target population and number of doses required of each); stated distribution schedule (e.g., monthly distribution to facility level and district); target population of each facility and district; and vaccine characteristics (vial size, cubic liters per dose, wastage rate, buffer stock). This is assessed against the total net cubic liters of the PQS-approved CCE available and functioning at the facility and used for vaccines. Utilization categories are defined as appropriate if 10–80% of capacity is used; underutilized if <10% of capacity is used; and as constrained if >80% of capacity is used. Appropriate capacity use is considered ideal. Results indicate that health facilities have sufficient space for both routine and COVID vaccines, with more than 70% of the facilities using less than 10% of the space available. The district level has a similar result with only one district with constrained capacity (this district is using the regional warehouse for additional space); analysis also shows that the majority of districts could shift to quarterly distribution of both routine and COVID vaccines and accommodate the required vaccine quantities. At the district level, 28% of facilities do not have freezer space, which, if available, could be used for the polio vaccine to extend its shelf life, making more refrigerator space for COVID and other vaccines.

Facility energy needs assessment.

Local, regional, and district health facilities were also analyzed according to their anticipated electricity assumptions and energy access status. Based on data from the MOH and ESCOM, an estimated 83% of health facilities in Malawi are connected to the ESCOM national grid. At present, there are an anticipted 92 off-grid health posts and 94 off-grid health centers. For off-grid health posts and health centers, standalone solar systems have been designed for inclusion in implementation of rural electrification programs for a required investment of USD $3.6M. Additional solar-battery hybrid retrofits have been designed to improve cold chain resiliency in existing grid-tied health facilities, at a total investment opportunity requirement of USD $17.6M. These estimates include facility power systems that are capable of powering CCE, but not the costs of CCE itself.

Best practices and recommendations for cold chain management and COVID

Malawi is implementing a their new vaccine introduction plan and has created processes, campaign strategies, and reporting structures to track progress. This vaccine distribution and energy analysis provides insight into a few key areas of cold chain management that, if addressed, could strengthen the overall vaccine supply chain in the country. These recommendations should be validated with the MOH and EPI team and can be used as justification and advocacy for donor investment. First, as the country plans to expand and upgrade their cold chain system to newer, more efficient and reliable CCE, investments should also be made in the CCE maintenance system to ensure longevity and performance and contribute to improved management of spare parts. A decommissioning plan should be developed and implemented for the older and non-functioning equipment that will removed from the system. EPI could consider changing the distribution frequency to the district level to take advantage of the CCE available space and reduce transport costs. Finally, EPI has already demonstrated their ability to manage a flexible and agile supply chain for the COVID vaccine by proactively shifting stock to different warehouses to avoid constraints. This best practice would benefit the routine immunization supply chain as well and could potentially reduce overall costs.

MALAWI IEP – COLD CHAIN

Project Scope of Work: Vaccine Distribution Plan

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Project context and objectives: Vaccine Distribution Plan

OVERALL PROJECT OBJECTIVE:

- To develop an updated and enhanced Integrated Energy Plan (IEP) for Malawi, by
  - Updating the existing geospatial analysis, incorporating more recent data-sets
  - Overlaying a clean-cooking layer into the model
  - Overlaying the energy requirement for productive uses
  - Ensuring the new IEP, including and their underlying tools and data are well understood
  - Ensuring that the model output is accessible and usable by external stakeholders (Malawi IEP Tool)

VACCINE DISTRIBUTION PLAN SPECIFIC ANALYSIS:

- Overview of COVID vaccine introduction
- Cold chain capacity assessment
- Assessment of facility energy needs
- Best practices for cold chain planning
- Recommendations for COVID campaign planning

...AND OUTPUTS:

- Detailed report that articulates the recommended approach for distribution of the COVID-19 vaccine, cold chain storage and logistics requirements and cost implications of meeting the cooling and energy needs associated with a nation-wide rollout of the vaccine.

MALAWI IEP – COLD CHAIN

Routine and COVID Vaccine Overview

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Malawi Health System Overview

Total number of facilities	1,580
Number of facilities with grid electricity	593
Number of facilities without grid electricity	346
Number of facilities with CCE and providing immunization	939
Number of District Vaccine Stores	29
Number of Regional Vaccine Stores	3
National Vaccine Store with CCE	1

Vaccines must be stored in the cold chain, mostly at 2°C to 8°C.

Exceptions:

- Pfizer COVID vaccine is stored at -70°C for up to 6 months before shifting to a health facility (2°C) to 8°C).
- It is recommended for Polio Vaccine to be stored in a freezer (-20°C) at the National, Regional and District level to extend the shelf life of the vaccine.

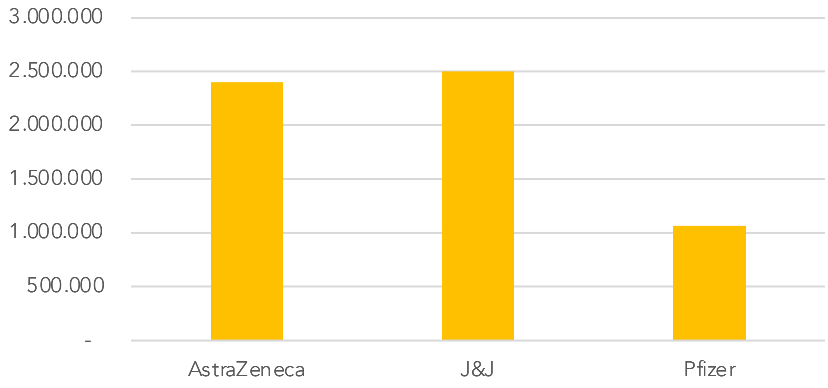
Source: MOH and ESCOM

COVID community campaign, "Vaccinate My Village"

COVID Vaccine Roll-Out: Current Situation

- About 6 million doses of the COVID vaccine have been received in country since March 2021. Pfizer is used for 12-17 year olds.
- Almost 2.9 million doses have been administered. 14% of population is fully vaccinated as of the end of June 22. While coverage is lower in the southern part of the country, that is likely due to vaccine hesitancy. The MOH has introduced a new strategy to address this roadblock.

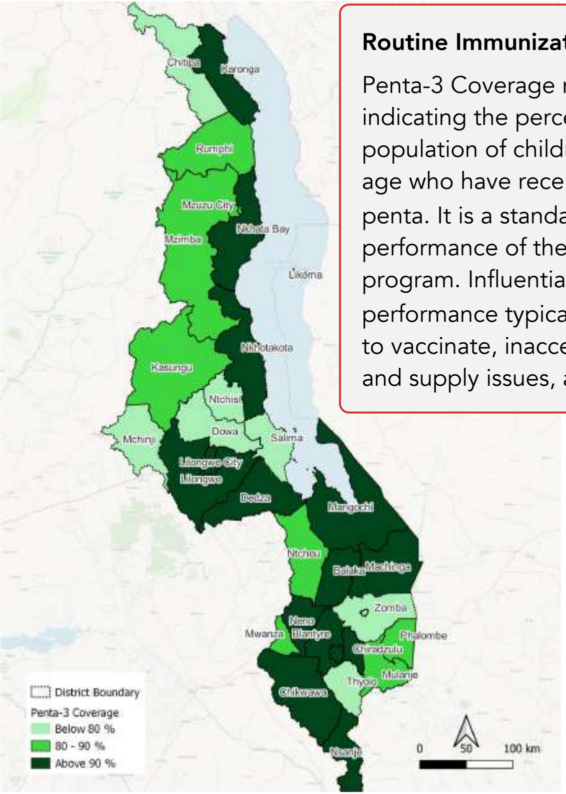
Number of Doses Received, March 2021 - June 2022



COVID vaccine roll-out strategy:

- "Vaccinate My Village" campaigns are planned for 2 weeks of every month for the immediate future:
  - A team of 4-5 health workers travel in a vehicle to outreach sites at community locations (school, church, market)
  - Vaccines are transported from the DVS by a cold box or vaccine carrier, carrying some risk of temperature excursions
  - Health workers promote door-to-door, engage community leaders and administer vaccines
- The COVID vaccine is also available in health facilities for routine administration; school campaigns are also conducted to reach 12-18 year olds
- The country is concurrently implementing a polio campaign to address recent polio cases, adding additional strain to the health system.

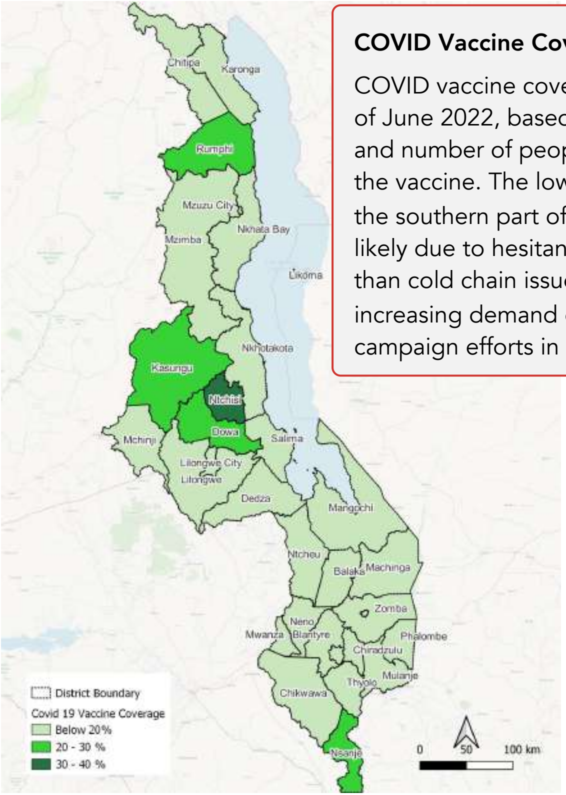
Comparison: Routine immunization coverage and COVID vaccine coverage



Routine Immunization Coverage (2021)

Penta-3 Coverage rate by district, 2021, indicating the percent of the target population of children under 1 year of age who have received the third dose of penta. It is a standard to indicate performance of the immunization program. Influential factors of low performance typically include hesitancy to vaccinate, inaccessibility to a facility, and supply issues, among others.

Source: EPI health information system



COVID Vaccine Coverage (June 2022)

COVID vaccine coverage by district, end of June 2022, based on target population and number of people who have received the vaccine. The lower coverage rate in the southern part of the country is most likely due to hesitancy to vaccinate rather than cold chain issues. The MOH is increasing demand creation activities and campaign efforts in these areas.

Vaccine Storage

Country Cold Chain Landscape
1 National Vaccine Store (NVS): 11 WICR, 2 WIFR, 5 UCC
3 Regional Vaccine Stores (RVS): 8 WICR, 4 WIFR, 2 UCC
29 District Vaccine Stores (DVS): Refrigerators and freezers
Health Facilities (HF): Health posts, health centers, hospitals (939 cold chain points)

NVS: Receives routine vaccines from the international shipments bi-annually, COVID vaccines as necessary. Procurement done through UNICEF. Walk-in cold rooms and freezers (WICR, WICF) maintain the vaccines in the ideal temperature range

RVS: North, Centre, South, hold quarterly stock

DVS: operational districts, collect vaccines on monthly basis from their corresponding RVS

HF: Receives vaccines monthly from District

WICR: Walk-in Cold Room; WIFR: Walk-in Freezer Room

Vaccine Distribution

Supply Chain Level	Method for Routine Vaccines
National	Stores vaccines, makes decisions about quantities to distribute
Regional	Use own vehicles (7-20 ton trucks) to fetch from National on a quarterly basis using cold boxes
District	Use own vehicles (1-3 ton, typically Toyota Land Cruiser/Hilux) to fetch from Regional, monthly basis, packed in cold boxes. WHO standards recommend quarterly distribution to the district level; however, Malawi follows monthly distribution due to the unreliability of the electricity to avoid spoilage of large quantities of stock if the CCE fails.
Health Facility	Delivered by district via truck and cold boxes, monthly basis
Outreach	Health facility staff use bicycles or motorcycles with small cooler for a day of service provision 5-10 km away from the facility

COVID-19 Vaccines

Vaccines are delivered directly from the NVS to the district using consumption to calculate quantities. The long-term plan is to begin using Regional stores to relieve constraint at the National level. COVID vaccines are stored in the same cold chain as routine vaccines. Pfizer is the exception that must be stored –60°C up to 9 months; because of the special temperature needs, distribution is conducted by an outsourced logistics group.

Policy versus Practice

This distribution schedule is the standard practice as designed by the MOH. Experience shows that reality may shift the frequency of delivery, depending on truck or fuel availability, or emergency "top-ups" between scheduled deliveries, particularly at lower levels.

Data collection methodology

- Based on close collaboration with MOH, EPI, UNDP and UNICEF, the study team was able to obtain data sources, cross-check sources, validate assumptions, and clarify remaining questions

Limitations:

- Information was variable across data sources; health facility lists are not regularly updated and some facilities may now be inactive.
- Missing data points (especially related to population data) were filled in with assumptions based on similar circumstances; detailed assumptions are available in the master data set.

Data	Source	Granularity
Health facility names and types	MOH master sheet	Facility level (RVS, DVS, facility)
Health facility GIS coordinates	MOH master sheet, UNDP	Facility level (RVS, DVS, facility)
Population/ catchment data	MOH Planning Department	Facility level (RVS, DVS, facility)
Cold chain equipment (CCE) assets	EPI inventory (updated 2022), WHO PQS catalogue	Facility level (RVS, DVS, facility)
Vaccine item dimensions	WHO prequalified list	By type of vaccine
Routine immunization schedule	EPI	MOH level
COVID vaccine roll out updates	EPI, supply planning tool	District

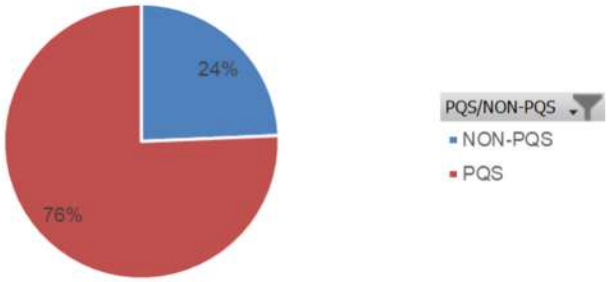
MALAWI IEP – COLD CHAIN

Cold Chain Assessment

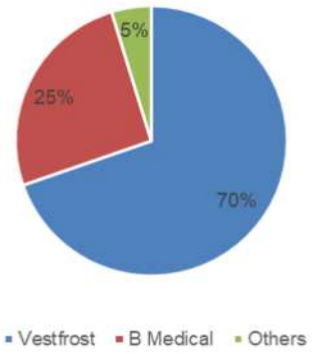
Cold chain equipment overview

- The supply chain has about 2,000 pieces of CCE across the multiple levels of the system, with larger walk-in cold rooms and freezers (WICR, WICF) at the national and regional levels.
- The WHO Performance, Quality and Safety (PQS) process prequalifies products and devices to assure of their suitability for use in immunization programs.
  - 24% of the CCE is non-PQS; while these may still function, they are being phased out of the system to newer, more reliable equipment
- The cold chain system is dominated by two PQS-approved manufacturers (B Medical, Vestfrost).

% OF CCE BY PQS AND NON-PQS



% OF CCE BY MANUFACTURER



Source: Cold Chain Equipment Inventory, April 2022

Number of PQS pieces of CCE by manufacturer

Manufacturer	Functional	Non-functional	Working But Need Repair	Grand Total
A	1032	63	8	**1103**
B	367	35	3	**405**
C	30	4	0	**34**
D	19	0	0	**19**
E	2	0	0	**2**
F	1	1	0	**2**
G	5	0	7	**12**
H	1	0	0	**1**
I	0	1	0	**1**
J	2	0	0	**2**
Grand Total	**1459**	**104**	**18**	**1581**

It is typical for a country to have multiple CCE manufacturers and models. While this provides options if one brand/model is underperforming, it adds a layer of complexity for cold chain technicians to provide maintenance or repair, and to plan, procure and manage spare parts.

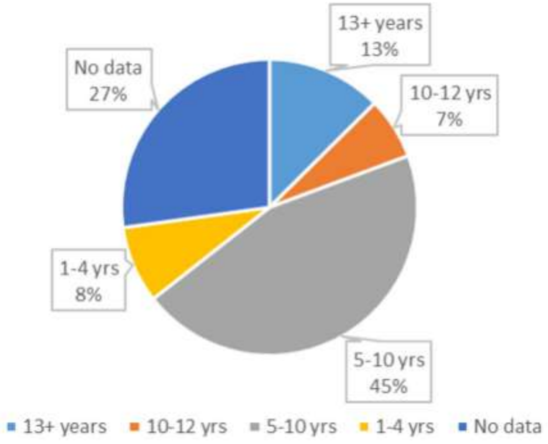
CCE: TCW 3000AC, capacity 150 liters, often used at larger health facilities

PQS-Approved CCE is largely functional with varying ages

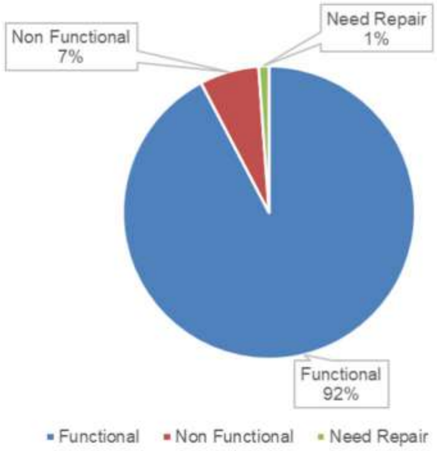
The CCE inventory tracks all CCE, including walk-in cold and freezer rooms at the national and regional levels. The equipment is largely functioning, with 7% non-functional (and should be decommissioned and moved out of the facility space) and 1% that needs repair.

The industry standard life expectancy of CCE is ~10 years, which is the benchmark EPI uses for long-term planning. CCE in Malawi ranges from 20 years old to brand new. Older equipment, even if still working, should be prioritized for replacement with newer, more reliable and energy-efficient equipment. Based on the reported age of the CCE, almost 50% of the CCE will need to be replaced in the next 3-5 years.

AGE OF FUNCTIONAL EQUIPMENT



FUNCTIONALITY OF PQS APPROVED CCE



Source: Cold Chain Equipment Inventory, April 2022

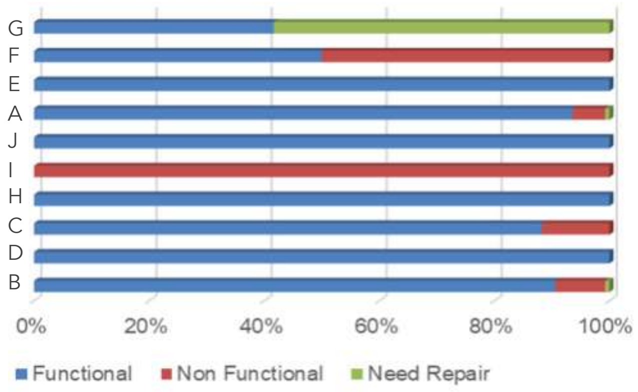
Multiple models require different spare parts and maintenance

The CCE includes equipment that runs on solar, from the electricity grid, and by gas/propane. The gas/propane models are older and no longer recommended; EPI is in the process of removing these from the system.

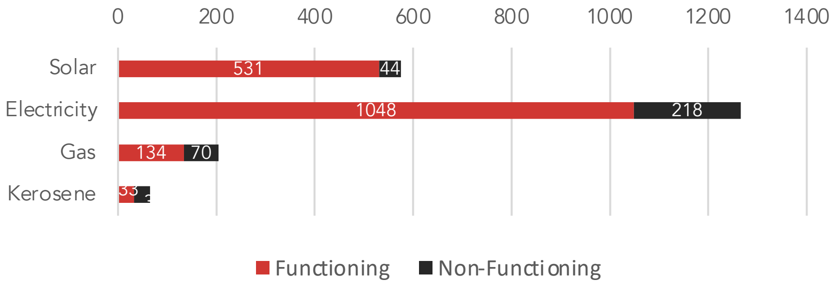
The cold chain has 10 PQS-approved CCE manufacturers with up to about 50 models across all CCE. For example, the two largest suppliers, Vestfrost and B Medical have respectively 25 and 13 different models. While the technology is similar across manufacturers and models, the spare parts are unique to each model, thus complicating the maintenance system.

Vestfrost and B Medical are recently installed equipment through Gavi's CCEOP procurement process and are working relatively well. They are also still covered under warranty for manufacturing errors (i.e., it does not include problems related to user error) for the next 2-3 years.

FUNCTIONALITY BY MANUFACTURER



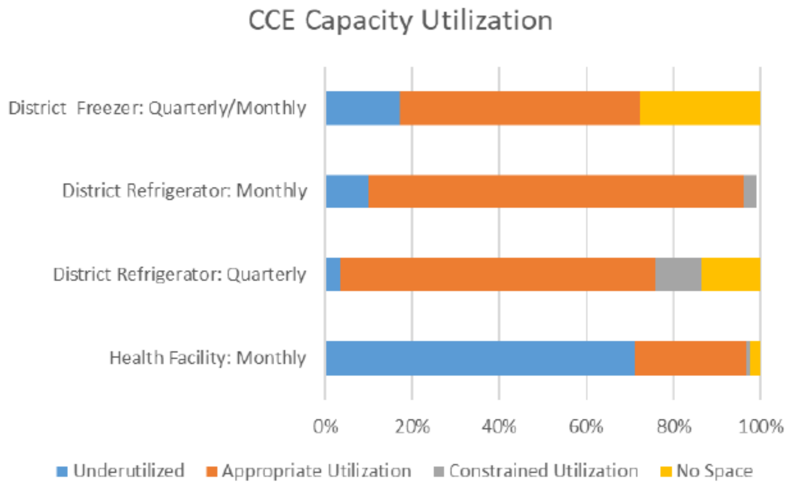
NUMBER OF CCE BY ENERGY SOURCE



Source: Cold Chain Equipment Inventory, April 2022

Capacity Utilization Analysis: Routine Vaccines

To determine the capacity utilization throughout the Malawi vaccine PQS cold chain for each store and facility, we used the vaccine quantity required based on the EPI schedule (e.g., vaccines and number of doses required of each); stated distribution schedule (e.g., monthly distribution to facility level and district); target population of each facility and district; and vaccine characteristics (vial size, cubic liters per dose, wastage rate, buffer stock). This is assessed against the total net cubic liters of the PQS-approved CCE available and functioning at the facility and used for vaccines. Utilization categories are defined as appropriate if 10–80% of capacity is used; underutilized



if <10% of capacity is used; and as constrained if >80% of capacity is used. Appropriate capacity use is considered ideal. The estimated need for the COVID-19 vaccine is based on average consumption to date by district to set a benchmark for expected on-going campaign efforts. Due to the multiple COVID-19 vaccines with different vial size characteristics and the unknown nature of which district will receive which vaccine, this analysis is generalized for COVID-19 vaccines with the focus on the routine schedule as baseline.

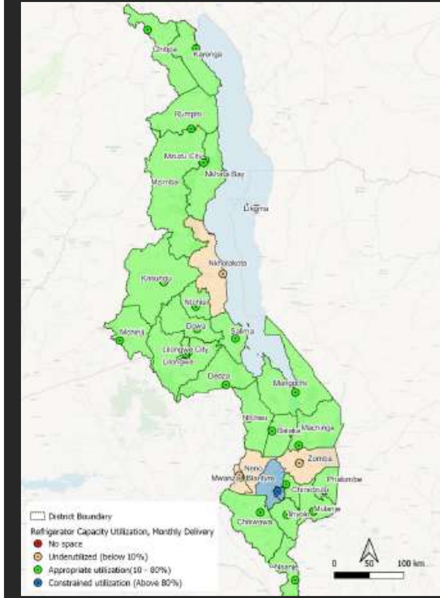
Key takeaways:

- Health facility: The majority of facilities with CCE (70%) use less than 10% of the space with the monthly distribution schedule, allowing more than sufficient space for COVID vaccine; about 500 facilities do not have CCE so do not provide vaccines regularly.
- District refrigerator: Vaccines are delivered to the district level monthly and only one district (Blantyre) has constrained space. Analyzing for quarterly distribution as an option for efficiency, the majority (72%) are still in the appropriate utilization category, indicating there is sufficient space with this alternative distribution frequency, except possibly in surge situations such as multiple campaigns (COVID, polio). Three districts are constrained and would benefit from additional CCE.
- District freezer: 28% of districts do not have freezer space, which, if available, could be used to extend the shelf life of polio vaccine and create more fridge space for COVID vaccine.
- Estimates of COVID-19 vaccine needs have a minimum impact on the CCE, increasing the utilization rate between 1% and 5%, depending on the population size.

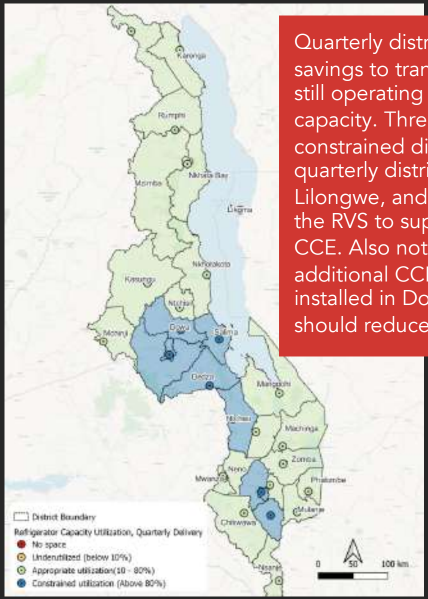
District CCE capacity utilization analysis with alternative distribution frequency

REFRIGERATOR SPACE

Monthly distribution to DVS (current policy)

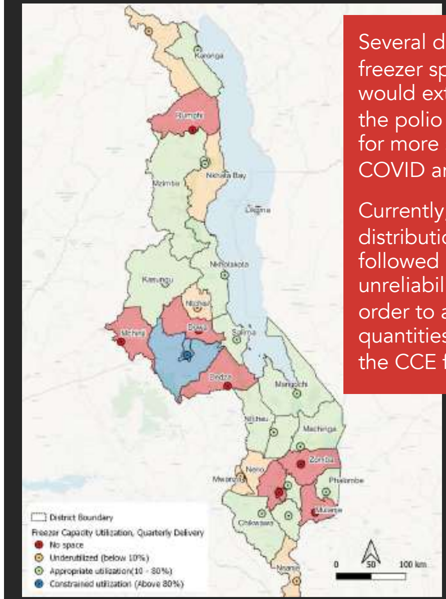


Optional quarterly distribution to DVS



Quarterly distribution could bring savings to transport costs while still operating with sufficient capacity. Three of the constrained districts with quarterly distribution (Blantyre, Lilongwe, and Lilongwe City) use the RVS to supplement their CCE. Also note anecdotally, additional CCE has been installed in Dowa district so this should reduce the constraint.

FREEZER SPACE, MONTHLY DISTRIBUTION TO DVS



Several districts to not have freezer space. If available, it would extend the shelf life of the polio vaccine, and allow for more space in the CCE for COVID and other vaccines.

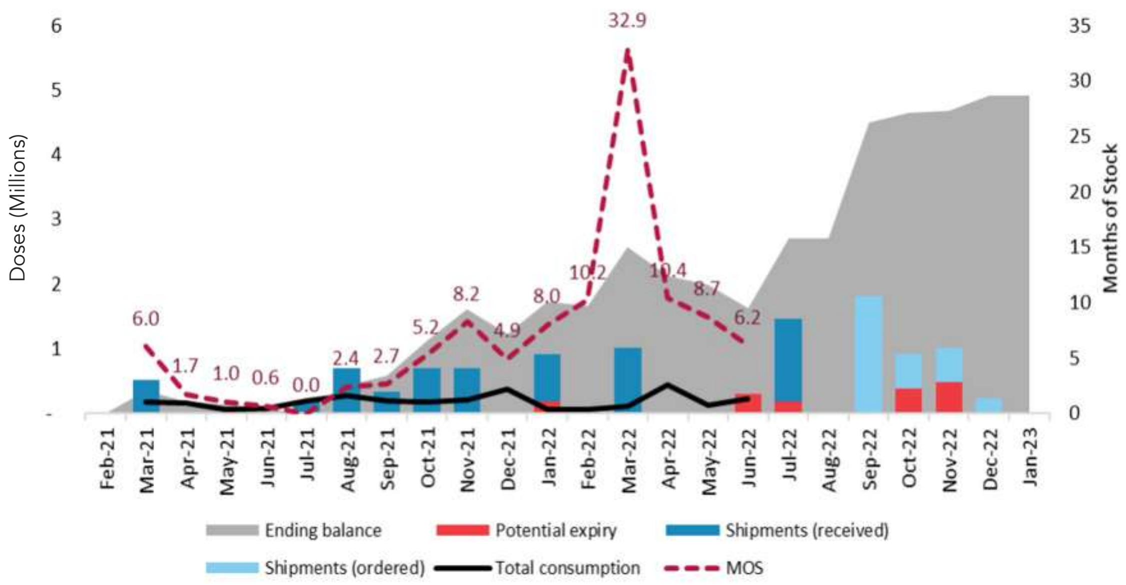
Currently, a monthly distribution schedule is followed due to the unreliability of electricity in order to avoid having large quantities of stock on hand if the CCE fails.

National and regional store capacity utilization

Store	Refrigerator Space	Freezer Space
National	14%	11%
South RVS	16%	3%
North RVS	6%	1%
Central RVS	57%	11%

Capacity utilization is calculated based on the quarterly stock that is held at the regional levels, and the periodic shipments received at national level for routine vaccines. The analysis shows there is sufficient capacity for routine vaccines and for the COVID vaccines. The Central RVS shares freezer space with the National store as it is not available at the RVS, which is an efficient work-around for this situation.

Malawi COVID vaccine: stock received, consumption, and planned shipments

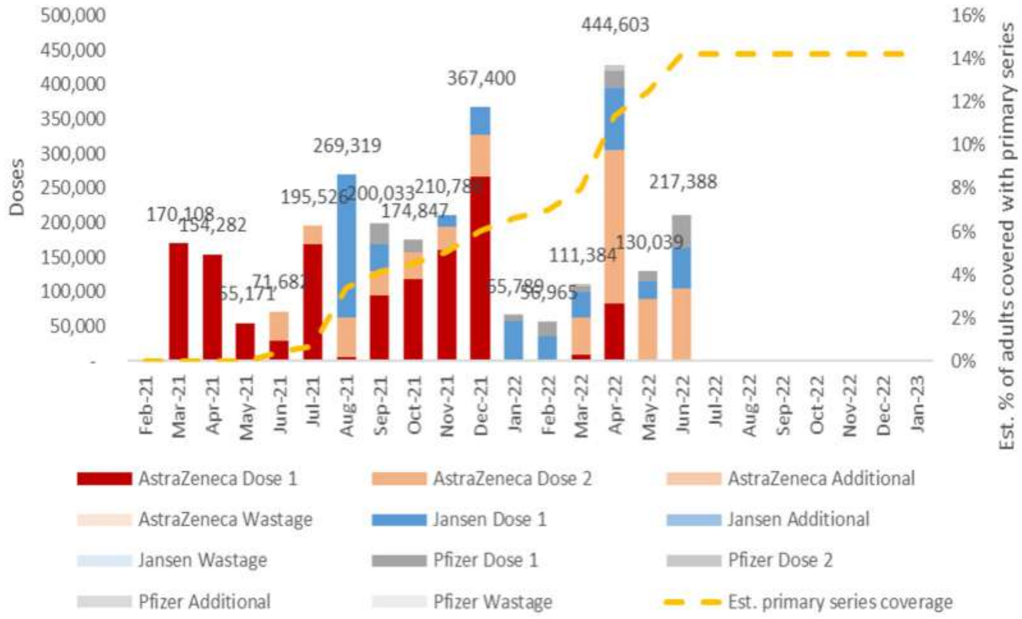


The EPI team is proactively planning and managing cold chain space with upcoming shipments of both COVID and routine vaccines, particularly for the on-going polio and malaria campaigns. The EPI is shifting COVID vaccines to the regional warehouses to create more space at national level. The EPI has adjusted its order for vaccines downward, based on the months of stock on hand, potential expiries, and realistic expectations of what can be administered.

Additional J&J shipments are planned for Sept, Oct, Nov, Dec.

Expiries are to be expected in this rapid vaccine introduction phase; additional campaign efforts in the recent past have been successful at reducing expiries.

Malawi COVID vaccine coverage and expected campaign efforts



The average consumption of COVID vaccines in Malawi, including successfully administered vaccines, plus expired/discarded vaccine doses, is approximately 264,000 per month. The highest consumption rate was over 444,000, achieved in April of 2022. However, due to reduced vaccine demand and increased supply availability, vaccine inventory is now at its highest point in the past 18 months of the pandemic.

When planning for cold chain volume in health facilities, it is common to forecast the estimated maximum vaccine consumption rates that can be sustained in proportion to the district population, which provides an estimate of cold chain space required. Reductions in demand could result in overstocking inventory, which could result in vaccine spoilage and wasted doses.

Additional factors to be considered in planning future cold chain investments include unknown or unspecified monthly targets by government or organizers of campaign efforts. Further complicating the Malawi COVID-19 vaccination program is the unknown timing and quantity of vaccines distributed to the district level, since the vaccines from different manufacturers have different vial sizes and doses.

District-level COVID vaccine management

Generally, based on the capacity utilization analysis, districts have sufficient space for the COVID vaccine. Using population estimates and assuming monthly campaign efforts, districts will require between 15 and 40 liters of cold chain space for the COVID vaccine, which translates into 3,000-7,000 doses. The average CCE space available at district is 1,000 liters, implying sufficient space for monthly distribution of the COVID vaccine, in addition to routine vaccines.

The three districts (Ntcheu, Salima, Thyolo) that are already constrained with routine vaccines will be more constrained with the COVID vaccine and would benefit from additional CCE or more frequent distribution, an estimated 500 liters in each one. Two additional districts would need an estimated 1,000 liters (Dedza, Dowa); Blantyre and Lilongwe are currently sharing space with the regional and national stores, so although their space may be constrained, they have created a workaround. Additional capacity up to 2,000 liters would reduce the constraints in each of these sites but also potentially require additional warehouse space for the CCE. Estimated purchasing costs of the CCE is between $3,000 and $6,000 USD, depending on the model. Ongoing maintenance and operating costs are additional considerations.

Pfizer should be stored in Ultra Cold Chain (UCC) for up to 9 months then can be stored in the traditional refrigerator for up to 10 weeks. Each district has UCC equipment for storage and transport of the Pfizer vaccine. National level has 5 UCC (828 liters each) for Pfizer; UCC is also available at two regional stores.

UCC Model DW-86L828J located at National and Regional stores

Capacity: 828 liters which can hold about 45,000 doses of Pfizer

UCC Model ULT25NEU for Pfizer transport and storage; available at each district

Capacity: 25 liters which can hold about 1,365 doses of Pfizer

Malawi Detailed Vaccine Transportation Logistics

1

2

1. Vaccines arrive at Kamuzu international Airport (Lilongwe) in specialized cooling containers as packaged by manufacturers. Vaccines are cleared at airport by Malawi Revenue Authority (MRA) .
2. Cold chain shipment is transported to the National Vaccine Store (NVS) using Central Medical Stores refrigerated van, checked and unpacked within 24 hours of flight arrival.
3. Vaccines are processed and then cleared with Pharmacy and Medicines Regulatory Authority (PMRA). This takes 1 to 14 days. At the National Vaccine Stores, the EPI Pharmacists perform additional quality checks, and the logisticians "break bulk," or split the packaging into units that can be transported to the 3 regions of the country.
4. Open trucks from the National Vaccine Stores (2 trucks of 20 ton capacity and 1 truck of 3 ton capacity) with support from trucks belonging to the 3 Regional Vaccines stores (5 trucks with, 10 ton capacity) are used to transport the vaccines in their original packaging to the Regional Stores on quarterly basis (routine vaccines).

5. Vehicles from the district (1 to 3 tons) collect and move the products from the Regional Vaccine Stores to the freezers/ fridges at District Vaccine Store on monthly basis. The trucks may also carry the syringes required to administer vaccine doses, or those can be transported separately. Transport usually takes one to 2 days for a one-way trip, depending on the distance to be covered.

6. For Pfizer, three specialized vehicles for third party logistics are used where mobile freezers are connected to cigarette lighter of vehicle (12V/120W) for charging to maintain the -60 to -80 degrees temperature. The vehicle is not turned off until it reaches its final district destination. For Pfizer and all COVID-19 vaccines, distribution is from NVS direct to district

7. In some circumstances, a healthcare facility may perform immunization-outreach visits to remote villages by motorbike or car using a small quantity of vaccines in a vaccine carrier with ice packs or other cooling agents.

Best practices for vaccine transportation resilience

Transport presents its own challenges to keeping vaccines cold:

- Temperatures within cold trucks may be variable, depending on how far or close they are from the cooling device
- Cold boxes risk heat and particularly freeze exposure. There is new technology for freeze-prevention cold boxes but not in wide use as of yet

Temperature monitoring during transport:

- Usually done with 30 Day Temperature Recorders (30DTR, or FridgeTag) that tracks temperature excursions and alarms; the data is typically reviewed only after delivery is completed
- Newer technology (Remote Temperature Monitoring Devices, RTMD) records temperature and other data points and actively sends SMS alerts in case of temperature excursions for immediate action and sends data to a dashboard for real-time monitoring

Outsourced transport for Pfizer vaccine in Malawi requires transporter to record and report on temperatures during distribution

Currently the standard best practice is to use dry ice for the product to arrive in country and then other phase change material is used to transport the product through the supply chain.

MALAWI IEP – COLD CHAIN

Health Facility Energy Analysis

SUSTAINABLE ENERGY FOR ALL

UNITY AND FREEDOM

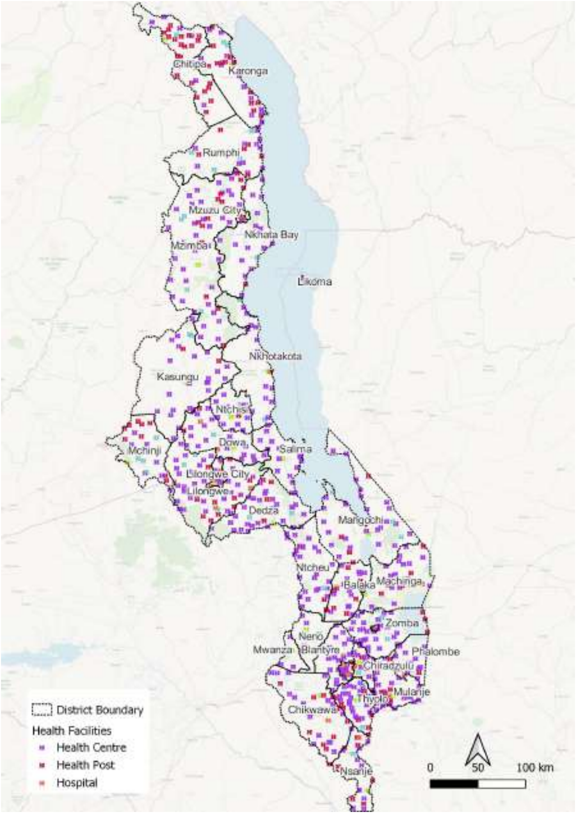
Energy Analysis

Based on data provided by the MOH, an estimated 83% of health facilities in Malawi are served by ESCOM, the national utility. These facilities may benefit from on-site solar hybridization, PQS equipment replacement, and battery energy storage retrofits to increase the reliability and resiliency of vaccine storage and distribution. For the remaining 17% of health facilities, standalone solar infrastructure is necessary for off-grid cold chain infrastructure to facilitate last-mile vaccine distribution.

Health Facility Type	Total Facilities	Facilities on grid (2022)	Facilities off-grid (2022)	Percent Electrified
Health Post (HP)	157	65	92	41%
Health Center (HC)	786	692	94	88%
Hospital (H)	109	109	-	100%
Regional/District Vaccine Store (S)	29	29	-	100%
Totals	**1081**	**895**	**186**	**83%**

Typical equipment and energy requirements by facility

Type of facility	Typical energy requirements and equipment
Health Post (HP)	Lighting during day and night, a power operated scale for pre-natal and post-natal services, and a refrigerator for vaccine storage
Health Center (HC)	Offer outpatient and maternity services; lighting and cold chain, oxygen concentrator, suction machine, incubator, nebuliser, resuscitation machine, autoclave, and basic laboratory equipment such as microscope and Haematology mixer.
Hospitals (H)	In addition to previous levels, sophisticated diagnostic devices such as x-ray machine, CD4 counters, blood-typing equipment
Regional and district vaccine stores (S)	Lighting, multiple pieces of cold chain equipment, computer, air conditioner; regional will have WICR and WICF



Energy needs assessments were based on Powering Health: Load Calculation Examples (USAID, 2020) and modified based on key stakeholder consultations with Malawian health officials.
https://www.usaid.gov/energy/powering-health/load-calculation-examples

Energy Analysis Assumptions and Methodology

- **Solar Resource:** Helioscope software was utilized to perform solar resource assessment in various parts of Malawi to establish an energy baseline for small scale solar. In the worst case, 4.0 kWh/m²-day equivalent solar insolation was observed in the southern-most part of Malawi, whereas 5.1 kWh/m²-day was observed in the north. Therefore, the energy analysis was conducted with An average value of 4.6 kWh/m²-day was used to evaluate provide indicative costs for all facilities.
- **System Configuration:** Solar modules are assumed to be rooftop-mounted in shade-free locations using rooftop mounting methods (small incremental cost increase may be necessary if using freestanding racking), tilted at 10°, with bottom edge parallel to and facing equator.
- **Solar Sizing:** Solar arrays were oversized by a 30% safety factor to account for inaccuracies in resource assessment as well as considering 0.5%/year panel degradation, 97% inverter efficiency, and 90% round-trip battery efficiency.

- **Energy Storage:** Batteries assumed to will be lithium iron phosphate (LFP) or equivalent batteries capable of withstanding 80% depth of discharge for a minimum of 3,000 cycles with a standard 10-year warranty. Off-grid health facilities are sized with 1.5 days battery autonomy. All grid tied facilities are sized with 0.5-day battery autonomy to ride through normal grid outages, considering that many of these larger facilities also have on-site diesel gensets for emergency power.
- **Load Growth:** HP facilities are sized for 50% load growth, over the life of the PV system since these small clinics may have a variety of future energy uses or additional refrigeration capacity requirements. All other facilities are sized for 30% load growth.

Energy needs by facility

Universal Energy Access: The energy analysis consists of sizing standalone solar kits for the off-grid Health Posts (HP) and Health Centers (HC), at a minimum, to ensure that all Malawi health facilities have basic electricity sufficient for refrigeration.

Cold Chain Resiliency: Another component of the energy analysis was to contemplate augmentation of electrical infrastructure in existing grid-tied facilities to allow greater cold chain resiliency and reduce the impact of disruptions in ESCOM service, such as the risk of vaccine spoilage during grid power disruptions.

Standalone solar kits for Energy Access at Off-Grid Facilities	# Off-Grid Facilities	Energy Consumption (kWh/day)	PV Size (kW)	Battery Size (kWh)	Cost per Facility (USD)	Total Cost (USD)
Health Post (HP)	92	0.876	0.3	1.6	$ 2,278	$ 209,576
Health Center (HC)	94	19.3	6	36.2	$ 35,735	$ 3,359,090
Hospital (H)	0	31.5	N/A	N/A	$ -	$ -
Regional/District Vaccine Store (S)	0	109	N/A	N/A	$ -	$ -
Totals	**186**					**$3,568,666**

Retrofit Grid-Tied Health Facilities for Cold Chain Resiliency	# Grid-Tied Facilities	Daily Consumption (kWh)	PV Size (kW)	Battery Size (kWh)	Cost per Facility (USD)	Total Cost (USD)
Health Post (HP)	65	0.876	0.3	0.55	$ 1,587	$ 103,155
Health Center (HC)	692	19.3	6	5	$ 16,027	$ 11,090,684
Hospital (H)	109	31.5	9.8	19.7	$ 35,136	$ 3,829,824
Regional/District Vaccine Store (S)	29	109	34	68.4	$ 89,559	$ 2,597,211
Totals	**895**					**$17,620,874**

The Ministry of Health (MoH) anticipates an additional 900 new health facilities will be added in Malawi by 2030. Of these proposed facilities, the locations have so far been determined for 96 health posts. To provide standalone solar power systems for these future facilities is estimated to cost an additional US$213,700.

Expansion plan: electricity and CCE needs

- Among the 900 anticipated future health care facilities, GIS location and cost data is presently available for 90 of them, as presented in the table at right.
- For planned facilities for expansion, target populations are unknown but we can assume smaller, more rural areas as compared to currently established health facilities. CCE with 60 liters or smaller would typically be sufficient for the vaccines required in these areas. Costs vary between $3,000 and $6,000 USD for these sizes (depending on if solar or grid-based).
- For the current 500 facilities that do not have CCE, similar assumptions can be made as to the size of the CCE required
- Additional costs to expand:
  - OpEx to manage a facility: estimated at $3,100/month as per MOH, including HR costs
  - Maintenance costs of equipment (depending on type of equipment and how well preventive maintenance is done), estimated between $15 and $215 per year, depending on equipment and location
  - Costs to support immunization services (i.e., demand creation and community engagement) largely depend on extent of services

Number	System Cost
1× Average Solar Cost	$2,278.20
90 New HP Facilities	**$205,038.04**

Additional information on maintenance gaps and systems can be found here: https://usaidmomentum.org/resource/cold-hard-truth-revolutionizing-cold-chain-maintenance/.

Map of Facilities and electrification status

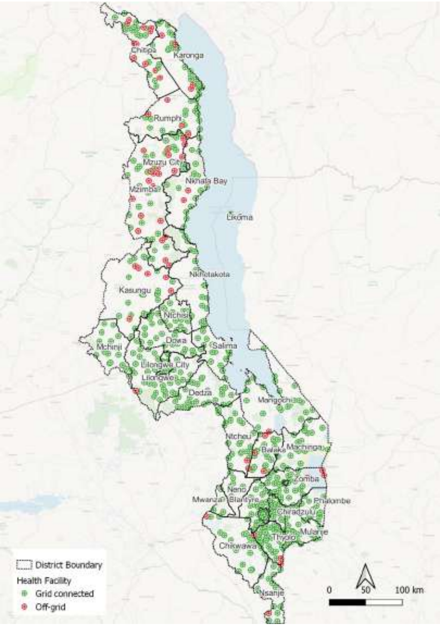
The present-day electrification status of Malawi's health facilities is presented in the 2022 status map (right).

As part of the national electrification analysis, all of the clinics that are presently unelectrified will gain access to electricity from either grid expansion, solar mini-grids, or standalone solar systems. Forecasted electrification gains are illustrated in the table below:

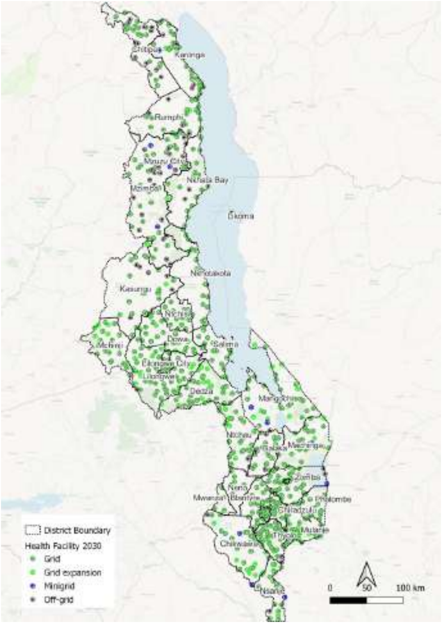
					2030 Electrification Modality		
Health Facility Type	**Total Facilities**	**Facilities on grid (2022)**	**Facilities off-grid (2022)**	**Percent Electrified**	**Grid Expansion**	**Mini-Grid**	**Standalone Solar Systems**
Health Post (HP)	157	65	92	41%	40	9	43
Health Center (HC)	786	692	94	88%	53	4	37
Hospital (H)	109	109	-	100%	-	-	-
Regional/ District Vaccine Store (S)	29	29	-	100%	-	-	-
Totals	**1081**	**895**	**186**	**83%**	**93**	**13**	**80**

Based on the electrification analysis, the ESCOM grid will reach an additional 40 health posts and 53 health centers by 2030. Meanwhile, a total of 9 health posts and 4 health centers will be interconnected to new solar mini-grids by 2030.

2022 ELECTRIFICATION STATUS: MOH AND ESCOM DATA



2030 ELECTRIFICATION STATUS: MALAWI IEP ELECTRIFICATION RESULTS



MALAWI IEP – COLD CHAIN

Considerations & Recommendations

SUSTAINABLE ENERGY FOR ALL

UNITY AND FREEDOM

Cold-chain capacity analysis

Health facilities with CCE have sufficient capacity for routine and COVID vaccines with 70% of the facilities using less than 10% of their available space for routine vaccines. This allows for more than enough space for the required amount of COVID vaccines when provided through routine or campaign services.

The majority of districts have sufficient cold chain space for routine vaccines following the monthly distribution frequency. Blantyre, as the exception, uses the nearby RVS for additional space. Switching to quarterly distributions would introduce cost savings for transportation costs through fewer distribution cycles; regarding CCE capacity, this switch could be easily accommodated in the northern region; a few districts in the central and southern region (7 out of 29) would benefit from additional refrigerator space (between 500 and 2,000 liters) if frequency is changed. Having a more reliable electrical grid could justify this shift in frequency.

Only 8 of 29 district stores do not have freezer space for storage of OPV vaccines, which requires freezing temperature (-20° C) at that level as per WHO recommendations. Provision of freezers to those DVS will free up refrigerator space for COVID and other routine vaccines. It would also extend the shelf life of the polio vaccine.

CCE: B-Medical Model TCW 40 SDD (solar)

Cold chain performance analysis and replacement planning

Generally the CCE that is available is working well with only 7% that is not functioning and should be decommissioned. A decommissioning plan maps out the country's approach to remove non-functional equipment from the system, considering best environmental practices, technical and safety considerations, and documentation in assets management systems. Additionally, about 1% of all CCE needs repair and should be prioritized.

As the country works with donors and partners to upgrade and expand the cold chain system, a few notable areas to prioritize include:

- Outdated equipment that is non-PQS should be replaced (about 24% of all CCE). Equipment that was previously PQS approved but no longer has this approval can still be used if functioning but should be included in the medium- and long-term CCE replacement and expansion plan.
- Prioritize replacing older equipment (10+ years), particularly those that rely on gas/propane.
- Consider moving some CCE from "under-utilized" sites to "constrained utilization" sites to alleviate some of the constraint.
- Consider procuring CCE for health facilities that currently do not have CCE (~500 facilities) yet are growing in population or have demonstrated a high need or demand for immunization. Expanding CCE to new health facilities must also consider the human resources required for expanding immunization services to a new facility, and the long-term costs of maintaining the CCE.
- CCE costs are between $3,000 and $6,000 per unit that would be applicable at facility or district level.

Reference: UNICEF, Decommissioning and safe disposal of cold chain equipment, 2018.

Health facility energy needs assessment

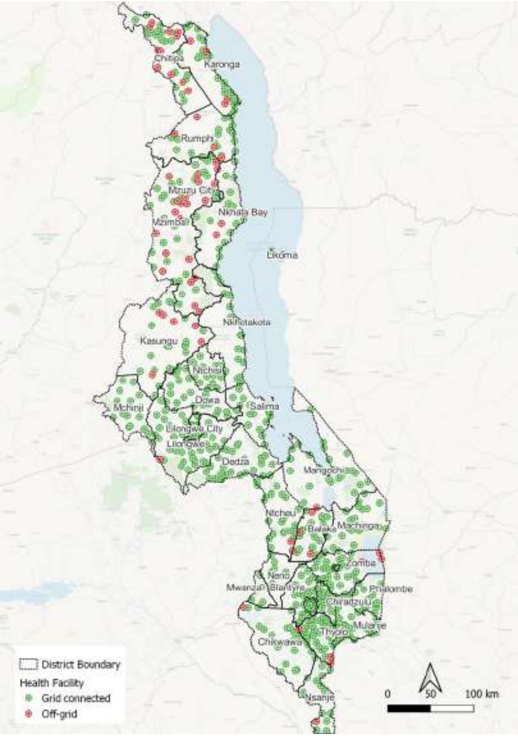
		Off-Grid Solar Systems			Grid-Tied Hybrid Systems			
Health Facility Type	**Total Facilities**	**# Off-Grid Facilities**	**Cost per Facility (USD)**	**Off-Grid Cost (USD)**	**# Grid-Tied Facilities**	**Cost per Facility (USD)**	**Grid-Tied Cost (USD)**	**Total Program Cost ($USD)**
Health Post (HP)	157	92	$ 2,278	$ 209,576	65	$ 1,587	$ 103,155	$ 312,731
Health Center (HC)	786	94	$ 35,735	$ 3,359,090	692	$ 16,027	$11,090,684	$14,449,774
Hospital (H)	109	0	$ -	$ -	109	$ 35,136	$ 3,829,824	$ 3,829,824
Regional/District Vaccine Store (S)	29	0	$ -	$ -	29	$ 89,559	$ 2,597,211	$ 2,597,211
Totals	**1081**	**186**		**$3,568,666**	**895**		**$17,620,874**	**$21,189,540**

There are 186 health facilities in Malawi that currently do not have access to the ESCOM national grid. Of these facilities, 92 are Health Posts and 94 are Health Centers. There are no hospitals or RVS locations that do not have grid access. The total capital cost to electrify these remaining 186 locations is estimated to be USD $3.6M in the near term, not including recurring operations and maintenance costs. In the longer term, 93 of these facilities are included in IEP grid expansion plans by 2030 and an additional 13 facilities are envisioned for mini-grid electrification by 2030.

The existing cold chain could be made more reliable by hybridizing solar and battery systems within the grid-tied facilities. The total cost to hybridize all grid-connected health facilities is USD $17.6M, however this investment could be prioritized according to facility type and other considerations.

Therefore, the total program cost for energy access and cold chain resiliency is estimated to require USD $21.2M in investment on behalf of 1,081 Malawian health facilities, or an average of USD $19,602 per facility.

2022 ELECTRIFICATION STATUS: MOH AND ESCOM DATA



Best practices and recommendations for cold chain management and COVID

The cold chain system in Malawi is typical of many systems across the African continent. Ministries of Health have had to pivot and quickly adjust to the COVID-19 pandemic and rapidly scale up introduction of this new vaccine, leveraging vaccine supply chains and health systems that were already constrained. Malawi is implementing their new vaccine introduction plan and has created processes, campaign strategies, and reporting structures to track progress. This vaccine distribution and energy analysis provides insight into a few key areas of cold chain management that, if addressed, could strengthen the overall vaccine supply chain in the country. These recommendations should be validated with the MOH and EPI team, and can be used as justification and advocacy for donor investment.

- The cold chain maintenance system is often overlooked yet is quite important for cost-effectiveness and to ensure functionality and longevity of the CCE. Typical entrenched obstacles to a maintenance system have been documented elsewhere, as well as novel ideas for redesigning maintenance to be more effective. Any investment by donors into the cold chain infrastructure in Malawi should also be accompanied by maintenance support, including forward-thinking planning for spare parts, training for technicians, and the financial flow to support the technicians to do their work.
- As cold chain space is largely sufficient at the district level, EPI could consider adjusting the distribution frequency to the DVS to quarterly deliveries instead of monthly to reduce costs in transport. This also reflects WHO standards.
- EPI has already demonstrated their ability to manage a flexible and agile supply chain for the COVID vaccine by proactively shifting stock to different warehouses to avoid constraints. This best practice would benefit the routine immunization supply chain as well, and could potentially reduce overall costs.

Reference: MOMENTUM, Cold Hard Truth: Revolutionizing Cold Chain Maintenance, 2021.

Recommended future analysis

While this analysis responded to the questions posed for this project, the insight raised additional questions that would be beneficial to explore further in future projects:

- True costs related to running an immunization program and its supply chain, including community engagement, different transportation routing options to optimize space and routes, outreach efforts and its effectiveness in reaching children if cold chain is not available.
- Accurate master health facility list cross-referenced to cold chain inventory and MOH expansion plans

MALAWI IEP – COLD CHAIN

Annex

Annex 1: Capacity Utilization Methodology

For routine immunization, vaccine quantity required is based on the EPI schedule (e.g., vaccines and number of doses required of each, approximately 90 cm^3 per child which is then converted to cubic liters); stated distribution schedule (e.g., monthly distribution to facility level and district); target population of each facility and district; and vaccine characteristics (vial size, cubic liters per dose, wastage rate, buffer stock). This is assessed against the total net cubic liters of the PQS-approved CCE available and functioning at the facility and used for vaccines. Utilization categories are:

- appropriate if 10–80% of capacity is used
- underutilized if <10% of capacity is used
- constrained if >80% of capacity is used

Supply chain industry standard assumes 80% capacity does not allow for flexibility or agility in the supply chain and should be addressed, either through additional space or changing delivery frequency. Appropriate capacity use is considered ideal. Underutilized implies an inefficient use of the cold chain to cool unused space. This methodology has been used in a recent CCE evaluation.

Due to the multiple COVID-19 vaccines with different vial size characteristics and the unknown nature of which district will receive which vaccine, this analysis focuses on the known routine schedule to identify space availability in general for the COVID-19 vaccines. Using average monthly COVID-19 vaccine consumption to date, the estimated CCE space requirement for the COVID-19 vaccine is between 1% and 5% increase, depending on the population size of the district and facility.

ANTIGEN	Schedule	Vial sizes in use dose/vial	packed volume per dose - cm3/dose	Total Volume (cm3/dose) without wastage rates	Wastage % per antigen in Malawi	Wastage multiplier	Total volume (cm3/dose) required including wastage
BCG	1	20	1.2	1.2	75	4.0	4.8
bOPV	4	20	1.1	4.4	15	1.2	5.18
IPV	1	10	2.46	2.46	15	1.2	2.89
DTP-HepB-Hib	3	10	2.61	7.83	15	1.2	9.21
PCV	3	2	2.4	7.2	5	1.1	7.58
Rota_liq	2	1	17.1	34.2	5	1.1	36
MR	2	10	2.6	5.2	25	1.3	6.93
RTS,S (malaria)	4	2	2.4	9.6	10	1.1	10.67
TD	2	10	2.9	5.8	15	1.2	6.82
Total net storage capacity per fully immunized child (cm3)							**90 cm^3**
OTHER VACCINES							
HPV	2	1	17.1	34.2	5	1.1	36
COVID (AZ)	2	10	2.6	5.2	10	1.1	5.78
COVID (Pfizer)	2	6	1.8	3.6	5	1.1	3.79

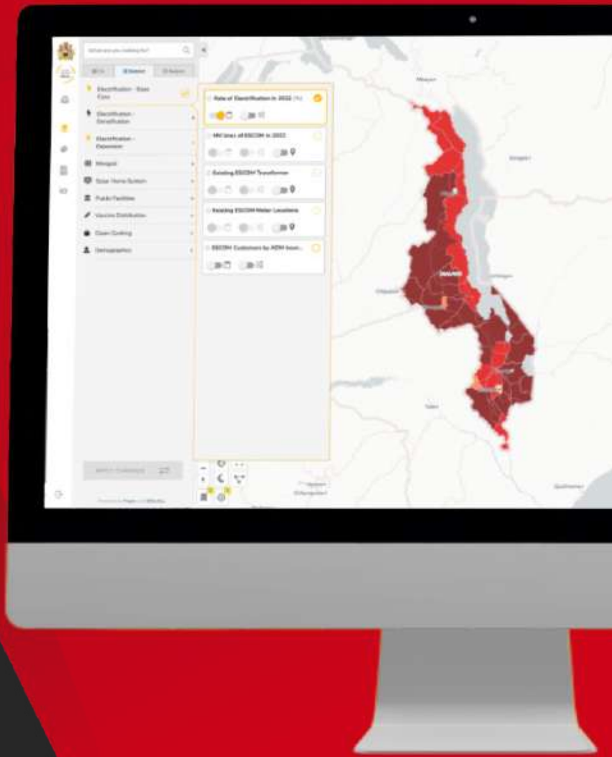
Annex 2: Target population and number of doses administered

	Routine Immunization Target Population, 2021	Penta 3 Doses Adminstered	Penta 3 Coverage	COVID Target Population (70% of total population)	COVID-19 Vaccine Doses Administered (Fully Immunized)	COVID-19 Vaccine Coverage (%) (July 2022)
Balaka	18,749	17,153	91%	343,563	31,662	9.22%
Blantyre	41,551	49,366	119%	948,964	116,679	12.30%
Chikwawa	23,117	21,603	93%	430,980	21,984	5.10%
Chiradzulu	13,222	12,846	97%	268,491	22,226	8.30%
Chitipa	10,282	7,819	76%	176,281	28,410	16.10%
Dedza	34,105	31,908	94%	635,941	53,892	8.50%
Dowa	33,516	24,600	73%	600,257	132,621	22.10%
Karonga	14,842	13,722	92%	277,968	33,751	12.10%
Kasungu	37,964	31,598	83%	649,930	146,396	22.50%
Likoma	492	496	101%	10,984	1,003	9.10%
Lilongwe	97,147	116,977	120%	1,935,914	259,897	13.40%
Machinga	32,865	31,689	96%	591,553	77,455	13.10%
Mangochi	50,633	48,727	96%	913,802	47,932	5.20%
Mchinji	26,927	19,041	71%	460,929	46,107	10.00%
Mulanje	26,663	22,700	85%	524,551	29,057	5.50%
Mwanza	5,729	4,837	84%	103,583	11,350	11.00%
Mzimba North	22,415	17,079	76%	428,909	75,102	17.50%
Mzimba South	23,807	21,413	90%	455,546	56,261	12.40%
Neno	6,214	5,720	92%	105,148	11,862	11.30%
Nkhatabay	10,941	10,218	93%	213,189	36,518	17.10%
Nkhotakota	17,310	16,954	98%	299,849	47,900	16.00%
Nsanje	12,977	14,102	109%	225,075	59,350	26.40%
Ntcheu	27,385	23,497	86%	515,159	30,084	5.80%
Ntchisi	14,688	11,296	77%	249,362	96,938	38.90%
Phalombe	18,288	15,767	86%	334,550	12,616	3.80%
Rumphi	9,095	7,713	85%	174,251	39,039	22.40%
Salima	21,814	17,080	78%	375,187	45,920	12.20%
Thyolo	28,114	21,376	76%	539,602	19,538	3.60%
Zomba	34,687	26,553	77%	650,145	51,773	8.00%
Malawi	715,540	663,850	93%	13,439,662	1,579,861	11.80%

Annex 3: Health Facility Equipment, Load, Sizing, and Cost Assumptions

EQUIPMENT	QUANTITY HP	QUANTITY HC	QUANTITY H	QUANTITY S	UNIT POWER	TOTAL POWER HP	TOTAL POWER HC	TOTAL POWER H	TOTAL POWER S	HOURS USED PER DAY	ENERGY USAGE HP	ENERGY USAGE HC	ENERGY USAGE H	ENERGY USAGE S
Lighting	1 ea.	40 ea.	120 ea.	120 ea.	10.0 W	10.0 W	400.0 W	1200.0 W	1200.0 W	10.0 h	100 Wh/day	4000 Wh/day	12000 Wh/day	12000 Wh/day
Power operated scale for prenatal and postnatal services	1 ea.	1 ea.	1 ea.	10 ea.	2.0 W	2.0 W	2.0 W	2.0 W	20.0 W	2.0 h	4 Wh/day	4 Wh/day	4 Wh/day	40 Wh/day
Fridge for vaccine storage	1 ea.	1 ea.	1 ea.	3 ea.	60.0 W	60.0 W	60.0 W	60.0 W	180.0 W	8.0 h	480 Wh/day	480 Wh/day	480 Wh/day	1440 Wh/day
Oxygen Concentrator		1 ea.	1 ea.	3 ea.	285.0 W		285.0 W	285.0 W	855.0 W	4.0 h		1140 Wh/day	1140 Wh/day	3420 Wh/day
Suction Machine		1 ea.	1 ea.	3 ea.	145.0 W		145.0 W	145.0 W	435.0 W	4.0 h		580 Wh/day	580 Wh/day	1740 Wh/day
Incubator		1 ea.	1 ea.	2 ea.	917.5 W		917.5 W	917.5 W	1835.0 W	4.0 h		3670 Wh/day	3670 Wh/day	7340 Wh/day
Nebuliser		1 ea.	1 ea.	3 ea.	85.0 W		85.0 W	85.0 W	255.0 W	4.0 h		340 Wh/day	340 Wh/day	1020 Wh/day
Resuscitation machine		1 ea.	1 ea.	2 ea.	165.0 W		165.0 W	165.0 W	330.0 W	4.0 h		660 Wh/day	660 Wh/day	1320 Wh/day
Autoclave		1 ea.	1 ea.	2 ea.	630.0 W		630.0 W	630.0 W	1260.0 W	4.0 h		2520 Wh/day	2520 Wh/day	5040 Wh/day
Microscope		3 ea.	5 ea.	5 ea.	30.0 W		90.0 W	150.0 W	150.0 W	2.0 h		180 Wh/day	300 Wh/day	300 Wh/day
Haematology Mixer		1 ea.	1 ea.	3 ea.	315.0 W		315.0 W	315.0 W	945.0 W	4.0 h		1260 Wh/day	1260 Wh/day	3780 Wh/day
X-ray machine			1 ea.	3 ea.	200.0 W			200.0 W	600.0 W	1.0 h			200 Wh/day	600 Wh/day
CD4 counters			1 ea.	2 ea.	200.0 W			200.0 W	400.0 W	4.0 h			800 Wh/day	1600 Wh/day
Blood-typing equipment			1 ea.	2 ea.	66.5 W			66.5 W	133.0 W	4.0 h			266 Wh/day	532 Wh/day
Fan				10 ea.	80.0 W				800.0 W	4.0 h				3200 Wh/day
Centrifuge				1 ea.	600.0 W				600.0 W	1.0 h				600 Wh/day
Water Bath				2 ea.	400.0 W				800.0 W	1.0 h				800 Wh/day
Spectrophotometer				2 ea.	63.0 W				126.0 W	1.0 h				126 Wh/day
Autoclave				1 ea.	630.0 W				630.0 W	1.0 h				630 Wh/day
Blood Chemical Analyzer				1 ea.	45.0 W				45.0 W	6.0 h				270 Wh/day
Air-Conditioning Unit				3 ea.	1500.0 W				4500.0 W	8.0 h				36000 Wh/day
Computer				4 ea.	120.0 W				480.0 W	4.0 h				1920 Wh/day
Radio				1 ea.	30.0 W				30.0 W	8.0 h				240 Wh/day
Cell Phone Charger				10 ea.	5.0 W				50.0 W	4.0 h				200 Wh/day
TOTAL WATT-HOURS USED PER DAY:											584 Wh/day	14834 Wh/day	24220 Wh/day	84158 Wh/day
Growth allowance (50%, 30%, 30%, 30%):											292 kWh/day	4450 kWh/day	7266 kWh/day	25247 kWh/day
Total System Design Load											876 kWh/day	19284 kWh/day	31486 kWh/day	109405 kWh/day
Off-grid Solar Requirement with 30% system insertion loss allowance:											973 kWh/day	27549 kWh/day	44980 kWh/day	156293 kWh/day
Total System Size:											1265 kWh/day	31999 kWh/day	52246 kWh/day	181541 kWh/day
Panel Rated Power Requirement:											275 Wp	6956 Wp	11358 Wp	39465 Wp
Off-grid											$2,278.20	$35,735.39		
Hybrid											$1,587.87	$16,026.64	$35,135.76	$89,558.84

INTEGRATED ENERGY PLANNING TOOL



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Any Questions:
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