PIH TECHNICAL TOOLKIT:
INFRASTRUCTURE FOR HOSPITAL CARE AND COVID-19 CARE

Build Health International

Partners In Health

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INTRODUCTION

COVID-19 mortality is highest in resource-constrained areas, which tend to have fewer hospitals, beds, ventilators, oxygen, and other resources per capita, making investment in infrastructure an essential component of a comprehensive pandemic response. A well-functioning healthcare system that addresses the needs of all patients cannot exist without well-built and maintained facilities that are adequately supplied and designed to limit the risks of disease exposure. In order to respond to the COVID-19 pandemic and strengthen clinical care administration for all diseases, investments must be made to improve resiliency in core health infrastructure.

Pandemics and health crises often push health facilities to capacity, exposing areas of infrastructural weakness. Poor or insufficient electrical power can lead to lack of additional oxygen concentrators. Without working incinerators, hospitals are unable to safely dispose of biohazardous waste. Water shortages can lead to lack of hand hygiene for staff and patients. Investment in resilient and redundant facilities is essential for the ongoing response to COVID-19, to prepare for future pandemics, and to provide ongoing care for people living with HIV, TB, and those requiring routine maternal and child health services.

Poorly planned or implemented infrastructure affects the ways in which clinical care is administered in many low- and middle- income countries (LMICs). Frequently, poorly designed or laid out infrastructure leads to unnecessary exposure to infectious diseases. Lack of storage spaces cause delays accessing clinical and biomedical supplies, harming patients. Unreliable electricity and unsafe water supplies limit equipment use and care delivery, notably affecting the availability of lifesaving oxygen. Finally, broken facilities prevent the dignified care that is essential to patient and staff wellbeing.

COVID-19 has exposed the need for strategic investments in infrastructure that meet both short emergency response needs and long term health systems strengthening goals. Investing in COVID-19 infrastructure should fulfill two objectives: a) respond to the COVID-19 pandemic by improving care quality and safety and b) address long-term health infrastructure gaps that cause unnecessary morbidity and mortality every day.

GOAL: Improve resiliency in core health infrastructure to allow quality clinical care delivery and reinforce infection prevention and control measures in order to ensure rapid response to COVID-19 and future pandemics

ACRONYMS

LMIC	Low- and middle- income countries
SPD	surge suppression devices
UPS	uninterruptible power supplies
WASH	Water, sanitation and hygiene
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization
DDA	Digital Dosing Advanced
DDE	Digital Dosing Essential
IPC	Infection Prevention and Control
BMET	Biomedical Equipment Technician
MSF	Medecins Sans Frontieres
UVGI	Upper room ultraviolet germicidal irradiation
PPE	Personal Protective Equipment
UV	Ultraviolet

OBJECTIVE 1: Ensure a safe, reliable, and resilient electricity supply at facilities to support routine and critical care of patients with COVID-19, TB, HIV, Malaria and other diseases.

Reliable and plentiful electricity is essential to providing care for COVID-19 and beyond. The assurance of safe, reliable, and resilient electricity supply directly improves oxygen availability. The cheapest oxygen source comes from bedside concentrators, which require 24/7 electricity and often fail due to poor power quality. High quality and reliable electricity availability will also enable cold chain storage and is critical for uninterrupted mechanical ventilation.

Strategy 1.1 Ensure two reliable (defined as 98% uptime) and adequately sized power sources for all secondary and tertiary health care facilities.

In many cases, generator power will be necessary to allow continuous electricity which is essential for bedside oxygen concentrators and many types of medical equipment. For COVID-19 investments, electricity sources should be prioritized for facilities being used as COVID-19 treatment centers and designed so that they can be used long-term. However, given that patients present to a wide range of facilities, investment in electricity will serve to prevent deaths at multiple levels of the healthcare system

Intervention	When solar power is not a short-term possibility, install backup diesel generators to provide an alternative to utility supplied power.
Intervention	Install primary bulk fuel storage tank with enough fuel holding capacity to run the hospital on generator power for a minimum of 5 days, more is preferred and dependent on-site location and susceptibility to natural disasters. Pipe this primary tank to a 2nd tank (see below) with in-line bulk fuel filtration for particulates and water removal. Install fuel metering device. Having a large fuel storage tank can lead to fuel cost savings through bulk purchasing or contracts.
Intervention	Install fuel storage tank sized to hold enough fuel for 48 hours of generator power. Pipe fuel from this tank directly to the generator.
Intervention	Where beneficial, install an automatic or manual transfer switch between primary and secondary power sources.
Intervention	Conduct maintenance training for generators, solar equipment, batteries, and primary electrical distribution equipment.

Strategy 1.2 Ensure safe power distribution from power source to main distribution panel to subpanels

In many older health care facilities in lower- and middle-income countries (LMICs), the primary power distribution system is disorganized and often dangerous. As facilities expand, for example to add surge capacity for COVID-19 care, this power distribution system is rarely retrofitted, resulting in electrical distribution cables that are undersized, circuit breakers that are oversized, poor ground connections, lack of ground fault protection devices, and no protection from lightning strikes. Also, typically there is no documentation or labeling of circuit breakers. These deficiencies lead to dangerous electrical hazards for staff and patients, fire hazards for the facility and equipment damage from low voltage or improper connections. Rectifying these issues can be overwhelming and fall low on priorities in very resource constrained environments, but upgrading power distribution is often an essential first step before other infrastructure improvements can be made to systems such as ventilation, cold chain, and/or oxygen production, all essential needs for COVID-19 treatment and vaccine readiness.

Intervention	Perform electrical assessment. See EMI's Electrical Design Guide & References **EMI Resource Library**
Intervention	Rectify any deficiencies found in system grounding, transformer sizing, wire sizing, wire connections.
Intervention	Produce up to date one line diagram of the electrical system.
Intervention	Where required, install a new main distribution panel or switchboard with properly sized breakers, room for expansion and with spare breakers of various sizes. Label main breakers and subpanels with permanent labels.
Intervention	Install lightning protection system if in an area with frequent storms.

Strategy 1.3: Assess and Improve Power Quality

Poor power quality frequently damages medical and laboratory equipment, including equipment for COVID-19. In many LMICs spare parts for medical and lab equipment are not readily available on the local market and in many cases this damaged equipment is never repaired. Even in a facility with a robust repair program and access to international parts sources, poor power quality results in significant equipment downtime and costly repairs. See Global Good Power Quality Challenges in Low Resource Settings

Intervention	Perform power quality assessment using power analyzer.
Intervention	Install electronic power meter with data logging capability. (example: Power Xpert Meter 2000). This is a simple intervention that can provide a facility valuable data when making decisions about their electrical infrastructure.
Intervention	Based on assessment, install equipment to reduce impact of power quality issues. Interventions essential for COVID-19 response include surge suppression devices (SPD), uninterruptible power supplies (UPS), constant voltage transformers, and voltage regulators. See EMI's Electrical Design Guide & References EMI Resource Library

OBJECTIVE 2: Ensure safe water supply that allows infection prevention and control and safe patient care

One important method for prevention of COVID-19 is handwashing, yet many health care facilities lack adequate hand washing areas for both clinicians and patients. Often facilities have challenges with intermittent water access, lack of adequate treatment of the water, and an insufficient quantity of water.

Strategy 2.1 Support existing national WASH plans.

See UN-Water Global Analysis and Assessment of Sanitation and Drinking Water Reports: National systems to support drinking-water, sanitation and hygiene - Global status report 2019

Strategy 2.2 Ensure health facilities have reliable improved sources of water and resilient supporting infrastructure in-line with WHO/UNICEF's Water and Sanitation for Health Facility Improvement Tool (WASH FIT) framework.

See A practical guide for improving quality of care through water, sanitation and hygiene in health care facilities

Intervention	Conduct well yield tests for existing wells without test data, and drill new boreholes and install pumps as needed
Intervention	Protect existing springs or dug wells
Intervention	Purchase a spare submersible pump to be kept as a backup. This is critical if the facility relies on a borehole for its primary water supply.
Intervention	Construct or install water cistern or water tower with enough capacity to store enough water to supply a health facility for general use and COVID-19 related hand washing stations for a 48 hr period.
Intervention	In facilities that have challenges with water supply, such as areas with little or no groundwater, install water flow metering devices at the main distribution point and multiple secondary branches. By regularly monitoring flow data, water leaks or wastage can be detected quickly to help conserve water. This data also aids a facility in planning and decision making around the facility's water supply. This aligns with sustainable development target 6.4.

Strategy 2.3 Water testing & treatment

Intervention	Test water sources for bacteria & parasites to ensure that COVID-19 patients do not experience secondary infection.
Intervention	Install water treatment equipment to make water potable. We have found that chemical dosing pumps (such as Grundfos DDE or DDA models) offer a simple, robust solution to treat incoming

water to a health facility with chlorine. These pumps require little maintenance and the only challenge is ensuring consistent supply of chlorine and regular testing of the water to ensure there is sufficient residual chlorine in the water.

See WHOs Guidelines for Drinking Water Quality: Guidelines for drinking-water quality, fourth edition

Strategy 2.4 Expand Water Access Points for Staff and Patients

Hand hygiene is one of the fundamental tenets of infection prevention and control, including for COVID-19. At a minimum, hand hygiene should be practiced during the '5 moments for hand hygiene.' Hand hygiene can be performed using alcohol based hand rubs or with soap and water. In many settings, supply of alcohol based hand rubs are unreliable, making soap and water the primary method for cleaning hands.

Intervention	Install additional hand washing points for staff and patients. Permanent hand washing stations will require plumbing and may be more difficult in the short term. However, facilities should identify key locations and plan for long-term hand washing stations in these locations. In the short-term, temporary hand washing stations with adequate drainage can be used. If buckets are used as drainage systems, ensure they can still be moved once full. Ensure drainage systems are designed to avoid larval breeding especially in malaria endemic regions.
Intervention	Ensure access to soap for all.
Intervention	Ensure adequate access for patients and patient families to sanitary and handwashing facilities, with special consideration taken "to meet the needs of women and girls and those in vulnerable situations" as outlined in Sustainable Development Goal 6.2

➔ See PIH IPC toolkit for further information on hand hygiene

For additional information, please see:

- WHO/Unicef WASH in Health Care Facilities Baseline Report
- Core questions and indicators for monitoring WASH in health care facilities in the Sustainable Development Goals
- Sphere Standards
- Water, sanitation, hygiene, and waste management for the COVID-19 virus

OBJECTIVE 3: Develop facilities & biomedical management systems to support procurement, maintenance, and upgrades of essential infrastructure and equipment

Facilities and biomedical equipment are essential for the treatment of COVID-19. Functioning systems are needed to ensure oxygen production and for essential clinical tools including pulse oximeters, vital sign machines, ultrasound and diagnostic equipment as well as advanced critical care equipment such as ventilators.

Strategy 3.1: Equipping and training biomedical staff

Biomedical staff in LMICs are often asked to repair a wide spectrum of equipment without specialized training and often without basic resources like the equipment operation manual. Some evidence suggests that over 60% of broken equipment could be repaired without highly specialized knowledge and without inputs of imported spare parts. See

"Evidence-based approach to the maintenance of laboratory and medical equipment in resource-poor settings."

This is particularly true for equipment essential in the treatment of COVID-19 such as bedside oxygen concentrators, pulse oximeters, and vital sign machines.

Examples of Biomedical Equipment needs for COVID-19:
Pulse oximeters
Vital sign machines
Ultrasound and diagnostic equipment
Advanced critical care equipment (ventilators, non-invasive machines)

Intervention	Purchase a set of tools and test equipment for biomedical use. Not having the right tools when trying to repair an item often leads to damaging the item.
Intervention	Purchase laptop for biomedical staff. This would enable biomedical staff to find and save equipment operation and service manuals, search for spare parts, and access the multitude of online learning resources. It also is an essential tool in being able to document repairs and develop a preventative maintenance plan.
Intervention	Fund training for biomedical staff. These could be: • Scholarship for biomedical staff to local university BMET courses • Online training such as offered through Medical Aid International. This particular course also includes tools, optional laptop, equipment manual library, and electronic textbooks. • Training in management

Strategy 3.2: Equipping and training facilities staff

Facilities staff are responsible for maintaining hospital infrastructure critical to COVID-19: electricity supply, water supply, wastewater treatment systems, incinerators, and mechanical ventilation equipment. They frequently lack the necessary tools, space and training to maintain this infrastructure.

Intervention	Construct or renovate a workshop space for facilities staff. Should include tool boxes, lockable storage area, work benches, shelving for spare parts.
Intervention	Purchase set of tools and spare parts and test equipment for facilities use. Not having the right tools when trying to repair an item often leads to damaging the item.
Intervention	Purchase laptop for facilities management team. Similar to biomedical, this is an essential tool in planning, budgeting, and searching for resources to help with decision making.
Intervention	Fund training for facilities staff. This could be: • Power distribution • Generator maintenance • Electrical safety • Management

Objective 4: Improve Hospital Waste Management systems to prevent disease transmission and improve occupational safety

Strategy 4.1: Strengthen waste disposal infrastructure

Lack of waste disposal infrastructure can lead to direct health impacts on the community, safety hazards to waste management staff, and damage to the surrounding environment. The treatment of COVID-19 produces a lot of waste in the form of single use, disposable PPE. Many facilities lack or have insufficient waste disposal equipment to effectively

deal with this increase in medical waste. Inappropriate waste management promotes disease spread and also poses safety risks, for example when open fires spread to nearby structures.

Guidance exists describing options for waste disposal and types of waste (Global Fund Technical Brief). In our experience, facilities often lack the funds to purchase a diesel fired incinerator and will instead choose to construct a brick incinerator. These locally built incinerators are frequently only a slight improvement over a burn pit either because of poor incinerator design or lack of strong operational systems to make them work effectively. In our experience, diesel fired incinerators, while requiring fuel and some maintenance inputs, are a good investment for hospitals and reach adequate temperatures to be able to safely dispose of biohazardous waste, sharps, and pharmaceutical waste.

Intervention	Support a facility's or region's existing waste management plan including outsourcing if necessary.
Intervention	Purchase and install diesel fired incinerators for secondary and tertiary hospitals. Where a large capacity incineration is needed, consider 2 incinerators for added redundancy. Include a full set of spare parts for oil burners, nozzle, electrode, fuel pumps, thermocouple, solenoid valves, etc.
Intervention	Purchase steel or fiberglass diesel storage tank piped to operate the incinerator.
Intervention	Construct multiple lined ash pits and unlined organic waste pits for the safe disposal of waste
Intervention	Construct a secure and lockable waste disposal area to house the incinerator, waste sorting and storage, ash pits, organic waste pits. When sizing the disposal area, take into account the continued need for future ash pits.

Strategy 4.2: Train and Equip Staff

Intervention	Train facilities staff and hospital waste management team on appropriate waste management practices
Intervention	Encourage protocols that separate infectious waste (bandages, used medical supplies, items with bodily fluids, sharps and syringes) from general waste (packaging, food waste, etc). Separation should begin at the location where waste is generated and continue through disposal steps.

➔ For more information on waste management, see PIH IPC toolkit

Intervention	Purchase appropriate durable PPE for incinerator operators and hospital waste management team.

For additional information, please see:

- Personal Protective Equipment for Waste Handlers and Incinerator Operators
- Safe management of wastes from health-care activities
- Global Fund Technical Brief: Sustainable Health Care Waste Management
- Water, sanitation, hygiene, and waste management for SARS-CoV-2, the virus that causes COVID-19

Objective 5: Provide appropriate isolation spaces to care for patients with COVID-19 and other infectious diseases and improve ventilation at health facilities to prevent spread of COVID-19 and tuberculosis.

Strategy 5.1: Construct or renovate permanent isolation wards suitable for COVID-19 and other infectious diseases

While many health care facilities had some existing isolation spaces, when COVID-19 cases increased, these spaces were either quickly overwhelmed or were in such disrepair that they were not suitable. While it's not possible to build an

isolation ward with infinite surge capacity, we recommend investing in permanent isolation wards either through new construction or renovation of old isolation wards. Consider isolation ward designs that guard against multiple modes of disease transmission to allow for flexibility in future outbreaks, for example cholera or ebola, where transmission patterns may differ.

Several good resources exist on the design of COVID-19 isolation wards

- Build Health International
- Construction for Change

Intervention	Design new isolation structures so that they do not rely fully on mechanical ventilation. Things to consider: prevailing wind direction, building orientation, windows, louvers, ceiling fans, roof design, etc. • WHO Natural ventilation for infection control in health-care settings • Heating, Cooling, Lighting: Sustainable Design Methods for Architects
Intervention	Install additional windows or fixed air louvers to increase outside air ventilation and ensure that screens are properly installed and in use on all open windows, especially in malaria-endemic regions.
Intervention	Install side wall or upblast exhaust fans. Have spare fans and belts if used. If good quality exhaust fans are used and the facility has good power quality, exhaust fans are very reliable and require very little maintenance
Intervention	Install "Ball-in-the-Wall" Pressure indicator between positive and negative pressure spaces. This is a simple technology and provides a visual cue on air pressure differential. Also consider magnehelic differential pressure gauges for more accurate quantitative pressure monitoring..
Intervention	For existing isolation facilities, consider replacing low quality exhaust fans with higher quality exhaust fans.

Strategy 5.2: Improve existing hospital ventilation

The WHO has said that: "to help prevent airborne infections, adequate ventilation in health-care facilities in all patient-care areas is necessary"

Intervention	Improve airflow in health facilities at large, prioritizing high traffic areas, crowded areas, or areas where people stay for an extended period of time, such as waiting areas or patient wards.
Intervention	Utilize UV lights to supplement ventilation systems and reduce the spread of COVID-19 and tuberculosis.

For additional information, please see:

- Upper room ultraviolet germicidal irradiation (UVGI) system
- Roadmap to improve and ensure good indoor ventilation in the context of COVID-19

COST CONSIDERATIONS

Objective 1

- Fuel
- Backup diesel generators
- Bulk fuel storage tanks with in-line bulk fuel filtration for particulates and water removal
- Fuel metering device
- Automatic or manual transfer switch for use between primary and secondary power sources
- Electrical cables
- Solar equipment

- Batteries
- Electrical Disconnects
- Main distribution panel or switchboard with properly sized breakers, labels for breakers
- Lightning protection system
- Power meter with data logging capability (example, Eaton Power Xpert Meter)
- Equipment to reduce impact of power quality issues:
    - Surge suppression devices (SPD)
    - Uninterruptible power supplies (UPS)
    - Constant voltage transformers
    - Voltage regulators

Objective 2

- Borehole drilling
- Water pumps
- Submersible pump for backup
- Water cistern or water tower
- Water flow metering devices
- Water testing devices/equipment
- Water treatment equipment
    - Chemical dosing pumps (such as Grundfos DDE or DDA models)
    - Chlorine storage tank
- Permanent and temporary hand washing stations
- Soap
- Drainage equipment or buckets

Objective 3

- Pulse oximeters
- Vital sign machines
- Ultrasound and diagnostic equipment
- Advanced critical care equipment (ventilators, non-invasive machines)
- Bedside oxygen concentrators
  (consider building an oxygen plant if a major District and/or regional hospital)
- Test benches
- Ultrasonic oxygen analyzer
- Digital Multimeter
- Electrical safety analyzer
- Pressure gauge and adapters
- Tool boxes
- Shelving for spare parts
- Equipment storage
- Tools and test equipment for biomedical staff
- Laptop for biomedical staff
- Trainings for biomedical staff
- Trainings for facilities staff

Objective 4

- Diesel fired incinerator or brick incinerator

- Spare parts for oil burners, nozzle, electrode, fuel pumps, thermocouple, solenoid valves
- Steel or fiberglass diesel storage tank
- Lined ash pits and unlined organic waste pits
- Digging materials
- Training for facilities staff and hospital waste management team on waste management practices
- Durable PPE for incinerator operators and hospital waste management team

Objective 5

- Windows
- Fixed air louvers
- Screens or LLINs
- Side wall or upblast exhaust fans
- Spare fans and belts
- Ball-in-the-wall pressure indicator
- Magnehelic differential pressure gauges
- UVC light fixtures

RESOURCES:

Airflow Direction Incorporated (home page)
Amazon Marketplace: Heating, Cooling, Lighting: Sustainable Design Methods for Architects
Build Health International COVID-19 Infrastructure Resources
Construction for Change COVID-19 Response Unit Prototype
Dwyer Series 2000 Magnehelic Differential Pressure Gauges
Eaton Power Xpert Meter 2000
EMI Resource Library
Global Fund Technical Brief: Sustainable Health Care Waste Management
Grundfos Digital Dosing Pumps
Malkin R., Keane A. Evidence-based approach to the maintenance of laboratory and medical equipment in resource-poor settings. Med Biol Eng Comput [Internet]. 2010 [cited 2021 April 16];48:721-726. Available from http://www2.stat.duke.edu/~banks/130-labs.dir/lab8.dir/Lab8_Malkin_paper.pdf

Medical Aid International - Biomedical Engineering
MSF Upper Room Ultraviolet Germicidal Irradiation (UVGI) System
PATH: Personal Protective Equipment for Waste Handlers and Incinerator Operators
The Global Good Fund: Power Quality Challenges in Low Resource Settings
The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response
WHO Guidelines for Drinking-Water Quality, Fourth Edition
WHO Natural Ventilation for Infection Control in Health-Care Settings
WHO Roadmap to Improve and Ensure Good Indoor Ventilation in the Context of COVID-19
WHO Safe Management of Wastes From Health-Care Activities
WHO UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) 2019 Report
WHO Water and Sanitation for Health Facility Imrpvoement Tool (WASH FIT)
WHO Water Sanitation Hygiene and Waste Management for SARS-CoV-2, the Virus That Causes COVID-19
WHO Water Sanitation Hygiene and Waste Management for the COVID-19 Virus
WHO/UNICEF Core Questions and Indicators for Monitoring WASH in Health Care Facilities in the Sustainable Development Goals
WHO/UNICEF WASH in Health Care Facilities Baseline Report 2019