Solar Power For Schools:

Workshop:

Creating solar power systems for schools as a student project.

James Skon, PhD

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Kenyon

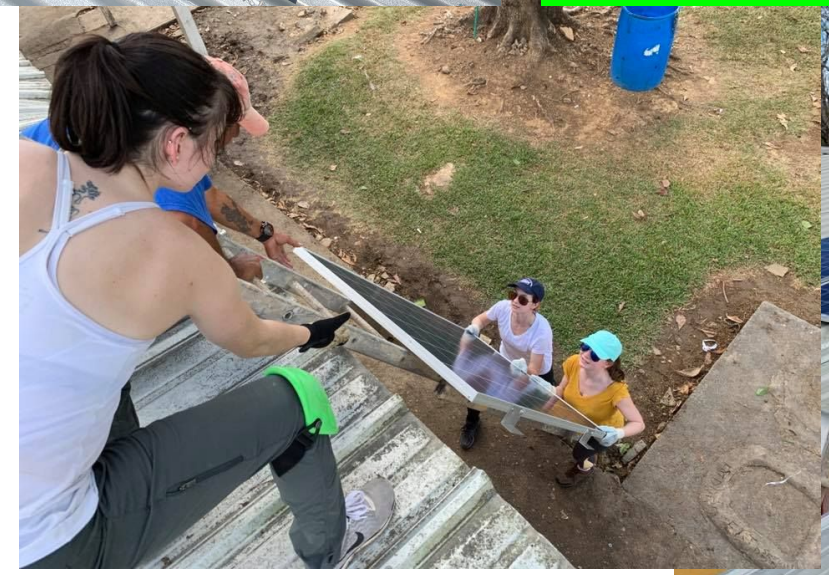
Workshop Objectives and disclaimer

I would like this workshop to:

1. Generate passion sound the idea that we can make a difference with very limited resources and but with loads of optimism.
2. Explain the processes and lessons learned in using students to build solar power systems for schools
3. Provide a starting point for student centric university solar projects

Disclaimer: I am not an expert in solar power. I figured things out as I went along. My colleagues kept me out of trouble. We made some mistakes, but I think we also made a positive difference.

For the past 35 years I have created and led student projects abroad.



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Big Picture

Since 2014 I have taken six students groups to Belize to install solar power systems on schools

- 7 days in country, plus 2 travel days
- Spring Break
- We install 1-2 systems at 5 schools
- We take 2 days for recreation

Since 2014:

31 solar systems on 19 schools

In Belize
Central america

Corozal Methodist School

Guinea Grass Primary

Saint Andrews Primary School

Faith Nazarene Primary School

Victorious Believers Primary

Alvin Young HS

Mount Carmel High School

United Pentecostal School

Arenal Primary School

Pueblo Viejo School

Aguacata Primary School

Sarteneja Nazarene Primary School

San Pedro High School

Brighter Tomorrow Preschool

Ambergris Caye Elementary School

New Horizon Primary School

Kings College

Light of the Valley Primary

Toledo Christian Academy

Kenyon

Certificate

ENERGY GLOBE NATIONAL AWARD *2020*

WINNER · BELIZE

PROJECT

Belize Solar Schools Project

APPLICANT

Dr. James Skon, Mr. Doug Karl
and Dr. Robert Alexander

Maneka Gandhi

Maneka Gandhi
ENERGY GLOBE Jury
Chairwoman

Wolfgang Neumann
ENERGY GLOBE Foundation
Founder

ENERGY GLOBE
The world award for sustainability

ADVANTAGE AUSTRIA WKO

UNIDO UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Kenyon

A vision (1986)

- Engage students abroad in meaningful service learning projects
- Create connections in culture, discipline, and humanity
- A course: *Seminar in International Development*
- Started with building out computer labs in Belize, Bahamas and Guatemala, the Philippines, Papua New Guinea

Papua New Guinea Hospital

- 2001 - Student project to setup database, wired and wireless network for hospital. (Worked with company that invented the Wifi router!)

Belize and Guatemala Computer Labs

2007-2013

- 12 Student trips to Belize
- January term for 3.5 weeks
- Spring break for one week

Belize and Guatemala Computer Labs

From 2007-2013 years we build about 30 computer labs, ~500 computers

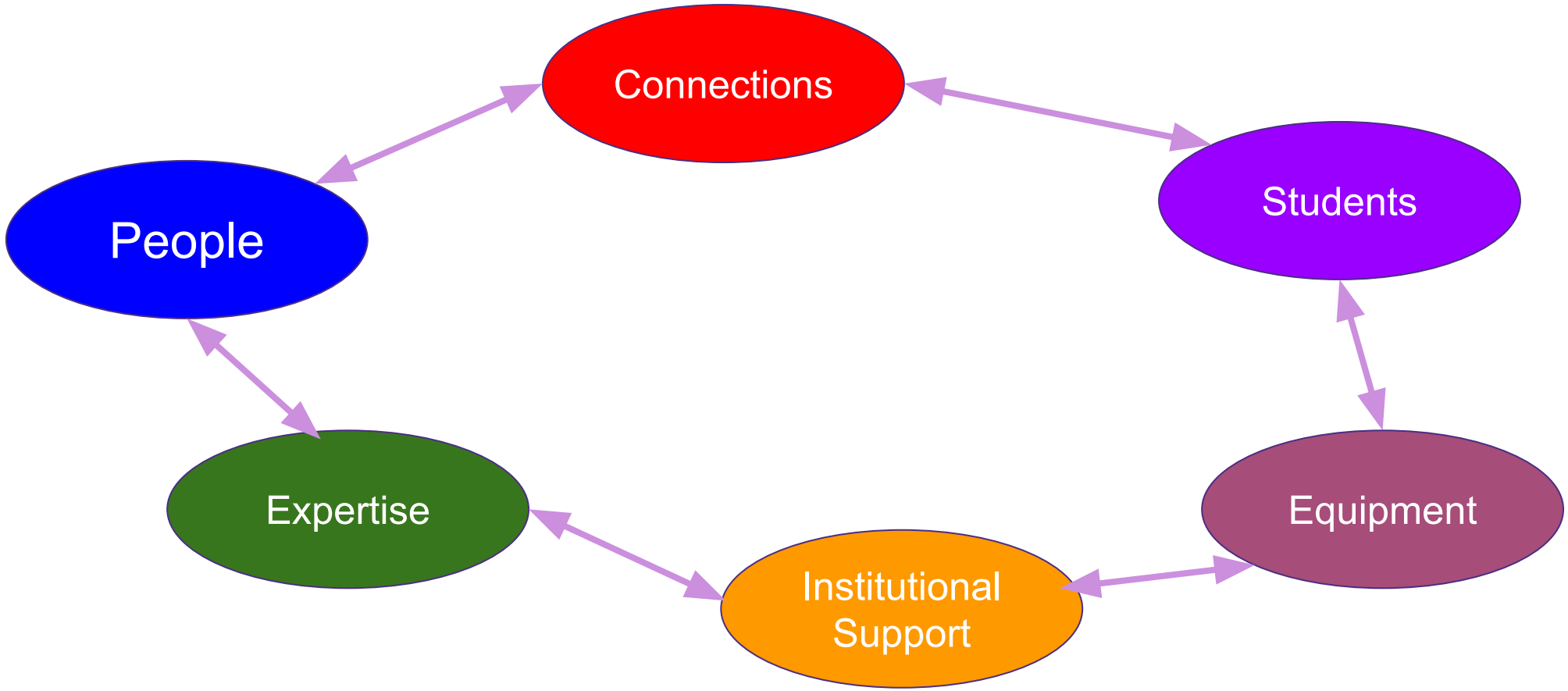
The Seed for a Solar Power project

- "*We can't afford the electricity to power our computers, so we don't use them*".
- Power is US$0.22/KWh in Belize
- For most schools in Belize the government pays for teachers salaries, but schools have to raise their own money for everything else.
- Tuition is charged ($5-$10 month) but many families can't pay it.

The Idea for Solar - 2013

- LOTS of sun in Belize!
- I noticed 230 watt panels were selling for about $150 in USA
- Inverters (1000 watt) were about $200
- I wondered if we could assemble a reasonable solar solution for under $1000/school?

The idea: create a student project to build solar power systems on schools abroad ?



My Local Co-conspirators

Doug Karl

- Met at Ohio State in 1980
- Electrical engineer and Computer scientist
- Invented the wireless router!

Rob Alexander

- Professor of Environment Studies at Kenyon College

Belizean Collaborators

Dwight Tillet

- Met in 1988 on first trip (Principal of High School)
- Later became the CEO of the Ministry of Youth and Culture later Transportation.
- Currently a general contractor
- One of my best friends to this day.

Belizean Collaborators

Luis Carballo

- General Manager of Ministry of Education
- Currently professor at Sacred Heart College
- Drove us all over Belize, introducing us to school Principals
- Sang with his CD of classic rock while he drove us around!

Organizational Collaboration

- Belize Ministry of Education
- Rotary Club of San Ignacio
- Church of the Nazarene
- Harcourt Parish Episcopal Church at Kenyon College

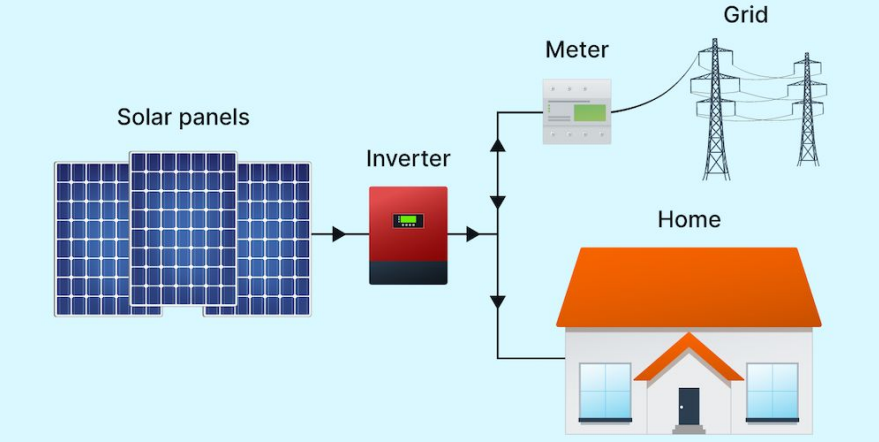
Connections

We needed schools! Luis and Dwight connected us with schools:

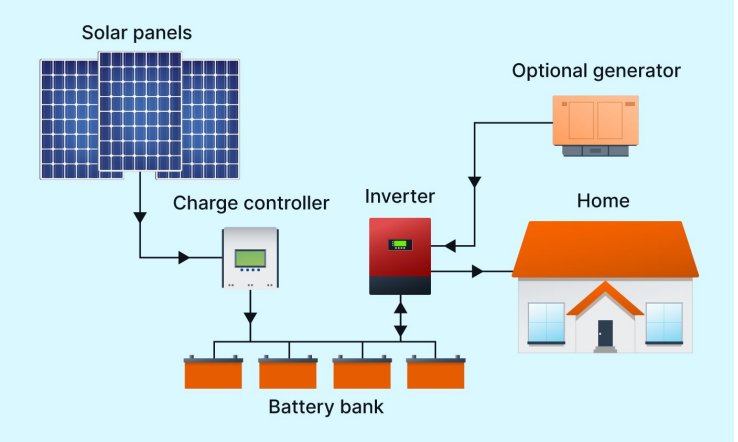
Knowledge (research)

- Technology
  - How do we build solar system?
  - What kind of system to build?
  - How big?
- Which Schools
  - What makes a good candidate?
- Logistics
  - Where do we get equipment
  - How to get it to the school

Design Choices: Grid-tie, off grid, or hybrid?

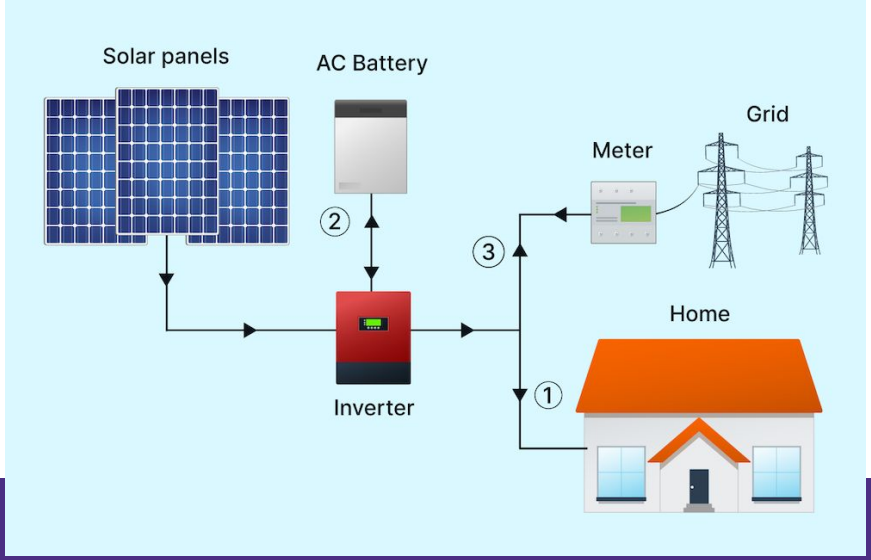


Grid Tie



Off Grid

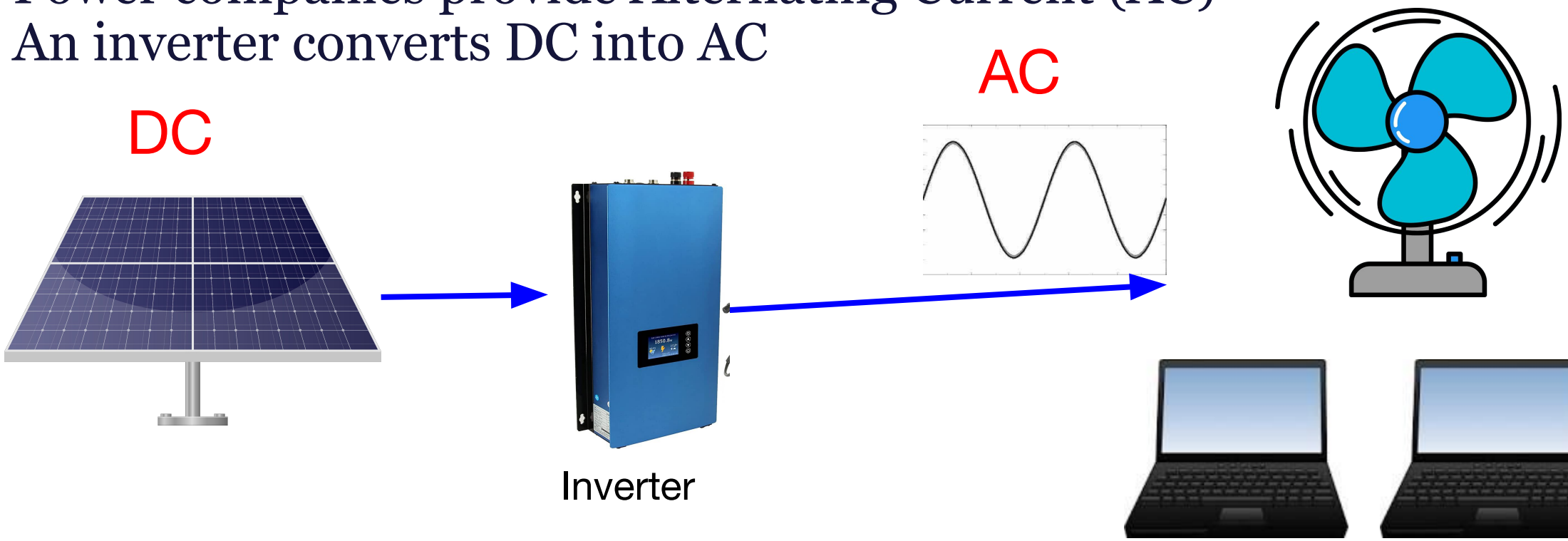
Hybrid



- We chose grid tie since most schools have electricity.
- Schools mostly need power during the day.

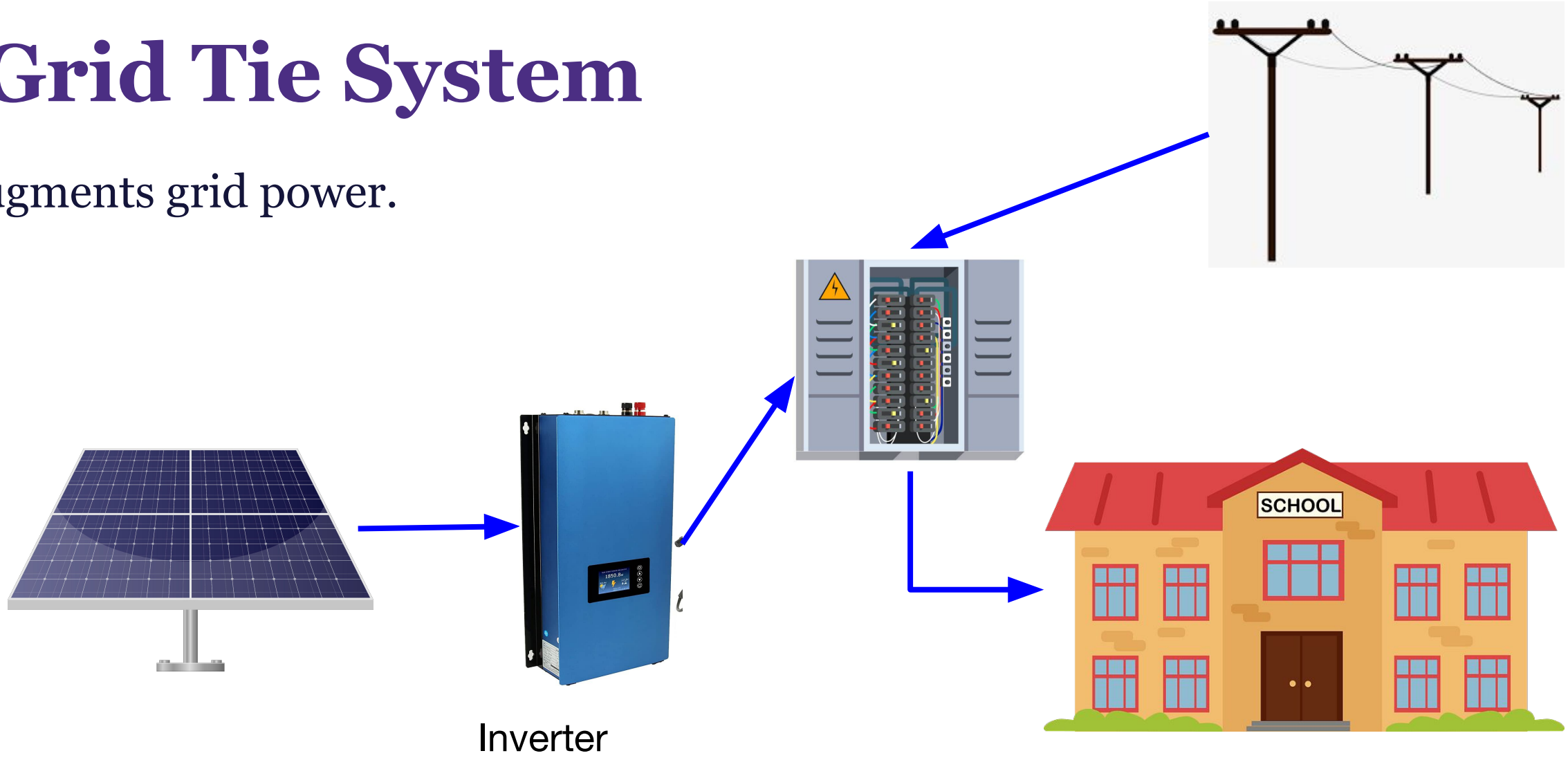
Inverter

- Solar panels and batteries produce Direct Current (DC) power
- Power companies provide Alternating Current (AC)
- An inverter converts DC into AC



Grid Tie System

- Augments grid power.



Inverter

Research

At each school we looked at:

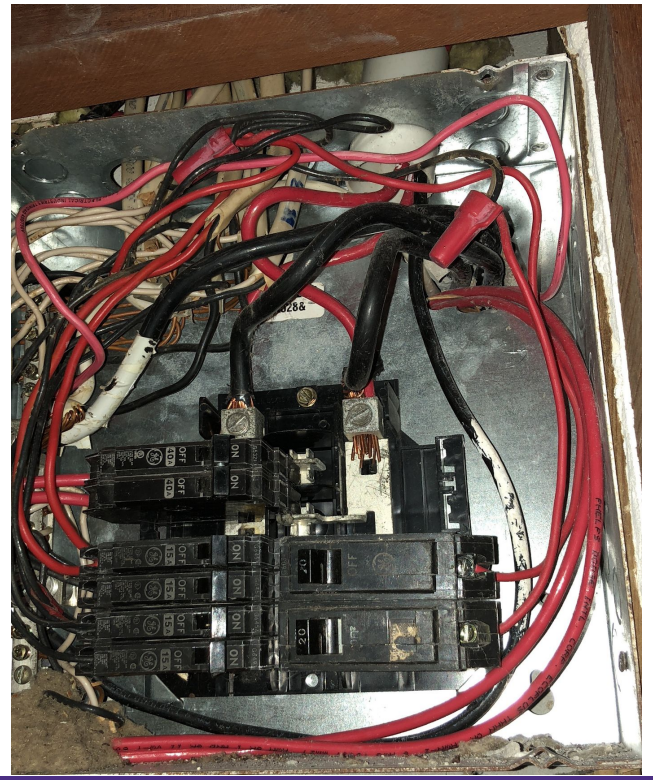
- Roofs
- Power boxes
- Power meters
- Power bills

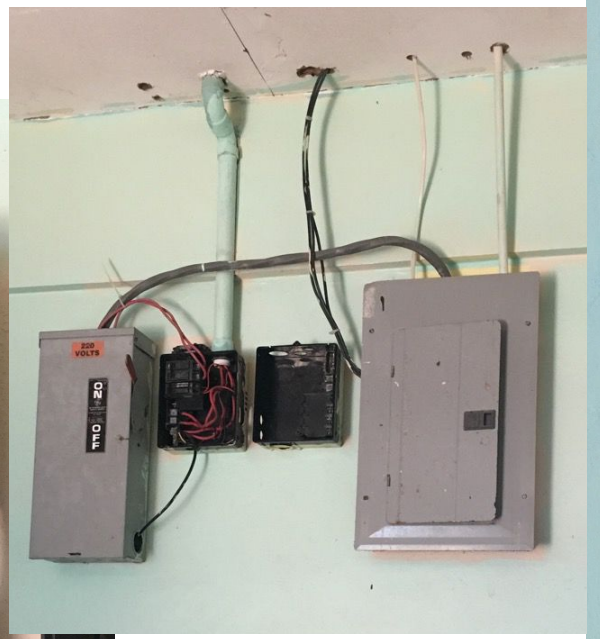
We evaluated:

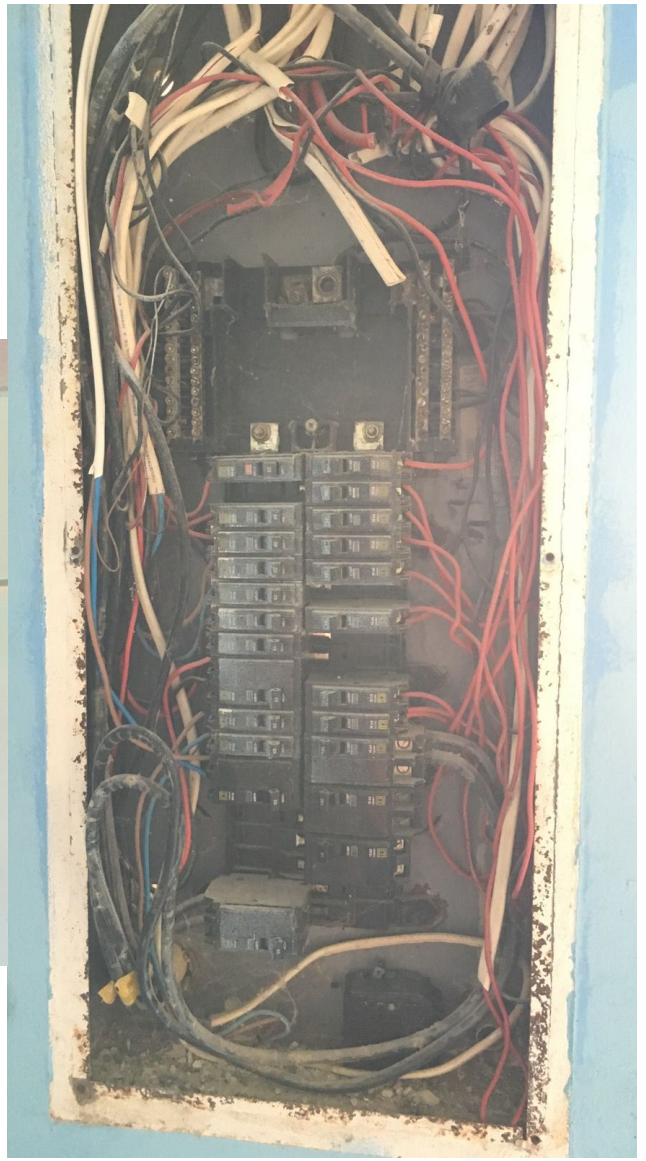
- School interest
- Available funding

In one week we can visit 30 schools!

Breaker Boxes



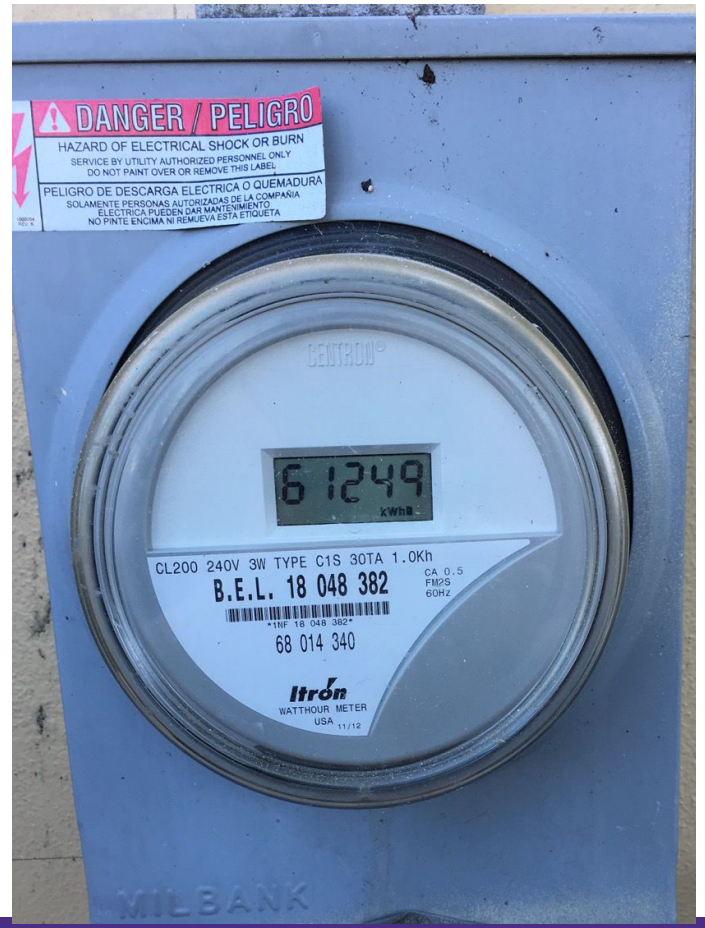




Power Meters

Mechanical

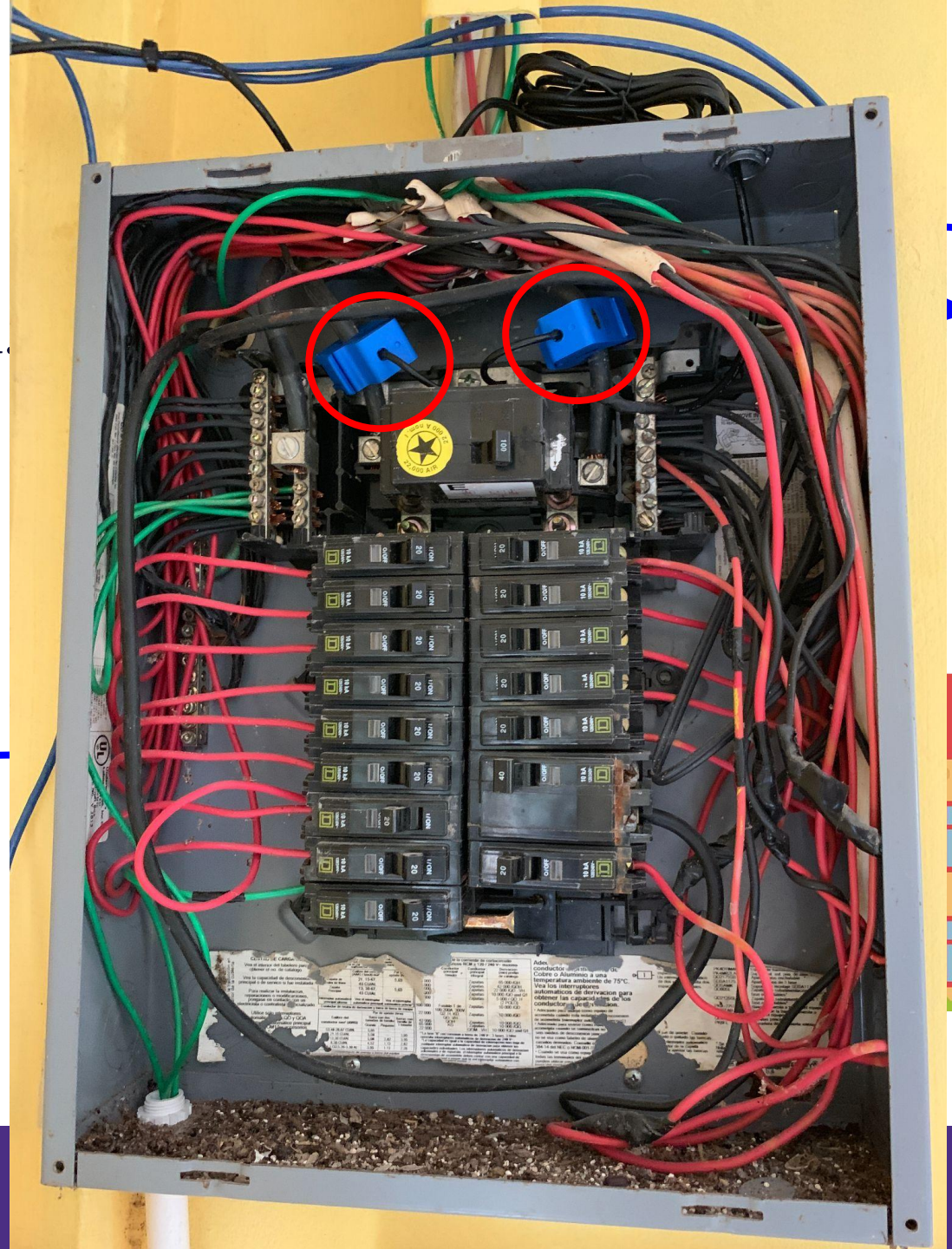
Digital

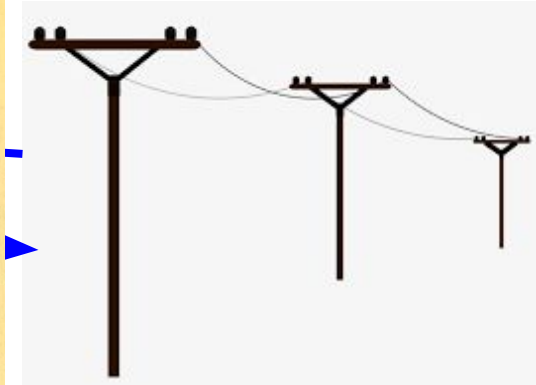


Limiter

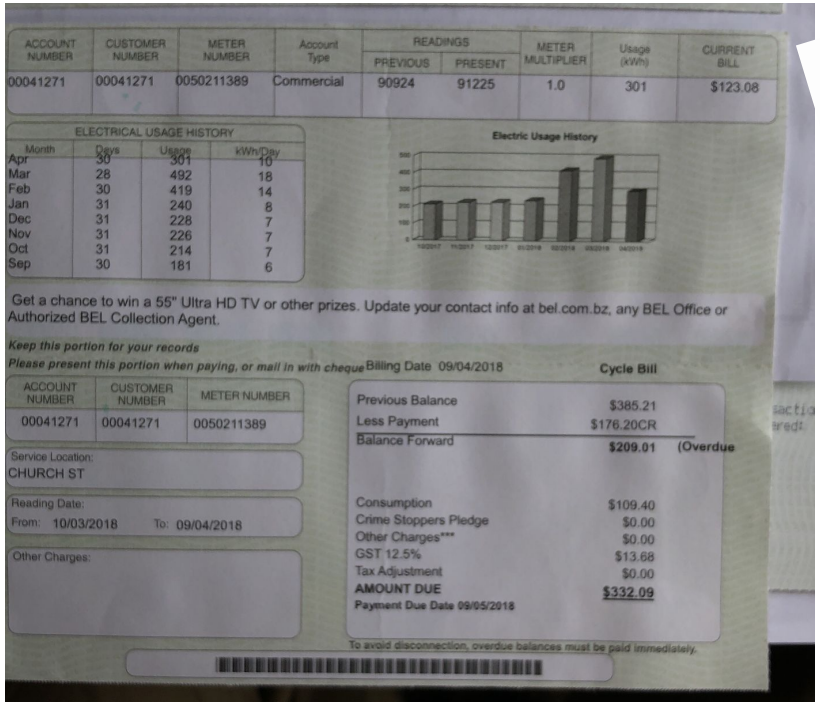
- Prevent backflow to grid.

Current sensing clamp can detect directions of current flow





Power Bills



ACCOUNT NUMBER	CUSTOMER NUMBER	METER NUMBER	Account Type	READINGS PREVIOUS	READINGS PRESENT	METER MULTIPLIER	Usage (kWh)	CURRENT BILL
00041271	00041271	0050211389	Commercial	90924	91225	1.0	301	$123.08

ELECTRICAL USAGE HISTORY

Month	Days	Usage	kWh/Day
Apr	30	301	10
Mar	28	492	18
Feb	30	419	14
Jan	31	240	8
Dec	31	228	7
Nov	31	226	7
Oct	31	214	7
Sep	30	181	6

Electric Usage History

Get a chance to win a 55" Ultra HD TV or other prizes. Update your contact info at bel.com.bz, any BEL Office or Authorized BEL Collection Agent.

Keep this portion for your records

Please present this portion when paying, or mail in with cheque

Billing Date 09/04/2018

ACCOUNT NUMBER	CUSTOMER NUMBER	METER NUMBER
00041271	00041271	0050211389

Service Location: CHURCH ST

Reading Date: From: 10/03/2018 To: 09/04/2018

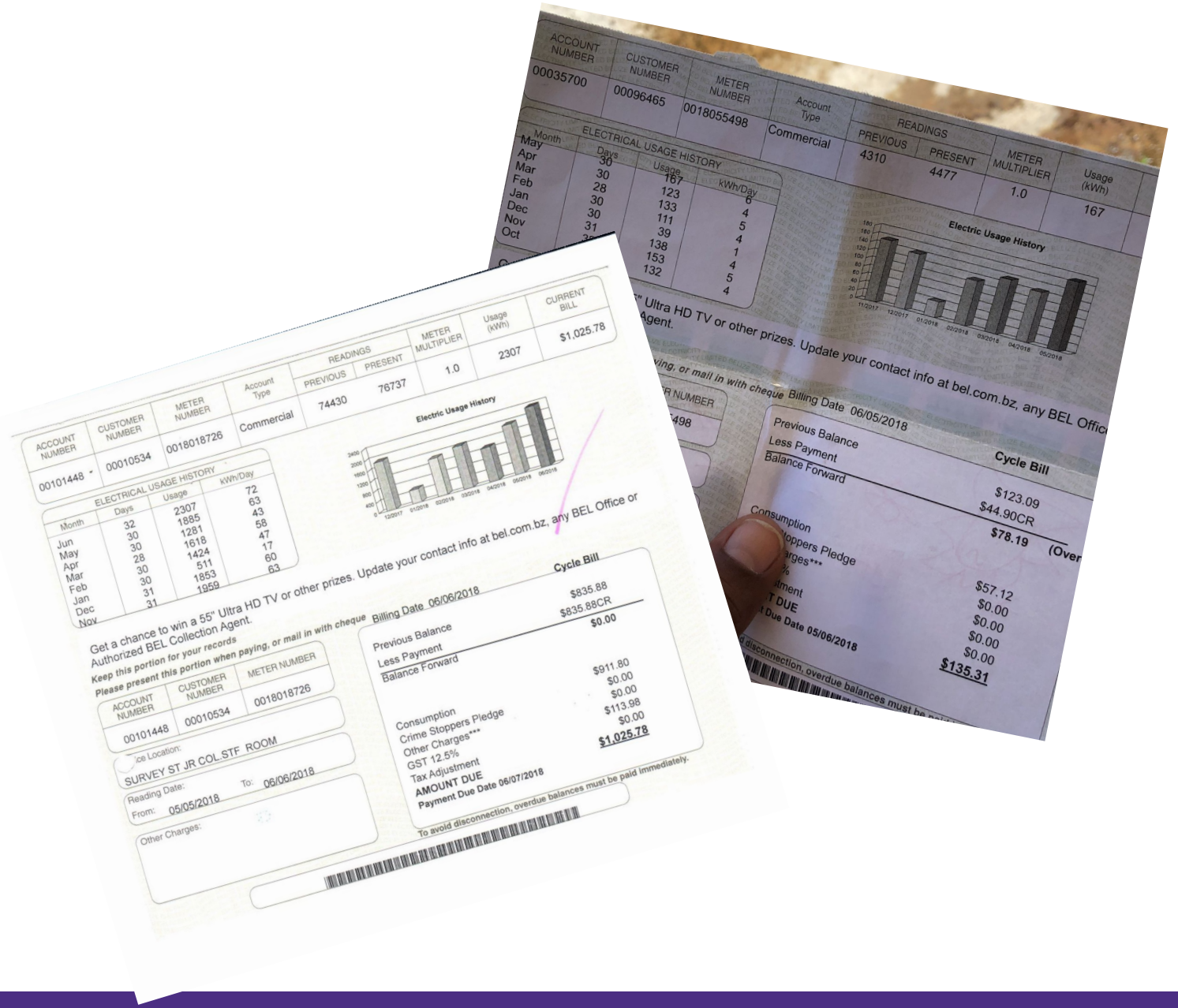
Other Charges:

Cycle Bill

Previous Balance	$385.21
Less Payment	$176.20CR
Balance Forward	$209.01 (Overdue
Consumption	$109.40
Crime Stoppers Pledge	$0.00
Other Charges***	$0.00
GST 12.5%	$13.68
Tax Adjustment	$0.00
AMOUNT DUE	**$332.09**

Payment Due Date 09/05/2018

To avoid disconnection, overdue balances must be paid immediately.



ACCOUNT NUMBER	CUSTOMER NUMBER	METER NUMBER	Account Type	READINGS PREVIOUS	READINGS PRESENT	METER MULTIPLIER	Usage (kWh)	CURRENT BILL
00101448	00010534	0018018726	Commercial	74430	76737	1.0	2307	$1,025.78

ELECTRICAL USAGE HISTORY

Month	Days	Usage	kWh/Day
Jun	32	2307	72
May	30	1885	63
Apr	30	1281	43
Mar	28	1618	58
Feb	30	1424	47
Jan	31	511	17
Dec	31	1853	60
Nov	31	1959	63

Electric Usage History

Get a chance to win a 55" Ultra HD TV or other prizes. Update your contact info at bel.com.bz, any BEL Office or Authorized BEL Collection Agent.

Keep this portion for your records

Please present this portion when paying, or mail in with cheque

Billing Date 06/06/2018

ACCOUNT NUMBER	CUSTOMER NUMBER	METER NUMBER
00101448	00010534	0018018726

Service Location: SURVEY ST JR COL.STF ROOM

Reading Date: From: 05/05/2018 To: 06/06/2018

Other Charges:

Cycle Bill

Previous Balance	$835.88
Less Payment	$835.88CR
Balance Forward	$0.00
Consumption	$911.80
Crime Stoppers Pledge	$0.00
Other Charges***	$0.00
GST 12.5%	$113.98
Tax Adjustment	$0.00
AMOUNT DUE	**$1,025.78**

Payment Due Date 06/07/2018

To avoid disconnection, overdue balances must be paid immediately.

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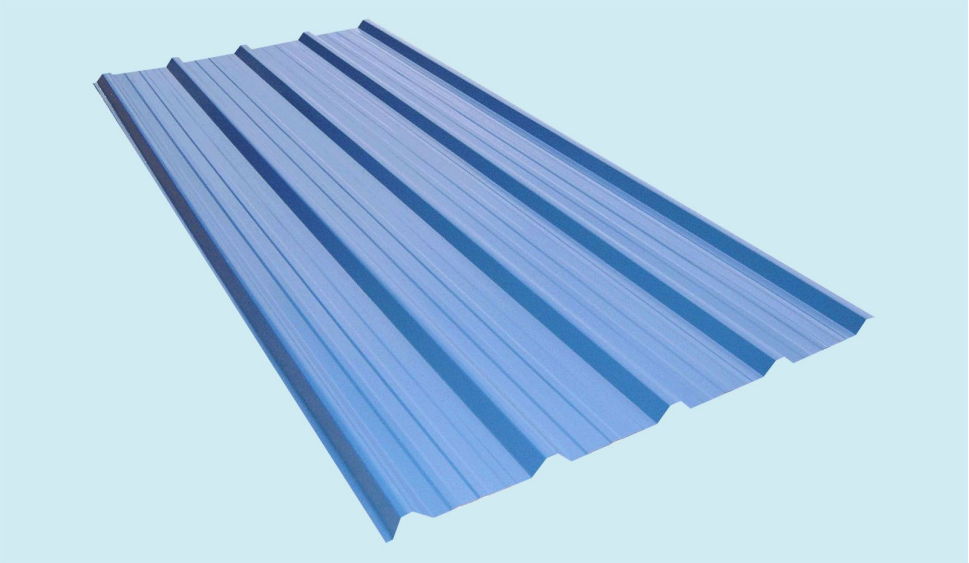
Mounting the Panels

General Rule: Mount the panels at the angle of the latitude. Belize at 14°.

Two common roof types in Belize:

Slanted Corrugated Steel Roofing



Can usually be mount flat on roof

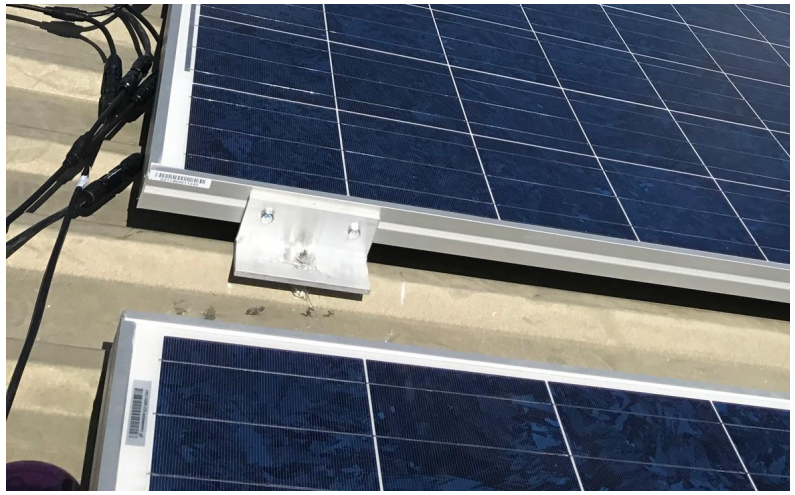
Flat Concrete Roof

Should be tilted toward the south

Mounting the Panels - Sloping metal roof

Four angle aluminum brackets with bolts

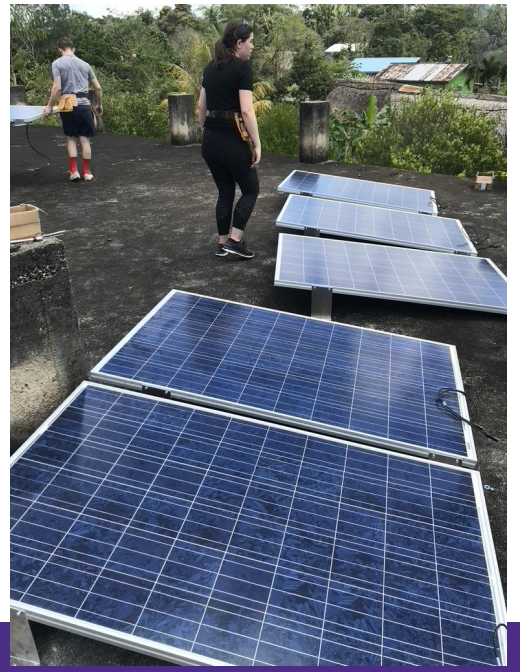
- Procure in country, cut and mount
- Screw into "purlins" using long roofing screws with gasket and silicone seal.
- Not ideal, but angle aluminum found everywhere, and easily cut and mounted.
- Cost: $5/panel



Mounting the panels flat concrete roof

We want to point the panels to the south at the angle of the latitude

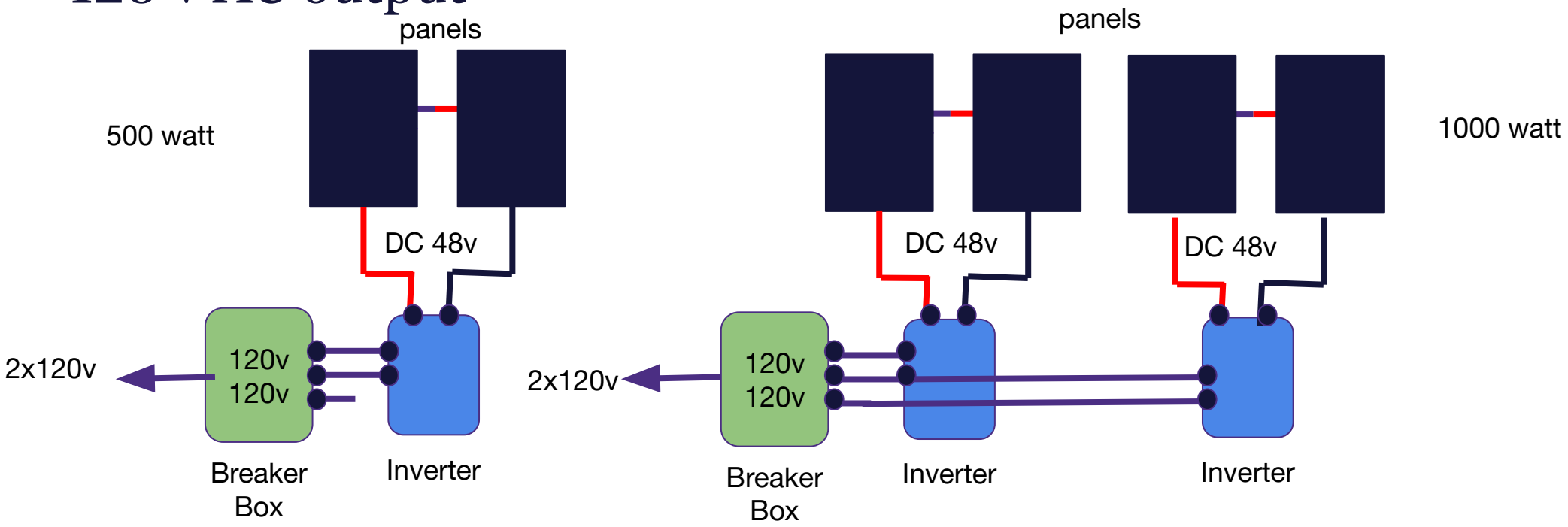
- Custom aluminum brackets with bolts, made in shop in USA
- Longer brackets on rear to create slope.
- Mount to roof with concrete anchors (Redhead)
- Cost: $25/panel



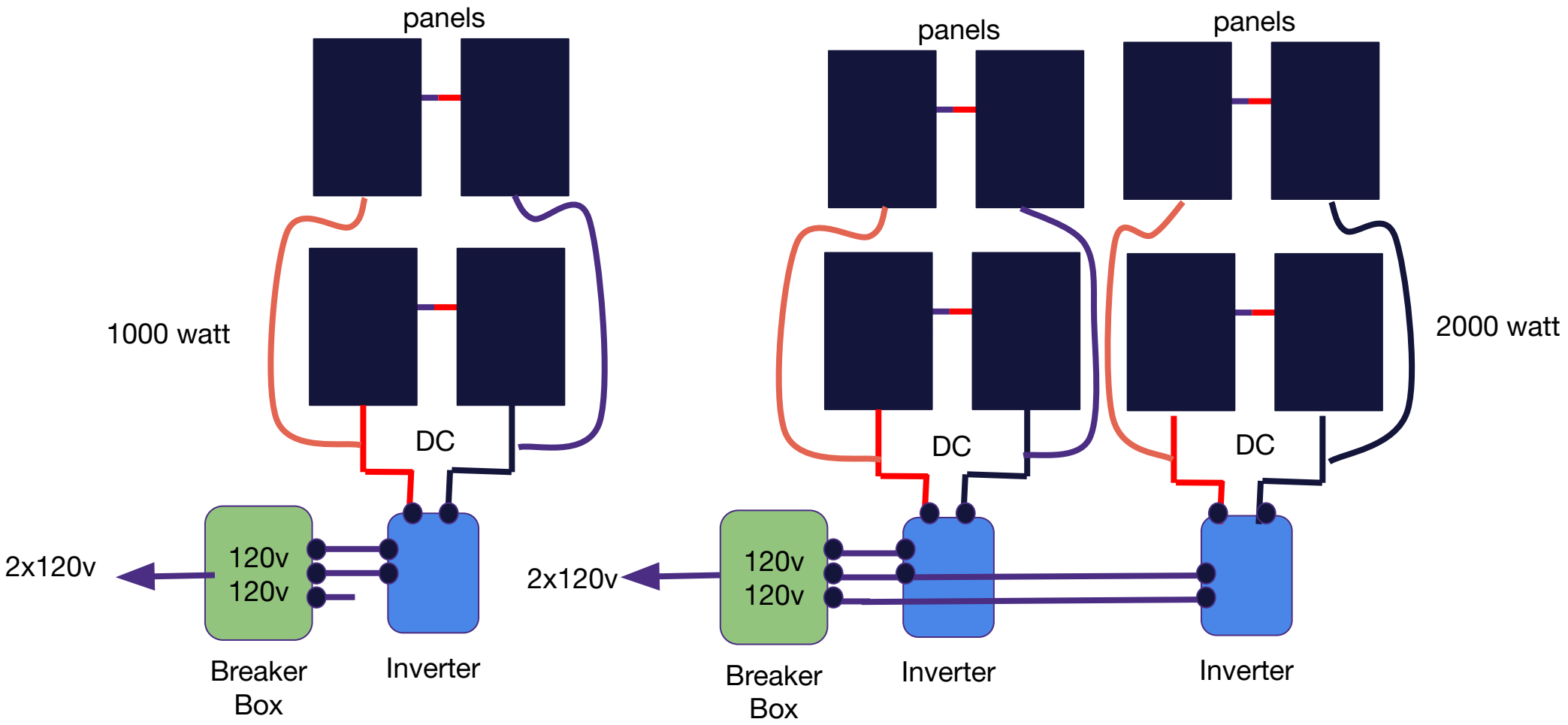
Overall system design

Lots of choices here:

- We (mostly) choose 48 volt DC inverters (two panels in series)
- Panels are 24v
- 120 v AC output



Overall system design



Institutional Support

- Kenyon College
- Center for Global Studies
- Must approve all organized international travel
- Require leadership of both genders present

Safety

- Conferred with legal
- OSHA rules for working on Roofs and with electricity
- Training prior to departure
- Always faculty/staff present
- No roofs over 30 degrees or more then 2 stories high

Equipment/Logistics

- Where to get the equipment?
- How to get it to the school

Equipment/Logistics

- Panels
  - Shipped from China
  - Shipped from US
  - Bought in Country
- Electronics/Tools
  - Packed in bin, everyone has a second "suitcase"
- Miscellaneous
  - Lots of trips to the hardware stores
- Duty waivers through Ministry of Education

Pickup trucks and vans to get everything around.

Funding

- Students pay their expenses ~$2000 USD.
- College provides funding for an additional staff member
- Use personal funds to procure equipment in advance
- We ask schools to raise funds for the cost of equipment ($1000-$2000 USD). Some schools we find donors for.
- I have a bank account in country that schools can put money into as they raise money.

Install Day

- On site, start by 8:00am
- Two Teams:
  - Inside wiring
  - Outside roof
  - Faculty with each

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Time for recreation


BELIZE


KENYON
COLLEGE

Our systems

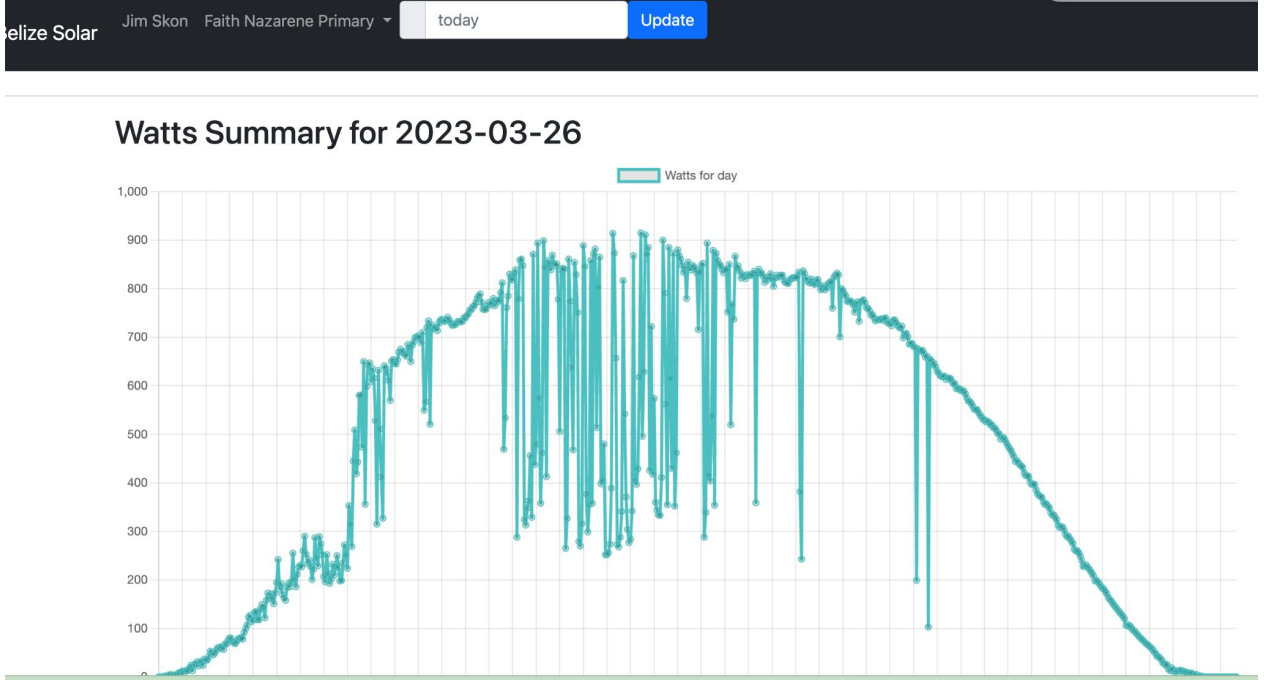
We have installed 31 systems on 19 schools:

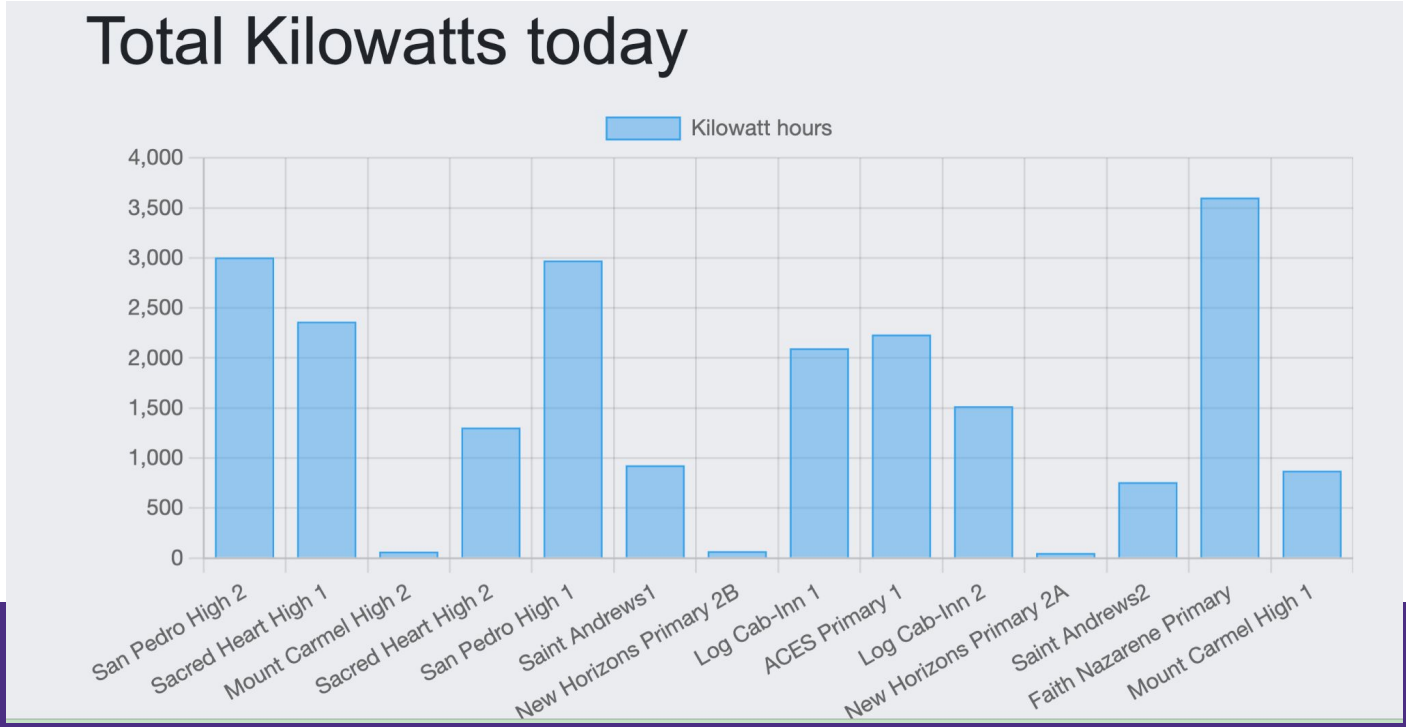
- 500-2000 watts
- 24v 230-250 watt solar panels
- 110v output
- Limiters when possible
- Schools report savings of $75-$150 USD per month.

Web Display

A work in progress

- Current output
- Historical output
- Diagnose problems





Can you start your own project?

- **Ask me**. I'm available for email questions, google meet, etc.
- **Host a Workshop**. I'm willing to do a 1-2 day workshop at your college or university.
- **Learn by experience** - For potential leaders I will host a solar trip to Belize March 2-11, 2024.
- **Start it on your own!**

Breakouts and brainstorm

- Small groups
- Consider:
  - **People/Organizations** - Who could you collaborate with? (even each other!)
  - **Connections/Relationships** - What countries and people do you have possible connections with, how could you start to cultivate those connections and relationships?
  - **Institutional Support** - what structures are in place at your organizations that could sponsor or assist you?
- Report back


The End

More information

James Skon

Kenyon

Solar Panels

Solar panels come in many sizes (physical and power wise) and with different voltage output.

- Chose the highest power/cost
- 24 volt (30 volts operating)
- 230-250 watts/panel (8 amps)
- Panels are 39" x 59"
- 45-50 lbs each
- Can be shipped 36/pallet
- About $100 USD each.

Grid Tie Inverters

Also many kinds

- 24 and 48 volt DC (30 or60 volt)
- 120 volt out
- 1000 watt - 1200 watt
- Limiters (more later)

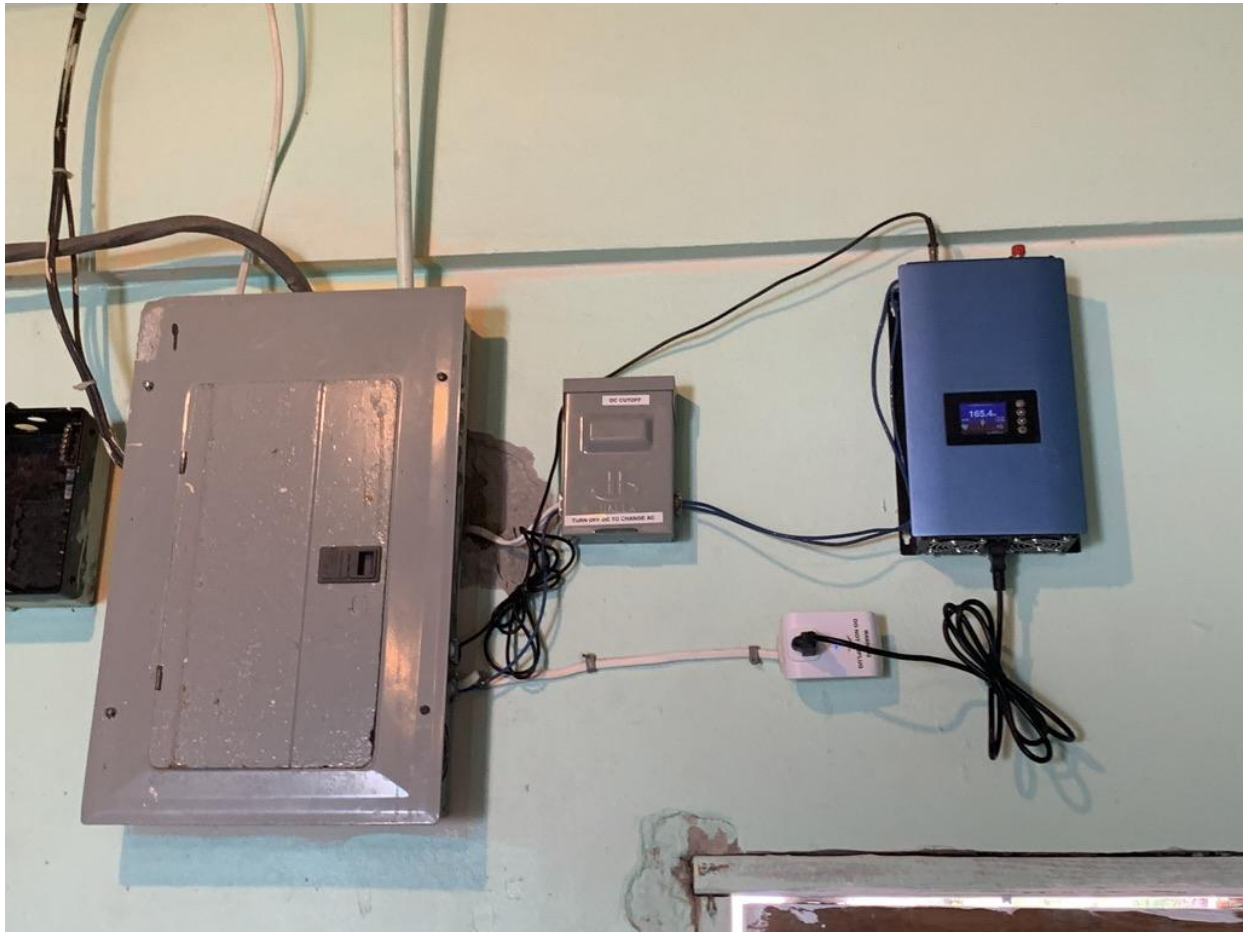
about $200 - $250 USD each

DC Wiring

- Need #10 wire for 1000 watts at 30 volts
- Wire outside should be UV protected, and best installed inside a conduit all the way to the inverter
- DC cut-off box with surge suppressors

AC Wiring

- Small inverters have AC plugs
- Install plug on new circuit with 15 amp breaker next to inverter.
- Mark with warning not to unplug, unplugging under load could damage inverter.
- With 2 inverters, put one in each side.



Limiter

Current sensing clamp can detect directions of current flow

Monitoring

We modified a Ubiquiti WiFi power control plug:

- Can measure power
- Has WiFi
- Linux operating system.
- Created scripts to report power output once a second
- Pushes data to a microservice running in US, stored in SQL database.
- Output to Web display

Pre-trip preparation and planning

Need contacts, schools, and people.

- Long history of working in Belize, relationships with government officials (school general manager, district managers)
- Pre-trip - travel country with school official reviewing possible schools for need, interest, and technical factors.
- We generally ask the school to raise the money for the materials ($1000/1000 watt system)
  - For schools with limited funding, we are often able to find donations.
  - Schools sometimes pay over time with deposits in a local bank account.
  - Our goal is "buy-in" buy charging them we are assuring they has a stake.

Project Preparation

- Advertise spring break project (March) in September
  - Students apply Students self fund at around $2000
  - usually accept 8-10 students
- Hold two information sessions
- Hold three training session
- Talk about the culture of Belize and the schools
- Learn theory and practice of solar power systems
- Review safety information for working:
  - on roofs
  - with electricity

Safety - Roofs

Pitched Roofs

- Max 4/12 pitch, One Story
- Stay 6 feet from edge
- Ladder must extend 3 feet above roof.
- Must always have someone holding ladder when being used, watching ladder when people are on roof.

Safety

Place safety board to prevent sliding off

Safety

Power tools

- Glasses and Gloves when working with panels/power tools

Safety

Electrical

- Always an "expert" present.
- Learn basics of AC and DC power systems
- Safety glasses
- Wear gloves when possible
- Always check wires for power with meter before touching.
- Someone always double checks work before powering on.

Transportation/Lodging/Food

- Goal of one school per day.
- Usually lease a 12 passenger van and pickup truck
- Reserve rooms in local hotels near each location.
- Eat at local restaurants for breakfast and dinner. During jobs work with schools to order out for meals (usually rice, beans, and chicken)

A typical day

- Get to school by 8:00 am
- Two teams: Roof and inverter/wiring.
- Roof team installs brackets, puts panel up, brings wires down
- Inside team installs electrical components, wires everything.
- Usually finished by 3:00 pm

Our work so far

Six projects between 2014 and 2019

- 19 schools and 1 lodge
- 140 panels
- 33 inventors.
- Schools range from 2 panels (one inverter) to 20 panels (5 inverters)
- Most schools are in the 4-8 panel range.

A review and lessons learned

- Systems install 2014-2019
- 2020-2022 no trips due to Covid-19
- Returned in January and March of 2023 to review

Element	Installed	Known Bad Jan 2023	Known Up Jan 2023	% Known Up
Solar Panels	128	3	99	82.50%
Wiring	31	3	23	79.31%
Inverters	31	9 (3*)	16	55.17%
Complete Systems	31	12	14	48.28%

- BAD FANS

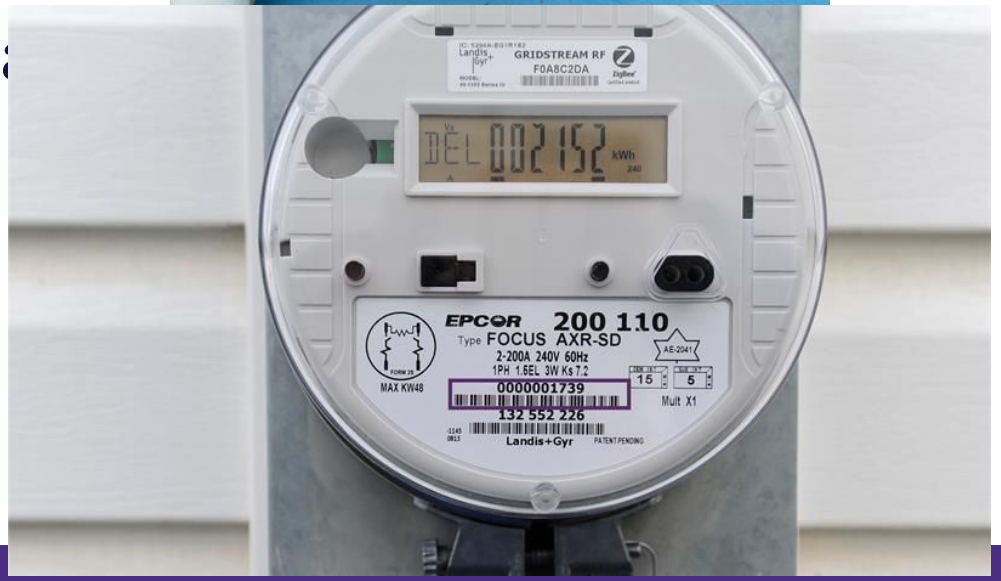
Bad Panels (2.5%)

- Panels are very reliable.
- We only definitely identified 3 as bad.
- One was smashed in hurricane
- Two looked fine, but zero output.

Limiters

Limiter prevent energy flow back to grid

- Mechanical meters run backwards!!
- Non-smart digital meters count backflow as usage - customer charged.
- We didn't put in limiters on schools tha always use a lot (A/C…)
- PROBLEM: Some schools turned everything during Covid break - got huge bills!



Bad panels - Diodes

- Diode prevent backflow
- On two panels we found shorted diodes

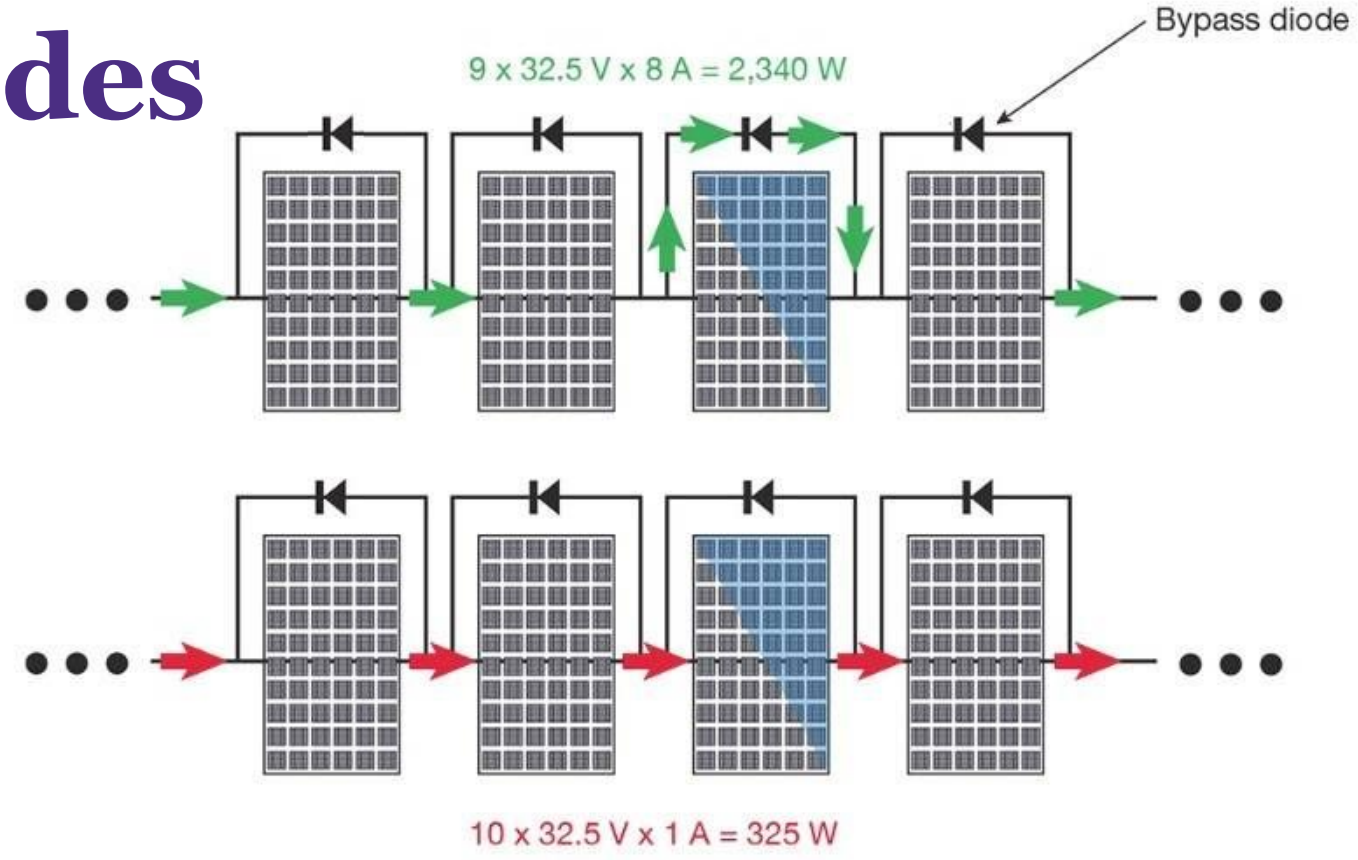


Figure 1 Bypassing a shaded module in a PV string (top) can lead to significantly higher total output power compared to forcing the string to operate at the low-current level of the shaded module (bottom).

Wiring Issues (10.4%)

Found

- At one school the Y-cables, and solar connectors had disintegrated.
- At another the pin in the connector had disintegrated
- Repaired with a hard wired connection.

Wiring Issues

Kenyon

Wiring Issues

We run 10 gauge stranded up to the roof, using in conduit or UV tube to protect the wire outside.

- If wires are not properly crimped and soldered to connector ends, they will corrode and either disconnect, ot have high resistance.
- Once we purchased 10 gauge wire in Belize for a very low price. After we installed it we found it was corroded every 12 inches.

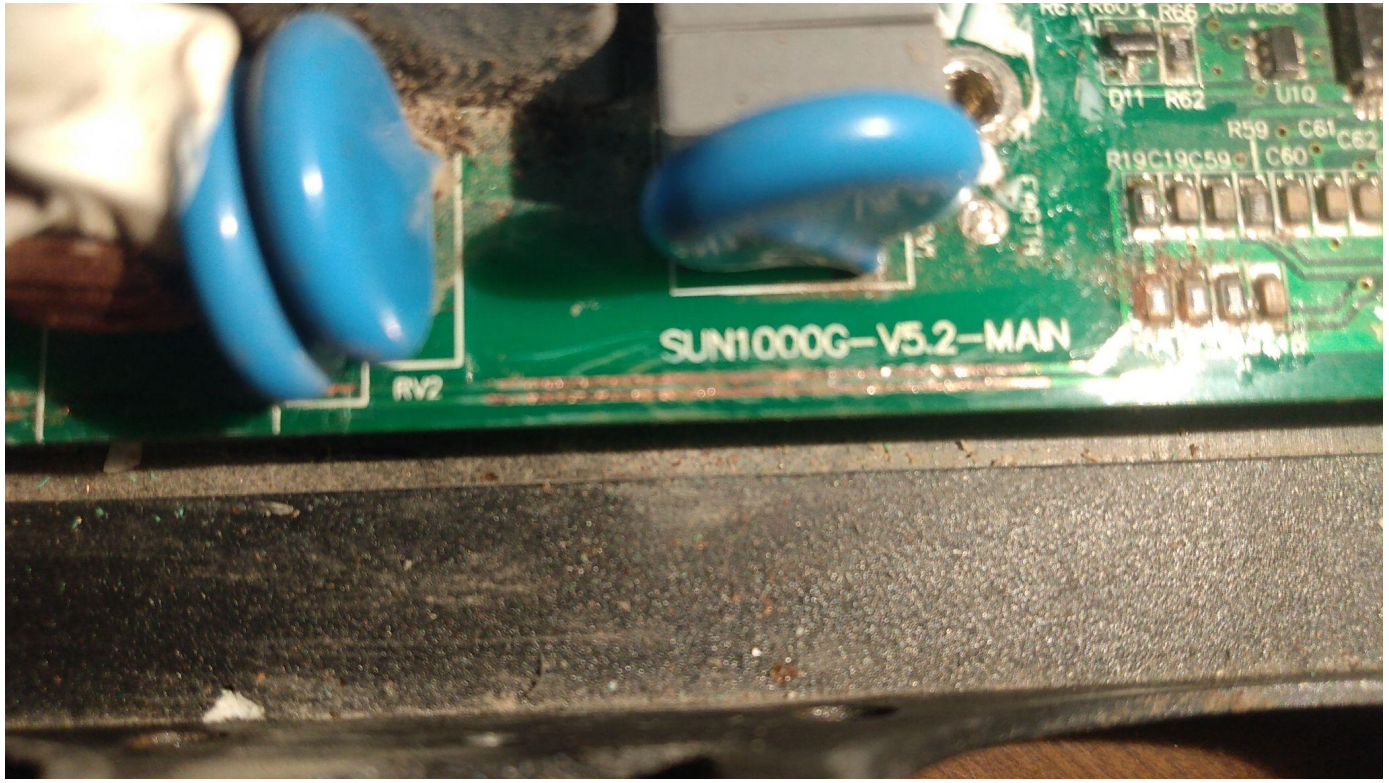
Bad inverters (41%)

This was a significant problem

- We purchased inexpensive units from China ($150-$300 each)
- Out of 29 inverters:
  - 3 - bad fans, still worked. Replaces fans
  - 5 - traces on the circuit board corroded, fixed with copper wire.
  - 1 - a couple of fried geckos
  - Several failed for unknown reasons. Dead or limited output.

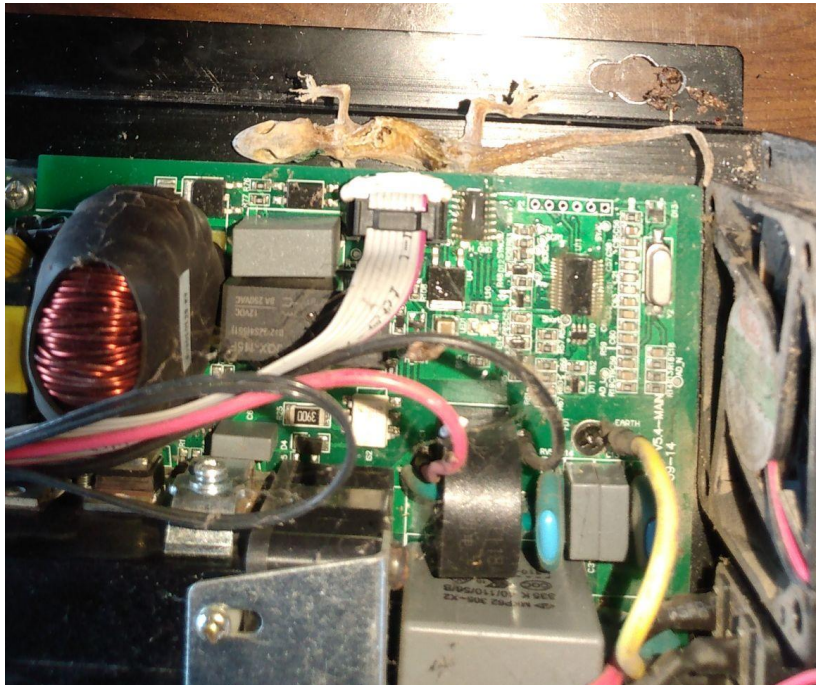
Inverters - bad circuit board traces

Corrosion can sometimes be fixed by soldering in a wire.



Inverters - Geckos!

Can cause issues!



What we found, what we fixed

Bad inverters: 12

Issue	Number	Fixed	Repair
Bad Fans	3	3	Replace fans
Corroded Circuit Board	1	1	Replace corroded trace with wire.
Bad daughter card			
Dead		Replaced	