## Stand-alone PV System Design Tool and 4 Example Site Designs

**Developed by the Schatz Energy Research Center at Humboldt State University**
**September 2021**

This Stand-alone PV System Design Tool an excel-based template that is intended to create initial designs of off-grid, stand-alone PV power systems for health care facilities, schools and other public facilities. This tool only considers PV-battery systems, and does not include designs for PV-diesel hybrid systems or grid-connected systems. This tool is intended for project managers and engineers to simplify the design process for such systems during the development of procurement documents. The tool was prepared under the World Bank ROGEAP program and can be used in conjunction with the "Requirements and Guidelines for Installation of Off-grid Solar Systems for Public Facilities" quality assurance framework (available here: https://www.lightingafrica.org/publication/requirements-and-guidelines-for-installation-of-off-grid-solar-systems-for-public-facilities/).

The tool sizes the PV-battery system for reliability, by designing to ensure the design load is met for a specified number of days of autonomy in the month with the lowest solar radiation. Assumptions regarding efficiency loss throughout the system are included to ensure an adequate system size. Flexibility is built into the tool to allow the user to enter detailed information about specific sites and expected loads, or use default values in the absence of detailed information. Additionally, all assumptions and key inputs can be updated by the user to ensure the tool can be adapted for different circumstances.

Detailed guidance on how to use the tool is include on each tab of the tool. Users should start at the “General Site Info” tab. Four example designs produced by the tool are presented below with an explanation about each system.

## Example Designs

The four designs below cover a variety of facility types, service levels, and system sizes ranging from 3 kW to 20 kW. The designs are based on a health clinic and school in the town of Gudupe in central Nigeria, though some details for this site have been embellished for instructive purposes. Each design includes a cover page that describes basic information about the site, a solar resource page that describes the solar data used for the site, including the available solar energy at the tilt of the proposed array(s), and a system design summary page that describes the sizing of the main components of the system and lists the loads that were considered in the design.

The system summary tab also lists key assumptions that were made in the design process, such as days of autonomy and efficiency losses. If information is available about potential roof-mounted locations for a PV installation at the site, the sizing of the roof-mounted array is presented. If no information is available, only the sizing of an "ideal" pole mounted array is presented. (This is labeled as "ideal" because it is placed at the best tilt and azimuth angle to maximize solar energy in the worst-case month of the year, whereas the roof mounts have a pre-determined fixed tilt and direction).

In addition to helping with initial scoping and costing of a project, designs similar to these created by the Stand-alone PV System Design Tool could be included in bid specifications to provide bidders with more information about the sites and anticipated system sizes.

**Example Design #1: "Basic" School**

This system is for a school that is electrifying only two classrooms and an office with minimal services including lighting, fans, mobile phone charging, and security lighting. The site has 3 building with multiple rooms in each, but only three rooms would be electrified, while outdoor security lighting would be provided for the entire site. The intention is that these services can enable schools to offer evening/night classes and provide additional support for teachers or staff to prepare lessons. This system is relatively small with an array of approximately 3 kW that could be pole-mounted or installed on a single roof face. When designing this system the minimal loads recommended for a "basic" school in Section 11.1 of the "Requirements and Guidelines for Installation of Off-grid Solar Systems for Public Facilities" were used. The recommended numbers of lights and fans were based on the size of each room and the number of appliances needed to provide a given service level for each space (162 $lm/m^2$ for lights and 1 70 W fan per 100 $m^3$ for fans).

**Site Overview**

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | LEA Primary School Gudupe | Primary school |

| | | | |
|---|---|---|---|
| **Latitude (°W)** | 9.18476 | **Number of buildings** | 3 |
| **Longitude (°N)** | 7.46742 | **Number of staff** | 5 |
| | | **Number of students** | 210 |
| | | **Open hours per day** | 5 |
| | | **Staff housing on site?** | No |

**EXISTING SOURCES OF ELECTRICITY**

| Source | Power (W) | Voltage (V) | Hours available per day | Functional? | Notes |
|---|---|---|---|---|---|
| None | -- | -- | -- | -- | |

**DESCRIPTION OF EXISTING WIRING and APPLIANCES (if applicable)**

The site has one 100 A service panel that is wired to service all exisiting loads if a generation source were present. The exisiting electrical infrustructure is assessed to be in good condition. The exisiting service panel is full; an upgrade would be required if additional loads were added. The site has 9 ceiling fans and 10 tubelights installed, though all should be upgraded for energy efficiency.

**NOTES ON SITE**

No exisiting generation sources are currently available at site. The school is adjacent to a clinic. The community as a whole is in demand of a borehole. The school site has good solar access. The school desires to add working security lighting.

**MAP (google.com/maps)**


**SITE IMAGE (google.com/earth or from site visit)**


**Site Overview**

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | LEA Primary School Gudupe | Primary school |

| **Month** | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insolation incident on a horizontal surface without shading (kWh/m2/day) | 5.88 | 6.09 | 6.27 | 6.06 | 5.58 | 5.06 | 4.44 | 4.19 | 4.73 | 5.31 | 5.98 | 5.86 |
| Surface Albedo | 0.19 | 0.2 | 0.21 | 0.21 | 0.21 | 0.22 | 0.23 | 0.23 | 0.22 | 0.21 | 0.2 | 0.19 |
| **Ideal Pole-mount** | Tilt [°]: | | 11 | | | Azimuth [°]: | | -180 | | | | |
| % not shaded (default 100%) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Insolation incident on the specified tilted surface and surface azimuth angles and considering shading (kWh/m2/day) | 5.16 | 5.55 | 5.96 | 5.99 | 5.66 | 5.18 | 4.50 | 4.17 | 4.58 | 4.95 | 5.30 | 5.07 |
| Minimum solar resource (kWh/m2/day) | 4.17 | | | | | | | | | | | |
| **Block 1 South-facing roof** | Tilt [°]: | | 37 | | | Azimuth [°]: | | -25 | | | | |
| % not shaded (default 100%) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Insolation incident on the specified tilted surface and surface azimuth angles and considering shading (kWh/m2/day) | 6.64 | 6.30 | 5.85 | 5.07 | 4.30 | 3.80 | 3.48 | 3.50 | 4.24 | 5.25 | 6.62 | 6.81 |
| Minimum solar resource (kWh/m2/day) | 3.48 | | | | | | | | | | | |

**System Design Summary**

Design type: Basic

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | LEA Primary School Gudupe | Primary school |

| PV | |
|---|---|
| *Ideal Pole Mount:* | |
| PV Size (kW) | 2.56 |
| PV array size ($m^2$) | 15 |
| Tilt (°) | 11 |
| *Roof Mount:* | |
| PV Size (kW) | 3.07 |
| PV array size ($m^2$) | 18.1 |
| Average Tilt (°) | 37 |
| System efficiency (%) | 45% |
| Module efficiency (%) | 17% |
| PV Oversize factor | 1.2 |

| Inverter and Battery | |
|---|---|
| Max power (kVA) | 1.0 |
| Max power (surge, kVA) | 1.0 |
| Max current (A) | 4.1 |
| AC Voltage (V) | 230 |
| Battery Size (Ah) | 845 |
| Battery Type | Lead-acid |
| Battery Voltage (V) | 48 |
| Days of Autonomy | 3 |
| Depth of Discharge (%) | 50% |
| Max Discharge Rate (h) | 10 |

| Loads and Assumptions | |
|---|---|
| Estimated Load (kWh/day) | 3.65 |
| Load growth factor | 1.1 |
| Design Load (kWh/day) | 4.02 |

Existing Loads that are excluded from the system:

This design only provides power for 3 rooms and outdoor lighting as shown below. All other existing appliances are excluded.

| Load | Qty | Power per load (W) | Total Power (W) | Average Use (Hours) | Notes |
|---|---|---|---|---|---|
| Fan | 5 | 70 | 350 | 4.0 | Fans only included in 3 rooms |
| Lighting (general interior) | 22 | 10 | 220 | 4.0 | Lights only included in 3 rooms |
| Lighting (outdoor/security) | 12 | 10 | 120 | 10.0 | |
| Mobile Phones | 5 | 10 | 50 | 1.0 | |
| Remote Monitoring Platform | 1 | 5 | 5 | 24.0 | |
| | | | | | |

**Example Design #2: “Basic” Primary Health Center**

This system is for a small primary health clinic consisting of one main building and a separate building for staff quarters. When designing this system the minimal loads recommended for a “basic” primary health clinic in Section 11.1 of the “Requirements and Guidelines for Installation of Off-grid Solar Systems for Public Facilities” were used; these include general lighting, security lighting, fans, a procedural lamp, mobile phone charging, a fetal heart monitor and a portable ultrasound. The recommended array is approximately 7.5 kW for an ideal pole mount. This system was sized using the minimal information possible about a site, assuming that the designer only had access to the site location and approximate external dimensions of the site. The recommended numbers of lights and fans were based on the size of each building (using the same assumptions as in Design #1). Roof areas were not considered for the design, so the “Roof mount” section of the Design Summary is left blank and no solar data is presented for available roof spaces.

**Site Overview**

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | Gudupe PHC | PHC |

| | | | |
|---|---|---|---|
| **Latitude (°W)** | 9.18484 | **Number of buildings** | 2 |
| **Longitude (°N)** | 7.46855 | **Number of staff** | 3 |
| | | **Number of patients per day** | 3 |
| | | **Open hours per day** | 24 |
| | | **Staff housing on site?** | Yes |

**EXISTING SOURCES OF ELECTRICITY**

| Source | Power (W) | Voltage (V) | Hours available per day | Functional? | Notes |
|---|---|---|---|---|---|
| Generator (Fuel Operated) | 900 | 230 | 2 | Yes | Generator supplies power to staff housing only. |

**DESCRIPTION OF EXISTING WIRING and APPLIANCES (if applicable)**

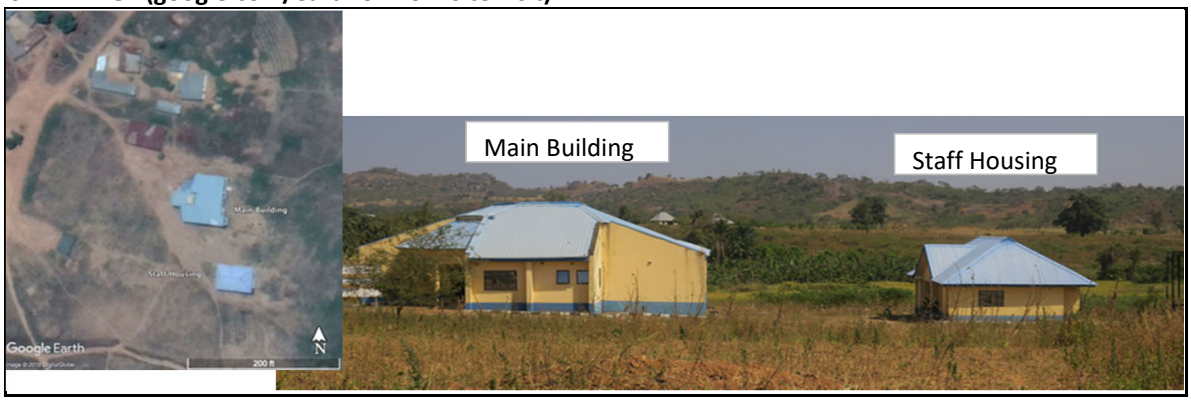
There is a 100 A service panel in the main building and a separate 100 A service panel in the staff housing; the cable size is adequate. Half conduit system wiring, all electrical appliances are wired. The exisiting service panels are full; an upgrade would be required if additional loads were added. The site has 20 ceiling fans and 85 fluorescent lights already installed.

**NOTES ON SITE**

The 900 W generator is used only for the staff housing; there is no electricity source for the main building and the main building service panel has never been energized. The clinic is adjacent to the Gudupe LEA school site and there is good solar access.

**MAP (google.com/maps)**


**SITE IMAGE (google.com/earth or from site visit)**



**Site Overview**

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | Gudupe PHC | PHC |

| **Month** | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insolation incident on a horizontal surface without shading (kWh/m2/day) | 5.88 | 6.09 | 6.27 | 6.06 | 5.58 | 5.06 | 4.44 | 4.19 | 4.73 | 5.31 | 5.98 | 5.86 |
| Surface Albedo | 0.19 | 0.2 | 0.21 | 0.21 | 0.21 | 0.22 | 0.23 | 0.23 | 0.22 | 0.21 | 0.2 | 0.19 |
| **Ideal Pole-mount** | Tilt [°]: | | 11 | | | Azimuth [°]: | | -180 | | | | |
| % not shaded (default 100%) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Insolation incident on the specified tilted surface and surface azimuth angles and considering shading (kWh/m2/day) | 5.16 | 5.55 | 5.96 | 5.99 | 5.66 | 5.18 | 4.50 | 4.17 | 4.58 | 4.95 | 5.30 | 5.07 |
| Minimum solar resource (kWh/m2/day) | 4.17 | | | | | | | | | | | |

**System Design Summary**

Design type: Basic

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | Gudupe PHC | PHC |

| PV | |
|---|---|
| *Ideal Pole Mount:* | |
| PV Size (kW) | 7.42 |
| PV array size ($m^2$) | 44 |
| Tilt (°) | 11 |
| | |
| *Roof Mount:* | |
| PV Size (kW) | -- |
| PV array size ($m^2$) | -- |
| Average Tilt (°) | -- |
| | |
| System efficiency (%) | 45% |
| Module efficiency (%) | 17% |
| PV Oversize factor | 1.2 |

| Inverter and Battery | |
|---|---|
| Max power (kVA) | 2.6 |
| Max power (surge, kVA) | 2.7 |
| Max current (A) | 11.4 |
| AC Voltage (V) | 230 |
| | |
| Battery Size (Ah) | 2446 |
| Battery Type | Lead-acid |
| Battery Voltage (V) | 48 |
| Days of Autonomy | 3 |
| Depth of Discharge (%) | 50% |
| Max Discharge Rate (h) | 10 |

| Loads and Assumptions | |
|---|---|
| Estimated Load (kWh/day) | 10.6 |
| Load growth factor | 1.1 |
| Design Load (kWh/day) | 11.6 |

Existing Loads that are excluded from the system:

Water heaters

| Load | Qty | Power per load (W) | Total Power (W) | Average Use (Hours) | Notes |
|---|---|---|---|---|---|
| Fan | 15 | 70 | 1050 | 6.0 | |
| Fetal Heart Monitor | 1 | 3 | 3 | 2.0 | |
| Lighting (general interior) | 83 | 10 | 830 | 4.0 | |
| Lighting (outdoor/security) | 8 | 10 | 80 | 10.0 | |
| Lighting (Procedure lamp - LED) | 1 | 50 | 50 | 2.0 | |
| Mobile Phones | 3 | 10 | 30 | 1.0 | |
| Portable Ultrasound | 1 | 28 | 28 | 1.0 | |
| Remote Monitoring Platform | 1 | 5 | 5 | 24.0 | |
| | | | | | |

**Example Design #3: "Improved" Primary Health Center**

This design is for the same health clinic as presented in Design #2, but in this case, the recommended loads and additional hours of use for an "improved" primary health clinic in Section 11.1 of the "Requirements and Guidelines for Installation of Off-grid Solar Systems for Public Facilities" were used. These include general lighting, security lighting, fans, a procedural lamp, mobile phone charging, a fetal heart monitor, a portable ultrasound AND an oxygen concentrator, general purpose refrigerator/freezer, laptop computer and USB modem. Additionally, to better accommodate the staff quarters two TVs are included. When this site was visited, two DVD players were present, so these were also considered in the total load estimate. The auditors also notices electric water heaters at the site; however, these require a very high power demand, so were excluded from the loads considered in the system design, and this exclusion would need to be discussed with the client and users at the site. More detailed interior dimensions measured at the site were used when creating this design, so the recommended numbers of fans and interior lights differ slightly from those presented in Design #2, but presumably, the recommended numbers are more accurate in this design.

The ideal pole-mounted PV array is 13 kW, while a roof-mounted array would require a slightly larger 13.9 kW array if installed at the steeper 26° angle of the east-facing roof.

In addition to a system design for the main system (which covers both the main building and the staff quarters), a separate design was prepared for a smaller PV+battery system that could support a vaccine refrigerator if a functional vaccine refrigerator with no power source was present at the site. In general, vaccine refrigerators should not rely on power from the main PV system and should instead have a dedicated power system to ensure their reliability 24/7. In general, most new installations of vaccine refrigerators will be solar direct drive (battery-less) based on their increased reliability and longevity, and this tool is not intended to design power systems for solar direct drive refrigerators. Solar direct drive refrigerators should use manufacturer's calculations for sizing.

**Site Overview**

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | Gudupe PHC | PHC |

| | | | |
|---|---|---|---|
| **Latitude (°W)** | 9.18484 | **Number of buildings** | 2 |
| **Longitude (°N)** | 7.46855 | **Number of staff** | 3 |
| | | **Number of patients per day** | 3 |
| | | **Open hours per day** | 24 |
| | | **Staff housing on site?** | Yes |

**EXISTING SOURCES OF ELECTRICITY**

| Source | Power (W) | Voltage (V) | Hours available per day | Functional? | Notes |
|---|---|---|---|---|---|
| Generator (Fuel Operated) | 900 | 230 | 2 | Yes | Generator supplies power to staff housing only. |

**DESCRIPTION OF EXISTING WIRING and APPLIANCES (if applicable)**

There is a 100 A service panel in the main building and a separate 100 A service panel in the staff housing; the cable size is adequate. Half conduit system wiring, all electrical appliances are wired. The exisiting service panels are full; an upgrade would be required if additional loads were added. The site has 20 ceiling fans and 85 fluorescent lights already installed.

**NOTES ON SITE**

The 900 W generator is used only for the staff housing; there is no electricity source for the main building and the main building service panel has never been energized. The clinic is adjacent to the Gudupe LEA school site and there is good solar access.

**MAP (google.com/maps)**


**SITE IMAGE (google.com/earth or from site visit)**


**Site Overview**

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | Gudupe PHC | PHC |

| **Month** | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insolation incident on a horizontal surface without shading (kWh/m2/day) | 5.88 | 6.09 | 6.27 | 6.06 | 5.58 | 5.06 | 4.44 | 4.19 | 4.73 | 5.31 | 5.98 | 5.86 |
| Surface Albedo | 0.19 | 0.2 | 0.21 | 0.21 | 0.21 | 0.22 | 0.23 | 0.23 | 0.22 | 0.21 | 0.2 | 0.19 |
| **Ideal Pole-mount** | Tilt [°]: | | 11 | | | Azimuth [°]: | | -180 | | | | |
| % not shaded (default 100%) | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% |
| Insolation incident on the specified tilted surface and surface azimuth angles and considering shading (kWh/m2/day) | 4.90 | 5.28 | 5.66 | 5.69 | 5.38 | 4.92 | 4.28 | 3.96 | 4.36 | 4.70 | 5.03 | 4.82 |
| Minimum solar resource (kWh/m2/day) | 3.96 | | | | | | | | | | | |
| **Main building (east-facing)** | Tilt [°]: | | 26 | | | Azimuth [°]: | | 84 | | | | |
| % not shaded (default 100%) | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% |
| Insolation incident on the specified tilted surface and surface azimuth angles and considering shading (kWh/m2/day) | 5.36 | 5.51 | 5.62 | 5.38 | 4.93 | 4.46 | 3.93 | 3.72 | 4.22 | 4.78 | 5.45 | 5.36 |
| Minimum solar resource (kWh/m2/day) | 3.72 | | | | | | | | | | | |

**System Design Summary**

Design type: Improved

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | Gudupe PHC | PHC |

| PV | |
|---|---|
| *Ideal Pole Mount:* | |
| PV Size (kW) | 13.0 |
| PV array size ($m^2$) | 77 |
| Tilt (°) | 11 |
| *Roof Mount:* | |
| PV Size (kW) | 13.9 |
| PV array size ($m^2$) | 81.5 |
| Average Tilt (°) | 26.4 |
| System efficiency (%) | 45% |
| Module efficiency (%) | 17% |
| PV Oversize factor | 1.2 |

| Inverter and Battery | |
|---|---|
| Max power (kVA) | 3.4 |
| Max power (surge, kVA) | 3.8 |
| Max current (A) | 14.8 |
| AC Voltage (V) | 230 |
| Battery Size (Ah) | 4079 |
| Battery Type | Lead-acid |
| Battery Voltage (V) | 48 |
| Days of Autonomy | 3 |
| Depth of Discharge (%) | 50% |
| Max Discharge Rate (h) | 10 |

| Loads and Assumptions | |
|---|---|
| Estimated Load (kWh/day) | 17.6 |
| Load growth factor | 1.1 |
| Design Load (kWh/day) | 19.4 |

Existing Loads that are excluded from the system:

Water heaters

| Load | Qty | Power per load (W) | Total Power (W) | Average Use (Hours) | Notes |
|---|---|---|---|---|---|
| Computer (laptop) | 1 | 60 | 60 | 6.0 | |
| DVD player | 2 | 20 | 40 | 1.0 | |
| Fan | 16 | 70 | 1120 | 9.0 | |
| Fetal Heart Monitor | 1 | 3 | 3 | 2.0 | |
| Lighting (general interior) | 73 | 10 | 730 | 6.0 | |
| Lighting (outdoor/security) | 8 | 10 | 80 | 10.0 | |
| Lighting (Procedure lamp - LED) | 1 | 50 | 50 | 4.0 | |
| Mobile Phones | 3 | 10 | 30 | 1.0 | |
| Oxygen Concentrator | 1 | 200 | 200 | 4.0 | |
| Portable Ultrasound | 1 | 28 | 28 | 1.0 | |
| Refrigerator/Freezer (General purpose) | 1 | 130 | 130 | 9.4 | |
| Remote Monitoring Platform | 1 | 5 | 5 | 24.0 | |
| Television | 2 | 100 | 200 | 4.0 | |
| USB Modem | 1 | 2.5 | 2.5 | 6.0 | |

**System Design Summary**

Design type: Separate PV + Battery System for Vaccine Refrigerator

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | Gudupe PHC | PHC |

| PV | |
|---|---|
| *Ideal Pole Mount:* | |
| PV Size (kW) | 0.89 |
| PV array size ($m^2$) | 5 |
| Tilt (°) | 11 |
| | |
| System efficiency (%) | 45% |
| Module efficiency (%) | 17% |
| PV Oversize factor | 1.2 |

| Inverter and Battery | |
|---|---|
| Max power (kW) | 0.08 |
| Max power (surge, kW) | 0.17 |
| Max current (A) | 0.33 |
| Voltage (V) | 230 AC |
| | |
| Battery Size (Ah) | 926 |
| Battery Type | Lead-acid |
| Battery Voltage (V) | 24 |
| Days of Autonomy | 5 |
| Depth of Discharge (%) | 50% |
| Max Discharge Rate (h) | 10 |

| Loads and Assumptions | |
|---|---|
| Estimated Load (kWh/day) | 1.2 |
| Safety Factor | 1.1 |
| Design Load (kWh/day) | 1.32 |

Notes:

This additional, separate system is solely for powering the facility's PV battery vaccine refrigerator. [Solar direct drive refrigerators should use manufacturer's calculations for sizing.]

**Example Design #4: “Improved” School**

This design is for the same primary school as presented in Design #1, but in this case, the recommended loads and additional hours of use for an “improved” school in Section 11.1 of the “Requirements and Guidelines for Installation of Off-grid Solar Systems for Public Facilities” were used. These include general lighting, fans, mobile phone charging, security lighting AND a laptop computer, USB modem, and printer. Further, though not suggested as part of an “improved” system in Section 11.1, additional loads were included to show potential uses of a solar system at a school. These include a fleet of 30 palmtop student computers for introductory computer labs, a projector for instruction and a laminator for producing student ID badges and instruction materials.

For this “improved” design, the dimensions of all rooms in all three buildings were considered when estimating the total numbers of lights and fans. This results in a much higher estimated load than the “basic” 3-room system in Design #1.

The ideal pole-mounted PV array is sized as 17 kW, while a roof-mounted system would require installing modules on three different roof faces and would require a 20 kW array to provide the same daily energy.

**Site Overview**

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | LEA Primary School Gudupe | Primary school |

| | | | |
|---|---|---|---|
| **Latitude (°W)** | 9.18476 | **Number of buildings** | 3 |
| **Longitude (°N)** | 7.46742 | **Number of staff** | 5 |
| | | **Number of students** | 210 |
| | | **Open hours per day** | 5 |
| | | **Staff housing on site?** | No |

**EXISTING SOURCES OF ELECTRICITY**

| Source | Power (W) | Voltage (V) | Hours available per day | Functional? | Notes |
|---|---|---|---|---|---|
| None | -- | -- | -- | -- | |

**DESCRIPTION OF EXISTING WIRING and APPLIANCES (if applicable)**

The site has one 100 A service panel that is wired to service all exisiting loads if a generation source were present. The exisiting electrical infrustructure is assessed to be in good condition. The exisiting service panel is full; an upgrade would be required if additional loads were added. The site has 9 ceiling fans and 10 tubelights installed, though all should be upgraded for energy efficiency.

**NOTES ON SITE**

No exisiting generation sources are currently available at site. The school is adjacent to a clinic. The community as a whole is in demand of a borehole. The school site has good solar access. The school desires to add working security lighting.

**MAP (google.com/maps)**


**SITE IMAGE (google.com/earth or from site visit)**


**Site Overview**

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | LEA Primary School Gudupe | Primary school |

| **Month** | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Insolation incident on a horizontal surface without shading (kWh/m2/day) | 5.88 | 6.09 | 6.27 | 6.06 | 5.58 | 5.06 | 4.44 | 4.19 | 4.73 | 5.31 | 5.98 | 5.86 |
| Surface Albedo | 0.19 | 0.2 | 0.21 | 0.21 | 0.21 | 0.22 | 0.23 | 0.23 | 0.22 | 0.21 | 0.2 | 0.19 |
| **Ideal Pole-mount** | Tilt [°]: | | 11 | | | Azimuth [°]: | | -180 | | | | |
| % not shaded (default 100%) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Insolation incident on the specified tilted surface and surface azimuth angles and considering shading (kWh/m2/day) | 5.16 | 5.55 | 5.96 | 5.99 | 5.66 | 5.18 | 4.50 | 4.17 | 4.58 | 4.95 | 5.30 | 5.07 |
| Minimum solar resource (kWh/m2/day) | 4.17 | | | | | | | | | | | |
| **Block 1 South-facing roof** | Tilt [°]: | | 37 | | | Azimuth [°]: | | -25 | | | | |
| % not shaded (default 100%) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Insolation incident on the specified tilted surface and surface azimuth angles and considering shading (kWh/m2/day) | 6.64 | 6.30 | 5.85 | 5.07 | 4.30 | 3.80 | 3.48 | 3.50 | 4.24 | 5.25 | 6.62 | 6.81 |
| Minimum solar resource (kWh/m2/day) | 3.48 | | | | | | | | | | | |
| **Block 2 East-facing roof** | Tilt [°]: | | 37 | | | Azimuth [°]: | | 57 | | | | |
| % not shaded (default 100%) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Insolation incident on the specified tilted surface and surface azimuth angles and considering shading (kWh/m2/day) | 6.07 | 5.96 | 5.78 | 5.25 | 4.62 | 4.13 | 3.71 | 3.62 | 4.25 | 5.06 | 6.10 | 6.16 |
| Minimum solar resource (kWh/m2/day) | 3.62 | | | | | | | | | | | |
| **Block 1 North-facing roof** | Tilt [°]: | | 37 | | | Azimuth [°]: | | 155 | | | | |
| % not shaded (default 100%) | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Insolation incident on the specified tilted surface and surface azimuth angles and considering shading (kWh/m2/day) | 3.46 | 4.71 | 5.44 | 5.84 | 5.76 | 5.34 | 4.55 | 4.07 | 4.29 | 4.34 | 4.25 | 3.87 |
| Minimum solar resource (kWh/m2/day) | 3.46 | | | | | | | | | | | |

**System Design Summary**

Design type: Improved

| Country | State | District | Facility Name | Facility Type |
|---|---|---|---|---|
| Nigeria | FCT | Bwari | LEA Primary School Gudupe | Primary school |

| PV | |
|---|---|
| *Ideal Pole Mount:* | |
| PV Size (kW) | 17.01 |
| PV array size ($m^2$) | 100 |
| Tilt (°) | 11 |
| *Roof Mount:* | |
| PV Size (kW) | 20.1 |
| PV array size ($m^2$) | 206 |
| Average Tilt (°) | 37 |
| System efficiency (%) | 45% |
| Module efficiency (%) | 17% |
| PV Oversize factor | 1.2 |

| Inverter and Battery | |
|---|---|
| Max power (kVA) | 5.5 |
| Max power (surge, kVA) | 5.6 |
| Max current (A) | 23.9 |
| AC Voltage (V) | 230 |
| Battery Size (Ah) | 5608 |
| Battery Type | Lead-acid |
| Battery Voltage (V) | 48 |
| Days of Autonomy | 3 |
| Depth of Discharge (%) | 50% |
| Max Discharge Rate (h) | 10 |

| Loads and Assumptions | |
|---|---|
| Estimated Load (kWh/day) | 24.2 |
| Load growth factor | 1.1 |
| Design Load (kWh/day) | 26.6 |

Existing Loads that are excluded from the system:

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| Load | Qty | Power per load (W) | Total Power (W) | Average Use (Hours) | Notes |
|---|---|---|---|---|---|
| Computer (laptop) | 1 | 60 | 60 | 6.0 | |
| Fan | 14 | 70 | 980 | 6.0 | |
| Laminator | 1 | 20 | 20 | 0.5 | |
| Lighting (general interior) | 63 | 10 | 630 | 6.0 | |
| Lighting (outdoor/security) | 12 | 10 | 120 | 10.0 | |
| Mobile Phones | 5 | 10 | 50 | 1.0 | |
| Palmtop Student Computers | 30 | 65 | 1950 | 6.0 | |
| Printer | 1 | 100 | 100 | 2.0 | |
| Projector | 1 | 150 | 150 | 6.0 | |
| Remote Monitoring Platform | 1 | 5 | 5 | 24.0 | |
| USB Modem | 1 | 2.5 | 2.5 | 6.0 | |