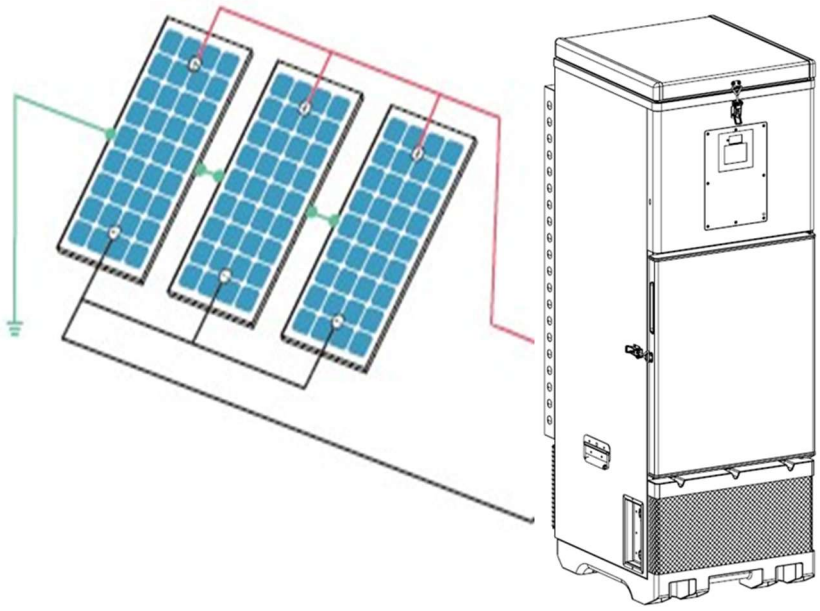
AUCMA

CFD-50 SDD MetaFridge™

Solar Power Kit Installation Manual



⚠ Please read the manual carefully before use

Keep the manual in a safe place for future reference

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Aucma CFD-50 SDD MetaFridge™ Solar Power Kit Installation Manual

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STEPS OF A SUCCESSFUL INSTALLATION

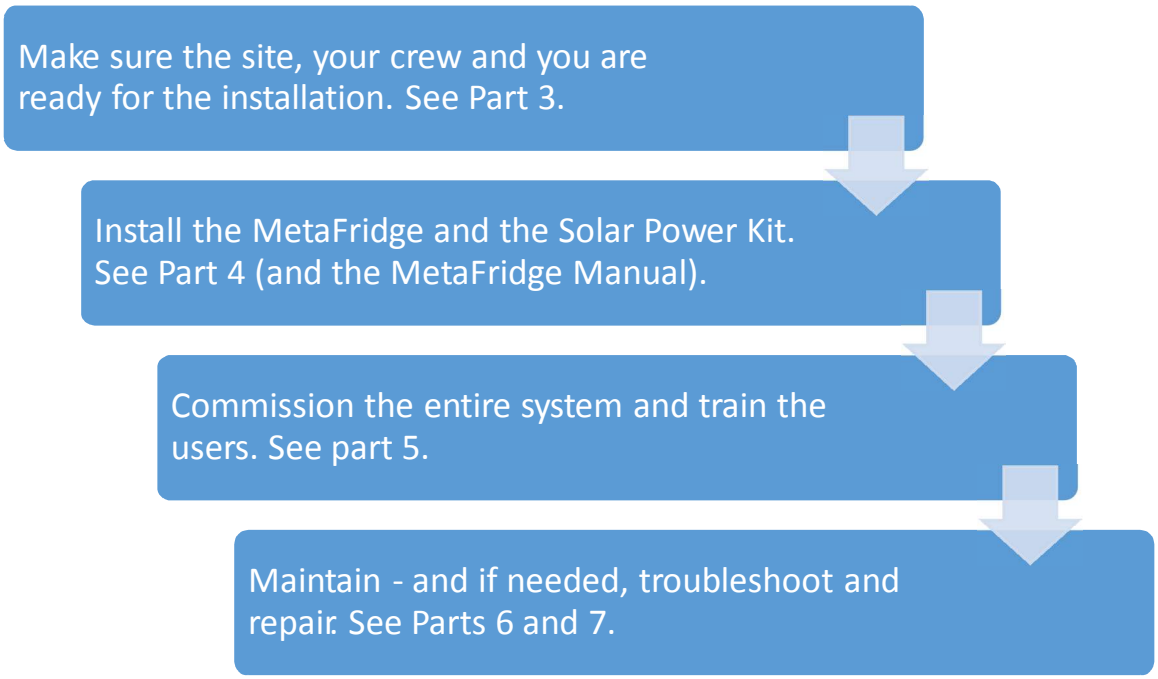
This manual will describe how to successfully install and sustain an Aucma CFD-50 SDD MetaFridge Solar Power Kit.

CFD-50 SDD MetaFridge has passed rigorous testing and is undergoing the final steps for prequalification by the World Health Organization's (WHO) Performance, Quality and Safety (PQS) program. CFD-50 SDD is listed in the WHO PQS Catalog with PQS code E003/098.

The Aucma Solar Power Kit complies with the WHO PQS E003 PV01.3 specification.

The Aucma Solar Power Kit is matched to the energy needs of the CFD-50 MetaFridge and you must follow these instructions to assure it will operate correctly for many years.

The general steps of a successful installation are to:



HOW TO USE THE MANUAL

First read the entire Manual.

Remember, always make safety your first priority.

The Aucma Solar Power Kit is complete and usually will have the necessary parts to complete an installation. However, each site is unique and may require a slightly different solution. Therefore, it is strongly recommended that before the installation have a qualified person visit the installation site to make sure the site is ready and all necessary parts, supplies and tools will be available on the site. Then the installation can be completed safely, correctly and in just one installation trip.

The Manual includes detailed Annexes where topics like Working Safely at Heights are described and helpful forms like the Site Assessment Worksheet and Installation Tool Checklist can be copied and used.

Please also refer to the Aucma CFD-50 SDD MetaFridge refrigerator manual and any component specifications included in the solar power kit (e.g. solar modules and mounting structure). If this Manual contradicts product specific instruction please use the product specific instructions and report the contradiction to Aucma at email: info@aucma.com.cn or website: www.aucmaglobal.com.cn.

ABBREVIATIONS

Ω – Ohms (resistance)
°C – degrees Celsius
DC – direct current electricity
°F – degrees Fahrenheit
Imp – solar electric current (amps) at maximum power point
Isc – solar electric short circuit current
LED – light emitting diode
PAHO – Pan American Health Organization
PQS – Performance, Quality and Safety program (WHO)
PV - photovoltaics
SDD – solar direct drive
UNICEF – United Nations Children's Fund
Vdc – volts (direct current)
Vmp – solar electric volts at maximum power point
Voc – solar electric open circuit voltage
W - Watts
WHO – World Health Organization

GLOSSARY

Acceptable temperature range – for vaccine storage is between +2°C and +8°C.

Autonomy – time in days that a solar refrigerator can maintain the vaccine between +2°C and +8°C acceptable temperature range under low sunlight conditions (e.g. rainy days, night).

Climate zone – the highest constant ambient temperature at which a WHO-prequalified vaccine refrigerator can maintain the vaccine storage compartment between +2°C and +8°C.

Continuity – a continuous path for conducting electricity.

Cool down time – time required for a WHO-prequalified vaccine refrigerator to first reach and sustain the acceptable temperature range between +2°C and +8°C.

Ground – connecting the metal components of the solar array to earth with an equipment grounding conductor (ground wire) to a grounding electrode (e.g. ground rod driven in the earth).

Minimum rated ambient temperature – the lowest constant ambient temperature at which a WHO-prequalified vaccine refrigerator can maintain the vaccine storage compartment between +2°C and +8°C.

Multi-meter – handheld electrical measuring device with settings for volts, amps, ohms (resistance) with other optional readings possible (e.g. temperature).

Open circuit – an electrical circuit which has no continuity and thus current cannot flow.

Open circuit voltage (Voc) – a solar module or array voltage specification that is measured with no load (amps). Because there is no current flowing, it is an open circuit.

Orientation – angle (degrees) a solar array faces in reference to the equator.

Parallel – method of connecting solar modules to increase current (amps) without increasing voltage. Positive terminals are all connected to each other and negative terminals are connected to each other.

Photovoltaics – the direct conversion of sunlight to electricity.

Polarity – measurement of an electrical circuit to determine positive (+) and negative (-).

PQS – (Performance, Quality, Safety) A WHO program setting equipment standards and test protocols for vaccine cold chain equipment.

Resistance – measurement (Ohms) of the opposition to electrical flow.

SDD – solar direct drive refrigerators that do not require a battery for energy storage instead relying on cold mass (e.g. cold water inside the refrigerator walls).

Service provider – the person or organization that provides in-country support usually including product storage, transport, installation, user training and post installation support such as troubleshooting, repair and warranty work.

Shading analysis – a means of quantifying the impact of obstructions that block sunlight that may reduce the amount and duration of solar array production.

Short circuit – improper electrical conducting path when positive (+) and negative (-) conductors connect bypassing a load.

Short circuit current (Isc) – a solar module or solar array current (amp) specification that is measured with multi-meter set to DC amps and connected across the array terminals, short circuiting them. No load is connected during the test.

Solar module – a packaged, connected assembly of solar cells with frame, glass and positive (+) and negative (-) output cables. Also called solar panel, photovoltaic module or photovoltaic panel.

Solar array – two or more of solar modules electrically connected together and mounted on a support structure**.**

Tilt angle – angle (degrees) of a solar array as referenced to horizontal.

WHO – United Nations organization setting global health standards.

PART 1: CFD-50 SDD METAFRIDGE SOLAR POWER KIT DESCRIPTION

1A THE SOLAR POWER SYSTEM

Photovoltaic (PV) technology uses sunlight to make direct current (DC) electricity. This electricity can directly run the CFD-50 SDD MetaFridge compressor motor.

Known as "solar direct-drive" (SDD), this extremely reliable technology does not rely on batteries to run the compressor. Instead of batteries, energy is stored in the form of cold water and ice within the upper portion of the refrigerator cabinet. An internal heat transfer system surrounds the vaccine compartment with stable, cool surfaces that keep the vaccines in the acceptable temperature range of +2°C to +8°C.

The CFD-50 SDD has just three major parts (see Figure 1.1). They are:

1.) Array of connected solar modules to collect and convert solar energy to electricity;

2.) Safe electrical wiring and earth grounding; and

3.) A vapor compression refrigerator to store vaccines.

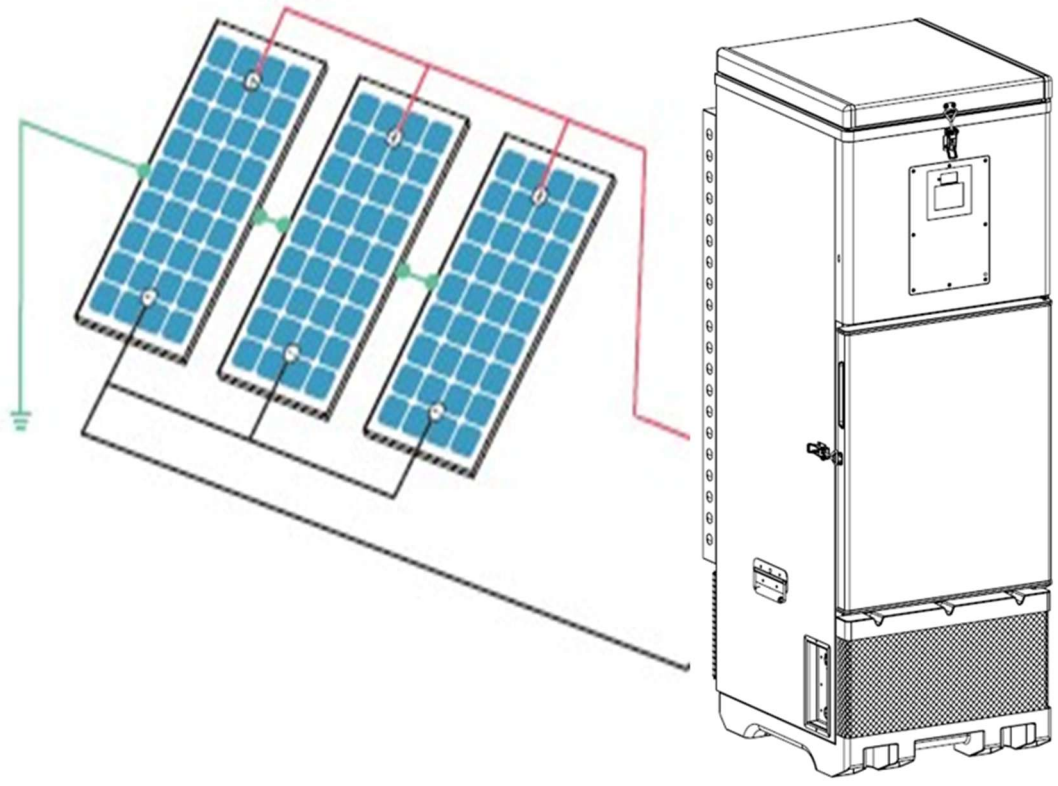


FIGURE 1.1: *Solar direct drive (SDD) refrigerator system.* Graphic (here and on the cover page) includes elements of graphics courtesy of FGL/IM-PAHO and Solar Electric Light Fund (SELF)

1B TYPICAL OPERATION

Solar direct drive (SDD) refrigerators differ from battery-powered refrigerators systems by using solar power to directly freeze water inside the CFD-50 SDD cabinet and then use the store of cold to keep vaccines cool during the night and for 5 days or more with low sunlight (rainy days).

A new CFD-50 SDD installation will take two or three days to freeze enough water to build up sufficient autonomy for safe vaccine storage.

After the initial cool down the operation of an SDD will change depending on the level of sunlight and if the CFD-50 SDD needs more cooling. Typical operation includes:

Sunny day: SDD compressor motors can only operate during the day when enough sunlight falls on the solar array. If the CFD-50 SDD thermostat is calling for cooling and enough power is being generated the SDD compressor motor will run and a green LED will be lit.

Partly cloudy day: A passing cloud can cause the compressor motor and green LED to turn off temporarily. When the cloud passes and enough sunlight is again available the compressor and green LED will be on again.

Rainy day: In cases when it is extremely cloudy or raining the compressor motor and green LED may not come on.

Night: At night there is no solar power and the CFD-50 SDD relies on the ice block to keep the vaccines cold. The compressor motor and green LED cannot come on.

The ice block will keep the CFD-50 SDD cold for an autonomy period of up to 5 days at a constant +43°C and can remain cold even longer if the ambient air temperatures are less than +43°C.

⚠ Shading from plants, buildings and other obstructions can stop electricity generation from the solar array.

Dirt and soiling from animals can reduce and even stop electricity generation from the solar array.

It will be important to train the health worker to keep the solar array clean and unshaded. Even small shading and soiling can reduce the amount of electricity from a solar array. See Figure 1.2 for examples of shading losses.

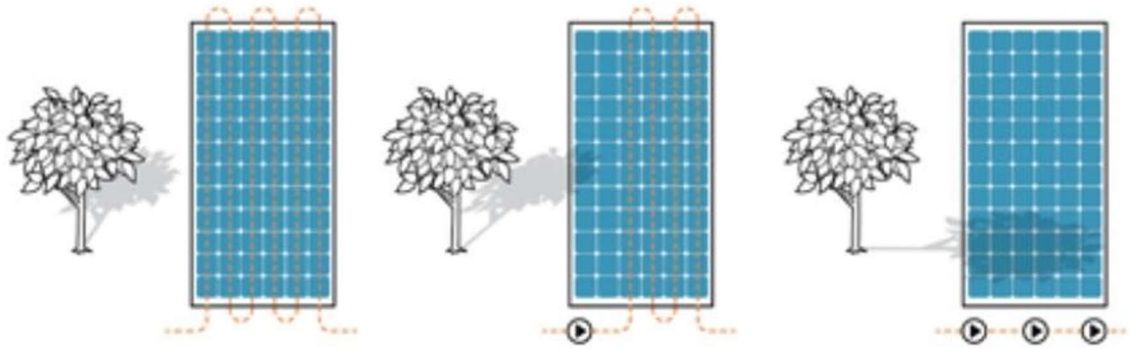


Figure 1.2: *Shading examples. On the left there is no shading and 100% of the electricity is available. In the middle a small part of the solar module is shaded but 33% of the electricity flow is blocked. On the right where shading crosses the entire solar module all electricity flow is blocked.* Graphic courtesy of FGL/IM-PAHO and Solar Electric Light Fund (SELF).

1C ELECTRCIAL SCHEMATIC DRAWING

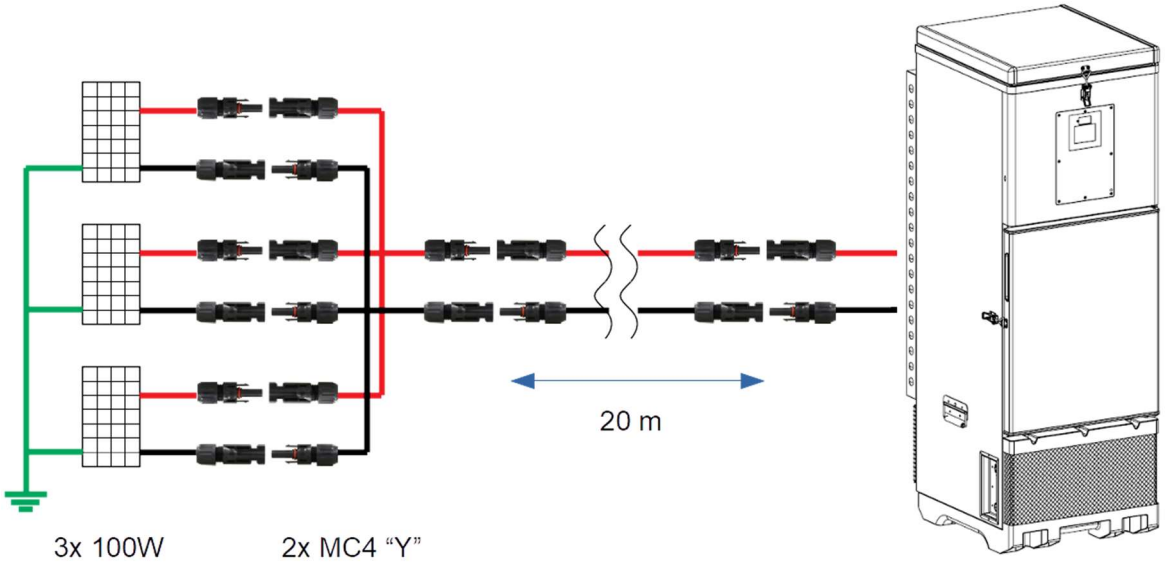


Figure 1.3: *Electrical drawing.*

1D SPECIFICATIONS

Refrigerator **Aucma CFD-50 SDD MetaFridge**

WHO PQS code	E003/098
Vaccine storage volume	50 liters
Temperature range	+10°C to +43°C
Initial cool down time	2 days of full sun in moderate temperature conditions
Autonomy	120 hours (5 days)
Solar Power System	**Aucma Solar Power Kit**
Solar module (qty 3)	CNSDPV100(36)M5, 100Watt, 22.70 Voc, 5.69 Imp / 18.9 Vmp, 5.54 Imp
Solar array	300 Watt, 22.70Voc, 17.07 Isc / 18.9 Vmp, 16.62 Imp
IEC 61215	Yes
Array structure	Aucma Universal Mount Structure (anodized aluminum roof/ground/pole)
Array tilt	Adjustable 0° to 45°
Fasteners	Stainless steel, theft deterrent
Solar array cable	PV Wire, UV resistant, 10 AWG (6mm^2), 65 feet (20 meters)

Electrical connectors	MC4 “plug and play”, IP67
Ground wire	6 AWG ($16mm^2$) bare copper, 65 feet (20 meters)
Ground rod	9/16” x 4.76 feet (14.2 mm x 1.5 meters), copper clad steel

1E PARTS LIST

1. **CFD-50 SDD MetaFridge vaccine refrigerator (1)**
2. **100 W Solar modules (3)**
3. **Solar array cable kit (1)**

Quantity	Unit	Part Number	Description
1	SET	3009900403	Photovoltaic wire,SDD,CFD-50,6*20M (include 2)
1	SET	3009900404	Four-way connector,SDD,CFD -50 (include 2)
50	EA	3109900015	Lock strap,300*7.6,nylon UV,black
10	EA	3404001037	Unilateral tube card,SDD,CFD-50,ϕ23, galvanized
10	EA	3406000759	Cement steel nails,3.8*60
10	EA	3406000699	Washers,Outer DiameterΦ20Inner DiametersΦ4.5 thick 1.5,Galvanised

4. **Ground wire kit (1)**

Quantity	Unit	Part Number	Description
1	EA	3009900412	Photovoltaic Ground Wire,SDD,CFD-50
1	EA	3009900411	Ground rod,SDD,CFD-50
1	EA	8106011891	Operator clip,SDD,CFD-50,U-type
3	EA	3405000255	Ground clip,SDD,CFD-50,AL6005-T5

5. **Universal Mount Structure (1)**

Quantity	Unit	Part Number	Description
2	EA	3405000247	Ground base tube, ground, SDD,CFD-50,Q235hot galvanizing1422.4MM
2	EA	3405000250	Rail,SDD,CFD-50,Q235 hot galvanizing, 1981.2MM
18	EA	3405000251	Carriage Bolt,SDD,CFD-50,SUS304,M8*75
26	EA	3405000252	Theft-deterrent nut,SDD,CFD-50,SUS303,M8
2	EA	3405000249	Support,SDD,CFD-50,Q235hot galvanizing,1422.4MM
12	EA	3405000244	Side pressure,SDD,CFD-50,SUS304,38MM
2	EA	3405000248	Ground base tube, column,SDD,CFD-50,Q235hot galvanizing,819.15MM
4	EA	3405000245	U-bolt,SDD,CFD-50,SUS304,M10*160,Φ110MM
8	EA	3405000246	Square gasket,SDD,CFD-50,Q235hot galvanized,2.67MM
8	EA	3405000253	Theft-deterrent nut,SDD,CFD-50,SUS303,M10
8	EA	3406000929	Expansion bolt,SDD,CFD-50,SUS304,M8*120
1	EA	3305000035	Modified Silicone sealing adhesive/sealant, MS1937, gray
4	EA	3405000256	Wood screws,SDD,CFD-50,Q235hot galvanizing,M10*140

6. **Tool kit (1)**

Quantity	Unit	Part Number	Description
1	EA	3500003215	Mop, SDD, CFD-50,520mm x 1300mm
1	EA	3500003216	Water bucket ,SDD,CFD-50,16L
1	EA	3405000254	Theft-deterrent fasteners SDD,CFD-50,SUS303
1	EA	3406000715	Hacksaw, SDD, CFD-50, alloy
1	EA	3406000714	Wrench, SDD, CFD-50, M8/M10
1	EA	3406000930	Hex wrench,SDD,CFD-50,Q235 hot galvanizing,M8

PART 2: PRECAUTIONS

2A SAFETY AND SOLAR ELECTRICITY

Even low voltage solar power installations have hazards.

Always make safety your priority. This symbol - ⚠ - is used in this Manual to alert you to safety and performance concerns.

Solar vaccine refrigerators use low voltage direct current (DC) electricity but there are hazards anytime you work with electricity. A solar array will require a secure mounting structure and this often is attached to a roof or tall pole that requires installers to work at heights. Some roof structures are not strong enough to support the weight of the equipment or the weight of the installer.

You will need to know:

a.) Hazards associated with this work;
b.) How to use equipment and tools safely;
c.) Where the first aid kit is located;
d.) How to safely work at heights; and
e.) How to safely work with low voltage electricity.

⚠ **Safety and First Aid**

Know where the first aid kit is located in your vehicle and at the installation site.

Always keep the first aid kit fully stocked.

Always carry a first aid kit when travelling to installation site.

Wear hard hats on work sites.

Know where your co-workers are.

Use the correct eye protection when hammering, drilling and power sawing.

When working in direct sunlight protect yourself with hats, sunglasses and sunscreens, take breaks and drink plenty of water.

Refrigerators

⚠ All refrigerators are a suffocation hazard for children. Prevent child accidents by keeping children away from the installation site and removing the door when decommissioning.

CFD-50 SDD MetaFridge has refrigerant R600a and R600a is flammable.

CFD-50 SDD MetaFridge can be extremely heavy, especially after it is filled with water.

Solar Array

Solar modules produce electricity when exposed to sunlight and there is risk of electrical shock.

Do not work on live electrical wiring or parts. Disconnect the solar power input at the CFD-50 SDD "on/off" switch or cover the solar array with opaque material like a blanket, tarp, or cardboard. Then confirm electricity is off with a multimeter.

⚠ Even low voltage will create an arc of electricity that can cause accidents, ignite fires, damage tools and damage the MC4 connectors.

Do not disconnect the "plug and play" MC4 connectors when the solar array is generating electricity.

To stop electricity production cover the solar array with an opaque object.

Do not exceed 22 Voc when connecting solar modules.

Handle with care as most solar modules are made with metal frames with sharp corners and glass covering.

Working at Heights

⚠ See **ANNEX A: Working Safely at Heights, which was provided courtesy of FGL/IM-PAHO and Solar Electric Light Fund (SELF).**

Ladders must be safe and in good repair.

Position ladders firmly to avoid movement.

Use rope and harness systems.

Use crawling boards when walking on roofs.

If you fall from the roof or ladder do not move until professional help arrives.

For the health worker/user there must be a safe and convenient way to access the solar array for routine cleaning.

PART 3: PRE-INSTALLATION SITE ASSESSMENT

3A PRE-INSTALLATION SITE VISIT GOALS

Each installation site is going to be different. A visit to the site beforehand is recommended. A qualified person can then meet staff, plan for the dates of the installation, assess the health facility building and record the details required to safely and properly complete the installation. The goal is to get enough details to be able to complete the installation safely and professionally in just one trip. The required information (including a tools list) is summarized in **ANNEX B: Site Assessment Worksheet, provided courtesy of World Health Organization (WHO)**.

The Site Assessment Worksheet has 10 sections:

1. Site assessment details (complete before traveling to site)
2. Transportation details (complete before traveling to site)
3. Site survey and assessment tool list (prepare before travel)
4. Facility details
5. Refrigerator placement
6. Solar array siting
7. Solar array cable
8. Ground wire
9. Photographs (as needed)
10. Construction detail sketches (as needed)

Before travelling for the pre-installation site visit complete sections 1, 2 and 3 to get complete directions to the site, prepare transport and assure you will have the needed tools.

Once at the site the assessor interviews the responsible health center worker(s) to find out where to place the various parts of the system and schedule the installation date.

The pre-installation site assessment must be accurate enough to provide information to plan, prepare and later complete the installation. Take the time to carefully observe and make well informed decisions. Anything less may mean delayed vaccination programs, added costs, extra trips, added time, unsafe work conditions and possible improper equipment choices during the installation.

3B CFD-50 SDD METAFRIDGE POSITIONING

During the pre-installation site assessment meet with the facility staff to discuss CFD-50 SDD MetaFridge location.

Remember the solar array cable will need to enter the facility and then connect with the CFD-50 SDD.

This guidance on positioning the CFD-50 SDD is taken from the refrigerator installation manual supplied with the CFD-50 SDD.

a. Place the CFD-50 SDD MetaFridge on flat and solid ground and ensure the unit is level.
b. No pallet is required. CFD-50 SDD has an integrated plastic base.
c. Position the CFD-50 SDD near where the solar array cable can be connected to the CFD-50 SDD power cord. Its length is about 1 meter.
d. Position the CFD-50 SDD away from direct sunlight and any source of heat (e.g. gas stove, fireplace, etc.).
e. CFD-50 SDD must not be placed in or around flammable or corrosive gases that could cause an explosion.
f. In order to prevent rust or electrical leakage, the CFD-50 SDD should not be placed in a high humidity environment or in a location where it could be splashed with water or rain.

g. Position the CFD-50 SDD in a well-ventilated area and make sure there is a minimum of 10 cm of empty space around the sides and back of the unit. The door latch must be accessible and the door must be able to open freely to at least 90°.
h. Allow a minimum of 60 cm clearance above the CFD-50 SDD for accessing the water tank lid.

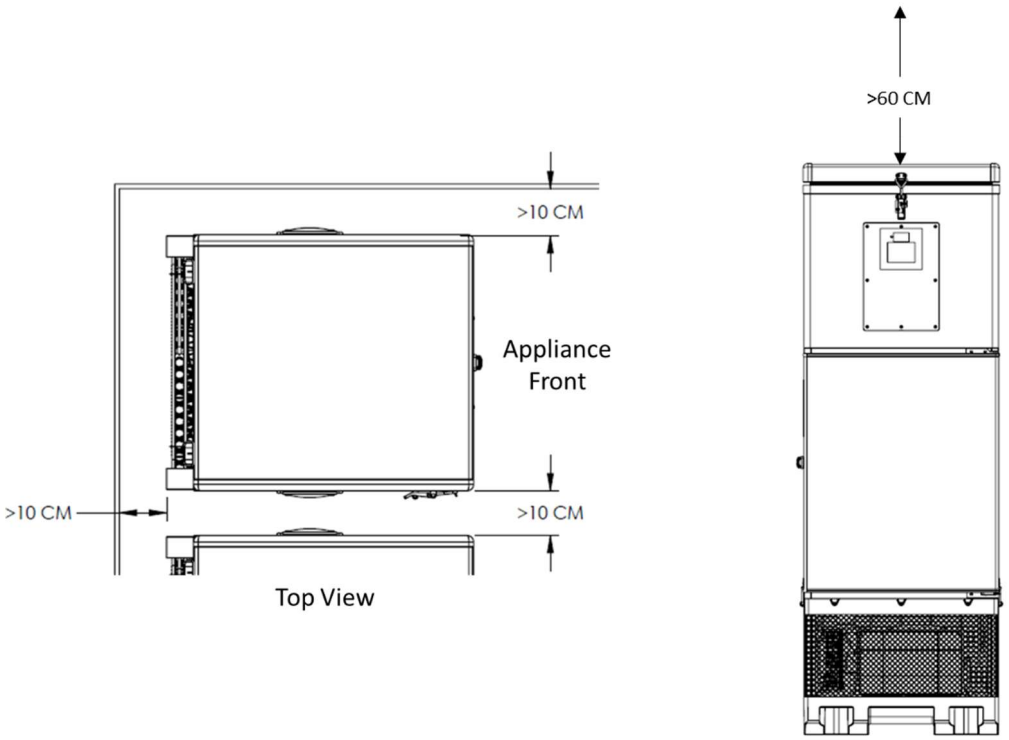


Figure 3.1: *CFD-50 SDD placement.*

3C SHADING ANALYSIS AND SOLAR ARRAY PLACEMENT

Solar site analysis is crucial to properly position the solar array. The position of the array is extremely important. Even partial shading of a solar module can nearly stop power output. More power is produced the longer the sun directly shines on the array. A good solar site has no shading and receives direct sunlight from 7AM to 5 PM all year long. It is best to conduct the solar site analysis using a specialized solar siting device like the Solar Pathfinder shown in Figures 3.2 through 3.5.



Figure 3.2: *Parts of the Solar Pathfinder where reflections seen on the dome can be traced onto a "sun path" diagram to assess shading impact.* Photo courtesy of FGL/IM-PAHO and SELF.



Figure 3.3: *Assembled Solar Pathfinder*. Photo courtesy of FGL/IM-PAHO and SELF.



Figure 3.4: *Checking for impact of tree shading at one possible solar array location. A white pencil is used to trace the shading on the black paper "Sun Path" diagram that shows the times of shading by month, time of day and the percentage lost to shading.* Photo courtesy of FGL/IM-PAHO and SELF.



Figure 3.5: *Tracing shows too much tree shading for an SDD. Solar array location can be moved to avoid shading.* Photo courtesy of FGL/IM-PAHO and SELF.

When selecting a location for the SOLAR array, consider the following questions:

- Does the array receive direct sunlight from at least 9 AM to 3 PM all year long?
- Is there shading from trees, buildings, pipes or fencing?
- Are there any future changes that may cause array shading (e.g. tree/plant growth)?
- Are there local weather conditions like morning fog or afternoon cloudiness that would limit solar radiation at times of the year?
- Is the array location safe from damage due to wind, animals, people, vehicles or accidents?
- Is theft a concern?
- Can the roof support the weight of the array and the installation crew?
- Will installation damage the building in any way?
- How can solar array cable and ground wire be kept short and neat?
- How will a solar array look at the proposed site?

Refer to **Annex B: Site Assessment Worksheet** and take a blank copy to each site to be visited. Complete all questions before leaving the site. Answer each question thoroughly enough for someone else to be able to adequately prepare for the installation.

3D SOLAR ARRAY CABLE AND GROUNDING

When both the CFD-50 SDD MetaFridge and solar array positions are decided then the solar array cable and ground wire placements can be determined.

The CFD-50 SDD solar power system kit includes a 20 meter solar array cable and a 20 meter ground wire, ground rod and grounding connectors.

Select the route for the solar array cable that is:

a.) The shortest distance (less than 20 meters) from solar array to CFD-50 SDD (including all bends required to secure cabling to building)
b.) Safe; and
c.) Allows the cable to be secured.

Select the route for the ground wire that is:

a.) The shortest distance (less than 20 meters) from solar array to the earth (including all bends required to secure ground wire to building);
b.) Safe; and
c.) Allows the ground wire to be secured.

Note: An alternate ground connection can be made to concrete metal reinforcement bars that are exposed on rooftops or building foundations.

Record the distance of both the solar array cable and ground wire.

⚠ If distances are greater than 20 meters for either solar array cable or ground wire consider moving the solar array or moving the CFD-50 SDD location. If you are unable to re-locate the solar array cable and/or the ground wire and require length(s) greater than 20 meters then a special order will be required to obtain the custom length(s).

If conduit is required to sheath the cables, be sure to add it to the materials list and obtain it before the installation visit. Conduit is not supplied as part of the installation kit.

PART 4: INSTALLATION

4A PRELIMINARY SITE CHECK

The solar array location selected in the site visit should be reviewed. Before installing, confirm that:

1) Solar array location is correct.
2) Solar array will attach to a secure foundation or roof.
3) Solar array will face the equator (+/- 20 degrees).
4) Solar array tilt angle will be equal to site latitude (and at least 10 degrees from horizontal).
5) Solar array will be unshaded between the hours of 9 AM and 3 PM.
6) Solar array cable and ground wire of 20 meters (maximum) will be sufficient.
7) Health worker will have safe access for washing the solar array.
8) Unauthorized persons will not have ready access.
9) Theft will be prevented or at least minimized.
10) All parts required are on site.

4B TESTING SOLAR MODULES

⚠ Always handle solar modules carefully. The aluminum frame has sharp corners that can cut skin or damage other materials. The cover is made of glass and if cracked or broken the module cannot be installed. Cracked glass can cut skin or other materials.

Open the box carefully. You can use the packaging for protecting the module while handling and for covering the solar array when measuring short circuit current (Isc). Remember to clean up all packaging when completing the installation.

See the label on back of the solar module for the specific ratings of the PV modules provided in the kit. The three most important ratings you will use are:

1) Watts;
2) Open circuit voltage (Voc); and
3) Short circuit current (Imp).

Before installing the modules read the specification. Are the total number of Watts specified in Part 1.D provided? For example, if the system requires 300 Watts and the kit includes three (3) 100 Watt solar modules then you have the 300 Watts required (3 x 100 Watts = 300 Watts).

A typical 100 Watt solar module will be rated at 22 Volts (Voc) and about 5 amps (Imp).

Next measure the open circuit voltage (Voc) of the panels. Prepare your multi-meter to measure DC volts. See Figure 4.1 below. Connect the red lead of the meter to the positive cable of the panel and the black lead to the negative cable of the panel. For more information see

ANNEX F: Using multi-meters with solar refrigerator systems, provided courtesy of FGL/IM-PAHO and SELF.

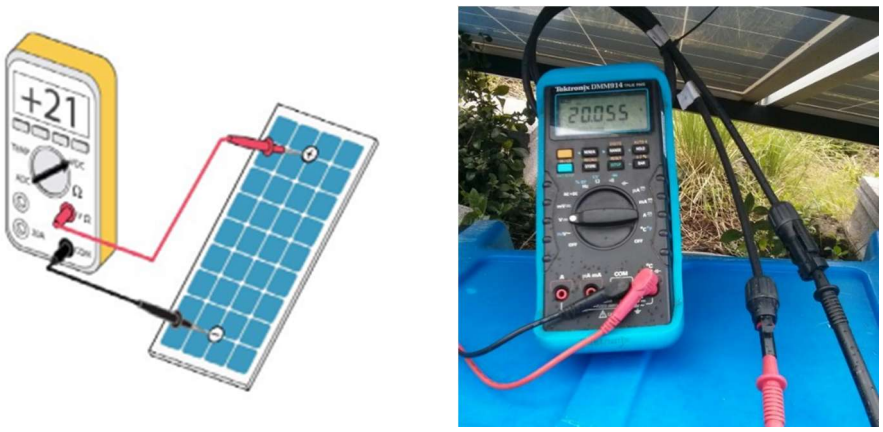


Figure 4.1 *Measuring Voc – set multi-meter to measure Volts DC and connect multi-meter to the solar module positive (+) output and negative (-) output.* Graphic on left courtesy of FGL/IM-PAHO and SELF.

Next, measure the module short circuit current (amps).

⚠ ***Always cover the solar module before connecting and disconnecting the meter leads. If uncovered the module will arc electricity and damage the module connections and meter leads***.

The solar module amp specification is based on laboratory tests with full sunlight (for laboratory testing this is 1000 Watts/m²). If it is cloudy the amps will be lower than the specification. Figure 4.2 shows the multi-meter settings and measurement points. The table below shows general difference in amps with different sunlight conditions.

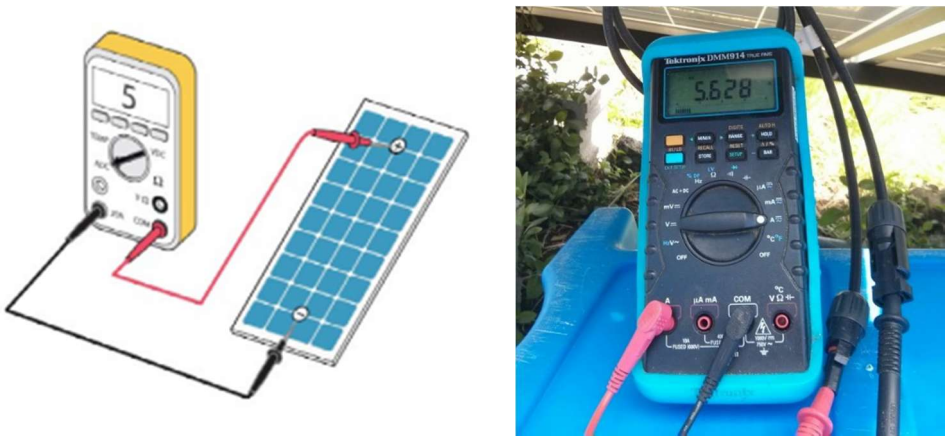


Figure 4.2: *Measuring Imp – set meter to measure DC Amps (use 10 or 20 Amp DC range for single panels). Connect multimeter to the solar module positive (+) and negative (-) output.* Graphic on left courtesy of FGL/IM-PAHO and SELF.

Change of solar module amps with different sunlight conditions

Sunlight Intensity	Output of 100 Watt, 5 amp solar module
Full sunlight – noon, clear day (1000 W/m²)	100% of Imp specification (5 amps)
Half sunlight – cloudy day (500 W/m²)	50% of Imp specification (2.5 amps)
Low sunlight – rainy day (50 W/m²)	5% of Imp specification (0.25 amps)

4C UNIVERSAL MOUNT STRUCTURE OPTIONS

The Aucma Solar Power Kit includes the Aucma Universal Mount Structure, the most versatile solar array structure available anywhere because it includes parts for three different mounting options including:

1.) Sloped (tilted) roof (adjustable 0 to 45 degrees)
2.) Flat roof or ground mount
3.) Pole mount (pole and concrete are not supplied).

The Universal Mount Structure can be used for any of the following eight mounting possibilities. See Figure 4.3. Select the version that best matches the site. For tilted roofs, use Section 4C-1. For flat roofs and ground mounts, use Section 4C-2. For pole mount, use Section 4C-3.

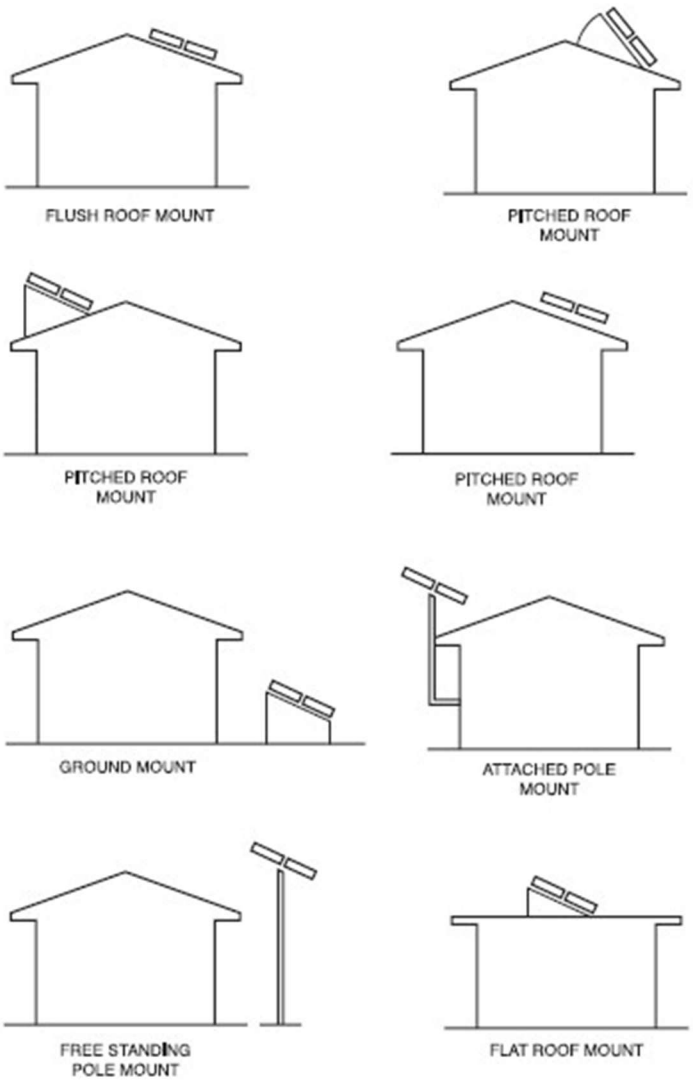


Figure 4.3: *Aucma Universal Mount Structure possibilities.* Graphic courtesy of FGL/IM-PAHO and SELF.

⚠ Solar array mounting structures must be secured to a solid foundation or roof. Accidents can occur on roofs that are not structurally adequate to carry the weight of workers and equipment.

⚠ Solar array mounting structures must be permanently installed to prevent injuries, damage from wind and theft. Solar modules have warranty of 25 years - your work should be for 25 years (minimum) too!

4C-1 Sloped Roof Instructions

The components of the Universal Mount Structure can be used on a sloped (pitched) roof for both flush mounts (see Figure 4.4) and for tilt up mounts (see Figure 4.5). Flush mounts will be parallel to the roof slope. Sloped roof mounts adjust from 0 to 45 degrees.

⚠ Sloped roof installation hazards include working at heights, weak to failing roof structure, slippery roof covering, sharp roof materials, live electric cables, high winds and sunlight glare. To avoid injury from falling tools and parts prevent health workers and patients from access under the roof work area.

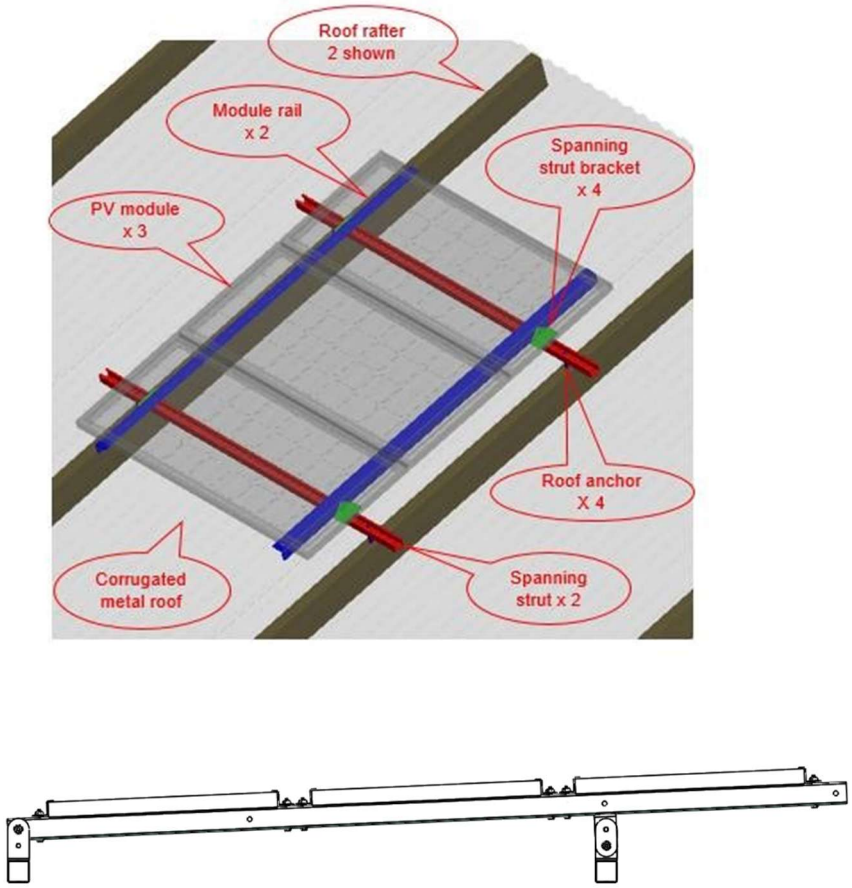


Figure 4.4: *Structural components of the Universal Mount Structure used as a flush mount. Top: transparent view with color-coded components. Bottom: side view of flush mount*

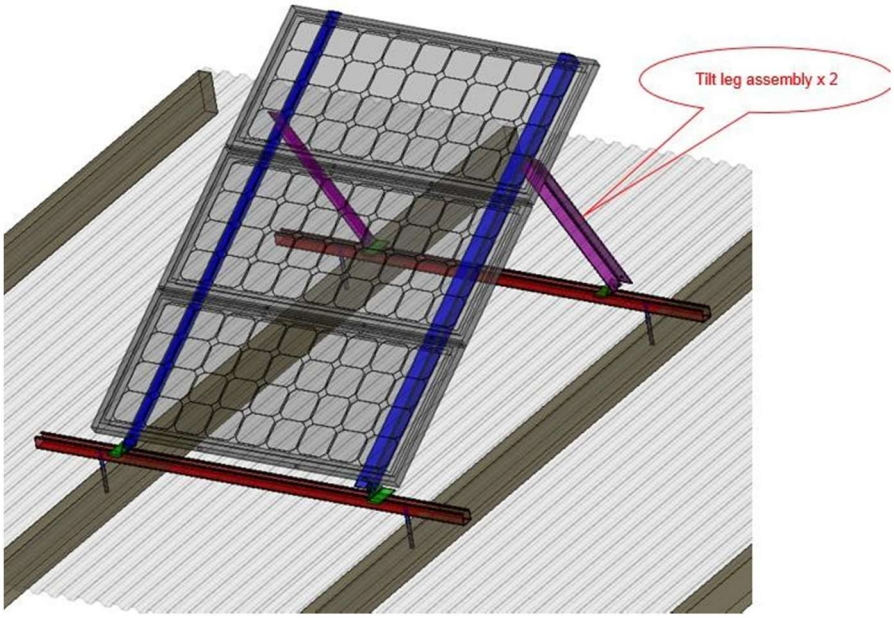
Positioning a Sloped Roof Mount

Orientation: Using your compass, check roof orientation and select a location where the solar array will face the equator. In the northern hemisphere an orientation of ±20 degrees of true south is usually acceptable. In the southern hemisphere an orientation of ±20 degrees of true north is usually acceptable.

Tilt angle: The minimum slope of a solar array is 10 degrees measured from the horizontal to allow rain to drain off the modules while cleaning some dirt and dust. If rain does not drain it can cause mold to grow on the module leading to partial shading and power loss.

Use an inclinometer (protractor) to measure the roof slope angle. If the pitched roof slope angle is the same as the site latitude and at least 10 degrees then use a flush mount. See Figure 4.11 for how an inclinometer (protractor) can be used to confirm the tilt angle is correct.

The flush mount will place the modules at the same slope as the pitched roof. If the solar array slope needs to be adjusted see the module tilt leg instructions below.



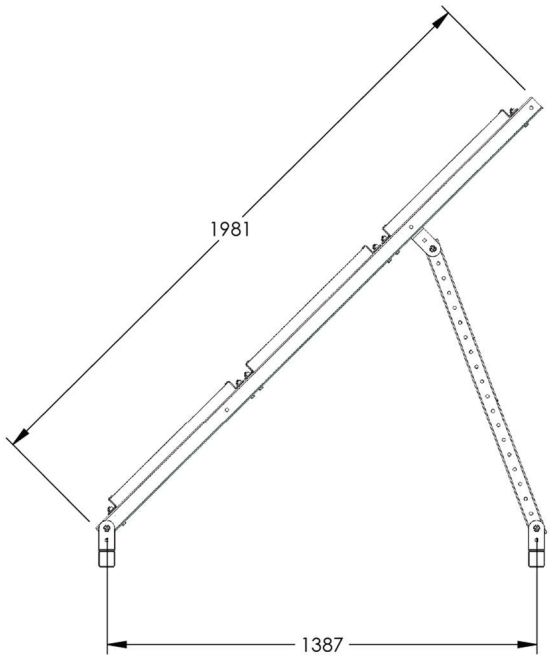


Figure 4.5: *Tilted roof mount used on an equator-facing sloped roof. The same components from Figure 4.4 are used plus the two rear tilt legs. Top: transparent view with color-coded components. Bottom: side view at about 45 degrees from surface.* ***Note: Dimensions in mm***

Spanning Strut Layout: Position base spanning strut in an east – west direction so that the two fasteners will anchor it into the roof substructure (i.e. beam, purlin or roof rafter as shown above). See Figures 4.4 and 4.6. Secure with theft deterrent bolts supplied. Drill holes through the top of corrugated roofing to prevent roof leaks.

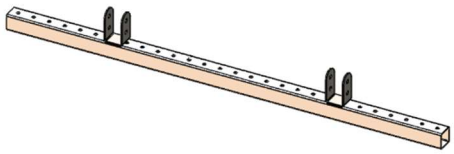


Figure 4.6: *Base spanning strut.*

Attach the two module rails to the base strut with carriage bolts and theft-deterrent nuts as shown in Figure 4.7. See the detail of carriage bolt usage also. Do not tighten the fasteners because you will need to move the rails during assembly.

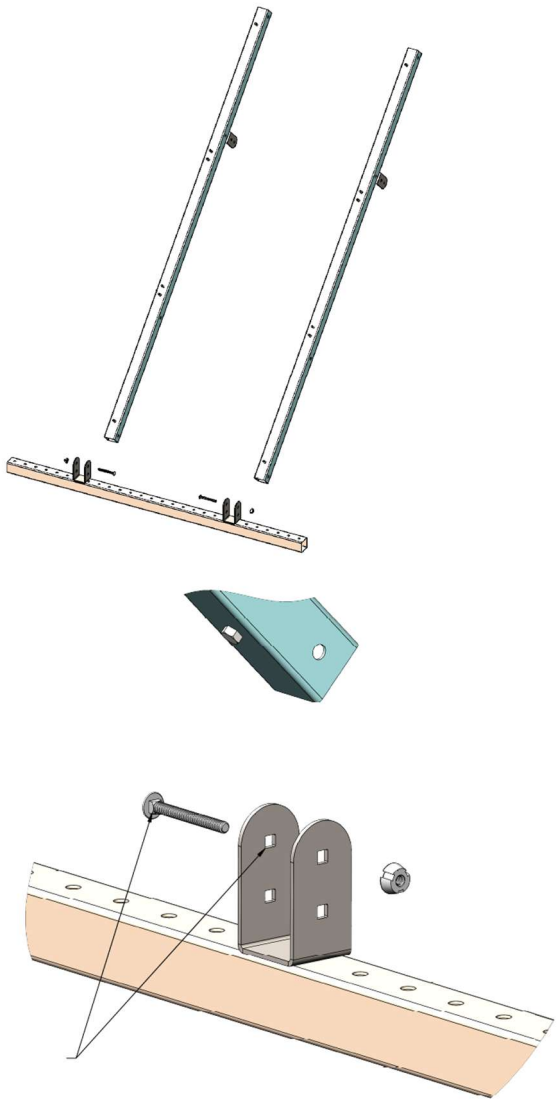


Figure 4.7: *Attach module rails. Left: base strut and module rails. Right: carriage bolt detail. Note how square hole prevents carriage bolt from spinning during tightening*.

Position the second spanning strut in an east-west direction spaced 1390 mm ±50 mm from the base spanning strut. For flush mounts, make sure the spacing will allow the welded-on brackets on the rails and the spanning strut to connect. It is recommended that you temporarily connect the second strut to the rails to ensure correct spacing. See Figure 4.8. For tilted mounts, the spacing is a little more forgiving, see Figure 4.5. Secure the strut to the roof with theft deterrent bolts supplied. Seal all roof penetrations with the sealant supplied. Save some sealant for wall penetrations.

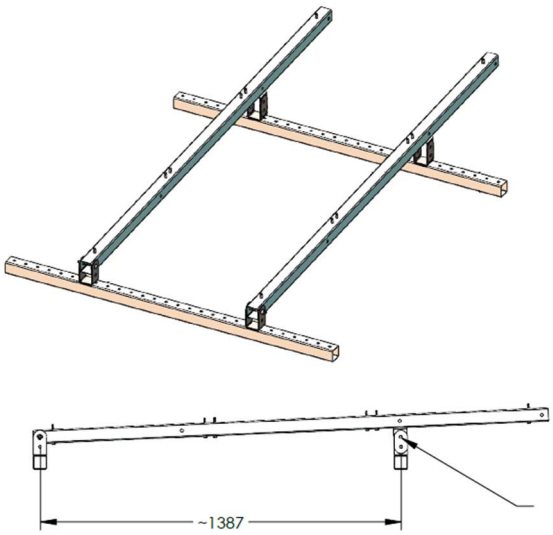


Figure 4.8: *Positioning second spanning strut for flush mount option. Be certain to align the mounting holes as shown by the arrow.*

Module to rail attachment: Attach the solar modules to the module rail with the theft deterrent fasteners supplied. The top clamp fasteners are theft deterring. See Figure 4.9.

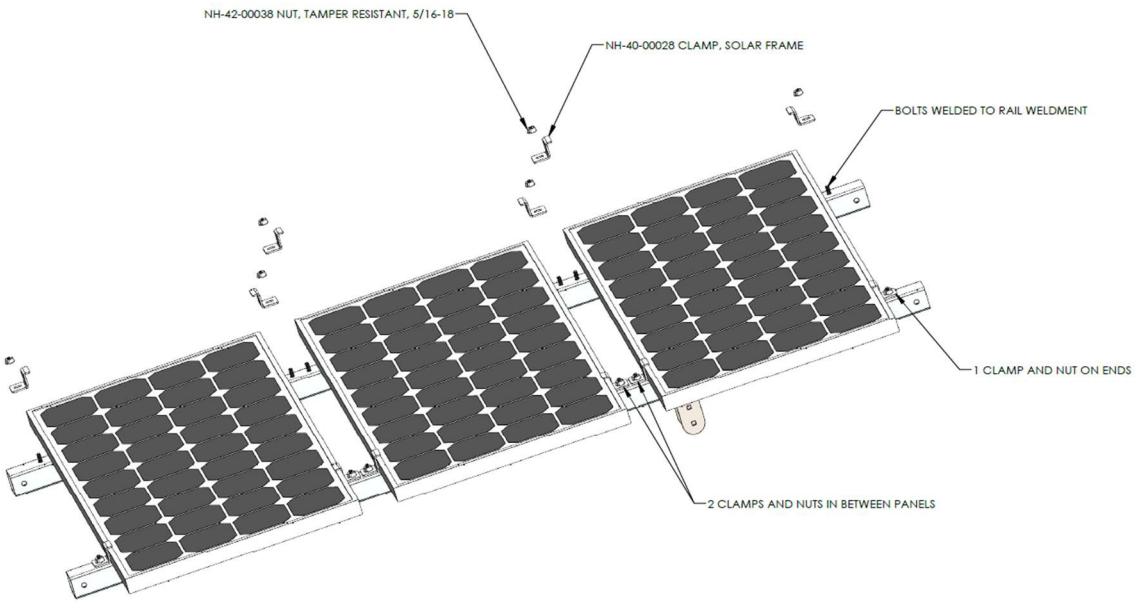


Figure 4.9: *Top clamp details.*

Module ground connections: With the module glass protected and facing down (the assembly has been removed from the spanning struts), attach one ground lug to each module in the ground lug hole on the module frame. See Figure 4.10.

For flush mounts you must now attach the 20 meter ground wire that will later connect to the earth ground rod. Set the free wire aside.

For tilt up mounts the ground wire step can optionally be delayed if it is more convenient to complete after the mount and tilt legs are secured.



Figure 4.10: *Solar module ground lug, fastener and ground wires connected.* Photos courtesy of FGL/IM-PAHO and SELF.

Module output cable connections: Continue with the module glass protected and facing down. Attach the solar module positive (+) output cables in parallel using the MC4 positive (+) branch connector supplied. All module positive output cables are connected together now. Next attach the solar module negative (-) output cables in parallel using the MC4 negative (-) branch connector supplied. All module negative output cables are connected together now. See Figure 4.11.

For flush mounts now you must attach the 20 meter solar array cable to the MC4 branch connectors that will connect to the CFD-50 SDD and tie any loose cables with the UV resistant, black nylon cable ties supplied. Set the solar array cable aside. For mounts that will use the tilt leg this step can optionally be delayed if it is more convenient to complete after the tilt legs are secured to the module rails.



Figure 4.11: *Branch connectors for joining three solar modules in parallel with positive (+) output to the left. Note careful wire management has tied loose wires.* Photos courtesy of FGL/IM-PAHO and SELF.

Flush mount: Attach module rails to strut brackets with carriage bolts and theft-deterrent nuts.

Tilt leg: Tilt up solar arrays will use the strut brackets (2) at the base spanning strut to attach the tilt legs. Tilt legs must provide the correct tilt angle by attaching to brackets welded to the module rail. Test the assembly using the inclinometer to confirm the correct angle is found. In some cases the tilt legs may need to be cut and then attached to the module rails to achieve the correct tilt angle. Loosely attach both tilt legs to the spanning strut bracket and then carefully raise the solar array and attach tilt legs to the module rails. Fasten securely with the theft deterrent fasteners supplied.

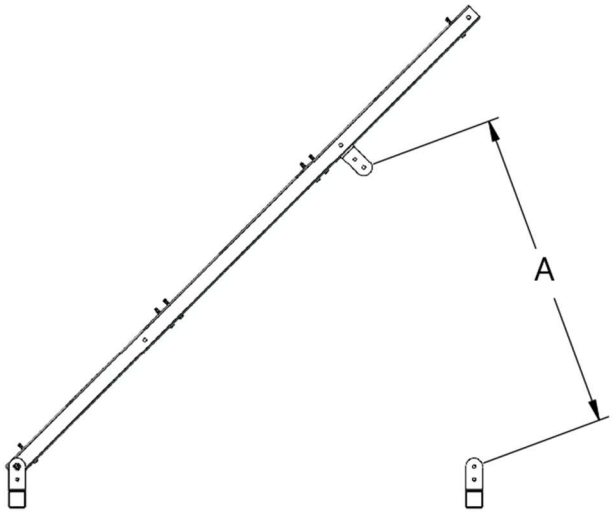


Figure 4.12: *Determine distance "A" between holes in strut that gives the proper tilt.*

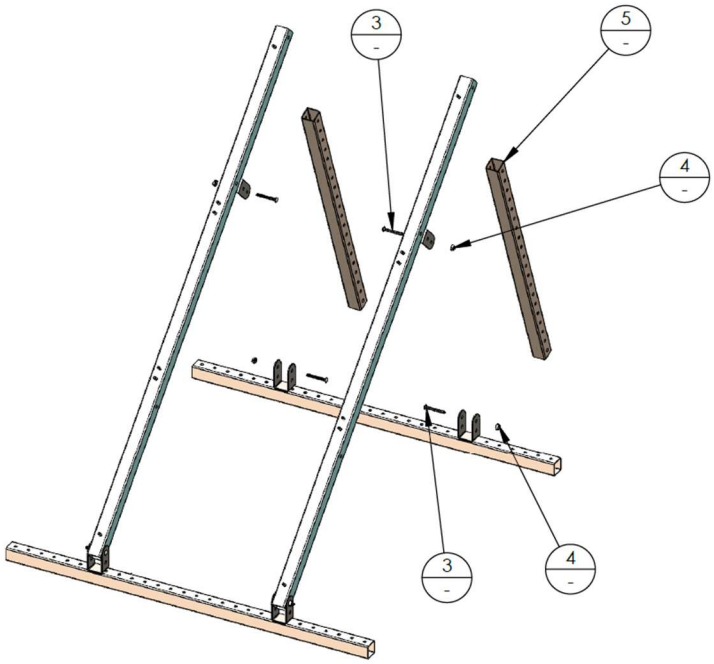


Figure 4.13: *Assemble tilt legs (5) using carriage bolts (3) and theft-deterrent nuts (4). Modules not shown for clarity.*

Tighten all fasteners: Once the structure with solar modules has been positioned retighten all theft deterrent fasteners.

4C-2 Flat Roof /Ground Mount Instructions

Flat Roof/Ground Mount use the same components as the Pitched Roof Mount (see 4C-1). The only differences are the fasteners that attach the spanning struts to the concrete foundation or concrete roof. See Figure 4.3 for flat roof or ground mount options adjustable up to 45 degrees. Select the version that best matches the site.

Ground mounts are not used often because they are the most expensive option, require significant concrete foundations, underground conduit or overhead cable and usually require a security fence to prevent people, vehicles and animals from contacting the solar array. Theft is less preventable since the solar array is easy to see and easy to access.

⚠ Flat roof installation hazards include working at heights, weak to failing roof structure, slippery roof covering, sharp roof materials, live electric cables, high winds and sunlight glare. To avoid injury from falling tools and parts prevent health workers and patients from access to under the roof work area.

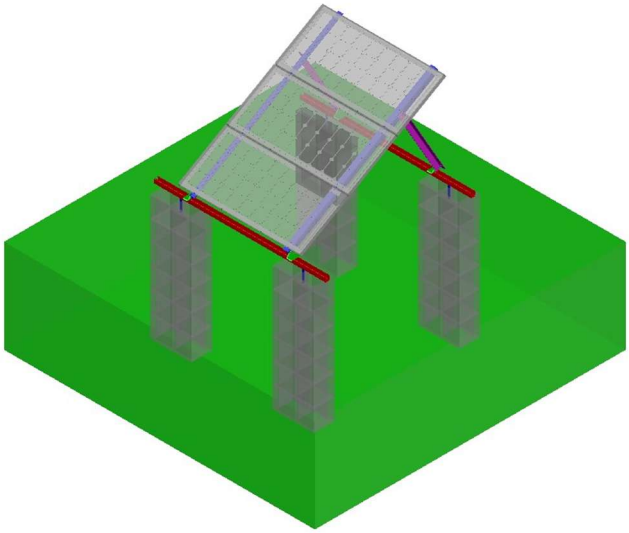


Figure 4.14: *The Aucma Flat Roof Mount can also be used as a Ground Mount.*

⚠ Ground mount installation hazards include open foundation excavations and open conduit trenches.
Prevent health workers, patients, vehicles and animals from access to the ground mount work area to avoid injury from falls and encountering the sharp metal corners of the solar array.

Positioning a Flat Roof/Ground Mount

Orientation: Using your compass, check orientation and select a location where the solar array will face the equator. Ground mount installation will require a concrete foundation to be built. This manual does not detail concrete construction techniques required for the foundation. See a construction manual for concrete forming, mixing, pouring and curing requirements.

Tilt angle: The minimum slope of a solar array is 10 degrees measured from the horizontal to allow rain to drain off the modules while cleaning some dirt and dust. If rain does not drain it can cause mold to grow on the module leading to partial shading and power loss. See Figure 4.15 for how an inclinometer (protractor) can be used to confirm the tilt angle is correct.



Figure 4.15: *An inclinometer (protractor) can be used to confirm the tilt angle is correct.* Photo courtesy of FGL/IM-PAHO and SELF.

Spanning Strut Layout: Position base spanning strut in an east – west direction so that the expansion anchor fasteners holes can be drilled to attach the spanning strut to the concrete roof substructure (or for Ground Mount attach spanning strut to the anchor bolts used in the concrete foundation). Position the second spanning strut in an east-west direction spaced 1390 mm ±50 mm from the base spanning strut. See Figure 4.5 for spacing. Secure with theft deterrent nuts supplied. Seal all expansion anchor holes with sealant supplied. Save some sealant for wall penetrations.

Module rail: At the base spanning strut attach the module rail to the strut bracket as in Figure 4.7 using carriage bolts and theft-deterrent nuts. Repeat for the second module rail. Do not tighten fasteners yet.

Tilt leg: Tilt up solar arrays will use two strut brackets at the second spanning strut. Tilt legs must provide the correct tilt angle by attaching to in the brackets welded to the module rail. See Figure 4.12. Test the assembly using the inclinometer to confirm the correct angle is found. In some cases the tilt legs may need to be cut and drilled and then attached to the module rails to find the correct tilt angle. Loosely attach tilt legs to the spanning strut bracket and then attach to the module rail; see Figure 4.13. Fasten securely with the theft deterrent fasteners supplied.

Module to rail attachment: See Figure 4.16 for side view of a Ground Mount. Begin with the solar module (#1) at the lowest position and attach with clamps. Tighten clamps to hold module level and firmly in place. The next module (#2) will attach between modules #1 and #3. Tighten mid clamps. Module #3 attaches at the top. Tighten all clamps. See Figure 4.9.

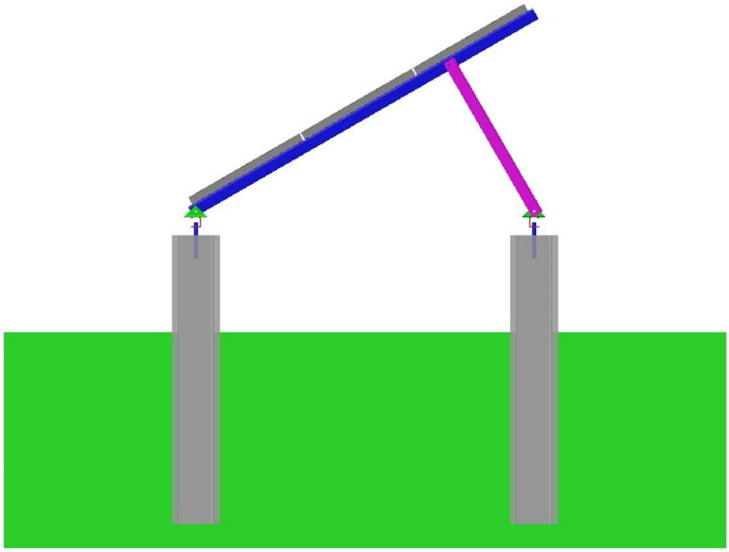


Figure 4.16: *Ground mount and concrete foundation. Flat concrete roof installations can attach to the concrete roof directly or an added foundation can be cast on top of existing roof.*

Module ground connections: Attach one ground lug to each module in the ground lug hole on the module frame. Connect ground wire starting at the module farthest from the ground rod location and feed the wire through each module. Set the ground wire aside. See Figure 4.10.

Module output cable connections: Attach the solar module positive (+) output cables in parallel using the MC4 positive (+) branch connector supplied. All module positive output cables are connected together now. Next attach the solar module negative (-) output cables in parallel using the MC4 negative (-) branch connector supplied. All module negative output cables are connected together now. See Figure 4.11.

Attach the 20 meter solar array cable to the MC4 branch connectors that will connect to the CFD-50 SDD and tie any loose cables with the UV resistant, black nylon cable ties supplied. Set the array cable aside.

Tighten all fasteners: Once the structure with solar modules has been positioned retighten all theft deterrent fasteners.

4C-3 Pole Mount Instructions

Pole mounts are used when the roof is not suitable because of shading, weak structure or theft concerns. See Figure 4.3 for two pole mount options. Select the version that best matches the site.

Side of pole mount uses the same Universal Mount Structure components with different struts plus four U-bolts (see Figure 4.18).

Note that the Aucma Universal Mount Structure used for pole mount will require that you obtain a pole and foundation materials for a free standing pole or customized wall attachments for building attached poles. Conduit is recommended for protecting the solar array cable and usually must be buried underground with a free standing pole. Conduit is not included with the Aucma Solar Power Kit.

⚠ Pole installation hazards include heavy weight of the pole, working at heights, high winds and sunlight glare. Freestanding poles require foundation and underground conduit excavations. To avoid injury from falling tools and parts prevent health workers and patients from access under the pole work area.

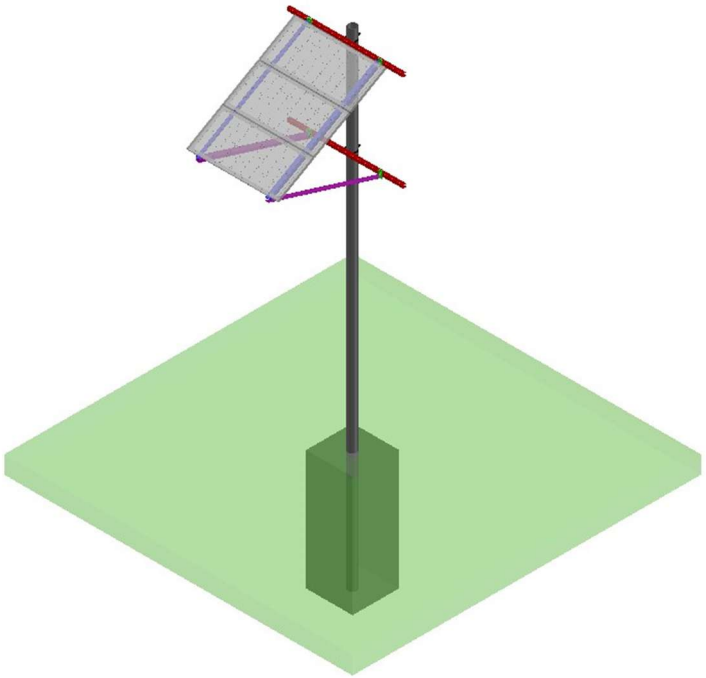


Figure 4.17: *Free standing pole mount and concrete foundation.*

⚠ Free standing pole mount installation hazards include open foundation excavations and open conduit trenches. Prevent health workers, patients, vehicles and animals from access to the pole mount work area to avoid injury from falls.

Positioning a Pole Mount

Orientation: Using your compass, check orientation and select a location where the solar array will face the equator. Free standing pole mount installation will require a concrete foundation to be built. This manual specifies the depth and diameter of the foundation but does not detail concrete construction techniques required for the foundation. See a construction manual for concrete forming, mixing, pouring and curing requirements.

Pole: free standing pole/foundation or building attached pole requirements: The following components are not included in the Aucma Solar Power Kit and will be obtained locally:

Pole: 4" x 20' Schedule 40 galvanized steel pole. Preferably threaded with 1 end cap used at top.

⚠ A 4” by 20’ (10 cm by 6 meter) schedule 40 galvanized steel pole can weigh over 220 lbs. (100 kg).
Foundation: Concrete, 4’ (1.22 m) deep by 2’ (0.6 m) diameter requires approximately 1 cubic yard (0.75 cubic meter).

Wall attachment: This is a customized option and must be engineered. Use welded attachment fittings, hot dipped galvanized (recommended) or zinc painted. Stainless steel or galvanized steel fasteners must be theft deterring.

Conduit and supports: As needed. All metal to be stainless steel or galvanized steel.

Freestanding pole placement: Dig foundation, form and place pole in hole. Use three wood braces to hold pole in place while pouring concrete. Minimum recommended size for braces is 2” x 4” x 8’ to 10’ (100mm x 50 mm x 2.5 to 3 meters) staked in a tripod pattern and wired to pole. Pour concrete and allow to harden overnight.

Set up scaffold: Scaffold is the safest, most convenient way to install a free standing pole mount. See **ANNEX A: Working Safely at Heights - Scaffold Safety**.

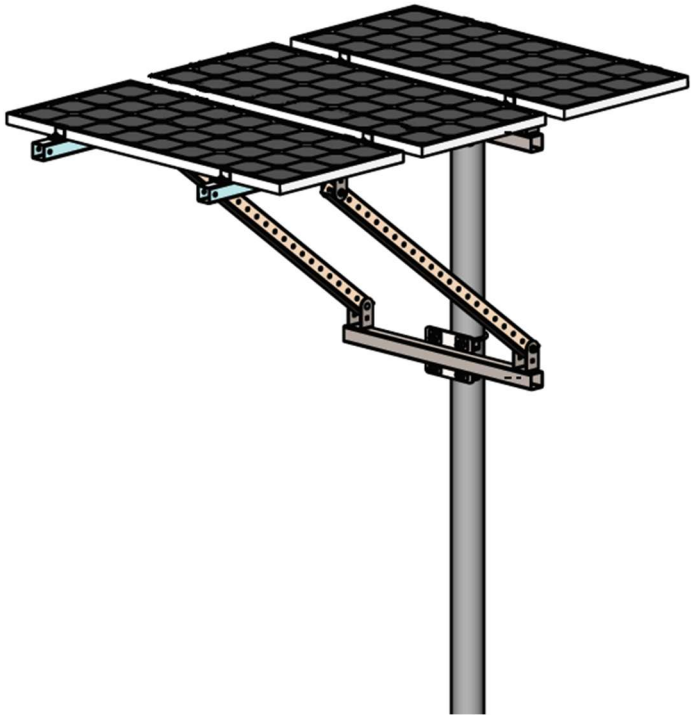


Figure 4.18: *Pole mount structure uses four U bolt pipe clamps for attachment to the pole (approximately flat example).*

Tilt angle: The minimum slope of a solar array is 10 degrees measured from the horizontal to allow rain to drain off the modules while cleaning some dirt and dust. If rain does not drain it can cause mold to grow on the module leading to partial shading and power loss. See Figure 4.15 for how an inclinometer (protractor) can be used to confirm the tilt angle is correct.

Crossmember Layout: Thread on cap at top of pole to keep pole from filling with rain water. Attach top crossmember (1) to pole with two U-bolts (2), four pole mount washers (3), and four theft-deterrent nuts (4). Position top crossmember in an east – west direction so that the U-bolts

hold the strut level and near the pole top. See Figure 4.19. Position lower crossmember in an east-west direction, level and spaced 760 mm ±25 mm from the top crossmember. See Figure 4.20.

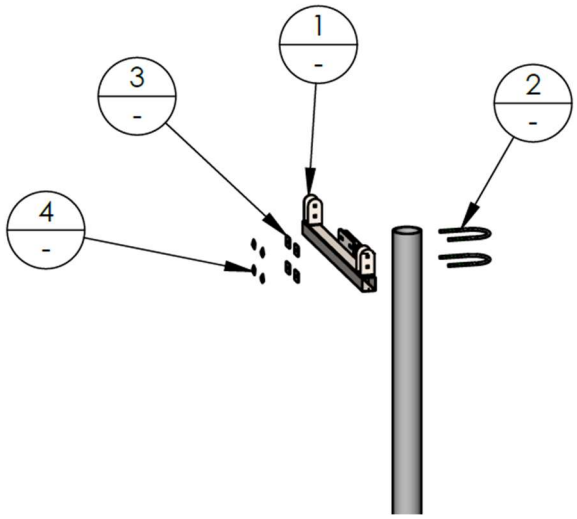


Figure 4.19: *Assemble top crossmember.*

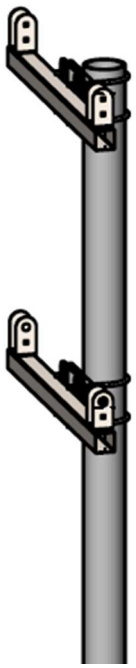


Figure 4.20: *Assemble lower crossmember 762 mm below the first (center to center).*

Module rail and tilt leg: Attach module rail (5) to top crossmember using carriage bolts (6) and theft-deterrent nuts (7). Then attach module rail to tilt leg(8). Finally attach tilt leg to lower crossmember bracket. Confirm correct orientation with compass and confirm correct tilt angle with inclinometer (protractor). Tighten all theft deterring fasteners. Repeat for the second module rail. See Figure 4.21.

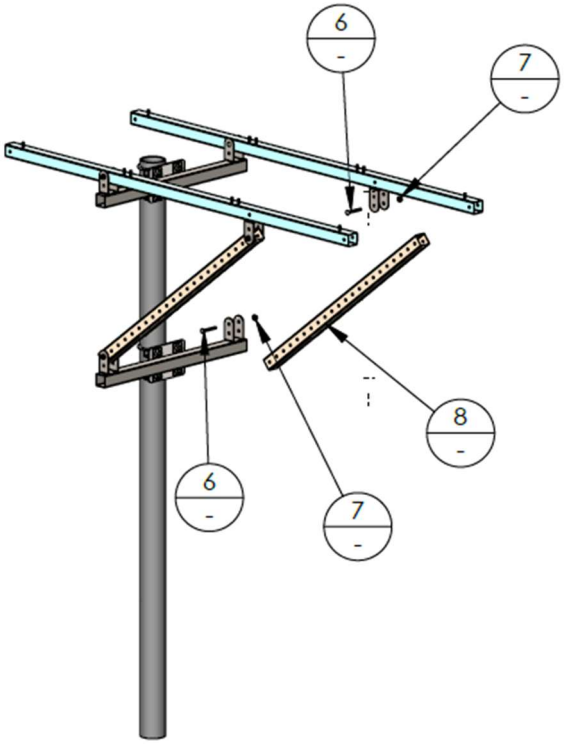


Figure 4.21: *Assemble module rails and tilt legs to crossmembers.*

Module to rail attachment: Begin with the solar module (#1) at the lowest position and attach at bottom with clamps. Tighten clamps (10) with theft-deterrent nuts (7) to hold module level and firmly in place. The next module (#2) will attach with clamps between modules #1 and #3. Tighten clamp. Module #3 attaches at the top. Tighten all clamps. See Figure 4.22 for first module assembly and Figure 4.9 for detail on the clamps.

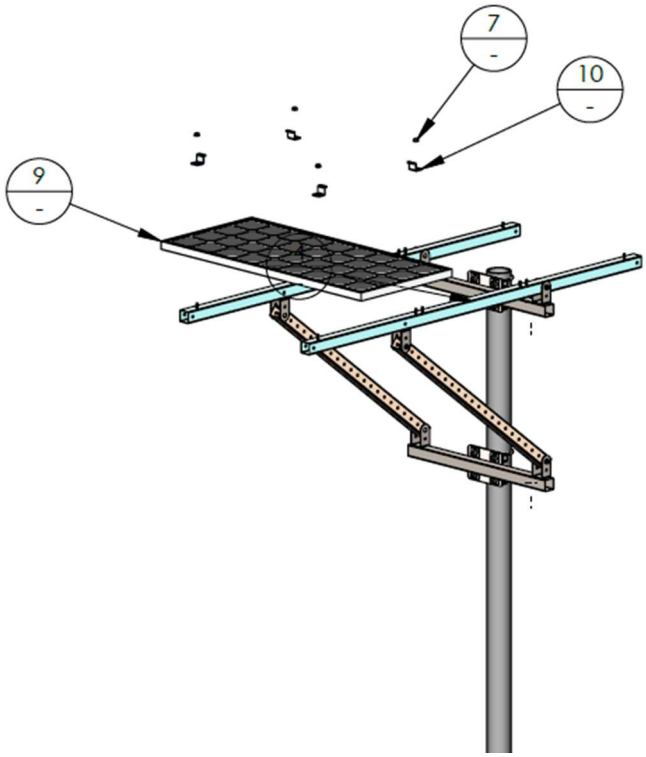


Figure 4.22: *Assemble modules to module rails (first module shown).*

Module ground connections: Attach one ground lug to each module in the ground lug hole on the module frame. Connect ground wire starting at the module farthest from the ground rod location and feed the wire through each module.

Feed the ground wire along the outside of the conduit used for the solar array cable. Secure with the cable ties provided. See Figure 4.10.

Module output cable connections: Attach the solar module positive (+) output cables in parallel using the MC4 positive (+) branch connector supplied. All module positive output cables are connected together now. Next attach the solar module negative (-) output cables in parallel using the MC4 negative (-) branch connector supplied. All module negative output cables are connected together now. See Figure 4.11.

Attach the 20 meter solar array cable to the MC4 branch connectors that will connect to the CFD-50 SDD. Feed the solar array cable through the top of the conduit electric service entrance through the conduit into the building. Tie any loose cables with the UV resistant, black nylon cable ties supplied.

Tighten all fasteners: Once the structure with solar modules has been positioned retighten all theft deterrent fasteners.

4D THEFT DETERRENT FASTENERS

If the solar array is stolen the lives of the community are threatened and valuable vaccine will be spoiled. The Aucma Solar Power Kit includes theft deterrent fasteners and unique tools (see Figure 4.23):



Figure4.23: *Theft deterrent carriage bolt, security nut, and security nut socket driver*

4E GROUNDING THE SOLAR ARRAY

Each solar module is required to be grounded to an earth rod or steel foundation reinforcement rod. Most DC electrical systems are attached with bare copper ground wire to an 5' (1.5m) copper clad steel rod driven into the earth. The ground wire should take the shortest distance to earth and avoid bends as much as possible. The wire must be secured to the building or pole. Consider conduit protection where it is likely that health workers, patients, children or animals will come intact with the ground wire.

See Figure 4.10 for module to module ground connections. See Figure 4.24 for details of the ground wire to ground rod connection.



Figure 4.24: *Ground wire, connector and 5' (1.5 m) copper plated steel rod.* Photo courtesy FGL/IM-PAHO and SELF

To be sure the solar array ground has continuity set your multi-meter to Ohms (Ω) and measure from the farthest solar module frame to the ground rod. The resistance should be 0.5 Ohms or less. See Figure 4.25. Record the resistance in the Commissioning Report. See **ANNEX F: Using Multi-Meters with Solar Refrigerator Systems**.

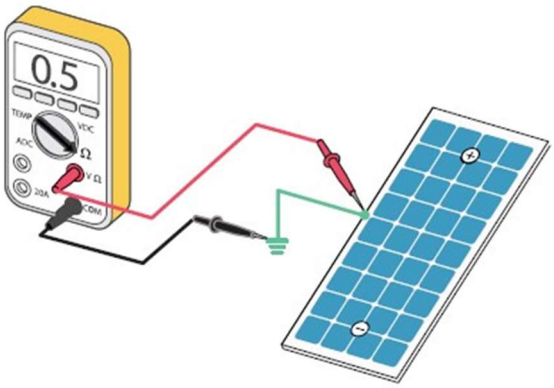


Figure 4.25: *Measuring ground system continuity.* Graphic courtesy FGL/IM-PAHO and SELF.

4F CABLE ENTRY INTO THE BUILDING

The solar array cable is designed for direct exposure to sunlight. However the cable should not lay in wet areas and the cable should be protected from abrasion, sharp edges, animals and accidental cutting. Electrical fittings are provided to protect the cable where it enters the building. Sealant is provided to weatherproof any penetrations in the building roof and walls.

Some installations will route the solar array cable over the roof edge and through the wall. The cable must be protected against damage and sharp bends at roof edge and when passing through walls. Conduit body boxes can be used to pull wire through sharp bends. Cable entering the wall often make a sharp turn and then pass through the wall. Walls may settle and pinch cables. Rodents can chew through cable insulation.
Conduit protection is one acceptable method to protect cable when entering through a wall. See Figures 4.26 and 4.27.



Figure 4.26: *Flush mount solar array with cable entry through electrical service entrance and then through the wall of the health facility.* Photo courtesy of FGL/IM-PAHO and SELF.



Figure 4.27: *Example of exterior conduit with conduit body and short conduit passing through the wall where the solar array cable is in the health facility.* Photo courtesy of FGL/IM-PAHO and SELF.

Alternately, a direct penetration through the roof surface can be made as shown in Figure 4.28. For direct penetration you will need a special component roof flashing (not included in the Aucma Solar Power Kit). Follow the roof flashing instructions carefully to avoid leakage.



Figure 4.28: *Roof flashing with gasket (not part of the Aucma Solar Power Kit).* Photo courtesy of FGL/IM-PAHO and SELF.

4G PRE-TESTING SOLAR ARRAY AND CONNECTING TO THE CFD -50 SDD METAFRIDGE

Test the solar array cable for polarity and Voc before connecting it to the CFD-50 SDD. Make sure the positive (+) solar array cable MC4 connector will match the red SDD positive (+) input cable / connector Record in the **ANNEX D: Commissioning Report**.

The Voc of an Aucma solar array will usually be between 17 and 22 Vdc (depending on the temperature of the solar module). Record the solar array Voc in the Commissioning Report.

The Isc of a 300 Watt solar array will be about 15+ amps (at midday if weather is sunny and clear). In order to safely measure the Isc of the whole array your multi-meter must have a 20 Amp (DC) setting. Cover the solar array, connect the meter leads to the MC4 connectors, remove the cover, record the amps, cover again and then remove the multi-meter leads. If you have a hand-held solar radiation meter measure solar radiation (instant reading of Watts/m²) at the same time as you measure the Isc. Record the solar array Isc (and the optional solar radiation measurement) in the Commissioning Report.

If the ground resistance is 0.5 Ohms or less, the polarity is correct, the Voc is between 17 and 22 Vdc and the Isc is reasonable for the sunlight conditions then the solar array is wired correctly. Congratulations!

With the CFD-50 SDD power switch (located at the rear of the CFD-50 SDD) the "Off" position connect the solar array cable to the CFD-50 SDD cables.

To start the CFD-50 SDD first follow all instructions in the **Aucma CFD-50 SDD MetaFridge User's Manual**.

PART 5: INSPECTION, COMMISSIONING, USER TRAINING AND ACCEPTANCE

5A INSPECTION CHECKLIST

After you have completed the installation fill out the inspection checklist to document that the installation is complete and correct per WHO PQS requirements. If you discover any aspects of the installation that were not completed this is the time to finish the work. See **Annex C: Installation Checklist, provided courtesy of the World Health Organization (WHO)**.

5B COMMISSIONING REPORT

The commissioning report documents the refrigerator temperatures and electrical measurements you have taken including CFD-50 SDD temperature, polarity confirmation, ground system resistance, solar array Voc and solar array Isc. It is the record of how the entire system performs at the completion of the installation. See **ANNEX D: Commissioning Report**.

5C HEALTH WORKER TRAINING OUTLINE

For: Day-to-day users of the CFD-50 SDD MetaFridge (health workers and their direct supervisors).

Goal: Certify that each user has successfully learned about the new equipment and is prepared to safely use it, to maintain it, record basic information on operation and to understand when to report equipment problems.

Outcome: Certificate of Successful Completion awarded to health workers participating in hands-on activities and (optionally) passing a short test.

Suggested Course Outline:

1. Solar energy basics

2. Battery-free solar direct drive refrigeration

3. Aucma Solar Power Kit
   - Parts – solar array, structure, solar array power cable, ground wire
   - Operations – cool down, sunny day, cloudy day, rainy day and night
   - Autonomy
   - Maintenance

4. Cold chain basics
   - Refrigerator safety
   - Refrigerator placement
   - Keep vaccine +2°C to +8°C
   - Do not use refrigerator for any other purpose

5. CFD-50 SDD MetaFridge refrigerator
   - Parts
   - Operations
   - Daily temperature measurements and recording
   - Energy Harvesting
   - Maintenance

Annex G: Health Worker Quiz
Annex H: User Training Checklist

Lesson Plan

***GOAL*:** Staff is comfortable with the solar power equipment, can safely operate and maintain it and know who to report to if there is a problem

Training materials: a.) CFD-50 SDD MetaFridge and Aucma Solar Power Kit (installed).

b.) Cleaning supplies and tools.

c.) Contact details for authority to whom problems must be reported (determine this in advance of the training).

***OBJECTIVE 1*:** After a brief introduction the user can identify the components of a solar powered direct drive system and describe how each system functions.

***Task*:** Present and describe the components – solar array, structure, array cable, ground wire and CFD-50 SDD.

***Outcome*:** Upon successful completion the user will be able to name the main components.

***Evaluation*:** Informal, do as a class exercise by asking for a volunteer to name the CFD-50 SDD and point to and name the components of a solar direct drive power system.

OBJECTIVE 2: Describe typical daytime operation of a solar direct drive refrigerator – sunny day, cloudy day, rainy day and night.

Task: Describe why the fan and or compressor may go on and off with passing clouds.

Outcome: Upon successful completion the trainee will describe the weather conditions that can cause the fan and/or compressor to cycle on and off.

Evaluation: Informal: Announce that the test will have a question asking what causes the fan and/or compressor to cycle on and off. Ask for a volunteer to answer this question.

OBJECTIVE 3: Recognize the impact of shading and soiling on a solar direct drive system.

***Task*:** Describe the impact of shading and soiling. Alternately demonstrate shading impacts by partially shading the solar array when the compressor is running. The shading will turn off the compressor or slow its speed.

***Outcome*:** Upon successful completion each student will be able to describe what happens when even a small portion of a solar module is shaded. Each student will be able to list two maintenance tasks for the surface of the solar module (e.g. keep clean, keep unshaded).

***Evaluation*:** Informal, do as a class exercise by asking for a volunteer to describe what happens when just part of the solar array is shaded.

OBJECTIVE 4: The student can disconnect and reconnect the power system for routine maintenance at the on/off switch.

Task: Using the completed installation show the trainees the location of the on/off switch and have each student disconnect and then reconnect the system.

Outcome: Upon successful completion the student will be able to locate the on/off switch and operate the on/off switch and to disconnect and reconnect the power system.

Evaluation: Formal, each student will be required to disconnect the power by operating the on/off switches. Record the names of the trainees who have performed this function.

OBJECTIVE 5: Knowledge and practice using the solar module cleaning supplies and tool.

Task: Using the cleaning tool demonstrate the correct steps in cleaning the solar module including preparation of mild detergent and water mix, applying the mix and cleaning the glass until clean.

Outcome: Upon successful completion each student will demonstrate their skill in applying mix and use of the cleaning tool.

Evaluation: Formal, require each student to correctly apply mix and properly clean a solar module. Record the names of the trainees who have performed this function.

OBJECTIVE 6: The student can name the person(s) who they report problems with equipment including temperature alarms.

Task: Prior to training determine who the health worker is to report to when there are either vaccine-related concerns or equipment concerns. Communicate with the supervisors and note the date of the solar power installation and training, invite the supervisor and obtain their permission to instruct staff to report problems directly to them (or their designee) and get their contact information. List problems that the staff should report including vaccine refrigerator temperature alarms and equipment observations (e.g. power is not on during sunny days, plants are shading solar modules, etc.).

Outcome: Upon successful completion the student will be able to name the supervisor they must report problems to and provide their full contact information.

Evaluation: Informal, each student will be required to name the supervisor(s) they must report problems to and name two type of problems that must be reported.

OBJECTIVE 7: Accurately read and record the daily temperatures from the integrated 30 day temperature logger and then enter in a daily temperature log (two times per day). Describe when the refrigerator is sufficiently cooled and the cold storage is sufficiently charged (cooled) to store vaccine.

Task: Using the standard temperature log already used on site (or a copy of an approved temperature log sheet) have each trainee read the temperature on the CFD-50 SDD and then input the date, time, temperature and any other observation(s). Compare the recorded temperatures to the CFD-50 SDD instructions for when the refrigerator is ready to store vaccine.

Outcome: Upon successful completion, each trainee will correctly read the thermometer and accurately record date, time and temperature.

Evaluation: Formal, ask each student to read the present temperature on the display and then complete a "dummy" temperature log for the date, time and temperature presently displayed. Ask each student to write the number of the days the fridge must cool down before using the first time or after a prolonged period of no use. Record the names of the trainees who have performed this function correctly and answered the question correctly.

OBJECTIVE 8: Health workers will be required to periodically clean the interior and exterior of the CFD-50 SDD. Training will include this step to assure participants are practiced at carrying out this step.

Task: Following CFD-50 SDD instructions the trainee will clean the interior of the vaccine storage compartment.

Instructions (reprinted from CFD-50 SDD User's Manual)

Cleaning maintenance:

a. Switch off the power supply to the CFD-50 SDD before cleaning. Wipe both inner and outer surfaces using a soft cloth dipped with neutral non-corrosive cleaning agent. Do not use any brushes, acidic or alkali detergents. Use a dry cloth to wipe clean surfaces. Do not use any organic solvents, hot water, detergents, or other harmful substances for cleaning

b. Do not pressure wash nor use any hard scrub to clean the CFD-50 SDD in order to avoid water leakage to electric components and damage to the exterior

c. Use warm water to scrub and clean the door gasket quarterly in order to maintain its flexibility and elasticity. Rub the door gasket with talcum powder to prolong its usage.

d. Use a piece of paper to check if the door gaskets are still tight. Close the door on the paper and if the paper falls out the door latch needs to be adjusted or the gaskets must be replaced.

Outcome: Upon successful completion students have carried out the cleaning procedure per CFD-50 SDD instructions.

Evaluation: Informal, do as a class exercise and record names of each user who participates.

OBJECTIVE 9: Health workers will understand the operation of the Energy Harvesting Control (EHC).

Task: Describe energy harvesting: when the solar panel produces more energy than the fridge needs, the fridge makes it available at the outputs on the side of the refrigerator. This energy is not guaranteed, as it depends on the amount needed to keep vaccines cool and the amount being produced by the solar panel. Remind them that a clean solar panel produces more energy. Describe how to use: just plug in devices and they will take energy when it is available. Describe the LEDs: they show when energy is available.

Outcome: Upon successful completion each student will be able to describe what the EHC is for and how to use it.

Evaluation: Informal, do as a class exercise and record names of each user who participates.

5D ACCEPTANCE

When an installation has been correctly completed, inspected, commissioned and the user has received training the installation is ready for the responsible health worker to accept the equipment and sign the acceptance form. The funding agency/buyer may have a specific Acceptance Form. See a sample form in **ANNEX E: Acceptance Form**.

PART 6: MAINTENANCE

6A USER MAINTENANCE (ROUTINE / PREVENTATIVE)

The health worker is responsible for day-to-day maintenance. Their main task is to monitor the CFD-50 SDD MetaFridge temperature for acceptable vaccine storage temperature of +2°C to +8°C. The health worker also will be responsible for keeping the CFD-50 SDD ventilation areas open and clean.

If the refrigerator is moved they will need to assure the CFD-50 SDD is in a secure, dry, level location out of sunlight and away from rain hazards.

Quarterly (or more frequently if Ministry of Health policies mandate) they will be responsible for assuring the solar array is clean, unshaded and undamaged. Solar array cable damage can occur from people, vehicles, large animals, small rodents and birds.

If equipment problems occur the health worker must know who to contact first (usually a supporting technician with cold chain experience).

For more details see both **Part 5C: Health Worker Training Outline** and **Annex I: Maintenance Checklist.**

6B TECHNICAL MAINTENANCE (ANNUAL / CORRECTIVE)

The solar power system has no moving parts or controls.

Each year it is recommended to have a technician inspect the solar array, cable and grounding.

Look for shading, soiling and damage to the cable. Look for signs of corrosion and clean.

Check each electrical connection and tighten all grounding parts and tighten mechanical connections.

Train any new health workers in operations and maintenance and if necessary, retrain veteran health workers.

See the CFD-50 SDD MetaFridge User's Manual for appliance specifics.

PART 7: TROUBLESHOOTING AND REPAIR

7A SOLAR POWER SYSTEM TROUBLESHOOTING

Most solar arrays operate trouble-free for years with only routine, preventive maintenance. Solar direct drive (SDD) power systems are the simplest type of solar power system. There are no fuses, switches or controls between the CFD-50 SDD on/off switch and the solar array. There are two troubleshooting conditions that are possible – **no power** or **not enough power**. See CFD-50 SDD refrigerator troubleshooting for other possible troubleshooting conditions within the CFD-50 SDD.

NO POWER: If power is not available at the CFD-50 SDD its temperature will eventually rise and the green LED will not be lit when there is enough sunlight to start the compressor. If this occurs the most likely causes are:

1.) CFD-50 SDD "on/off" switch is in the "off" position; or
2.) Solar array is shaded or too dirty; or
3.) Solar array cable has an open circuit; or
4.) Solar modules are damaged; or
5.) Solar modules are missing; or
6.) Solar modules have failed.

To troubleshoot when there is no power to the CFD-50 SDD:

-Record CFD-50 SDD temperature, status of green LED and alarms and power icons on 30DTR display

-Check that CFD-50 SDD "on/off" switch is in the "on" position.

-Check solar array cable is securely connected to CFD-50 SDD cable (near the refrigerator).

-Check solar array cable is securely connected to solar array MC4 branch connectors (near the solar array).

-Carefully inspect the solar array, structure and cable to:
- -Check that solar array is clean.
- -Check that solar array is not shaded.
- -Check that solar modules are not damaged, broken or missing.
- -Check that mounting is secure, at correct tilt and orientation.
- -Check that wiring is not damaged and is secure.

If no apparent fault is found next test the solar array for acceptable Voc and Isc.

⚠Safety first! For review see **Annex F: Using Multi-meters.**

-Switch the "on/off" switch on the CFD-50 SDD to "off".

-Disconnect both solar array cable MC 4 connectors from the CFD-50 SDD MC4 connectors near the refrigerator.

-Check that the polarity of the solar array cable and the CFD-50 SDD cable are correctly matched. If reversed, correct and test for CFD-50 SDD operation.

-Measure the solar array Voc.

-If zero (0) Vdc there is an open circuit. Find and repair.

-If the Voc is acceptable (e.g. at least 15 Vdc on hot day) then test for solar array Isc (short circuit current). Two technicians are recommended.

-Cover the solar array

-Set the multi-meter to read 20 Amp DC and position test leads in the solar array cable positive (+) and negative (-).
-Uncover the solar array and record amperage reading (and optionally record the solar radiation level with a hand-held solar meter).

-Cover the solar array.

-Remove the test leads now (this prevents dangerous direct current arcing that will damage both the MC4 connectors and the test leads).

-If the Isc is not acceptable repeat the Isc test with each solar module to determine which solar module(s) are faulty. Replace faulty solar modules.

NOT ENOUGH POWER: CFD-50 SDD is too warm but the compressor motor does operate for some on a sunny day. If this occurs the most likely causes are:

1.) Solar array is shaded or too dirty; or
2.) Power is being diverted for unauthorized use; or
3.) Solar module(s) cable has an open circuit; or
4.) Solar module(s) are damaged; or
5.) Solar module(s) are missing; or
6.) At times CFD-50 SDD "on/off" switch is accidentally in "off" position; or
7.) Solar module(s) have failed.

To troubleshoot when there is not enough power to the CFD-50 SDD:

-Record CFD-50 SDD temperature and status of green LED and alarms and power icons on 30DTR display

-Check that CFD-50 SDD "on/off" switch is in the "on" position.

-Check solar array cable is not connected to other devices.

-Check solar array cable is securely connected to CFD-50 SDD cable (near the refrigerator).

-Check solar array cable is securely connected to solar array MC4 branch connectors (near the solar array).

-Check that all solar modules are securely connected to the MC4 branch connectors.

-Carefully inspect the solar array, structure and cable to:
-Check that solar array is clean.
-Check that solar array is not shaded.
-Check that solar modules are not damaged, broken or missing.
-Check that mounting is secure, at correct tilt and orientation.
-Check that wiring is not damaged and is secure.

If no apparent trouble is found, you will need to test the solar array for acceptable Voc and Isc.

⚠Safety first! For review see **Annex F: Using Multi-Meters with Solar Refrigerator Systems.**

-Switch the "on/off" switch on the CFD-50 SDD to "off".

-Disconnect both solar array cable MC 4 connectors from the CFD-50 SDD MC4 connectors near the refrigerator.

-Measure the solar array Voc.

-If the Voc is acceptable (e.g. at least 15 Vdc on hot day) then test for solar array Isc (short circuit current). Two technicians are recommended.

-Cover the solar array

-Set the multi-meter to read 20 Amp DC and position test leads in the solar array cable positive (+) and negative (-).

-Uncover the solar array and record amperage reading (and optionally record the solar radiation level with a hand held solar meter).

-Cover the solar array.

-Remove the test leads now (this prevents dangerous direct current arcing that will damage both the MC4 connectors and the test leads).

-If the Isc is not acceptable repeat this test with each solar module to determine which solar module(s) are faulty. Replace faulty solar module(s).

7B SPARE PARTS – SOLAR POWER KIT

Service providers are advised to carry a spare solar module, spare MC 4 branch connectors (+ and -), extra solar array cable (for extensions and for replacing damaged cable), spare theft deterrent fasteners and spare theft deterrent fastener tools.

No solar power kit spare parts are needed at the health facility.

PART 8: WARRANTY

1. **Two-year warranty on the device, beginning on the date of shipment from Aucma, included at no extra cost.**
2. **Five-year warranty on energy harvesting components, included at no extra cost.**
3. Under warranty coverage, the manufacturer will repair or replace device components that have failed in the use of the device for its designed intent.
4. Warranty coverage does not include the following cases:
    (1) *Damage caused by improper use or improper maintenance.*
    (2) *Damage caused by attempted repairs done by a non-designated repair department.*
    (3) *Damage caused by force majeure.*
    (4) *Damage occurring after the warranty period has expired.*

PART 9: DISPOSAL AND RECYCLING GUIDE

9A SOLAR POWER KIT COMPONENTS

Solar modules have a 25-year power warranty. Typically, the solar module is warranted to provide 80% of its original rated power at year 25. There are reports of some solar modules still producing power after 30 years of continuous operation. Therefore, solar modules should be considered for redeployment for other uses once they are no longer useful electric generators for the CFD-50 SDD.

If the solar module no longer provides power (no voltage or no current) then contact local recycling authorities or the original solar module manufacturer (some have recycling programs to recover useful materials and capture any materials that could be dangerous, like lead solder).

Aluminum structure, copper wire and steel fasteners can be reused in some cases and all can be recycled.

REFERENCES and ACKNOWLEDGMENTS

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