SUSTAINABLE ENERGY FOR ALL

POWER AFRICA
A U.S. GOVERNMENT-LED PARTNERSHIP

DEEP DIVE #3

Technology

Powering Healthcare – Nigeria Market Assessment and Roadmap

Deep-dive on Technology and Costing

The Powering Healthcare Market Assessment and Roadmap for Nigeria was developed by Sustainable Energy for All (SEforALL), under the Power Africa-funded Powering Healthcare Africa Project. It includes a main report, and 5 technical deep-dives.

The main report is accessible here.

Market Assessment and Roadmap: deep-dives

Technology

Summary of findings

+/- 36 kWh
Daily energy need for a standard Type 2 PHC

5-10 kWp
Installed capacity sufficient to meet energy demand of Type 2 PHC

$6/Wp
Average installed cost for stand-alone solar PV and storage

$525m
To power 10,000 PHCs and keep operational for 15 years

Electricity supply technology mapped to ESMAP multi-tier framework

Note: MTF has limitations of being designed for residential consumption profiles rather than health facilities.

Tiers	Peak capacity/consumption (W, wh)	Electricity supply technology	Electricity services	Hours of supply (hours per day/ evening)	Recommended health facility type
Tier 1	Very low Min 3W (min 12wh+)	Solar lantern	Task lighting and phone charging	Min 4hrs/1hr	
Tier 2	Low Min 50W (min 200wh+)	Small solar standalone system	General lighting, phone charging, TV, fan	Min 4hrs/2hrs	Health post, Primary health clinics Type 1
Tier 3	Medium Min 200W (min 1kwh+)	Medium solar standalone system, mini-grid, hybrid systems	Tier 2 + medium power appliances	Min 8hrs/3hrs	Primary health clinics Type 1
Tier 4	High Minimum 800W (min 3.4kwh)	Large solar standalone system, mini-grid, hybrid systems, central grid	Tier 3 + high power appliances	Min 16hrs/4hrs	PHC type 2
Tier 5	Very high Minimum 2kw (min 8.2kwh)	Large solar mini-grid, central grid, fuel generator, hybrid systems	Tier 4 + very high power appliances	Min. 23hrs/4hrs	PHC, general hospitals, teaching/tertiary hospitals – type 2,3,4

Alternative multi-tier measurement of electricity supply for health facilities

- A WHO/WB publication (2014) proposed a framework for measuring electricity supply on a Tiered level, in line with the MTF.
- Based on daily power capacity needs of approximately 36kWh/day for Type 2 PHC (see page 36 for more info), this is in line with Tier 4 (advanced access) and above levels.

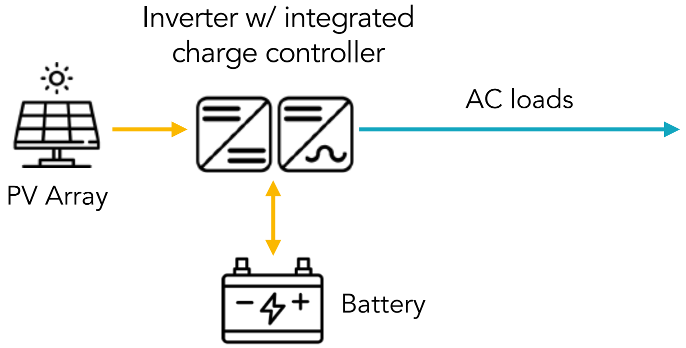
	Tier 0 No access	**Tier 1** Minimal access	**Tier 2** Basic access	**Tier 3** Intermediate access	**Tier 4** Advanced access	**Tier 5** Full access
Peak power capacity Watts (W)	<5	5–69	70–199	200–1,999	2,000–9,999	≥ 10,000
Daily energy capacity Watt hours (Wh) per day	-	20–279 Wh per day	280–1,599 Wh per day	1,600-31,999 Wh per day	32–220 KWh per day	>220 KWh per day
Duration of supply Hours/day	-	≥4	≥4	≥8	≥16	≥23
Evening peak hours supply Hours/day	-	-	≥2	≥2	4	4
Cost-effectiveness (affordability)* Lifetime costs per kilowatt hour	-	≤ 5 times benchmark	≤ 3 times benchmark	≤ 2 times benchmark	≤ 1.5 times benchmark	≤ 1 times benchmark
Quality No/poor/unstable voltage	-	-	-	Adequate	Adequate	Adequate
Reliability No outages of more than 2 hours in the past week	-	-	-	-	Adequate	Adequate
Operation sustainability Adequate operation and maintenance budget)#	-	-	-	Adequate	Adequate	Adequate
Environmental sustainability and health (g $CO_{2\text{-eq}}$ / kWh)[xxxii]	-	≤2,400 g $CO_{2\text{-eq}}$ / kWh	≤1,400 g $CO_{2\text{-eq}}$ / kWh	≤1,000 g $CO_{2\text{-eq}}$ / kWh	≤850 g $CO_{2\text{-eq}}$ / kWh	≤500 g $CO_{2\text{-eq}}$ / kWh

* The grid tariff applicable to health clinics located in the nearest electrified area is taken as a benchmark for affordability

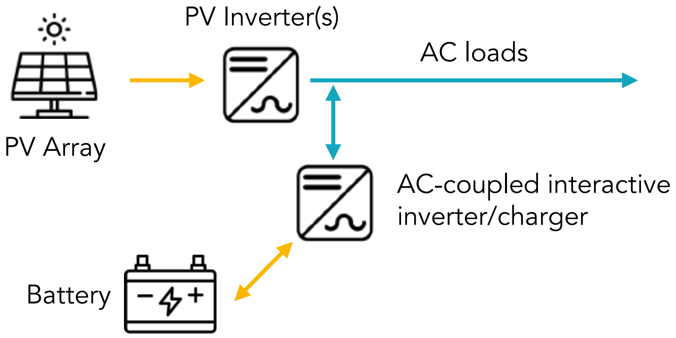
Electricity is not vulnerable to interruption as a result of: unpaid utility bills and/or lack of budget for fuel purchases; maintenance; lack of spare parts or (PV) battery replacement.

Electricity Supply Technology Configurations: Standalone Systems

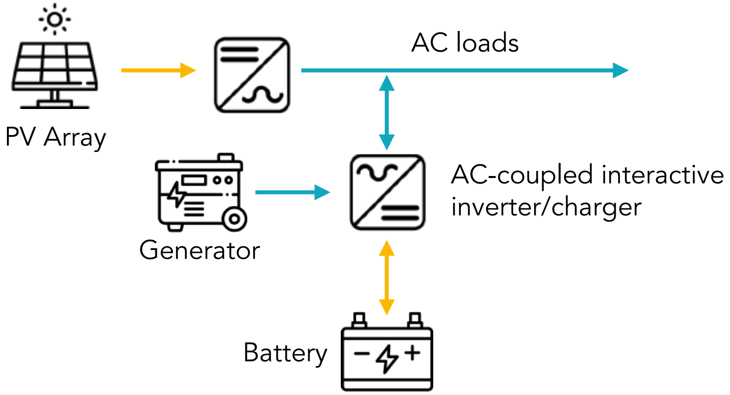
a Off-grid standalone system with charge controller integrated into inverter, battery storage bank and serving AC load.



b Off-grid standalone system with charge controller integrated into PV inverter, battery inverter with integrated charge controller, battery storage bank and serving AC load.



c Off-grid standalone hybrid system with charge controller integrated into PV inverter, battery inverter with integrated charge controller that will accept multiple AC generation inputs e.g. Generator, battery storage bank and serving AC load.



Inverter w/ integrated charge controller

- Regulates PV output
- Regulates battery charging
- Converts DC power to AC
- Controls AC loads

PV inverter(s)

- Converts DC power from PV to AC
- Synchronizes AC output to another AC source
- Cannot operate without another AC source

AC-coupled interactive inverter/charger

- Regulates battery charging
- Converts DC power from battery to AC for loads
- Can establish an AC grid
- In the case of option C, it can manage AC power input from generator

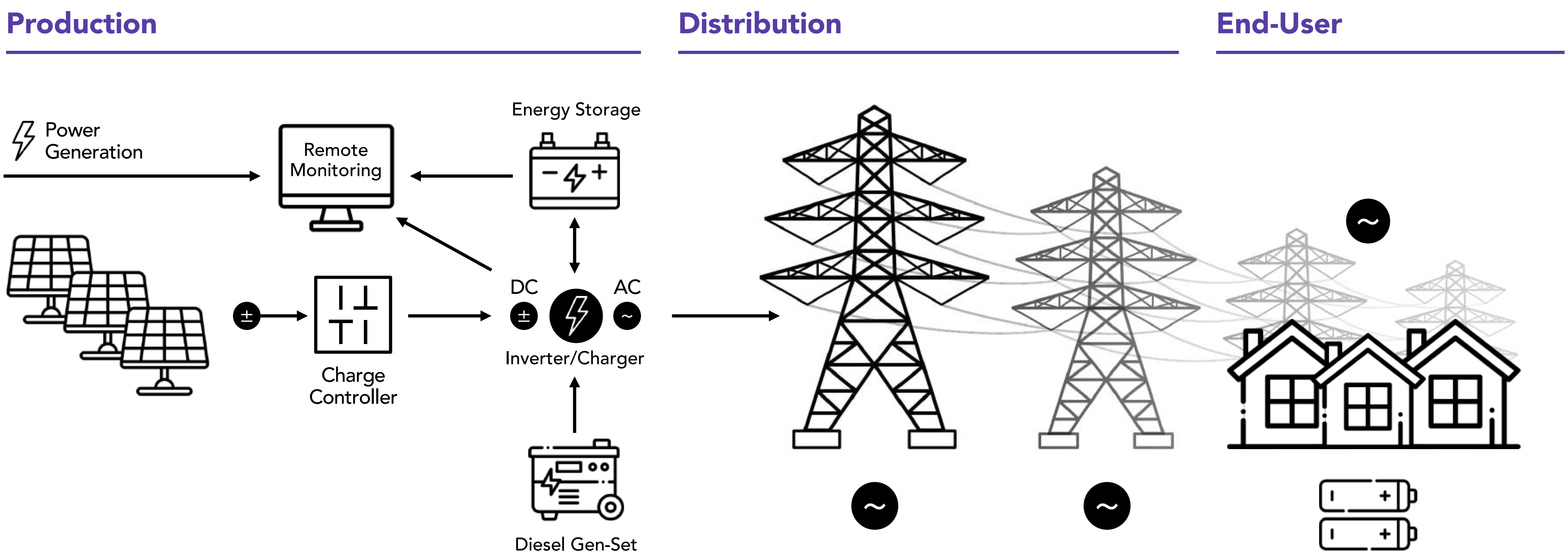
AC **DC**

Majority of installed systems across health facilities are standalone systems serving a single load or customer, i.e. health clinic.

Existing projects for both COVID-19 interventions and Health Facilities Electrification tend to fall within the Tier 3 to 5 category ranging from **5kWp and 150kWp** AC systems in terms of size, regardless of actual demand for the health facility type.

The typical assumption based on stakeholder interviews is that the demand will grow, and the capacity utilization will increase to meet the installed system capacity. This has often not been the case. **Majority of the installed systems therefore remain oversized for the purpose of the application.**

Electricity Supply Technology Configurations: Mini-grids



Some existing and planned projects are tilted towards installing mini-grids, to serve multiple loads and customers e.g. households, productive users, schools, health facilities within a community.

Existing projects for both COVID-19 interventions and Health Facilities Electrification in communities with mini-grids tend to fall within the Tier 3 to 5 category ranging from **10kWp and above (up to 1MW)** in terms of size.

Considering the mini-grids regulation, mini-grids with capacity up to 100kWp are exempt from being licensed.

Type 2 PHC appliances and load estimate

- Using the NPHCDA Minimum Standards for Primary Health Care in Nigeria document and the SERC WBG ECREEE Lighting Africa Requirements and Guidelines for Installation of Off-grid Solar Systems in Public Facilities document, the general and medical appliances were itemized, rated and the total power consumption estimated.
- The total power consumption over 24 hours is estimated at 36kWh per day, with a peak load of 3.6kW.
- Note that the general and medical appliances selected are indicative of an improved/model PHC electrification, going by the Type 2 PHC category.

Load	# Units per PHC	Power rating (W)	Hours of use (h)	Power consumption (Wh)
General appliances				
Ceiling Fan	15	50	12	9,000
Computer (laptop)	1	60	6	360
General Purpose Refrigerator/Freezer	6	130	24	18,720
USB Modem	1	2.5	6	15
Lighting (interior)	26	10	10	2,600
Lighting (outdoor/security)	4	10	10	400
Mobile phones	10	10	1	100
Remote monitoring	1	5	24	120
TV	1	100	6	600
Printer	1	100	2	200
Water pump	1	746	2	1,492
Medical appliances				
Procedure light	2	50	4	400
Centrifuge	1	110	2	220
Electric microscope	1	30	2	60
Fetal heart monitor	1	3	2	6
Oxygen concentrator	1	200	4	800
Portable ultrasound	1	28	1	28
Suction apparatus	1	185	5	925
			Total	**36,046**
			Peak load	**3,600 W**

Estimated system size for improved PHC

PRIMARY LEVEL

Type 2: primary health centre

- Mid-level, local referral services and emergency care
- Antenatal/postnatal care, higher-risk pregnancy delivery, newborn care
- IUD insertion, nutrition assessment, malaria treatment and other curative care
- Injectable immunization and STI treatment, measles treatment
- Operating 24 hours
- Standard 13 rooms and 2 units staff accommodation
- 10 staff
- Serving between 10,000 to 20,000 people

Solar PV

Between 5kWp to 10kWp

Battery bank

Between 36kWh and 72kWh with 1 day autonomy

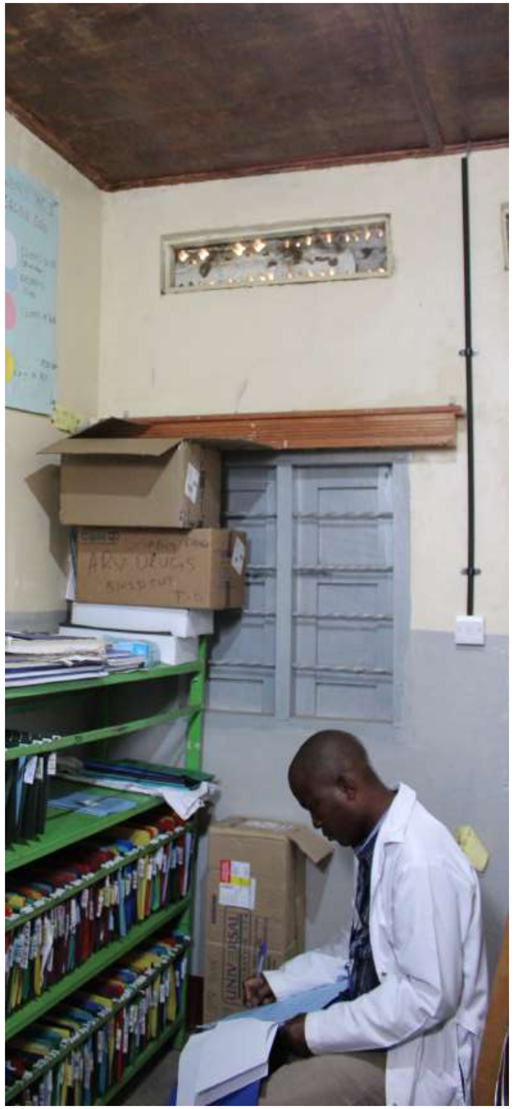
Inverter

Approx. 5KVA factoring in 30% oversizing

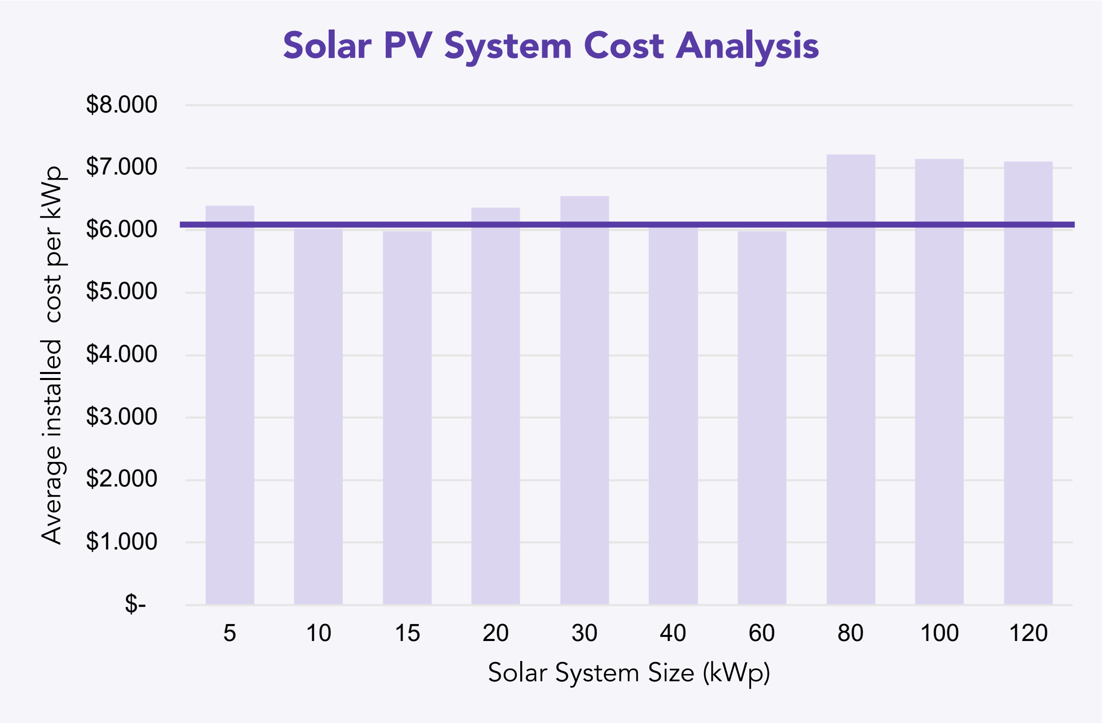
Diesel generator

Minimum of 10kVA

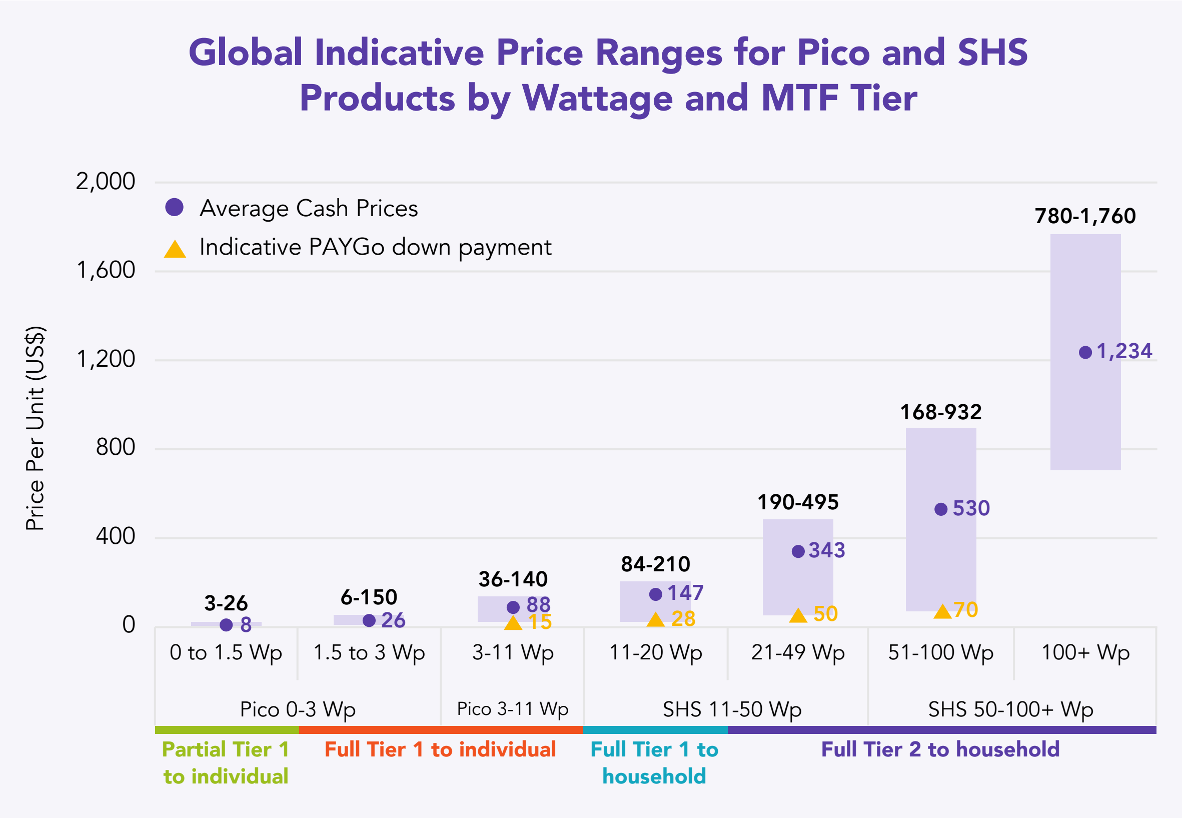
Further guidance on system design, component requirements, installation and safety, commissioning, operations and maintenance planning, service delivery and monitoring, and minimum energy service guidelines can be found in the Lighting Global document for off-grid solar system for public facilities



Installed Systems CAPEX Cost Analysis



Source: Own analysis of multiple project CAPEX data sets



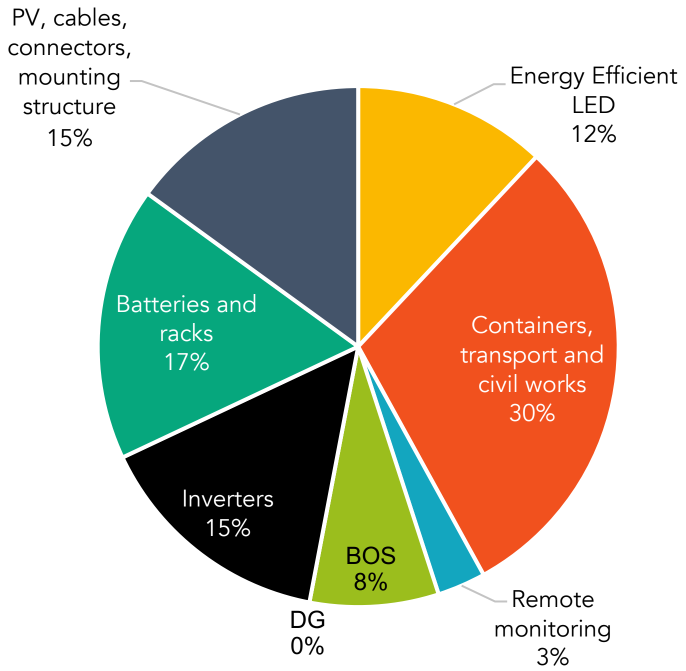
Source: GOGLA OGS Market Trend Report 2020 (Link)

System	Small Systems			Medium Hybrid Systems				Large Hybrid Systems		
Solar System Size (kWp)	5	10	15	20	30	40	60	80	100	120
Capacity use/hr over 24hrs (kWh)	1.25	2.08	3.13	4.17	5.83	7.50	10.83	8.33	10.42	12.50
MTF Electricity Tiers	⚡⚡⚡			⚡⚡⚡⚡				⚡⚡⚡⚡⚡		
Average cost/kWp installed	$6,388	$6,023	$5,977	$6,360	$6,541	$6,049	$5,985	$7,208	$7,141	$7,097

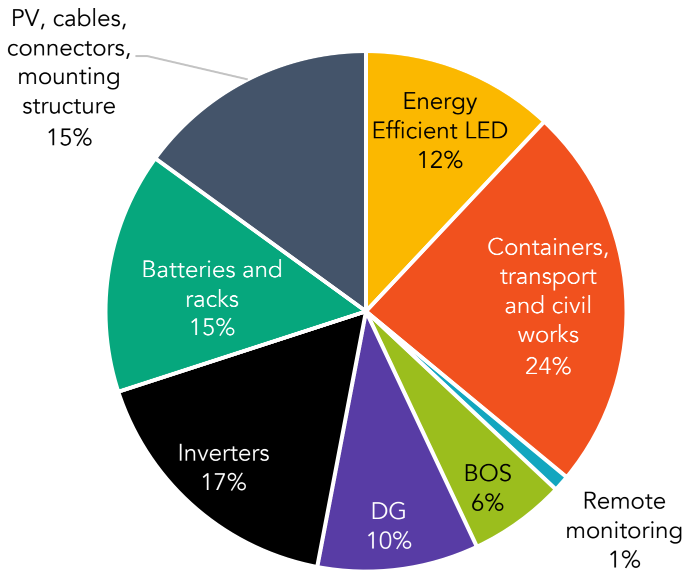
Source: Own analysis of multiple project CAPEX data sets

Installed Systems CAPEX Cost Analysis Composition

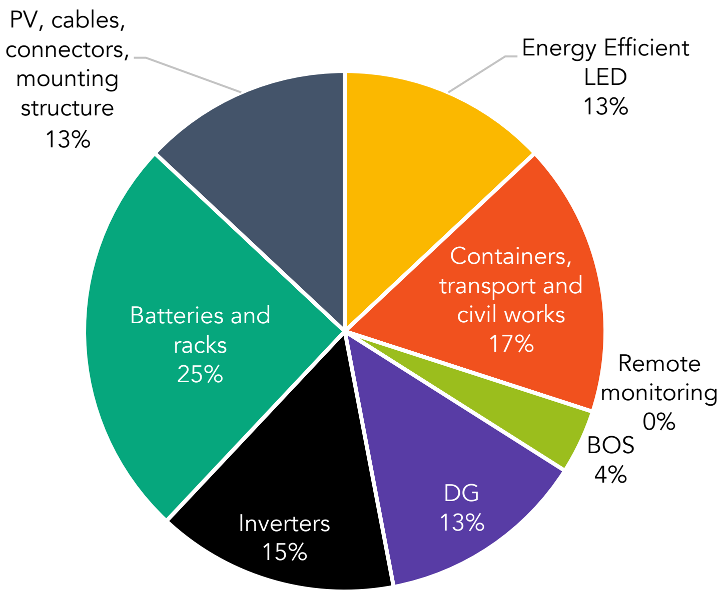
Small Systems



Medium Hybrid Systems



Large Hybrid Systems

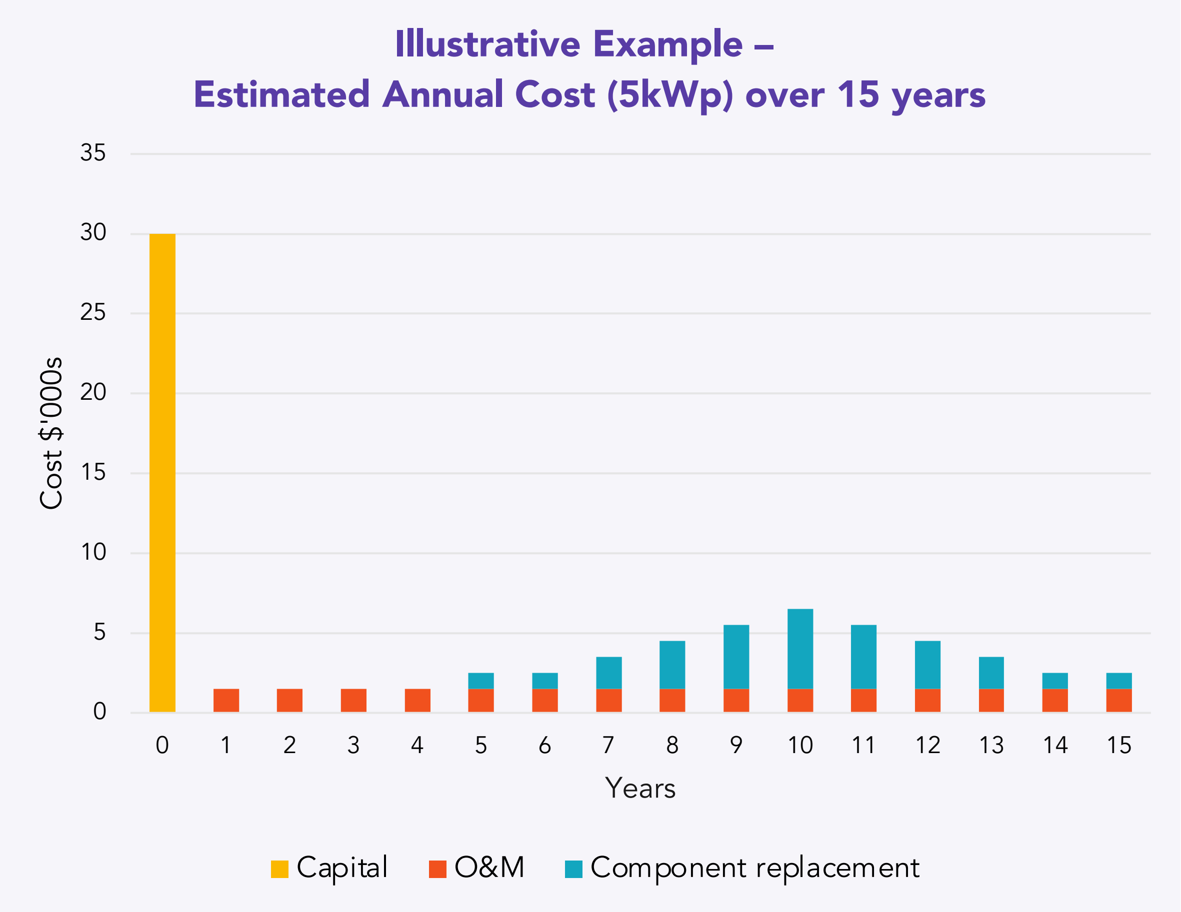


Analysis from multiple projects show that on average:

- Solar PV panels, cables, connectors and mounting structure costs account for 13% - 15% of total system costs.
- Battery bank and racks account 15% - 25% of total system costs
- Inverters account for 15% -17% of total system costs.
- Diesel generators account for 10% - 13% of total system costs.
- Balance of systems including cables, safety gears, AC distribution boxes account for 4% - 8% of total system costs.
- Remote monitoring accounts for 1% - 3% of total system costs
- Transportation, civil works and containers for the systems account for 17% -30% of total system costs.
- Energy efficient lights retrofit account for 12% - 13% of total system costs.
- Note that the estimates may vary depending on system design, technology options as well as distribution assets costs in the case of mini-grids.

CAPEX and OPEX Estimates

- **CAPEX** cost analysis comprising of several data sources, across various projects reveal that **average installed cost per kWp for solar PV-battery generation assets is between $5.3 to $6.5/Wp, and $6.5/Wp to $8/Wp for solar PV-battery-diesel gen hybrid systems.**
  - This is consistent with SEforALL's IEP system cost estimates for Tier 2 and Tier 3 range at $6/Wp (residential).
  - For solar hybrid containerized mini-grid systems, installed CAPEX costs for 6 – 24kW systems cost on average $8/Wp and estimate for larger system sizes closer to 50kW would cost between $4.7 to $5.7/Wp. (Bloomberg, SEforALL Mini-grids Market Report 2020).
  - **Note:** the estimated installed CAPEX may vary depending on system design, component technology option e.g. lithium versus lead acid batteries, quality, size and economies of scale, as well as distribution assets costs in the case of mini-grids
- **OPEX costs** are assumed to be **5%** per year for **standalone systems** and **35%** of total lifetime cost of the system **for hybrid mini-grid systems** (lower without diesel generator).
- Systems are assumed to have a 15-year lifespan.
- Replacements for inverter and batteries are estimated to occur in year 10, at 15% of initial capital cost.



Additional Technology Considerations

Standards

- Electrical wiring of the health facility needs to be up to the NEMSA standards.
- Component selection for health facility electrification need to adhere to the SON Solar PV Components Standards for panels, batteries, charge controllers, inverters, meters for quality assurance, as well as NEMSA standards when installed.
- Warranties for components need to be long-term (5 years and beyond).
- End of life disposal protocols for electronics and used batteries such as recycling guidelines as prescribed by Ministry of Environment - NESREA, ARBR need to be adhered to and incorporated into project implementation agreements for example.
- Ministry of Environment with support of GIZ have also developed **Environmental and Social Impact Assessment (ESIA) Guidelines for Mini-grids.**
- Most projects or investors have outlined specifications on ESIAs, or Environmental and Social Management Systems (ESMS) as may be required. Typically adhere to **country legislation, IFC Environmental and Social Performance Standards, EIB standards, and/or Sustainability principles advocated by the UN Global Compact.**

Energy efficiency

- Retrofits for typical fixtures such lights, fans, refrigerators, air-conditioners, water pumps as a first step before transitioning to solar PV electricity supply.
- Tamper proof load limiters may need to be incorporated in system design to safeguard system performance integrity.
- Trainings on load management and behavioral use of electricity required for PHC staff and public infrastructure facility managers.

Findings and recommendations

Situation

- Framing HFE energy needs according to the different types of facilities is challenging as pre-defined minimum standards for health facilities do not always apply (according to stakeholder interviews); energy needs load profiles can vary significantly based on the facility size and services offered.
- Mapping health facility energy consumption profile to ESMAP MTF is also subjective as the framework was developed for households.

Findings, gaps and opportunities

Technology types

- The two prominent solar PV technologies are standalone systems or mini-grids:
    - Standalone solar PV systems are more suited to PHC electrification in terms of dedicated service provision, cost and affordability for locations without access to electricity and where mini-grids are not already present.
    - Mini-grids can serve PHC electrification if the intended deployment is primarily driven by other productive anchor customers within the community.

Sizing

- Suitable system sizes for typical Type 2 PHCs, systems between 5kWp and 10kWp to adequately supply electricity for estimated peak load of 3.6 kW and an average approximate load of 1.5kW over a 24-hour period.

Gaps and opportunities

- Standards for electrical wiring, components, installations, and ESIAs need to be adopted for HFE.
- Energy efficiency measures need to be designed into programme interventions from design phase.
- Installed cost of $6/Wp was derived from analysis of multiple aggregated project cost datasets and recent industry reports.
- To power 10,000 Type 2 PHCs in the next 5 years and keep power solutions operational for 15 years, it is estimated that for a minimum sized system of 5kWp, a total of $525m (CAPEX of $300m and OPEX of $225m) would be required over the next 15 years. This excludes project development and technical assistance costs.

Recommendations

- Standards and energy efficiency measures are outlined as additional considerations that can significantly determine the performance, lifespan and sustainability outcomes of installed systems.
- Mechanisms for funding or contributing towards CAPEX and OPEX of solar systems over the project lifecycle need to be provided for in HF revitalization budgets and HFE intervention plans for technical sustainability.
- Capacity building for local HF staff needs to be prioritized for first level maintenance and troubleshooting especially for systems without remote monitoring.

About SEforALL

Sustainable Energy for All (SEforALL) is an international organization that works in partnership with the United Nations and leaders in government, the private sector, financial institutions, civil society and philanthropies to drive faster action towards the achievement of Sustainable Development Goal 7 (SDG7) – access to affordable, reliable, sustainable and modern energy for all by 2030 – in line with the Paris Agreement on climate.

We work to ensure a clean energy transition that leaves no one behind and brings new opportunities for everyone to fulfil their potential.

About Power Africa

Power Africa is a U.S. government-led initiative that addresses one of the most pressing challenges to sustainable economic growth and development in Sub-Saharan Africa: access to electrical power. Power Africa provides coordinated support from the U.S. public and private sectors to add cleaner, more efficient electricity generation capacity, which benefits residents and businesses across the continent.

In support of Power Africa, USTDA provides critical early-stage planning to spur new power generation, and transmission and distribution infrastructure. These activities support a range of energy development and deployment from power generation to grid modernization, which increase efficiency and improve access.

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Contact us to learn more

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