HOMER Powering Health Tool: User Guide

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This User Guide accompanies the HOMER Powering Health Tool: http://tools.poweringhealth.org. The note provides instructions and assumptions underlying the default electric load inputs by health facility tier and electric device, as well as links to further resources.

Introduction and instructions

What is this tool for?

The HOMER Powering Health Tool is a free online model to create initial designs of electric power systems for health care facilities that have no other power supply or have grid electricity available for a predictable period of hours each day. The tool is intended for project managers, engineers and financiers in the energy industry to simplify the design process for such systems. The tool models optimal combinations of power supply options to meet electrical loads of a health facility at least cost based on the given inputs. It compares combinations of grid electricity (if available), batteries (lithium-ion or lead-acid), solar photovoltaics (PV), and generator sets fueled by diesel, gasoline or propane. The model runs entirely online and can be used an unlimited number of times with no need to sign in or download software.

How to use the tool?

Follow the steps below to input data on local energy costs and health care facility electrical loads.

1. **Location and Time Zone** - Use the map to indicate your approximate location.

   The amount of energy available from the sun is directly related to location. HOMER obtains monthly average solar resource values from a variety of databases at NREL and NASA to synthesize a year of hourly data. These are calculated based on the latitude and longitude of a site and satellite measurements of annual cloud cover.

2. **Power Assumptions** – The values that are shown are simply default values. The user is encouraged to enter local values for cost and availability of the electric grid and on-site power generation equipment.

   In areas where the electricity grid is available only part of the day, the scheduling of the grid can have a significant impact on the design of a suitable power supply system. The availability and cost of supply and installation of PV panels, batteries and diesel fuel will vary by location. The default cost values entered here are roughly accurate for much of Africa but should not be relied upon without verification. Grid electricity costs may be estimated from a recent bill (e.g. total cost divided by kilowatt-hours consumed). When calculating the cost of PV, include the cost of all related components (the cost of the panels, installation, mounting frames and other hardware), but not the inverter or batteries, which are sized separately by HOMER. Retail pump prices by country for petrol/gasoline and diesel can be found at https://data.worldbank.org/indicator or https://www.globalpetrolprices.com.

3. **Financial Assumptions** - Enter the Real Interest rate.

   HOMER minimizes the discounted cash flow of the project. The interest rate determines the tradeoff between the initial capital cost and future operating costs. It has a significant effect on the optimal system design. Lower interest rates will favor PV over diesel generators. The real interest rate can be approximated as the difference between a bank's interest rate on loans and the estimated rate of inflation.

4. **Electric Load Inputs** - Enter the type and number of electrical devices used in the health facility and the time of day they are used. Select one of four health facility tiers as a starting point and the quantity of devices and hours of use can be then adjusted or entered manually. *The later sections of this User Guide explain assumptions for each tier and device.*

   The table is populated with common equipment types found in rural health facilities including typical power ratings. The time of day that power is needed and the peak power demand have an impact on the sizing of equipment and the optimal configuration. For the most accurate simulation, this step may require a walk-through of an existing clinic. **Note: The tool is not**

intended to design the health facilities themselves. In all cases, the equipment quantity, power, and hours of use are inputs that should be reviewed and adjusted as needed to meet the needs of a given facility, based on an energy audit for the specific site where possible. If there is no health facility yet, the information provided in the User Guide can inform an estimate of the potential electrical load.

5. **Click the 'Run HOMER®' button at the bottom of the webpage.**

   Once you have defined all the necessary inputs HOMER will analyze every possible combination of power supply options that meet the demand.

Note: The results will appear as a new page if your browser allows pop-ups or you will have the opportunity to open the results in a new page by clicking on a link after the calculation is complete.

- The new page will provide a table of optimized configurations ranked low to high based on the cost per unit of electricity over the project lifetime. Results will include configurations for PV-battery, PV-battery-backup generator, battery-generator, and generator only (for comparison).
- From the new page, you can select a configuration for detailed results based on the given inputs. The HOMER Pro output file for the simulation can also be downloaded for users with HOMER Pro desktop application.
- To run a new simulation, you can either load the tool again and start from the default parameters, or you may exit out of the pop-up linking the simulation results and you may start from your recently calculated inputs.

About the tool

The HOMER Powering Health Tool uses the proprietary optimization algorithm of HOMER (Hybrid Optimization Model for Multiple Energy Resources), originally developed at the United States National Renewable Energy Laboratory (NREL), and enhanced and distributed by HOMER Energy by UL, a subsidiary of Underwriters Laboratory (UL). The model has been made available online in this tool with funding and technical support from USAID, the Energy Sector Management Assistance Program (ESMAP) through the World Bank including with the Energy Storage Partnership, and We Care Solar, as well as contributions from numerous health and energy experts. Feedback on the tool is welcome and can be addressed to support@homerenergy.com.

Disclaimer

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General system design considerations

The HOMER Powering Health Tool designs systems to power the electrical needs of a facility with no other power supply or with grid electricity that is available for a predictable period of hours each day. This can be considered a 'centralized system' approach. Designing a single system for a known set of loads in this way has the advantage of improving system performance and efficiency by accounting for a diversity of loads. The tool adds some random variability to the load profile. This impacts the size of the peak load, which is important for sizing the generator and inverter. As a result, the tool is not intended for final sizing of these components. Particularly, for larger health facilities, further analysis is recommended with more detailed usage patterns, such as with *HOMER Pro*. This online tool can also be used to accommodate various other approaches and situations, within limitations, as follows.

- The tool can also be used to design a **mini-grid** to serve a facility plus other consumers nearby, provided that data is available to input for all loads, and that the consumers will have a way to appropriately share system costs.
- The tool's default values assume that the facility has no existing power supply, besides potentially some grid electricity. The tool can be used to upgrade a facility with a **pre-existing generator** by setting the "Generator installed cost" to zero. In this case, the tool will specify an optimal size of generator, subject to the default variability described above. This may be larger or smaller than actual generator on site.
- A key assumption underlying the default values of the tool is that all power output will be alternating current (AC), thus requiring an inverter to accommodate direct current (DC) output from batteries. In contrast, the tool can be used to design a **DC system**, as may be appropriate for small facilities, by setting the "Cost of bi-directional Inverter" to zero.

Modular approaches and DC system considerations are discussed further below.

The tool is thus *not* intended to design or optimize systems for facilities where grid electricity has sporadic outages and is otherwise available for most hours of most days. The tool is also not intended to design systems that feed PV power into a grid. For these latter circumstances, other tools can be used such as the licensed software of HOMER Energy or, for some systems, the free System Advisor Model (SAM) provided by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL). It is thus important that users consider different system options and design approaches to suit local circumstances.

Modular approaches

One approach to accommodate load growth or load uncertainty is to use standard energy packages dedicated to specific needs and separate buildings in a health care facility (e.g. lights in a building pack, vaccine fridge pack, maternity room pack, administration pack, laboratory packs of different sizes). New packages can be added flexibly, as and when appliances are made available on site.

For AC off-grid systems, another way to accommodate load growth and uncertainty is to add a back-up generator. This can be particularly important when health care demands surge such as during a pandemic response. If fuel supply is manageable and affordable, a backup generator can reduce the overall capital cost of systems by dramatically reducing the required size of the PV array and battery. A backup generator also allows better battery management by preventing excess battery discharge and enabling charge equalization. Finally, without a backup generator, the use of the electric appliances must be carefully managed during extended cloudy periods. This may not be a problem for small systems but could be problematic for larger systems.

Lower level off-grid systems can in many cases have exclusively DC systems powered by PV and batteries. Dedicated DC systems to power select loads can also be considered where a facility has AC power that is insufficient. DC systems have the advantage of doing without an inverter and a generator, and they are less susceptible to the risk of being used for extra AC power devices beyond what is called for in the health facility. An incremental modular approach is also well suited to smaller, 'plug-and-play' DC-based packs or kits with short cable runs. These have their own PV panel and battery and dedicated DC appliances. Examples of devices that are commonly available as DC-powered models include LED lights, vaccine refrigerators, blood bank refrigerators, and fans. Many other devices with batteries can work with DC power if they have the correct adaptors (e.g. with 12/24/48V output or 5V output USB connectors). Examples of such devices include laptop computers, nebulizers, portable ultrasound, portable X-ray, cell phones, and e-tablets. This HOMER Powering Health Tool does not specify devices suitable for DC solar electric systems.

Electric load inputs

The HOMER Powering Health Tool allows users to enter the electrical needs of a health facility in two ways. One way is to identify and select one of four health facility tiers with default values as a starting point. The second way is to manually enter the quantity of each device and the hours of use. In all cases, the equipment quantity, power, and hours of use should be reviewed and adjusted as needed to meet local circumstances.

Health care facility tiers

The four tiers provided, ranging from large to small, are: **District Hospital**; **Rural Hospital**; **Small In-Patient Facility**; and **Rural Dispensary**. The tiers vary by level of medical services offered, which in turn affects the type and quantity of devices assumed to be available based on a given number of beds and range of service units. The tiers correspond roughly to those found, for example, in Uganda and other Sub-Saharan Africa countries. **Annex 1** details the assumptions for each tier. Actual health facilities naturally vary across and within countries and regions. Analyses of larger facilities warrant more careful sizing than small facilities, as large facilities involve more equipment with diverse characteristics and different possible patterns of use.

Electric devices

Each listed device has a nameplate power and average power. Nameplate power is the rating on the appliance's nameplate, which is the peak power the appliance would draw at full speed or volume.[1] Average power is the power that the appliance would use over the course of one hour. For many appliances this is significantly lower than the nameplate power (as illustrated by the default values in the tool). For example, in one hour a fridge usually operates not for 60 minutes but alternates between powering on and off in a duty cycle over the hour. Overestimating average power will result in oversized power systems. For the pre-listed equipment, users can adjust the nameplate power. The tool automatically calculates average power for pre-listed equipment based on the nameplate power input and a default ratio. For example, average power is assumed to be half of the nameplate power for the vaccine fridge, and two-thirds of nameplate power for exam lights. The default values in the tool are maximums calculated based on usage 7 days per week. Whereas energy demand may vary on different days of the week, this can be taken into account when considering average energy needs for each equipment. In a solar-powered facility, where possible, it can be more energy efficient to operate equipment for a limited number of hours every day than to operate at high levels for just a couple of days per week. Users can add new rows at the bottom of the electric loads table to adjust both nameplate power and average power.

Annex 1 details the assumptions and notes about devices listed in the tool. The devices are grouped by medical service units that may be found in a health care facility: Expanded Programme on Immunization (EPI); out-patient department (OPD); maternal and child health (MCH); obstetric delivery; maternity ward; general ward; laboratory; administration and admissions; COVID-19 Isolation Ward; COVID-19 basic care ward; operating theatre; radiology department; ICU; mortuary; staff; water pumping; water heating; and cooking. Many health care facilities will have only some of these units (as detailed in **Annex 1**. Equipment such as lights and ceiling fans occur in many or all of the units. The description below repeats information for the equipment in each unit.

Energy efficiency

A wide variety of each type of equipment is generally available in different countries, ranging in level of energy efficiency. New sites should aim to use energy-efficient equipment from day one. Old equipment that exists on site may have high energy consumption such as inefficient refrigerators, fluorescent or incandescent light tubes, fans, air-conditioners, desktop computers, and ultrasound

[1] Start-up power can exceed the nameplate for milliseconds to a few seconds for very large motors. While this is not relevant for most rural health care facilities, it should be considered if a facility may have large motors.

machines. Standard or existing equipment can use high amounts of power and energy and thus are generally much less efficient (e.g. sterilisers, autoclaves, X-Ray machines, oxygen concentrators). The more inefficient equipment is used, the bigger and more costly the power supply will be. In designing power systems for sites with old equipment, it can be more cost effective to replace or retrofit some old equipment with newer, higher efficiency units, than to build a power system large enough to power inefficient equipment. High efficiency portable appliances with built-in rechargeable back-up batteries can also be considered (e.g. laboratory testing equipment, portable x-rays, portable ultrasound, patient monitors, medical lamps). Finally, some medical equipment may exist as manual versions for use in rural clinics (e.g. centrifuges, anaesthetic gas monitors, suction machines).

COVID-19 response

Energy needs for health facilities have received renewed attention in response to the COVID-19 pandemic. Equipment for a COVID-19 Isolation Ward and COVID-19 Basic Care Ward is assumed for the **District Hospital** tier, on the basis that COVID-19 patients would typically be referred to a district hospital from smaller facilities.

While most treatment response will likely be directed towards urban referral hospitals, facilities lower in the primary health care referral pyramid may have expanded utilisation and demands. The tool can be used to model individual COVID-19 Isolation Wards or Basic Care Wards by selecting the corresponding equipment. Similarly, a COVID-19 testing site can be modelled by selecting only the associated equipment such as lights, refrigerator, freezer, and fan.

Responding to COVID-19 may increase energy load substantially with fully-occupied ICU beds demanding higher energy. However, hospitals responding to COVID-19 may have less demand for electricity from routine medical activities such as elective surgeries, especially in communities practicing stay-at-home measures. Energy needs should consider not only spikes in demand due to COVID-19 response, but also realistic needs under future less demanding operating conditions. Designs for present needs can be done flexibly, to expand to meet future needs.

For additional information, see:

- World Health Organization (WHO) list of Priority Medical Devices https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance-publications
- WHO-approved refrigerators, freezers, and coolers https://apps.who.int/immunization_standards/vaccine_quality/pqs_catalogue/index.aspx
- SELCO Foundation COVID-19 response website http://www.covid-19.selcofoundation.org/
- USAID Powering Health: Electrification Options for Rural Health Centers http://www.poweringhealth.org/Pubs/PNADJ557.pdf
- Sustainable Energy for All (SE4All) Powering Health Care for Women, Children and Families http://poweringhc.org/ https://www.seforall.org/energy-and-health/covid-19-response-powering-health-facilities
- Energy Sector Management Assistance Program (ESMAP) Resource Hub http://esmap.org/resources

Annex 1: Health facility tiers assumptions and notes

The default tiers of health facilities provided by the tool cover a typical District Central Hospital and its feeder primary health care facilities, together making up the lower levels of the health-care referral pyramid.

District hospital

The district hospital used as the basis for the default values in the tool is assumed to have 145 total beds and include: Outpatient Department (OPD) services, 6 obstetric delivery beds, 30 maternity ward beds, 1 laboratory, 4 administrative stations, 100 general ward beds, 2 operating theatres, 10 Intensive Care Unit (ICU) beds, Radiology Department, and 6 mortuary trays.

- ***Notes:*** The default values assume a full suite of medical services operating at high capacity, but with few occupied ICU beds. Ward occupancy level will determine actual energy usage for these. A key factor is the number of intensive care unit (ICU) beds, and whether occupied, as these are very high energy consumption if used 24/7. Users may edit the number of ventilators, patient monitors, and active oxygen concentrators as a proportional proxy for the number of occupied beds.

Rural hospital

This is assumed to have **50 total beds** and include: OPD services, 2 obstetric delivery beds, 10 maternity ward beds, 1 laboratory services, 2 administrative stations, 30 general ward beds, 1 operating theatre, and no ICU beds.

- ***Notes:*** The default values assume the hospital is not operating at full capacity. For example, the operating theatre has an assumed use of only 3 hours per day. Whereas the tool assumes constant daily loads, the operating theatre may in practice be used only 2-3 times per week, such that energy demand may be lower. The tool's default value assume that the facility is not used for COVID-19 patients requiring intensive care. If respiratory support were needed, then energy demand would escalate significantly.

Small in-patient facility

The default values for this tier assume 14 total beds and include: OPD services, 1 obstetric delivery beds, 4 maternity ward beds, 1 laboratory service, 1 administrative station, and 10 general ward beds.

- ***Notes:*** The default values in the tool are maximums calculated based on usage 7 days per week. Actual energy demand may be correspondingly reduced to reflect use of outpatient services for only 3-5 days per week, and in-patient services provided as needed.

Rural dispensary

This is assumed to have no inpatient services but 4 emergency beds and to include: OPD services, 1 obstetric delivery bed and 2 maternity beds (emergency), 1 laboratory (basic), 1 administrative station, and 2 general ward beds (emergency).

- ***Notes:*** The default values in the tool are maximums calculated based on usage 7 days per week. Actual energy demand may be correspondingly reduced to reflect use of outpatient and MCH services 3-5 days per week, and obstetric deliveries only in emergency.

Annex 2: Electric device assumptions and notes

This section outlines the medical equipment listed in the tool and assumptions and notes about the default values of energy associated with each equipment.

The notes below include links to technical specifications for some equipment. These links are being provided as a convenience and for informational purposes only; they do not constitute an endorsement or an approval of any of the products, services or opinions of the corporation or organization or individual. No responsibility is born for the accuracy, legality, or content of the external site or for that of subsequent links. Contact the external site for answers to questions regarding its content.

Expanded Programme on Immunization (EPI)

- Vaccine refrigerator (per 75 liter capacity unit).
    - Critical appliance operating 24/7 with automatic duty-cycle to maintain temperatures.
        - *Average power* is pre-defined by duty-cycle operation in 24 hours (assumed to average out to half of the nameplate power)
        - Smaller vaccine fridges have capacity for 2-4 ice-packs per 24 hours.
    - Guide: for larger units, e.g. 150 liter unit, enter quantity = 2 x 75 liter units, or refer to WHO catalogue
    - WHO specification: https://apps.who.int/immunization_standards/vaccine_quality/pqs_catalogue/categorypage.aspx?id_cat=17

Outpatient Department (OPD)

OPD services in lower level facilities may be provided 3-5 days per week.

- ***Sterilisation equipment:*** for medical & dental tools. Operates 1 hr/day, 3-5 days/week
    - Energy efficient options
        - Thermal unit (steam autoclave) assumed 1,000 W nameplate, capacity 50, liter, 10-15 minutes
        - Irradiation UV units assumed lower power 15 W nameplate, capacity 11 liter, 10-15 minutes
        - Liquid steriliser requires zero power (but requires chemical disposal)

Maternal and Child Health (MCH)

MCH awareness and training is a principal, heavily utilised service provided by rural health facilities. This service addresses pre-and post-partum issues, as well as HIV awareness.

- ***TV/DVD:*** to educate expectant mothers 1-3 times per week. Also used in postpartum wards

Obstetric delivery

Lower level facilities may deliver babies only 2 - 5 times per week. Lighting must be available in the event of night time deliveries.

- ***Suction:*** Infrequent use, for short duration at the time of delivery.
- ***Examination Light:*** Small medical spotlight for obstetric deliveries and repair of episiotomies
    - Choose 50W dichroic halogen, or energy efficient 10-25W LED (preferred)
- ***Lighting:*** for 75 lux, allocate 1 ceiling light per 2 ward beds, assuming 18W LED providing 1,800 lumens.
    - Fluorescent tube equivalent is 45W, thus retrofit with 18W LED is preferred.
- ***Ceiling fan:*** Allocate 1 fan per 4 delivery beds.

- Usage hours to be reduced to suit the level of occupancy of the ward.
- Fans are rarely all on simultaneously, very rarely at full speed.
- Energy efficiency retrofit options can be justified:
    - Standard 1,200mm diameter fan 75W at full speed, 30W at lower speed.
    - Efficient fan less than <35W at full speed, <15W at slow*:* https://www.energystar.gov/most-efficient/me-certified-ceiling-fans

Maternity ward

This includes antepartum care, labor triage, and post-delivery wards. Lower level facilities may be largely unoccupied.

- ***Lighting:*** for 75 lux, allocate 1 ceiling light per 2 ward beds, assuming 18W LED providing 1,800 lumens.
    - Fluorescent tube equivalent is 45W, thus retrofit with 18W LED is preferred**.**
- ***Ceiling fan:*** Allocate 1 fan per 4 ward beds.
    - Usage hours to be reduced to suite occupancy of ward
    - Fans rarely all on simultaneously, very rarely at full speed.
    - Energy efficiency retrofit options can be justified:
        - Standard 1,200mm diameter fan 75W at full speed, 30W at lower speed.
        - Efficient fan less than <35W at full speed, <15W at slow*:* https://www.energystar.gov/most-efficient/me-certified-ceiling-fans
- ***Sterilization Autoclave (per 20 liter capacity):*** for medical tools, usually only once per week in lower level facilities (not daily). Guide: for larger units, e.g. 40 liter, use qty = 2x 20 liter.
    - High pressure steam unit, 3,500-2,000W high power 30 -minute operation.
    - Energy efficient options
        - Irradiation UV units assumed lower power 15W nameplate, capacity 11 liter, 10-15 minutes
- ***Portable ultrasound:*** Used to diagnose pregnancy complications such as twins, placental abruption, placenta previa. Uses 20 – 30 Watts for several minutes at a time.

Neonatal Care

- High level neo-natal care is not present in rural primary health care facilities. ***Infant warmer:*** Radiant heater used directly following birth. Open or Closed types, and High efficiency models available.
- ***Newborn incubator (NICU):*** Primarily for premature infants. When used, will run 24/7. Open or Closed types, and High-efficiency models available.
    - Average power is defined by duty-cycle operation in 24 hours
- ***Phototherapy Unit:*** Primarily for infants with neonatal jaundice. When used, will run 24/7.

General Ward

This comprises in-patient wards for men, women, or children. Lower level facilities may not be fully occupied. (See below later sections for COVID-19 wards).

- ***Lighting:*** for 75 lux, allocate 1 ceiling light per 2 ward beds, assuming 18W LED providing 1,800 lumens.
    - Fluorescent tube equivalent is 45W, thus retrofit with efficient 18W LED is preferred**.**
- ***Ceiling fan:*** Allocate 1 fan per 4 ward beds. Usage to be reduced to meet expected occupancy.

Laboratory

This is used for pathology, blood banking, and testing. Lower level facilities may have basic labs with only essential equipment, and not used 7 days per week.

- ***Sterilization Autoclave (per 20 liter capacity):*** for medical tools, usually only once per week in lower level facilities (not daily). Guide: for larger units, e.g. 40 liter, use qty = 2x 20 liter.
    - High pressure steam unit, 3,500-2,000W high power 30 -minute operation.
    - Energy efficient options
        - Irradiation UV units assumed lower power 15W nameplate, capacity 11 liter, 10-15 minutes
- ***Refrigerator (Reagents per 150 liter capacity):*** Operating on 24/7 with on/off duty-cycle. Guide: for 300 liter unit, enter quantity 2 x 150 liter units, or custom appliance. Domestic types are adequate, also used for ice-pack freezing.
    - *Average power* is pre-defined by duty-cycle operation in 24 hours.
- ***Centrifuges:*** Short-duty-cycle operation of minutes, several times per day.
- ***Microscopes:*** Used for viewing bacteria, microbes, histology, used intermittently for minutes at a time during the day
- ***Laboratory incubator:*** For growing cultures. Low average operating power on 24/7 with on/off duty-cycle, when used. High-efficiency models available.
    - *Average power* is defined by duty-cycle operation in operational hours.
- ***Water bath:*** Low average power operating with on/off duty-cycle, when used.
    - *Average power* is defined by duty-cycle operation in operational hours.
- ***CD4 machine (for HIV-related tests):*** short-duration rapid tester, several times per day.
- ***Refrigerator (Blood per 150 liter capacity):*** Operating on 24/7 with on/off duty-cycle. Guide: for 300 liter unit, enter quantity 2 x 150 liter units, or custom appliance. Domestic types are adequate, also used for ice-pack freezing.
    - *Average power* is pre-defined by duty-cycle operation in 24 hours.
- ***Hematology analyzer:*** short-duration rapid tester, several times per day.
- ***Blood chemical***: used intermittently during the day
- ***Molecular diagnostics system (TB / COVID / SARS test) 2 module***: 1 hour duration rapid tester, several times per day.
- ***PCR Machine (thermal cycler):*** 30 -minute duration rapid tester, several times per day. High efficiency models available.

Administration and admissions

- ***Light:*** For 50 lux daytime, allocate 1 ceiling light per 2 desks, assuming 18W LED providing 1,800 lumens.
    - Fluorescent tube equivalent is 45W, thus retro fit with efficient 18W LED is preferred**.**
    - Supplement with desklamp as required
- ***Ceiling fan:*** Allocate 1 fan per 2 desks
    - Energy efficiency retrofit options can be justified:
        - Standard 1,200mm diameter fan 75W at full speed, 30W at lower speed.
        - Efficient fan less than <35W at full speed, <15W at slow*:* https://www.energystar.gov/most-efficient/me-certified-ceiling-fans
- ***Computer:*** Allocate 1 per workstation. Desktops assumed at 90W. Laptops at 45-60W.
- ***Printer:*** Allocate 1 per administration. Assume 8 hours operational hours, 1 hour printing
    - *Average power* is pre-defined by duty-cycle operation in operational hours.
- ***Refrigerator (domestic, per 150 liter capacity):*** Operating on 24/7 with on/off duty-cycle. Guide: e.g. for 300 liter unit, enter qty = 2 x 150 liter units, or custom appliance. Domestic types are adequate, also used for ice-pack freezing.
    - *Average power* is pre-defined by duty-cycle operation in operational hours.

COVID-19 Isolation Ward

This is for symptomatic or positive tested patients and is likely housed within a sub-section of ***General Ward,*** but with additional isolation cubicles and extraction fans, as well as staff change cubicles.

- ***Exhaust fans:*** 40W per isolation cubicle, allowing 12 air changes per hour
- ***Lighting:*** for 50 lux, allocate 1 ceiling light per 2 beds, assuming 18W LED providing 1,800 lumens.
    - Fluorescent tube equivalent is 45W, thus retro fit with efficient 18W LED is preferred**.**

COVID-19 Basic Care Ward

This is for positive-tested patients needing closer monitoring, and is likely housed within a sub-section of ***General Ward***, but with additional isolation cubicles and extraction fans, as well as staff change cubicles.

- https://www.seforall.org/interventions/energy-and-health/covid-19-response-powering-health-facilities) and in guidance from WHO for "Priority Medical Devices" (available here: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/covid-19-critical-items)):
- ***Exhaust fans:*** 40W per isolation cubicle, allowing 12 air changes per hour
- ***Lighting (additional):*** >200 lux, allocate additional at least 1 ceiling light per bed, assuming 18W LED providing 1,800 lumens. Ideally on separate switches or dimmable.
- ***Oxygen concentrator:*** High power extracting O_2 from ambient air, consuming 300-400W. Portable rechargeable efficient versions available, from 90W power upwards. For 50% of the beds only.
    - Tech. specs. WHO: https://www.who.int/medical_devices/publications/tech_specs_oxygen-concentrators/en/
    - http://www.covid-19.selcofoundation.org/oxygen-concentrators-setting-up-medical-facilities-in-low-resource-areas
- ***BiPAP respirator:*** lower power respirator used for patient breathing assistance prior to oxygen contractor being required. 80W continuous draw typically.
- ***CPAP respirator:*** lower power respirator used for patient breathing assistance prior to oxygen contractor being required. 80W continuous draw typically.
- ***Pulse Oximeter (*rechargeable):*** Low power portable unit, typically recharged at night. May be available as battery-operated. *Only recharge energy cycle is captured as usage.*
- ***EKG / ECG monitor (*rechargeable):*** Cardiopulmonary function tests: resting ECG, exercise ECG. Low power , 4 hours use per recharge or 300 ECG.

Operating theatre

This is assumed to be used less than 8hrs/day 7 days per week. In lower level facility, 3hrs/day for only 2 days/week are more likely.

- ***Lighting:*** Allocate 10 lights per theatre, assuming 18W LED providing 1,800 lumens. Ideally on separate switches or dimmable.
    - Fluorescent tube equivalent is 45W, thus retro fit with efficient LED is preferred**.**
- ***Air-conditioner (inverter type):*** Allocate 1 AC per theatre. Efficient inverter type assumed.
    - Average power is defined by duty-cycle operation in operational hours.
- ***Surgery spot lights:*** High intensity, for operation duration only
    - 500W Dichroic halogen, or 120-150W LED
- ***Ventilator:*** Many different grades, power consumption and energy efficiencies, including basic manual versions:
    - Tech. specs. WHO: https://apps.who.int/iris/bitstream/handle/10665/331792/WHO-2019-nCoV-Clinical-Ventilator_Specs-2020.1-eng.pdf
    - http://www.covid-19.selcofoundation.org/solar-powered-ventilators-setting-up-medical-facilities-in-low-resource-areas/
- ***Anaesthetic machine:*** For gas flow measurement and control. Automatic and rudimentary manual versions available

- ***Suction:*** Short 1-minute duration operation, used multiple times during surgical procedures
- ***Cautery Diathermy (Cauterizer):*** Used in short duration, several seconds at a time, multiple times during operations
- ***Patient monitor Multi-par (PMS):*** Used intra-operatively to monitor the vital signs of the patient. Many grades and energy efficiencies available.
- ***Pulse Oximeter (*rechargeable):*** Low power portable unit used daytime and recharged at night. May be available as battery-operated. *Only recharge energy cycle is captured as usage.*
- ***Sterilization Autoclave (per 20 liter capacity):*** for medical tools, on operation days (not daily). Guide: for larger units, e.g. 40 liter, use qty = 2x 20 liter.
  - High pressure steam unit, 3,500-200W high power 30 -minute operation
  - Energy efficient options
    - Irradiation UV units assumed lower power 15 W nameplate, capacity 11 liter, 10-15 minutes

Radiology Department

The tool assumes that radiology departments occur only in the District Referral Hospital and Rural Hospital tiers for the purposes of default values.

- ***X-ray machine*** *(stationary):* The tool assumes a stationary X-ray machine only for the District Referral Hospital. High power for milli-seconds only, but up to 15-20kW, making power supply design for usage in off-grid facilities difficult. High efficiency portable units are preferred.
  - https://greenhealthcare.ca/wp-content/uploads/2015/04/Medical-Imaging-Equipment-Energy-Use-CCGHC-2017.pdf
- ***Portable X-ray machine (*rechargeable):*** High-efficiency, 300 exposure over 8hr day usage with overnight recharge. *Only recharge energy cycle is captured as usage*. Ideal for COVID response.
- ***Potable ultrasound:*** Short usage cycle, used for 5-15 minutes per exam
- ***Specialist scanning equipment*** such as nuclear magnetic resonance (NMR), computed tomography (CT) and similar are not provided in the tool default list. For examples that could be added manually, refer:
  - https://greenhealthcare.ca/wp-content/uploads/2015/04/Medical-Imaging-Equipment-Energy-Use-CCGHC-2017.pdf

Intensive Care Unit (ICU)

ICUs are evident in large hospitals and wards are usually not fully occupied. ICUs have high power needs when occupied, so the assumed level of occupancy is a key variable. Isolation chambers, each with a dedicated extraction fan, may be added for COVID response.

- ***Lighting:*** >300 lux, allocate at least 4 lights per bed, assuming 18W LED providing 1,800 lumens. Ideally on separate switches or dimmable.
- ***Air-conditioner (inverter type):*** Allocate 1 AC per ward. Efficient inverter type assumed.
  - *Average power* is defined by duty-cycle operation in 24 hours.
- ***Exhaust fans:*** 40W per isolation cubicle, allowing 12 air changes per hour
- ***Ventilator:*** Many grades, power and energy efficiencies. Used 24/7 per occupied bed.
  - Tech specs WHO: https://apps.who.int/iris/bitstream/handle/10665/331792/WHO-2019-nCoV-Clinical-Ventilator_Specs-2020.1-eng.pdf
  - http://www.covid-19.selcofoundation.org/solar-powered-ventilators-setting-up-medical-facilities-in-low-resource-areas/
- ***Patient monitoring system (PMS):*** Many grades, power, portable and energy efficiencies available. Used 24/7 per occupied bed.
- ***Oxygen concentrator:*** High power extracting O_2 from ambient air, consuming 300-400W serving multiple patient ventilators. Portable rechargeable versions not suitable for long term ICU.

- Tech specs: https://www.who.int/medical_devices/publications/tech_specs_oxygen-concentrators/en/
- http://www.covid-19.selcofoundation.org/oxygen-concentrators-setting-up-medical-facilities-in-low-resource-areas/

- **Pulse Oximeter (*rechargeable):** Low power portable unit, typically recharged at night. *Only recharge energy cycle is captured as usage.*
- **Defibrillator:** High discharge power but low recharge. *Only recharge energy cycle is captured as usage.*
- ***Portable X-ray machine (*rechargeable):*** High-efficiency, 300 exposures over 8hr day usage with overnight recharge. *Only recharge energy cycle is captured as usage*. Ideal for COVID response.
- ***Suction:*** Short 1-minute duration usage, multiple times per day

Mortuary

Evident in larger hospitals only. Temporary emergency units may use refrigeration vehicles.

- ***Lighting:*** for 100 lux, allocate 1 light per mortuary tray, assuming 18W LED providing 1,800 lumens.
- ***Ceiling fan:*** Allocate 1 fan per 3 trays
  - Energy efficiency retrofit options can be justified:
    - Standard 1,200mm diameter fan 75W at full speed, 30W at lower speed.
    - Efficient fan less than <35W at full speed, <15W at slow*:* https://www.energystar.gov/most-efficient/me-certified-ceiling-fans
- ***Air-conditioner (inverter type):*** Allocate 1 AC per mortuary. Efficient inverter type assumed.
  - *Average power* is defined by duty-cycle operation in 24 hours.
- ***Tray Refrigerator (per 3 trays):*** Operating on 24/7 with on/off duty-cycle, when used. Guide: for higher tray capacity, e.g. 6 trays, enter qty = 2 x 3 tray units.
  - *Average power* is defined by duty-cycle operation in 24 hours, and utilisation.

Staff

Staff are the most important asset for any health care facility. Staff retention is difficult for rural facilities, unless staff are adequately provided for, with a strong trend of transfer to urban facilities. Staff may be live on-site or off-site. Many on-site staff live with their families, which increases energy needs. Small DC lighting kits are generally inadequate on their own to the provide power for the energy allowances of on-site staff.

- ***Energy allowance.*** For provision of lights, phone charging, TV and laptop computers at minimum. Energy allowance is tiered per staff level.
  - Lights, TV, computers, cell phone charging are included.
  - Refrigeration may be considered for higher-tier staff
  - Excluded: Water heating and cooking.

Water pumping

Water supply for health facility as a whole is assumed to be pumped from borehole to a header tank. Pumps are assumed to be soft-start, moderately efficient (30-40%), operating daytimes only,

- Guidance:
  - Baseline usage may be 30 liters/capita/day for all staff and patients (0.03$m^{3/}$day/capita) for all needs.
  - Select Pump as multiple of 1m^3 water delivered at relevant head: i.e. for 100 persons, need approximates 3m^3/day, so select choose 3 x 1m^3/day pump at relevant head.

Water heating

Hot water is assumed for staff and patient non-medical needs such as cleaning and bathing. Hospital steam plant is specifically excluded.

- Energy efficient options
    - General water heating is often most economically achieved using LP gas.
    - Solar water heaters (SWH) may be viable for larger volumes.
    - Smaller quantities can be viably heated using electric geysers from solar PV during daytime using (which is often more viable then SWH).
- Steps for electrical hot water calculations:
    - Calculate hot water volume/day required, enter in the tool and assess impact on kWh/day energy usage. If impact is significant, reduce volume/day or replace with LPG or solar as appropriate, as will impact energy system cost dramatically.
    - Example of calculated quantity of liters of hot water required at 45^{o}C.
        - Assuming 10 liters/capita/day for staff, and 2 liters/capita/day for patient
        - i.e. for 15 staff and 90 patients = 150 + 180 liters = 0.330m^3/day.
        - Enter 0.330 into *Qty*.

Cooking

Cooking for staff and patients. This is most economically achieved using LP gas.