Gary Beckwith
(802) 377-6527
gary@greenheronsolar.com

More free solar education:
Solarbus.org/solar101

Let's Share the Sun Foundation
letssharethesun.org

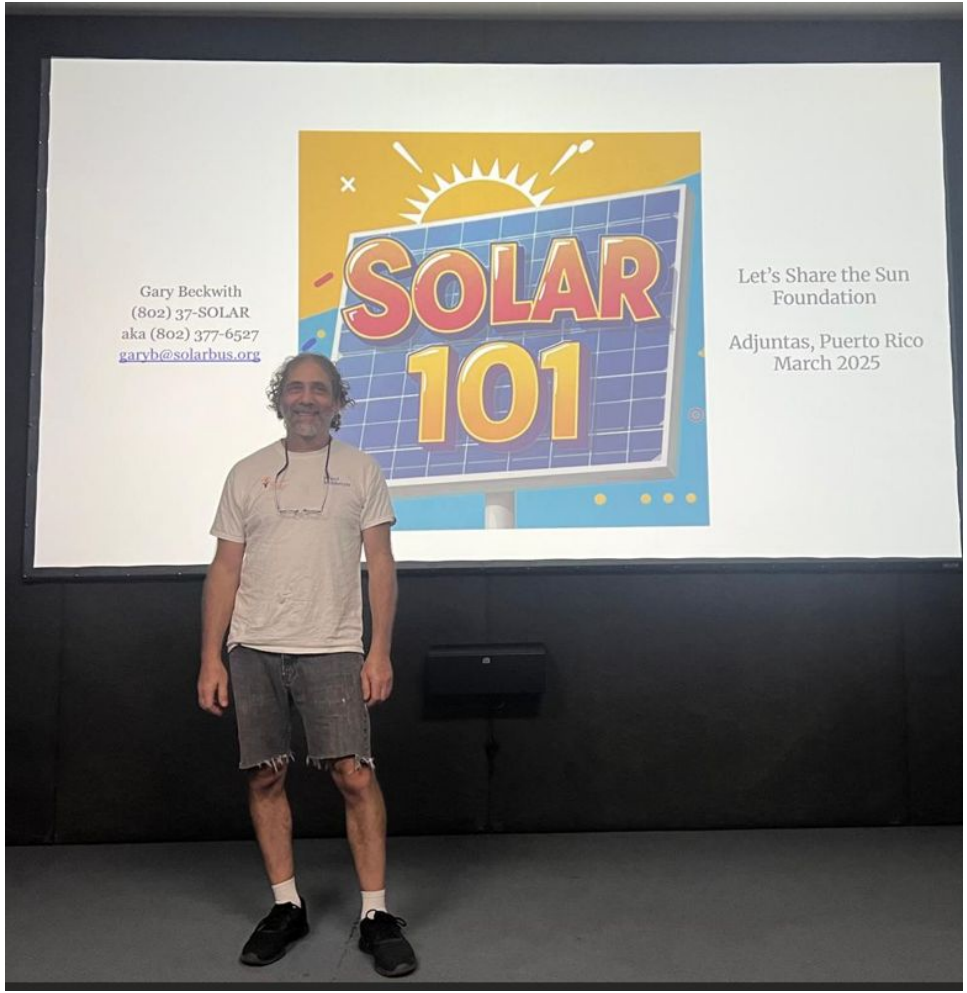
Adjuntas, Puerto Rico
April 2026

Solar 101 Class Outline

1. Solar, net metering, and types of systems
2. Solar system sizing
3. Basic solar installation hardware, methods, and safety

The following Solar 101 class was presented to a group of volunteers installing solar panels on homes in Adjuntas, Puerto Rico in April 2026.

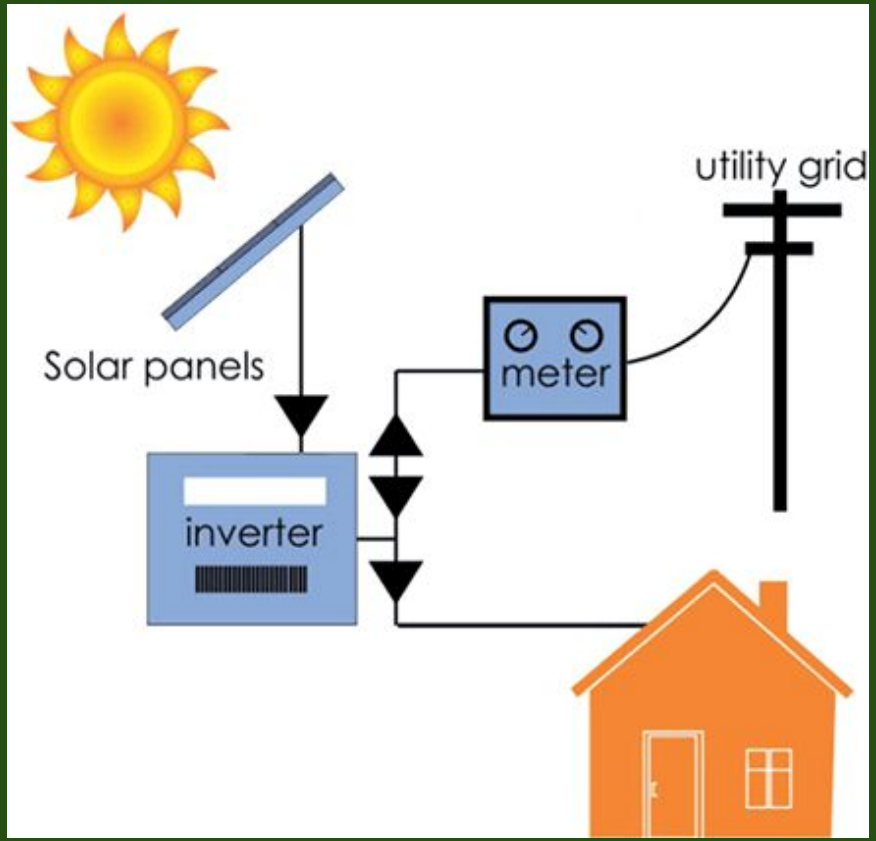
The project is spearheaded by Let's Share the Sun and its goal is to install solar systems on many homes in Puerto Rico who have medical needs that require electricity.



Types of Solar Systems

1. Net metered
2. Net metered with battery backup
3. Off grid

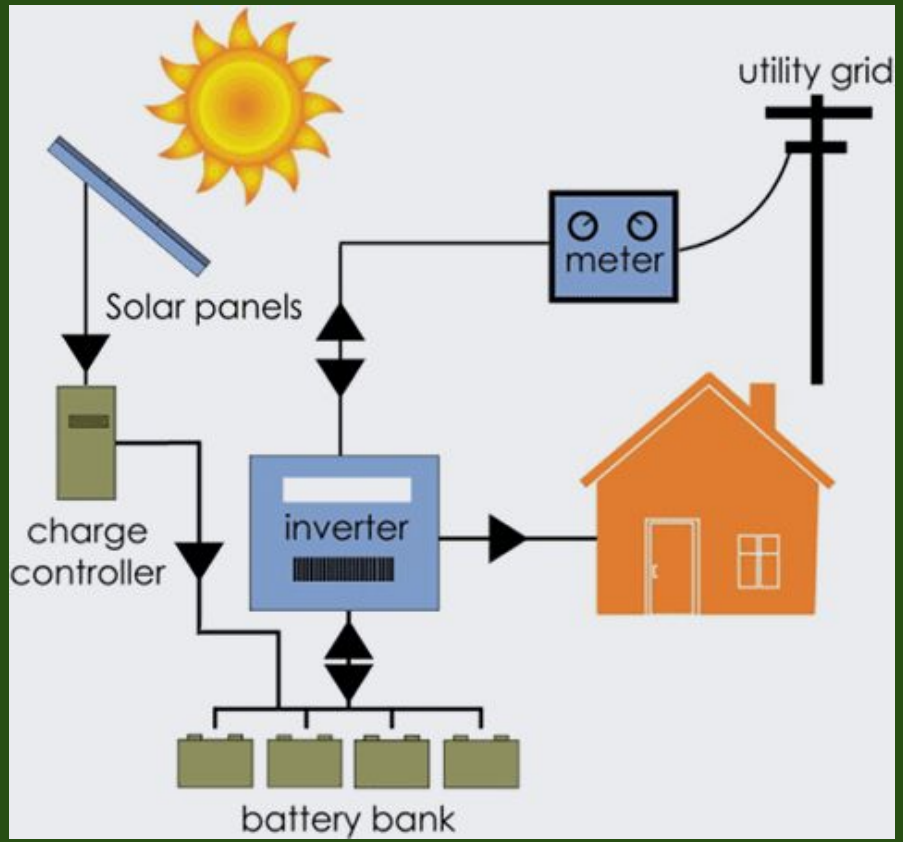
1. Net metered



1. Net metered

- When the sun is shining, power goes directly to appliances
- Excess power goes back to the grid
- The meter can spin forwards or backwards
- At the end of every month, customer is only billed for the net.
- If the solar made more power than they used in the month, they get a credit
- If they used more power than the solar made in a month, they can use credits from previous months (like “rollover minutes with phones)
- Usually they still have monthly fees not directly tied to usage
- Every state is different
- No batteries. No backup. When the power goes out, the system shuts down.
- The most cost effective type of system
- Best if there are not a lot of outages and the goal is to save money

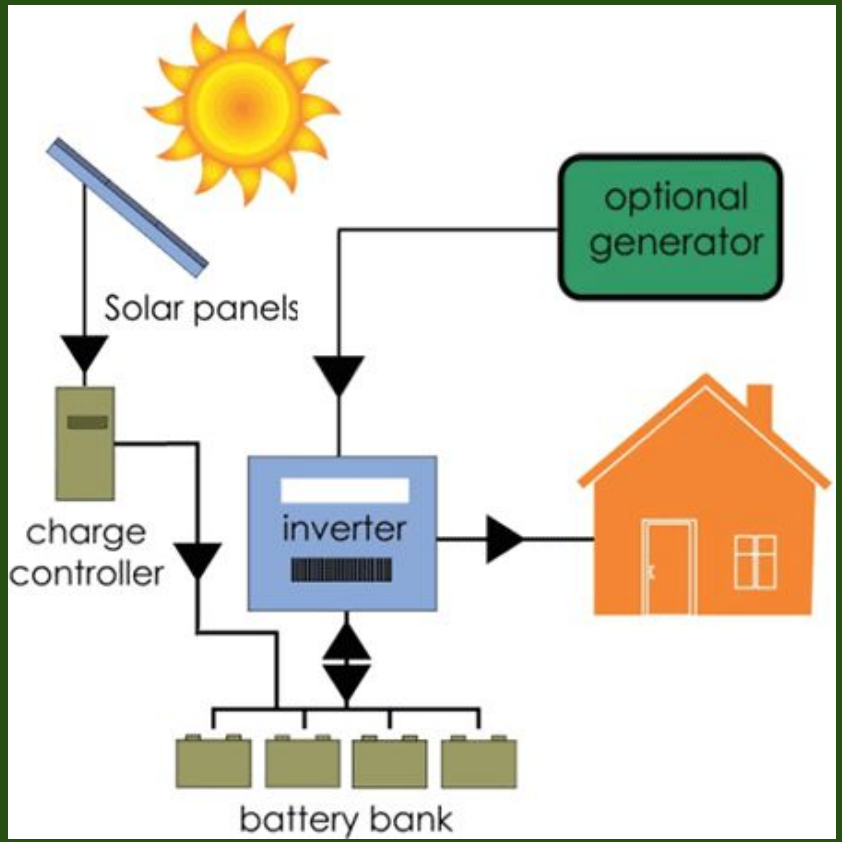
2. Net metered with battery



2. Net metered with battery

- This is the type of system we are installing on this trip
- Battery backup (storage) for outages
- Batteries significantly add to the cost of a system but provide many benefits
- Batteries are needed to run vital medical devices during power outages; this is one of the main purposes of our project.
- Battery can also be charged by a generator during an outage
- Power is still limited by the size of the battery and the size of the array, so sizing the system components properly is important.
- AC coupled
  - Mainly for adding batteries to an existing net-metered system
  - Two inverters - one for the solar and one for the batteries
  - More complex and expensive
- DC coupled
  - One “hybrid” inverter manages everything
  - All the systems on this trip are DC coupled

2. Off Grid


optional
generator
Solar panels
charge
controller
inverter
battery bank

3. Off grid

- Usually used where no utility power is available
- More essential to size array and battery properly, because there is no utility power to make up the difference
- Usually has a generator (or utility power) for backup

How many solar panels?

Match DEMAND to PRODUCTION

kWh used by house per year

=

kWh produced by solar panels per year

MATH CLASS!

The most complicated math equation you will have to use for solar is:

A x B = C

Remember this simple equation from 6th grade:

RATE x TIME = QUANTITY

mph (rate) x hours (time) = distance (quantity)
60 mph x 2 hours = 120 miles traveled

Watts (rate) x hours (time) = Watt-hours (quantity)
kW x hours per year = kWh per year

How many solar panels?

$$\text{Panels required} = \frac{\text{kWh used by house per year}}{\text{kWh produced by each panel per year}}$$

How many solar panels?

In order to know how much power one panel makes in a year we need two things:

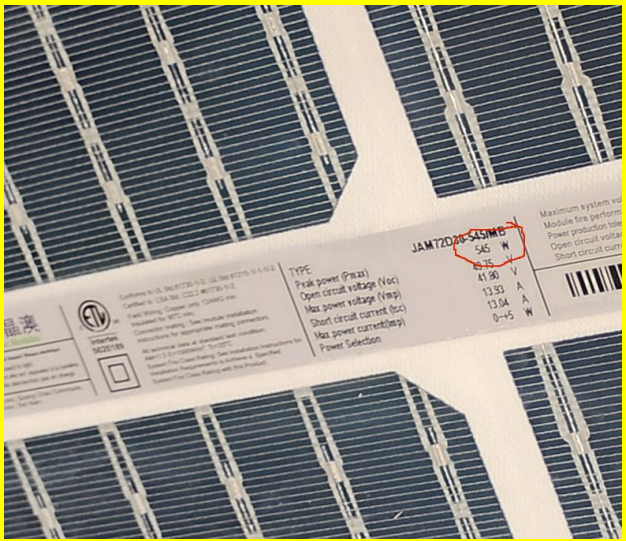
1) The rated wattage of the panel (RATE)
2) How many hours of charging per year (TIME)

Remember RATE x TIME = QUANTITY
WATTS x HOURS = WATT-HOURS (or kWh)

For design purposes, we need the quantity (kWh per year) for both the production (solar) and usage, so we can match the two.

How many solar panels?

Panel wattage



=

545 watts

- This is “peak power”
- Laboratory conditions
- Most panels put out about 80% of peak power in full sun
- This is what we use for calculations

How many solar panels?

So we have the RATE (watts) of the solar panels.

Now we need the TIME (hours of charging per year).

Then we multiply RATE x TIME to get the QUANTITY (kWh) of energy produced per year for each panel.

Watts x hours per year = kWh per year

Sooo…. How many hours of charging are there per year??????

How many solar panels?

PEAK SUN HOURS
(charging hours per year)

Puerto Rico: 1,600 peak sun hours per year
Vermont: 1,200 peak sun hours per year

- This is for “optimal” panel placement: proper orientation, tilt, and no shade
- Accounts for “peak” rating of panels

How many solar panels?

Annal power produced by one panel

Rate x time = Quantity

Watts x hours = Watt-hours (kWh)

=

545 watts
X
1600 hours

= 872,000
Watt-hours per year

= 872 kWh per year produced by each panel

How many solar panels?

Now we know how much power one panel produces per year.

We just need to know how much power the homeowner uses per year, to calculate how many panels they need.

Power use per year
÷
Power produced by one panel per year
=
Number of panels needed

How many solar panels?

How much power do they use/need?????

- Check history on electric bill
- Make a list of appliances and calculate an estimate
- Go with regional averages

- Average in mainland US is around 8,000 - 10,000 kWh per year
- 5,000 in Puerto Rico

How many solar panels?

Now we can calculate the number of panels required!

- Each panel makes 872 kWh per year
- House requires 5,000 kWh per year

YOU DO THE MATH!

The same formula applies with different numbers!

How many solar panels?

5.7 solar panels - now what?

- 5,000 ÷ 872 = 5.7 panels
- Always round up!
- Add 10-20%, solar panels are cheap!
- Consider possible future increase in demand.
- Add more for less-than-optimal site:
  - Shading
  - Orientation
- Even numbers are more aesthetic

How many solar panels?

Shortcut formula

$$\text{Number of panels} = \frac{\text{kWh per year demand}}{\text{kW per panel} \times \text{peak sun hours per year}}$$

Then add ~20%

Now you can design your own system!

- Check your electric bill. How many kWh did you use in the last year?
- Use 800 to 1,600 peak sun hours per year depending on where you live.
- Do the simple math!

Here's an example:

- 10,000 kWh per year
- sunny Colorado with 1,400 peak sun hours per year
- 400 watt panels

How many solar panels?

$$\text{Panels required} = \frac{10{,}000 \text{ kWh per year (ave. home in CO)}}{0.400 \text{ kW (each panel = 400 watts)} \times 1{,}400 \text{ (peak sun hours per year in CO)}}$$

How many solar panels?

$$\text{Panels required} = \frac{10{,}000}{0.400 \times 1{,}400}$$

How many solar panels?

Panels required =

17.8

Round up
Add a bit

20 - 22
Solar panels!

We did it!

Congratulations!

You are now a solar system designer and you can figure out how many solar panels are required for small and large systems!

One more example for fun.

How many solar panels would it take to make all the electricity the entire USA uses?

How many solar panels?

For fun let's design a system
For the whole USA!

$$\text{Number of panels} = \frac{\text{kWh per year demand}}{\text{Watts per panel} \times \text{peak sun hours per year}}$$

Then add ~20%

How many solar panels?

$$\text{Number of panels} = \frac{\text{4 trillion kWh per year}}{\text{500 Watts per panel X 1500 peak sun hours per year}}$$

How many solar panels?

$$\text{Number of panels} = \frac{4{,}000{,}000{,}000{,}000}{0.500 \text{ kW per panel} \times 1500 \text{ peak sun hours per year}}$$

How many solar panels?

$$\text{Number of panels} = \frac{4{,}000{,}000{,}000{,}000}{750}$$

How many solar panels?

Number of panels = 5,333,333,333

What does that look like?

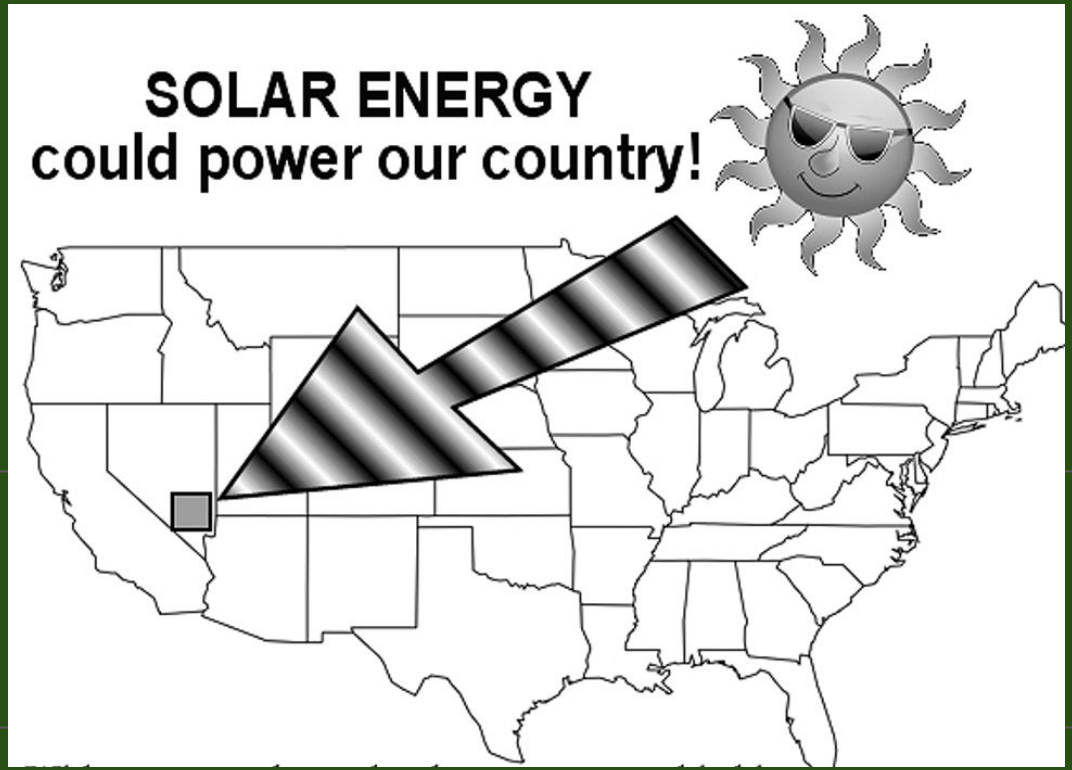
500 watts per panel = 5,333,333,333 X 0.5 kW per panel
2,666,666,666 kW
2,666,666 mW
5 acres per mW
13,333,333,333 Acres =

How many solar panels?

20,800 sq. miles
That is a square just 140 miles on each side!

Only 18% of the state of Arizona
could make all of our electricity!

How many solar panels?



Part 2.

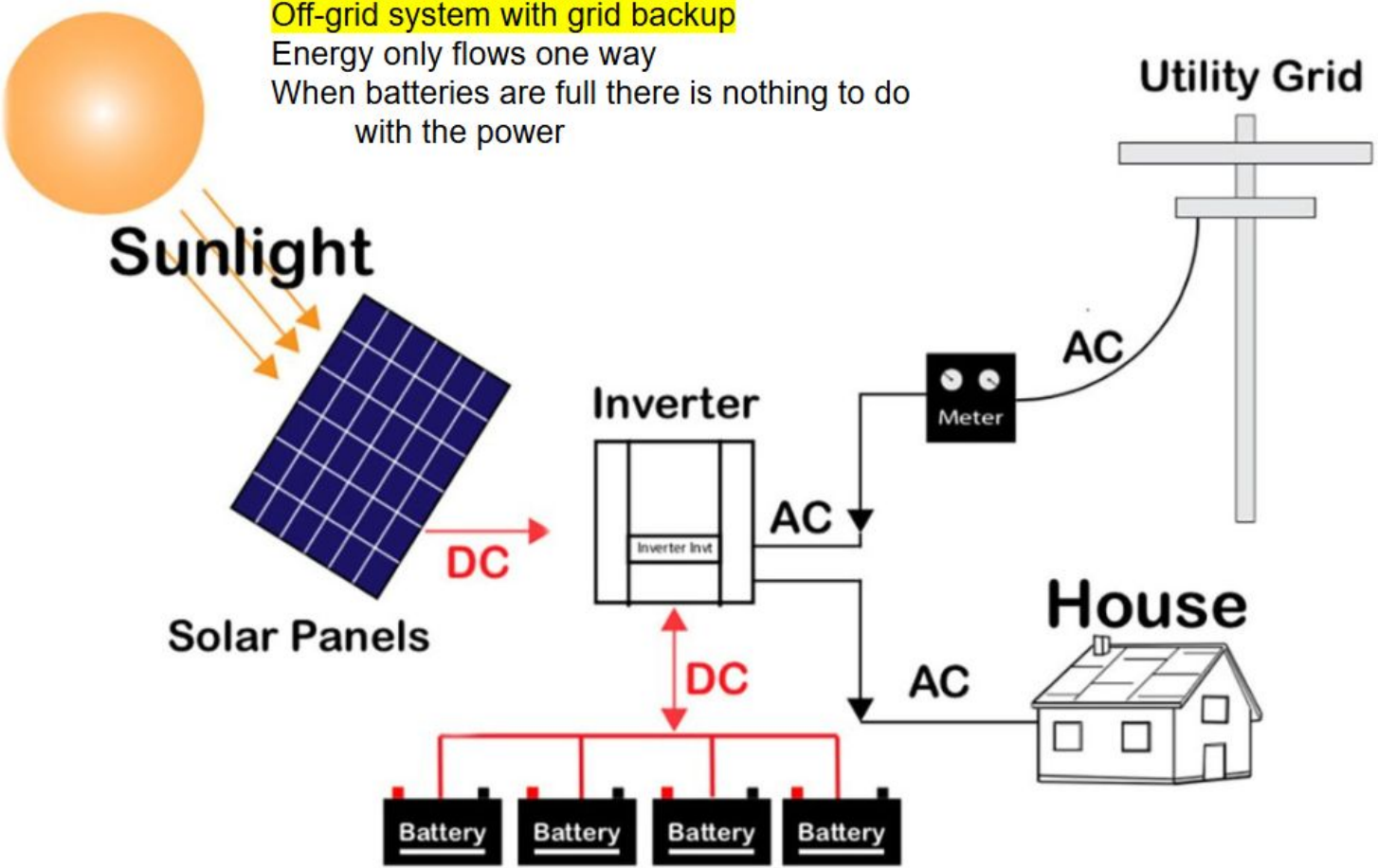
- Solar system hardware
- Basic installation

Previous projects

Off-grid system with grid backup

Energy only flows one way

When batteries are full there is nothing to do with the power

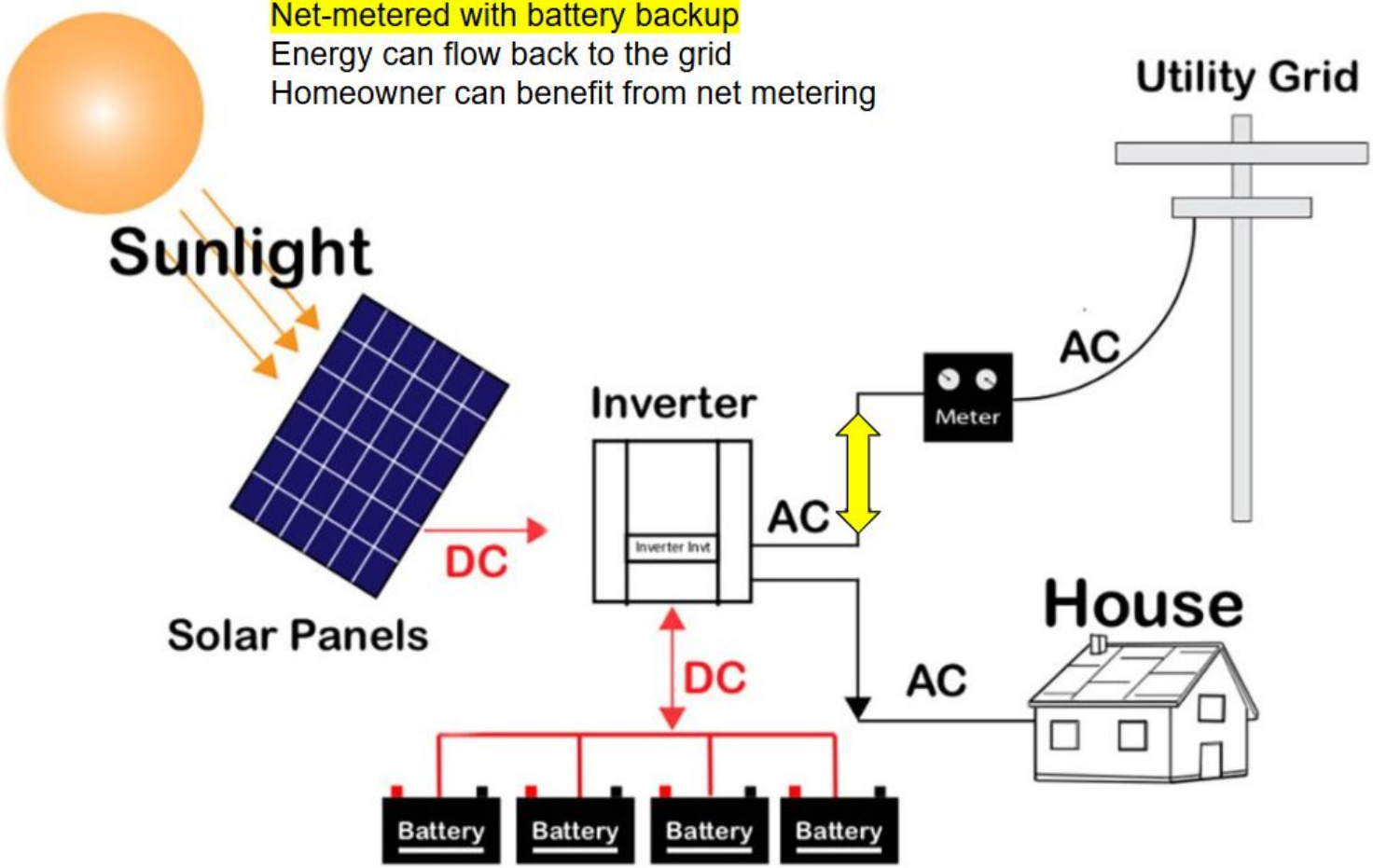


This year

Net-metered with battery backup

Energy can flow back to the grid

Homeowner can benefit from net metering



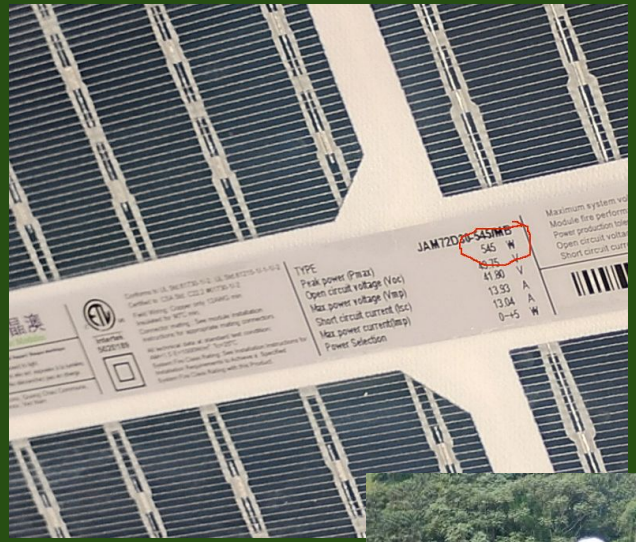
Solar Panels

Model: JA Solar

Watts: 545

Warranty: 25 years

Array size: 8 modules
8 x 545 = 4.3 kW



Inverters

- Convert DC (solar) to AC (utility power)
- Very efficient - 98%
- Maximum power point tracking (MPPT)
- Types of inverters
  - micro inverters
  - string inverters
  - hybrid inverters - a single inverter can interface with batteries, solar panels, and the grid. This is the best choice for net-metering with battery backup. If it is not hybrid, you would need two inverters (one for solar and one for battery).

HYBRID Inverter & Battery system

- “Hyrbrid” system interfaces with solar, utility, and battery.
- Programmable for different purposes and setups
  - Time of use, financial benefits
- Inverter can also charge the battery with utility power, solar, or generator
- Monitoring of system provides user-friendly graphics and data showing solar production, battery charge, energy use, and more.

Enough theory!

Let’s do some work!

Mounting solar panels on the roof

This is the main work we will do!

Mounting hardware

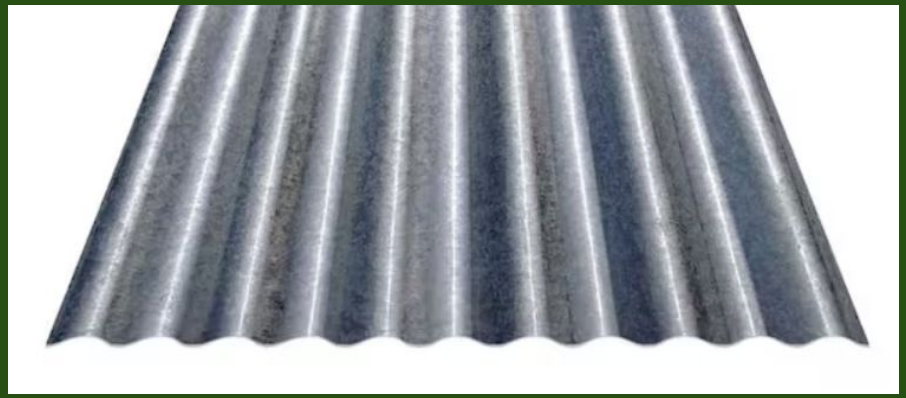
In this order:

1. Brackets
2. L-Foot
3. Rail
4. Modules
5. RSD devices
6. Wiring
7. Midclamps and endclamps

1. Brackets

VERY important to use the right kind of bracket to match the roof type!

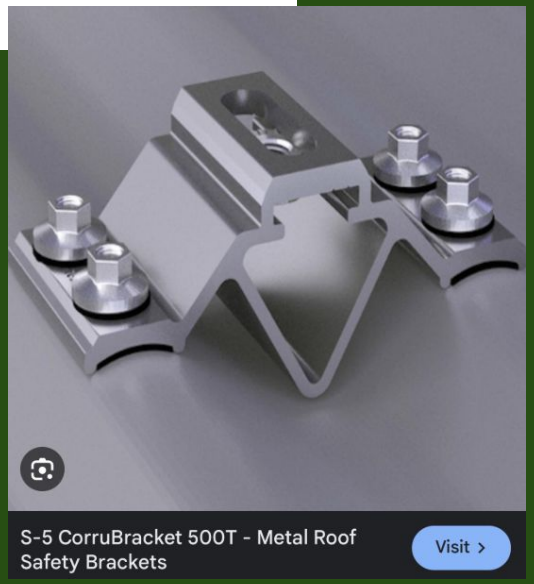
- **Corrugated metal roof**
- **Concrete roof (no bracket, just the Lfoot)**



1. Brackets

VERY important to use the right kind of bracket (and screw) to match the roof type!

There are many different types of metal corrugated roofs!



Flat concrete roofs

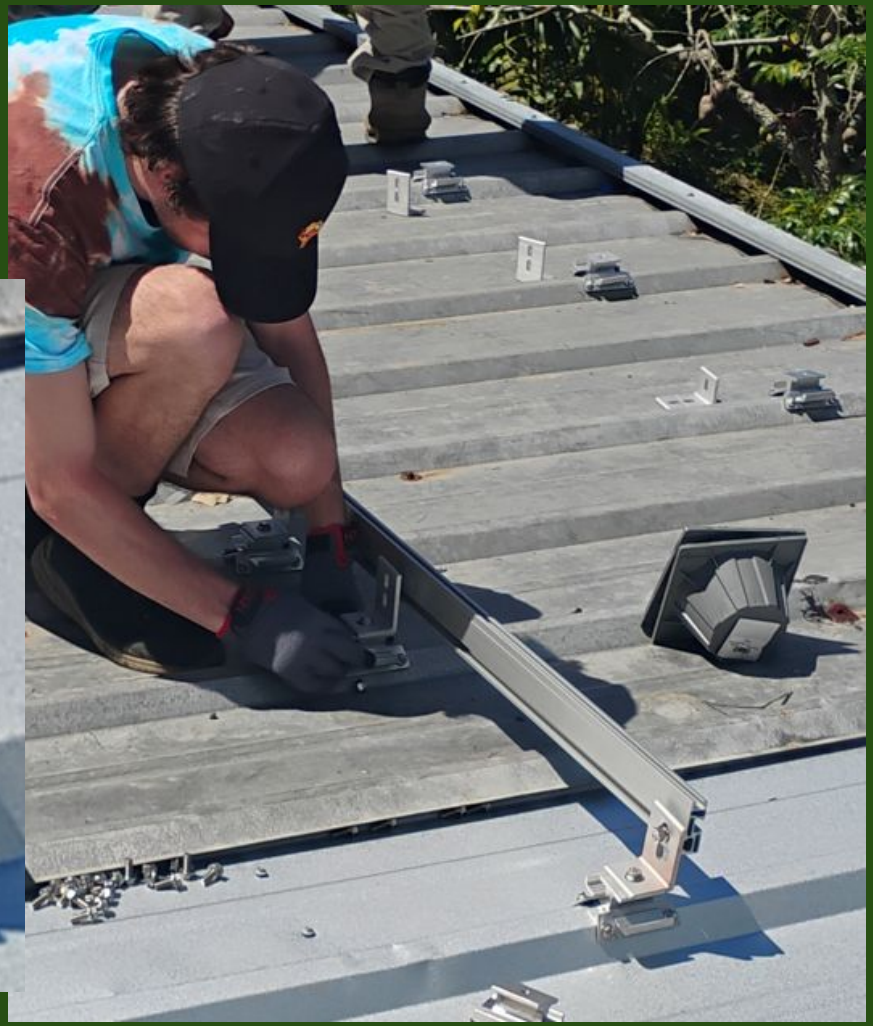
Safest roof to work on! Not slippery or sloped!

No bracket - directly from roof to L-foot

Since the roof is not sloped, the L-foot is longer in the back, to provide a tilt

Pre-drill a hole into the roof. Then fill the hole with epoxy and attach the L-foot with a lag bolt

2. L-foot and 3. Rail



4. Modules

5. What are those boxes under the panels????

Three types of devices:

- Rapid Shutdown Device (RSD)
- Optimizer
  Reduces effect of partial shading
  Increased production
- Microinverter
  Reduces effect of partial shading
  And is also the inverter

5. What are those boxes under the panels????

Three types of devices:

- Rapid Shutdown Device (RSD)
- Optimizer
  Reduces effect of partial shading
  Increased production
- Microinverter
  Reduces effect of partial shading
  And is also the inverter

5. What are those boxes under the panels????

Some RSDs and microinverters can handle two panels each.

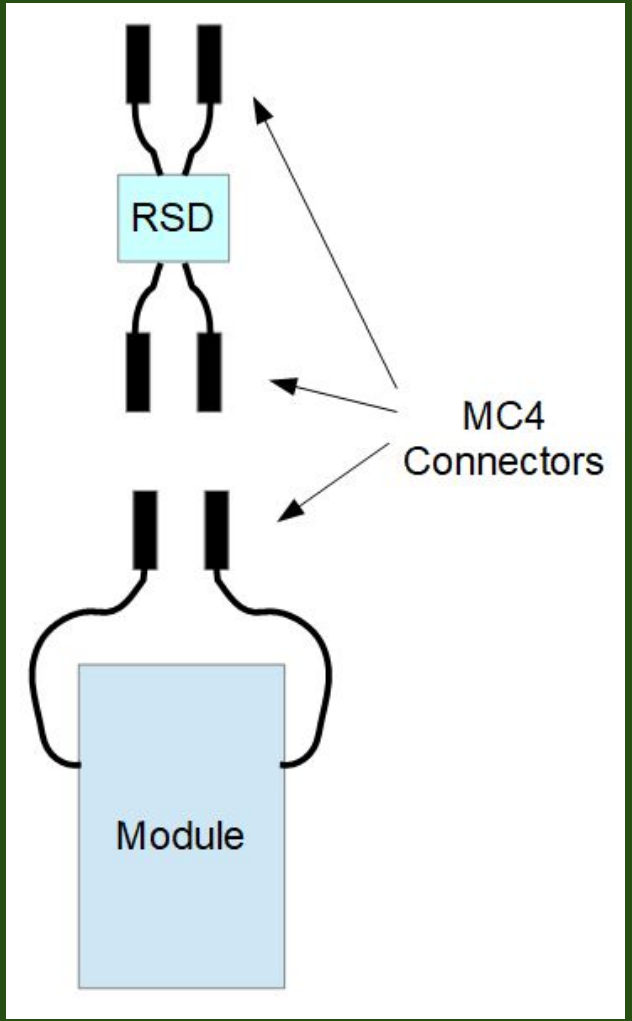
6. Wiring

MC4 Connectors:

- Pre-installed on modules and RSD devices
- “Male” and “female”
- You can’t connect them wrong or backwards
- Listen for the “snap”
- Use a special crimping tool to put one on a wire
- Special disconnect tool for pulling them apart

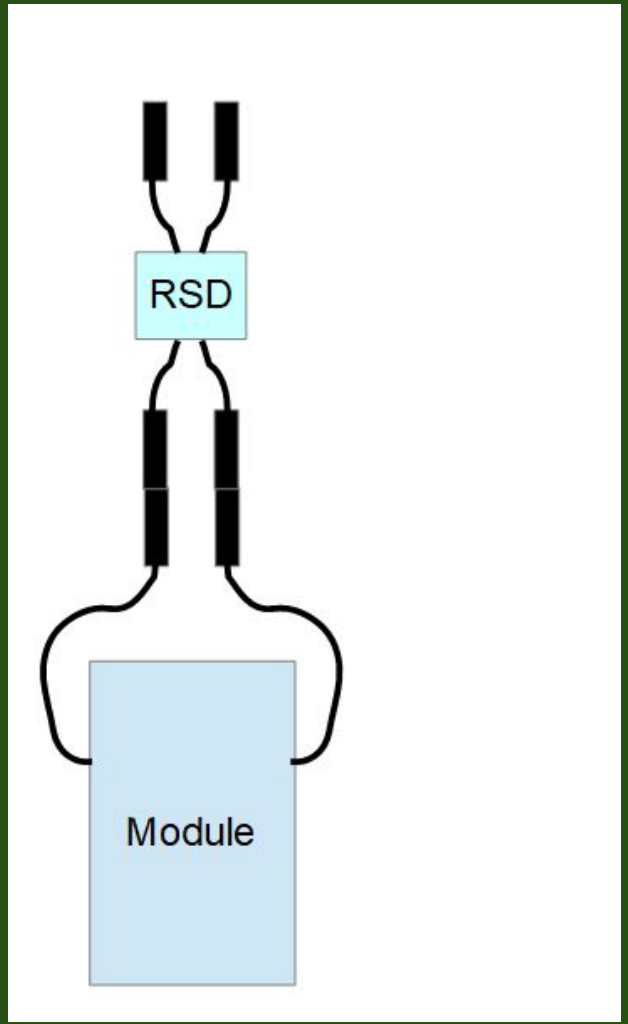
6. Wiring

MC4 connectors are pre-installed on modules and RSD devices



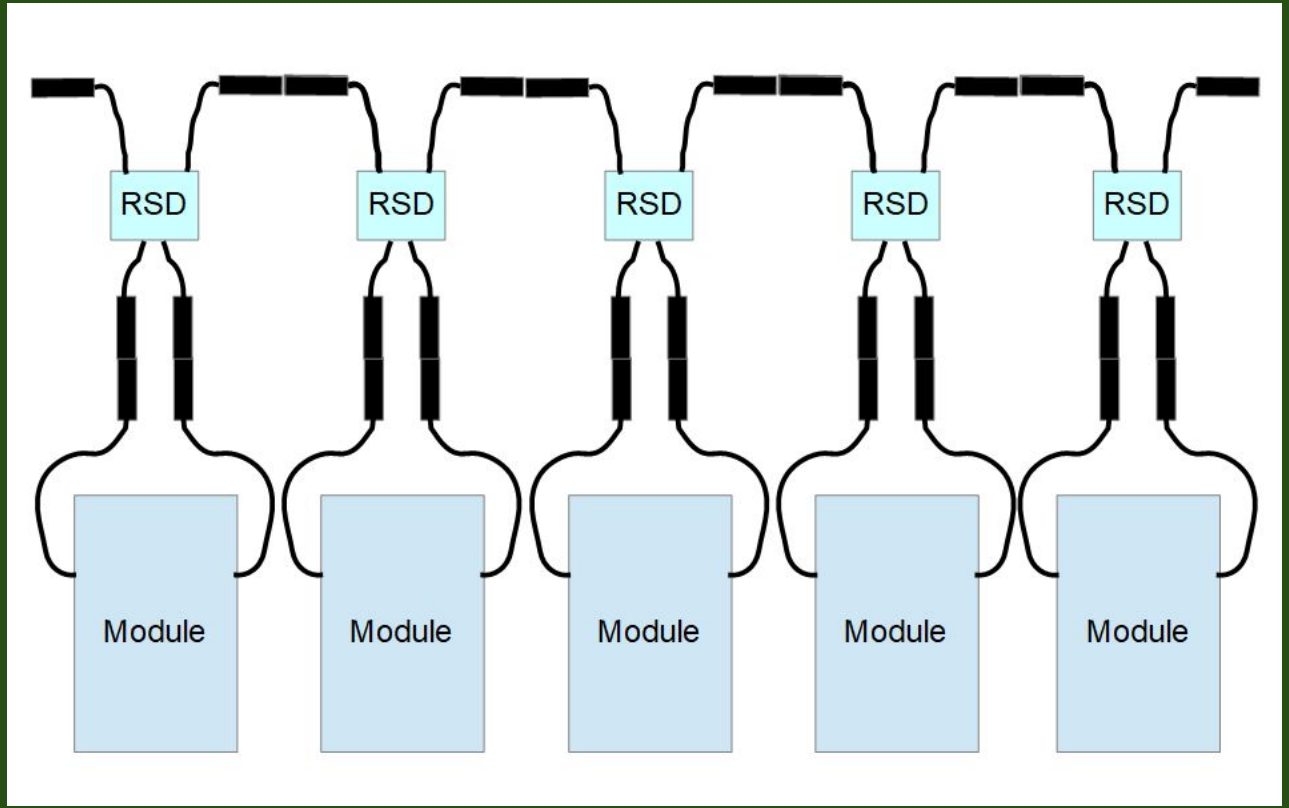
6. Wiring

Connecting the RSD
To the module



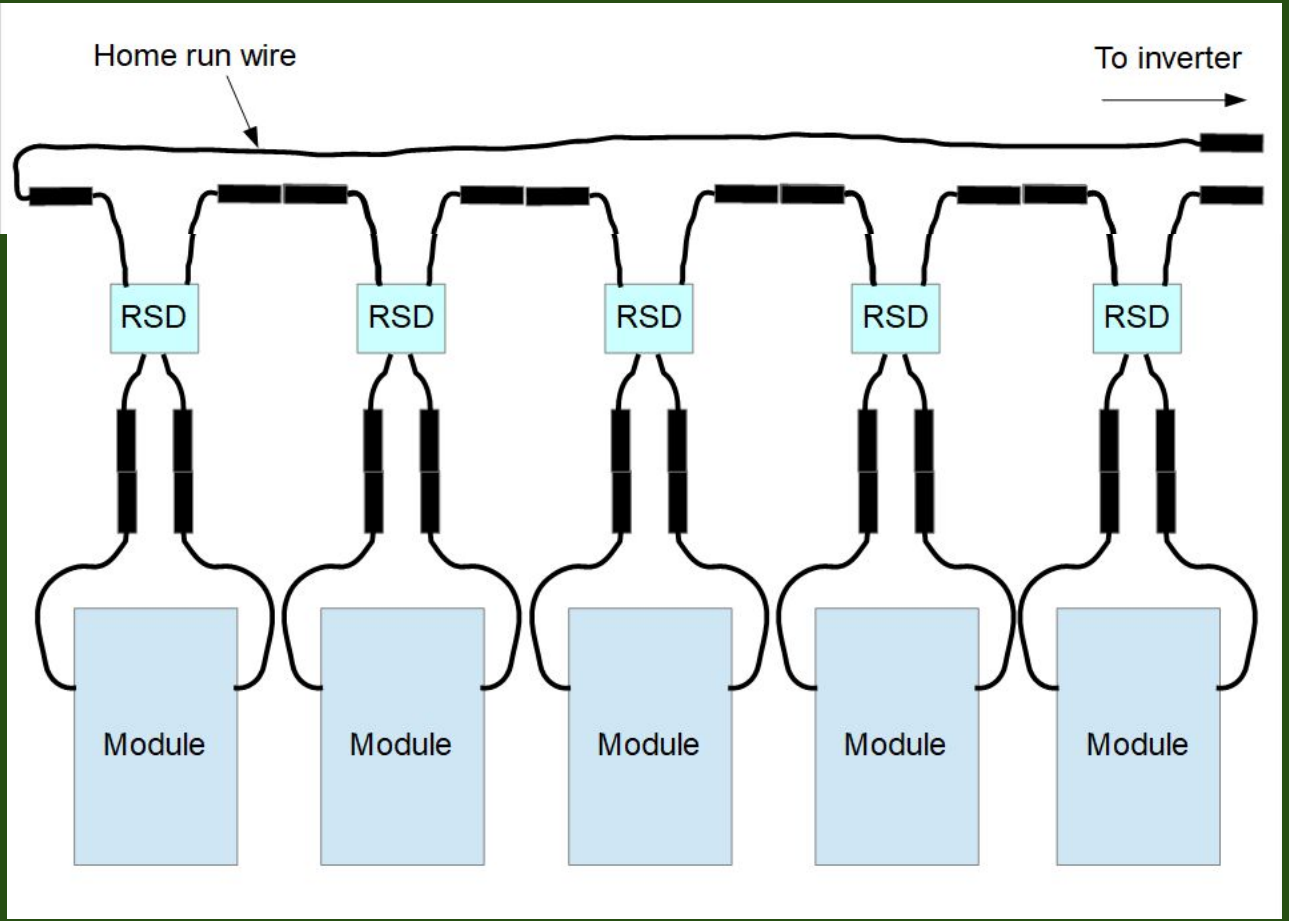
6. Wiring

Modules are wired in a SERIES STRING

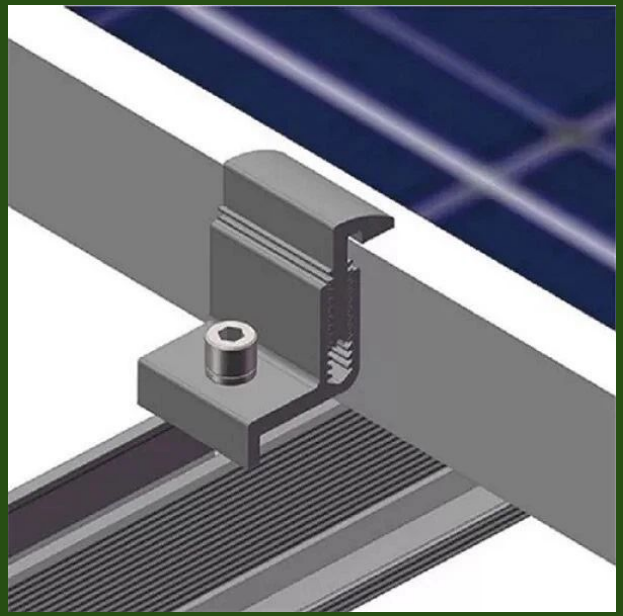


6. Wiring

The home run wire



6. Mid clamps & End clamps



Solar Safety!

- We will climbing ladders and on a roof. All buildings are one story, and fairly shallow roof slope.
- You don’t have to go on the roof. There is plenty of work to do on the ground.
- Be careful, use common sense!
- ALWAYS have a “spotter” when on a ladder.
- Never go up on a roof alone.
- Stay away from roof edges.
- Roof surfaces can get hot! Wear gloves. Be careful of exposed hands and knees.

We did it!

6 homes in 2 days!

Hope you learned something!

Special thanks:

Let's Share the Sun

Sol de la Montana

Stay in touch!

Gary Beckwith

(802) 37-SOLAR

greenheronsolar.com

solarseedproject.org