South County ARES

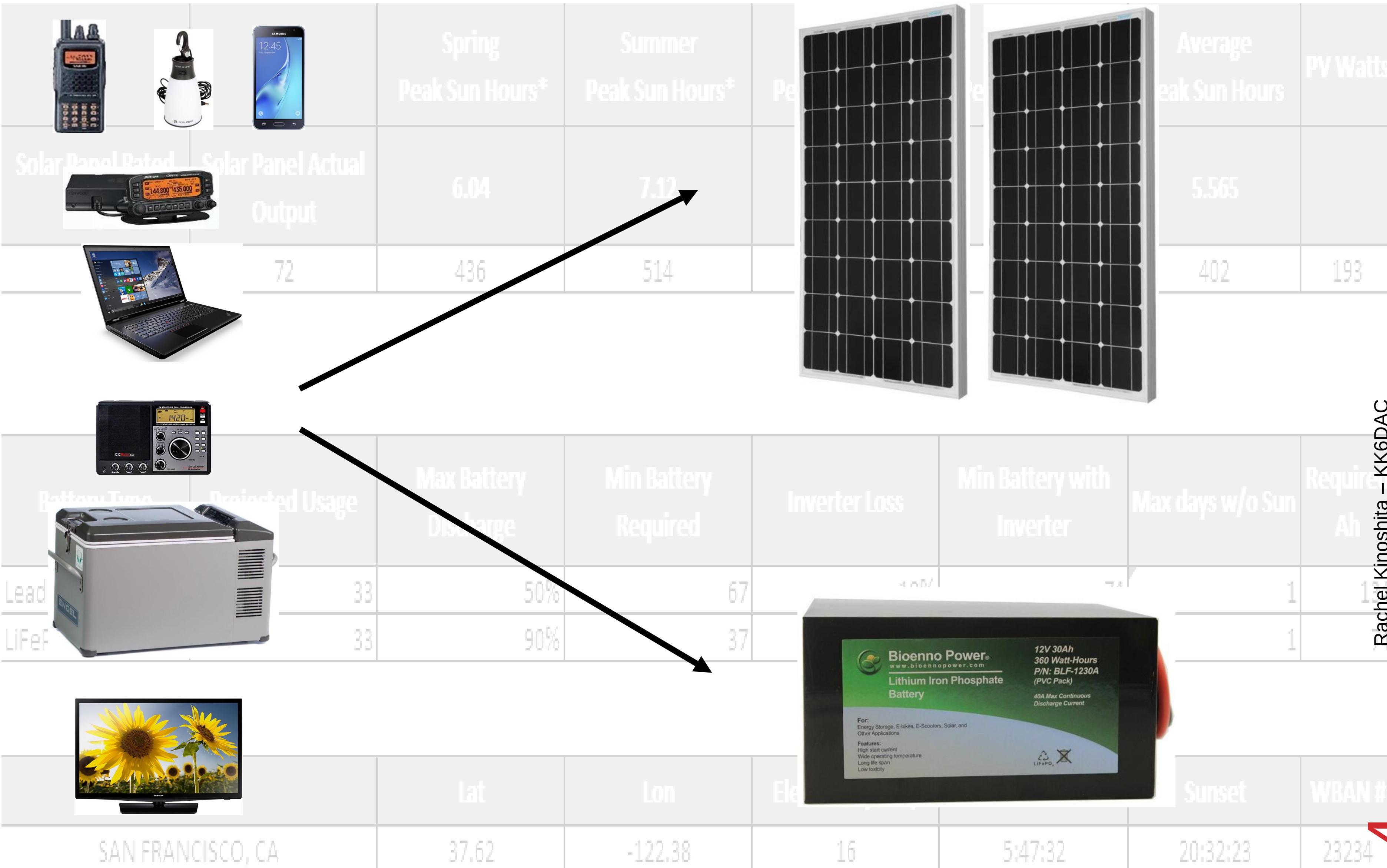
Solar 101

Agenda

- **Evaluating your needs**
- **Batteries**
  - Lead Acid
  - Lithium Iron Phosphate (LiFePO4)
- **Photovoltaic (Solar) panels**
  - Monocrystalline
  - Polycrystalline
  - Foldable
  - Hybrid
- **Charge Controllers**
  - Pulse width modulation (PWM)
  - Maximum power point tracking (MPPT)
- **Inverters**
  - Modified sine wave
  - Pure sine wave
- **Putting it all Together**
  - Designing Your System
  - Using Solar in Emergency Communications

Evaluate Your Needs

What Do You Need To Power Those Devices?



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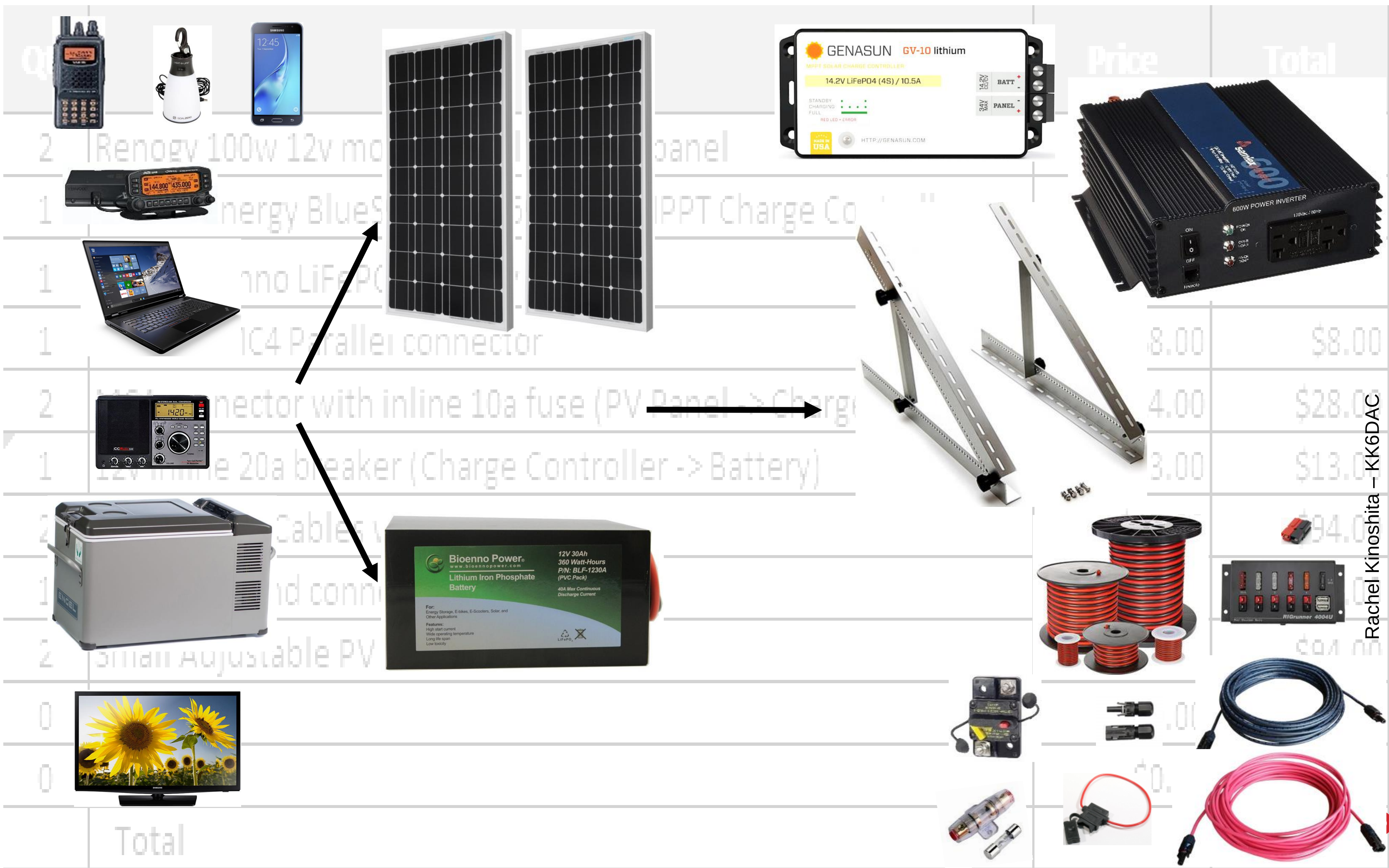
What Is Needed To Connect It All Together?



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Evaluating Your Needs

- **What do you need to power?**
  - Ham radio
  - Lights
  - Radios
  - Mobile phones
  - Laptop computer
  - Television
  - Refrigerator
  - Microwave
  - Medical Devices (CPAP, oxygen, refrigeration for insulin)
- **How long do you need it to run?**
- **Do you need both AC and DC?**

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- **How long do you need it to run?**
  - How many hours per day and days per week
  - Short outages during storms
  - Three to four weeks during after an earthquake
  - Months or perhaps even years after an major disaster
- **Do you need both AC and DC?**

Evaluating Your Needs

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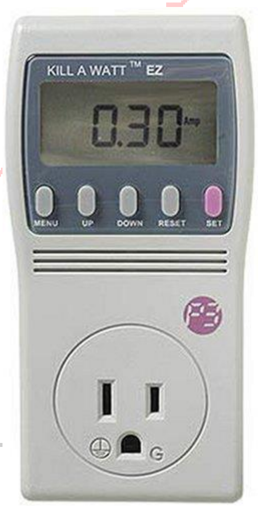
  - Months or perhaps even years after an major disaster
- **Do you need both AC and DC?**
  - Inventory your devices and see how many actually use DC, but are charged by AC
  - DC to AC and AC to DC is expensive, try to avoid it

Evaluating Your Needs

- **Measuring your usage**
  - For AC powered devices, get a Kill A Watt monitoring device and plug it into each appliance you plan to run. See how much power each uses over a 24 hour period
  - For DC powered devices, a Watts Up meter can be used to measure the watts used over time
  - Once you have identified the devices you want to power by solar, multiply the watts used per hour by each device times the number of hours you want to power them
  - Add up the watt hours for each device to determine your overall watt hour requirements



Evaluating Your Needs

- **Measuring your usage**
  - You can also look at the label on the device itself which should indicate the power usage for that device

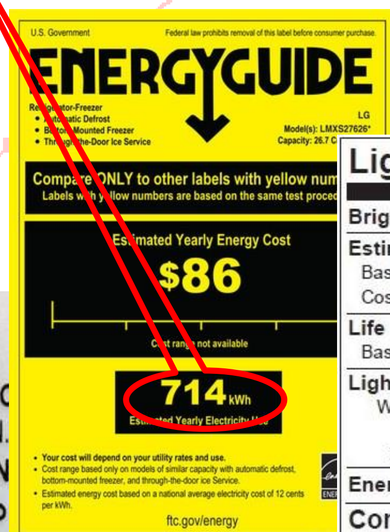
Fridge uses 714 kWh per year or 81.5w per hour

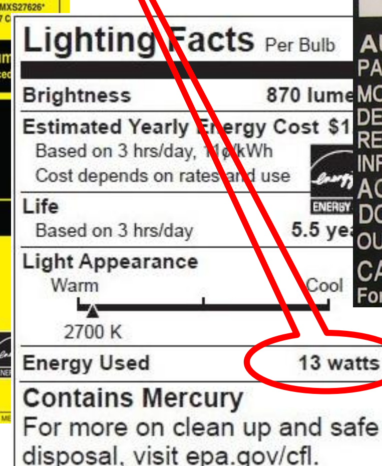
LED lightbulb uses 13w

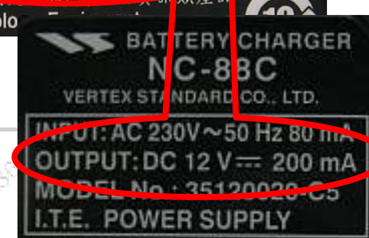
HT charger uses 2.4w

Laptop charger uses 65w

TV uses 35w







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It's better to conserve than to generate

- **Reducing your carbon footprint**
  - **Ham radio**
  - **Lights**
  - **Radios**
  - **Mobile Phones and tablets**
  - **Laptop Computers**
  - **Television**
  - **Refrigerator**
  - **Microwave**

It’s better to conserve than to generate

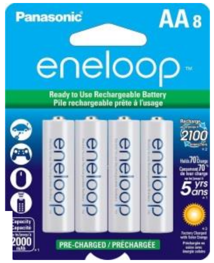
Reducing your carbon footprint

- **Ham radio**
  - Use a good antenna, tuned to the frequency you’re using
  - Ensure good elevation and as few obstructions as possible
  - Use the lowest power necessary
- **Lights**
- **Radios**
- **Mobile Phones and tablets**
- **Laptop Computers**
- **Television**
- **Refrigerator**
- **Microwave**
- **Medical Devices**

It’s better to conserve than to generate

Reducing your carbon footprint

- **Ham radio**
- ➢ **Lights**
  - Switch to LED lightbulbs (saves around $13 per year over incandescent)
  - 12v LED lights – Goal Zero, LED light strips, LED flood lights
  - Solar chargeable lights – LUCI Lights
  - Headlamps and flashlights
  - Batteries – Rechargeable’s - Panasonic Eneloop, Tenergy Centura
  - Battery charger – Charge AAA, AA, C, D 18650 with 12v
- **Radios**
- **Mobile Phones and tablets**
- **Laptop Computers**
- **Television**
- **Refrigerator**
- **Microwave**
- **Medical Devices**



It’s better to conserve than to generate

Reducing your carbon footprint

- **Ham radio**
- **Lights**
- **Radios**
  - Crank radios are good, but their tuners are often poor to mediocre
  - Purchase a good AM/FM radio that runs on AA’s and use Panasonic Eneloop batteries
  - For extended run-time consider an AM/FM radio that uses rechargeable “D” cells
- **Mobile Phones and tablets**
- **Laptop Computers**
- **Television**
- **Refrigerator**
- **Microwave**
- **Medical Devices**

It’s better to conserve than to generate

Reducing your carbon footprint

- **Ham radio**
- **Lights**
- **Radios**
- ➢ **Mobile Phones and tablets**
  - Typically use 5vdc USB chargers
  - Make sure you have a 12vdc to 5vdc USB chargers
- **Laptop Computers**
- **Television**
- **Refrigerator**
- **Microwave**
- **Medical Devices**

It's better to conserve than to generate

Reduce your carbon footprint

- **Ham radio**
- **Lights**
- **Radios**
- **Mobile Phones and tablets**
- ➢ **Laptop Computers**
  - Many laptops use 19vdc powered through a transformer
  - Use a 12vdc to 19vdc up converter to run direct from DC
- **Television**
- **Refrigerator**
- **Microwave**
- **Medical Devices**

It’s better to conserve than to generate

Reduce your carbon footprint

- **Ham radio**
- **Lights**
- **Radios**
- **Mobile Phones and tablets**
- **Laptop Computers**
- **Television**
  - Get a small, portable, battery operated ATSC LCD TV or a full size HDTV that runs off of 12 – 14vdc
  - Get an HDTV antenna
- **Refrigerator**
- **Microwave**
- **Medical Devices**

It's better to conserve than to generate

Reduce your carbon footprint

- **Ham radio**
- **Lights**
- **Radios**
- **Mobile Phones and tablets**
- **Laptop Computers**
- **Television**
- ➢ **Refrigerator**
  - See http://expeditionportal.com/overland-journal-portable-12v-fridge-review/
  - Most can run from 12 or 24vdc and 120vac
  - Expensive, but can be used as a small chest freezer for everyday use
  - Thermoelectric coolers are not refrigerators
- **Microwave**
- **Medical Devices**

It’s better to conserve than to generate

Reduce your carbon footprint

- **Ham radio**
- **Lights**
- **Radios**
- **Mobile Phones and tablets**
- **Laptop Computers**
- **Television**
- **Refrigerator**
- **Microwave**
  - Microwave – Use a generator to run your microwave or cook with a gas stove
- **Medical Devices**

Batteries

- **Capacity**
  - Car batteries are usually measured in Cold Cranking Amps (CCA)
  - Deep cycle batteries, AGM, LiFePO4 are usually measured in Amp hours (Ah)
- **Lead Acid**
  - Car batteries
  - Deep cycle batteries (Marine, Golf cart)
  - Sealed Lead Acid / Absorbent Glass Mat (AGM)
- **Lithium**
  - Lithium Iron Phosphate (LiFePO4)

Batteries

➢ Capacity (Amp Hour Rating)

- How many amps can be delivered over a period of time before the battery is completely dead

CAPACITY [B] Amp-Hours (AH) Trojan Group 27 - 100 AH AGM Battery				ENERGY (kWh)
5-Hr Rate 15.4 amps	10-Hr Rate 8.2 amps	20-Hr Rate 4.45 amps	100-Hr Rate 1 amp	100-Hr Rate
12 VOLT DEEP CYCLE AGM BATTERY				
77	82	89	99	1.19

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- Why the different rates and amp hour capacity?

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12 VOLT [illegible]			[illegible] M BATTERY	
77	82	[illegible]	99	1.19

Notice that the 5 hour rate isn't 20 amps (i.e. 5 hrs * 20 amps = 100Ah), but rather only 15.4 amps for a 77Ah rating

- Why the different rates and amp hour capacity?
- Peukert's Law - Lead acid batteries have a shorter amp hour life, the higher the amperage draw

Batteries

- **Capacity (Amp Hour Rating)**
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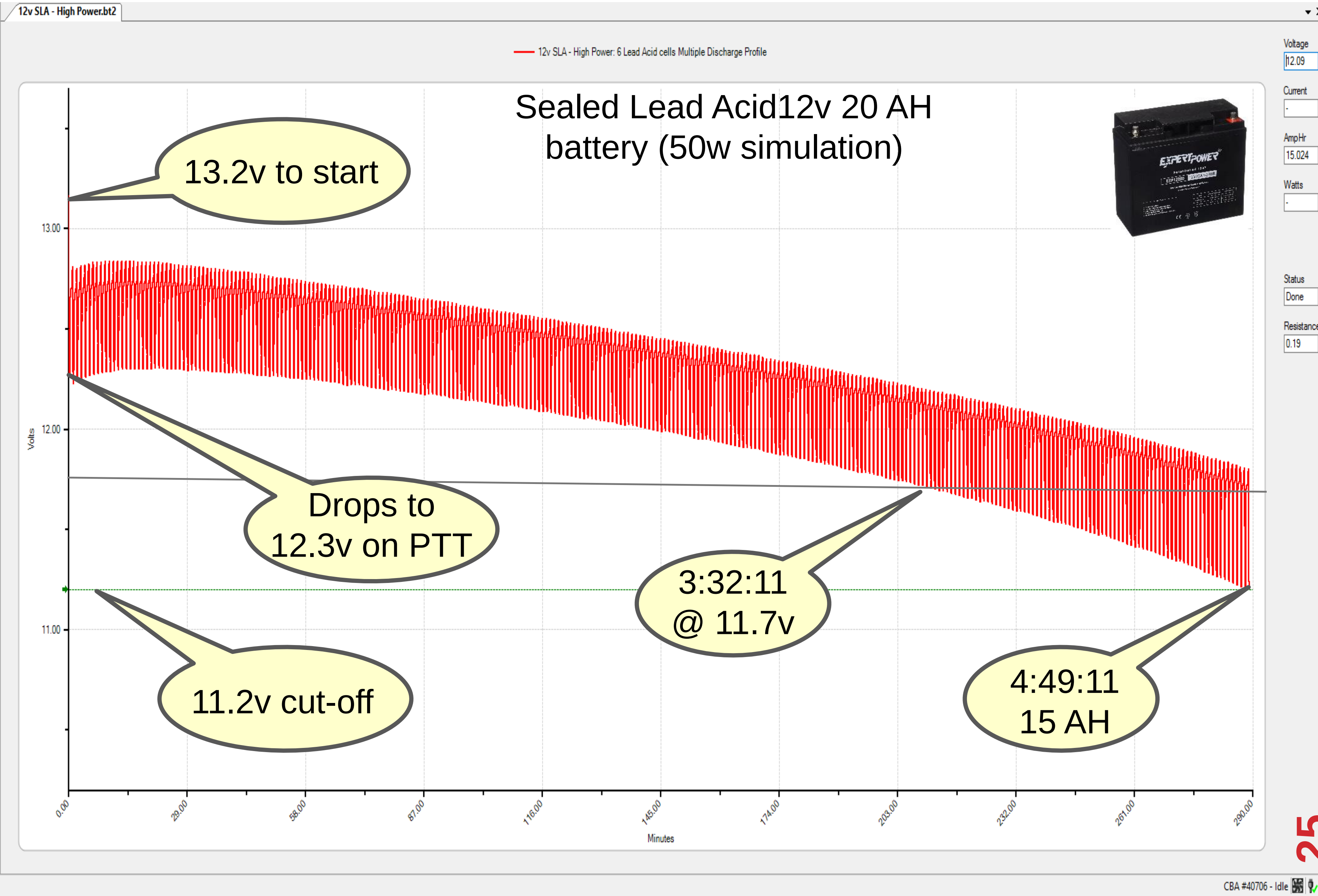
  - Why the different rates and amp hour capacity?
  - Peukert's Law - Lead acid batteries have a shorter amp hour life, the higher the amperage draw
  - And keep in mind that this battery will be completely dead (i.e. cannot be recharged) if you use all of this capacity

TEST RESULTS



Batteries

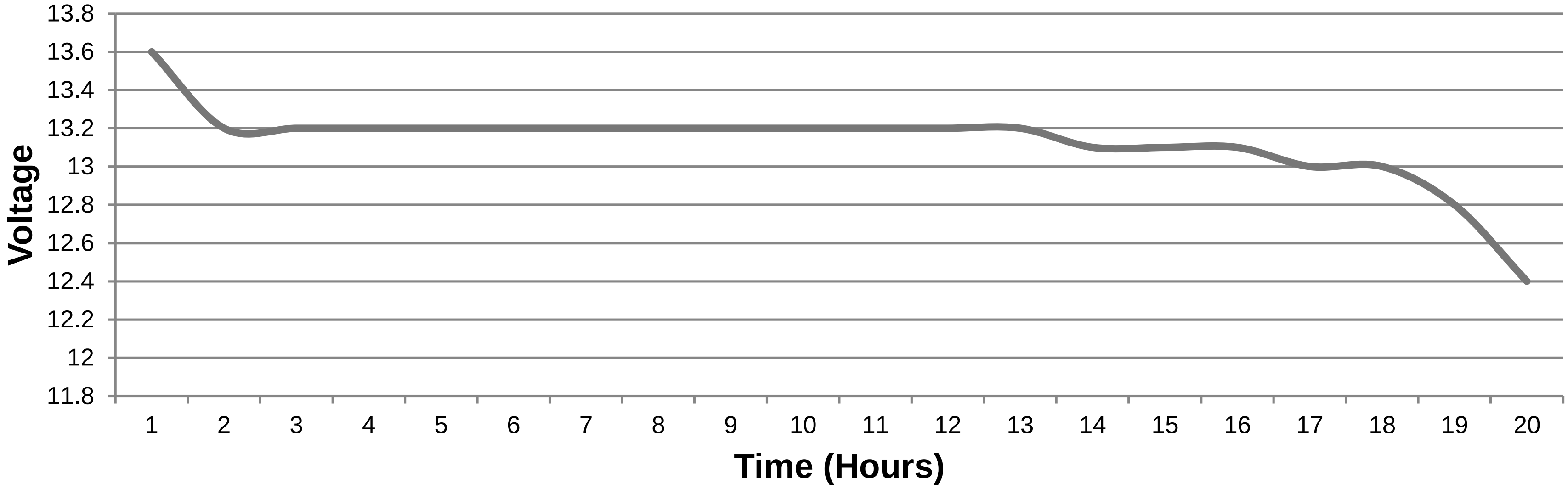
➢ **Capacity (Lead Acid)**

- Is the rate of discharge, the only factor that impacts capacity?
- No, other factors such as battery storage temperature and age also impact capacity
- Battery capacity is rated at 25° C / 77° F
- Lower temperatures reduce capacity
    - At 15.5° C / 60° F capacity is reduced to 90%
- Higher temperatures increase capacity
    - At 32° C / 90° F capacity is increased to 110%

Batteries

➢ **Capacity (Amp Hours)**

- LiFePO4 batteries typically have a much flatter discharge curve



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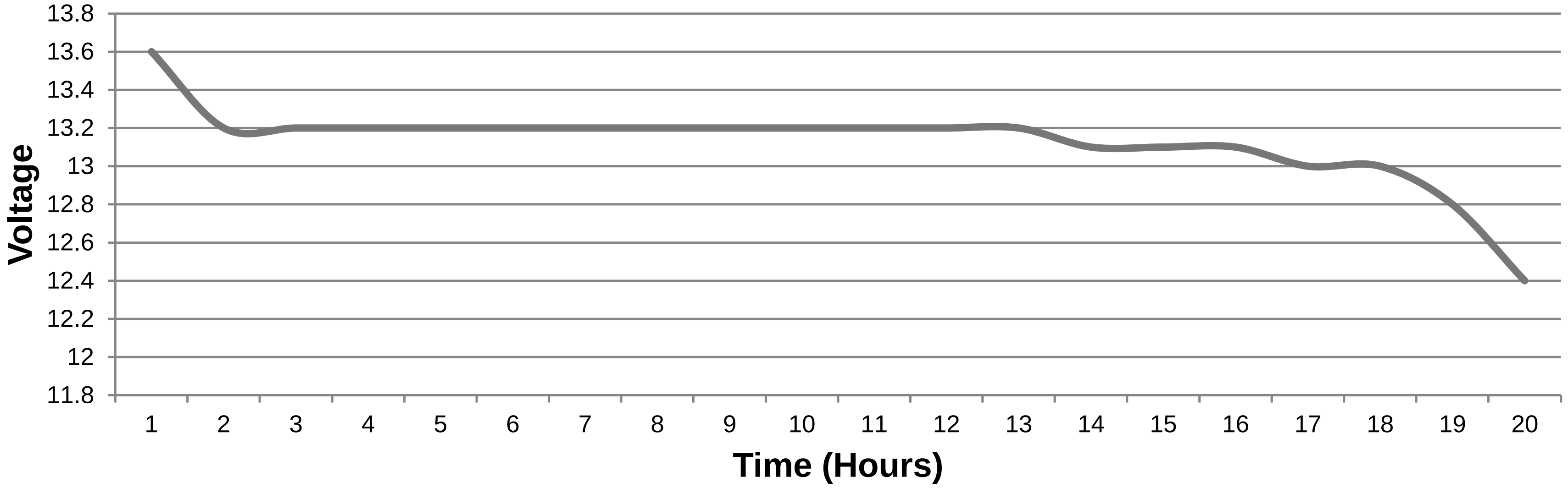
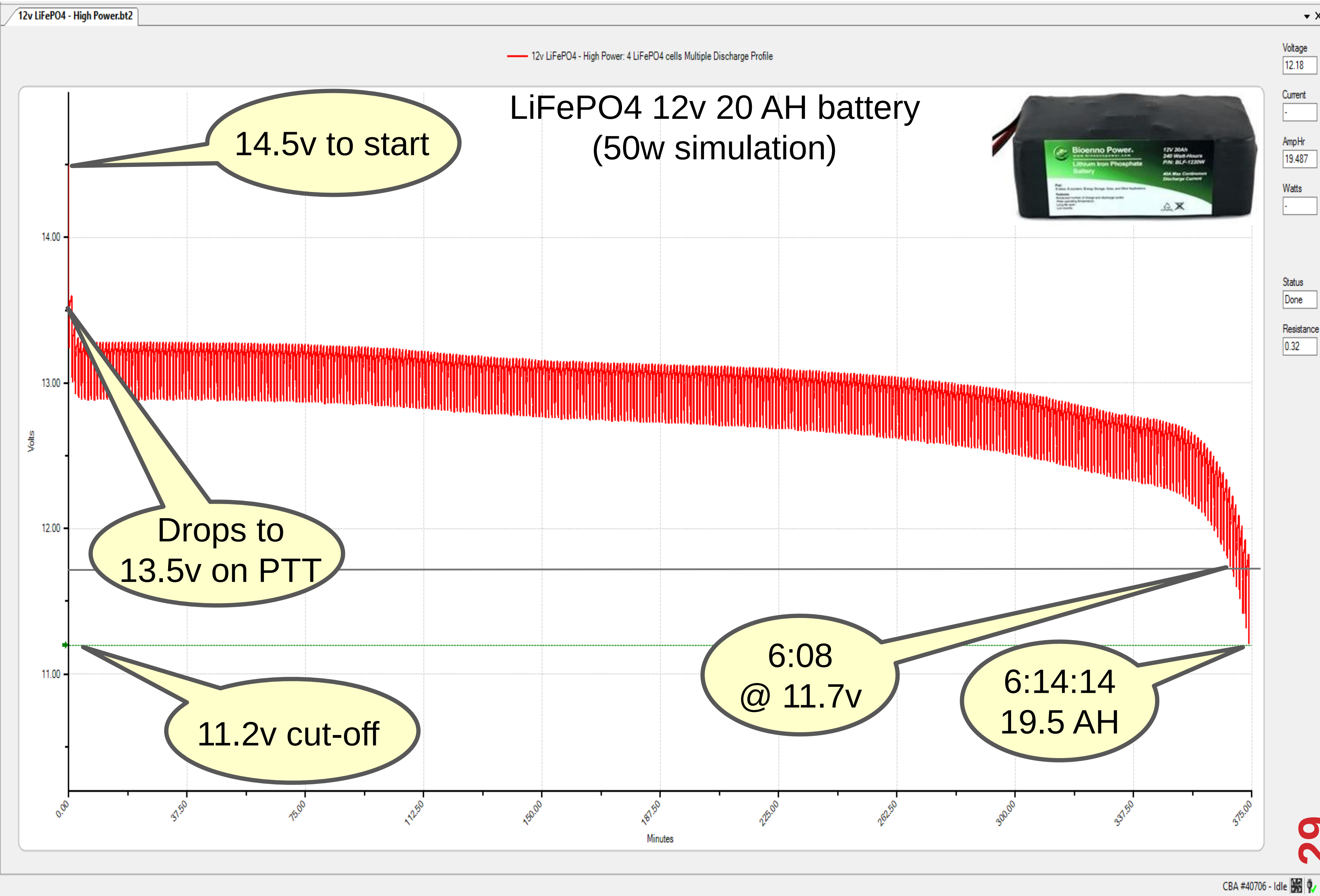


- A 40Ah LiFePO4 battery can provide nearly 40 amps for an hour and can still be recharged

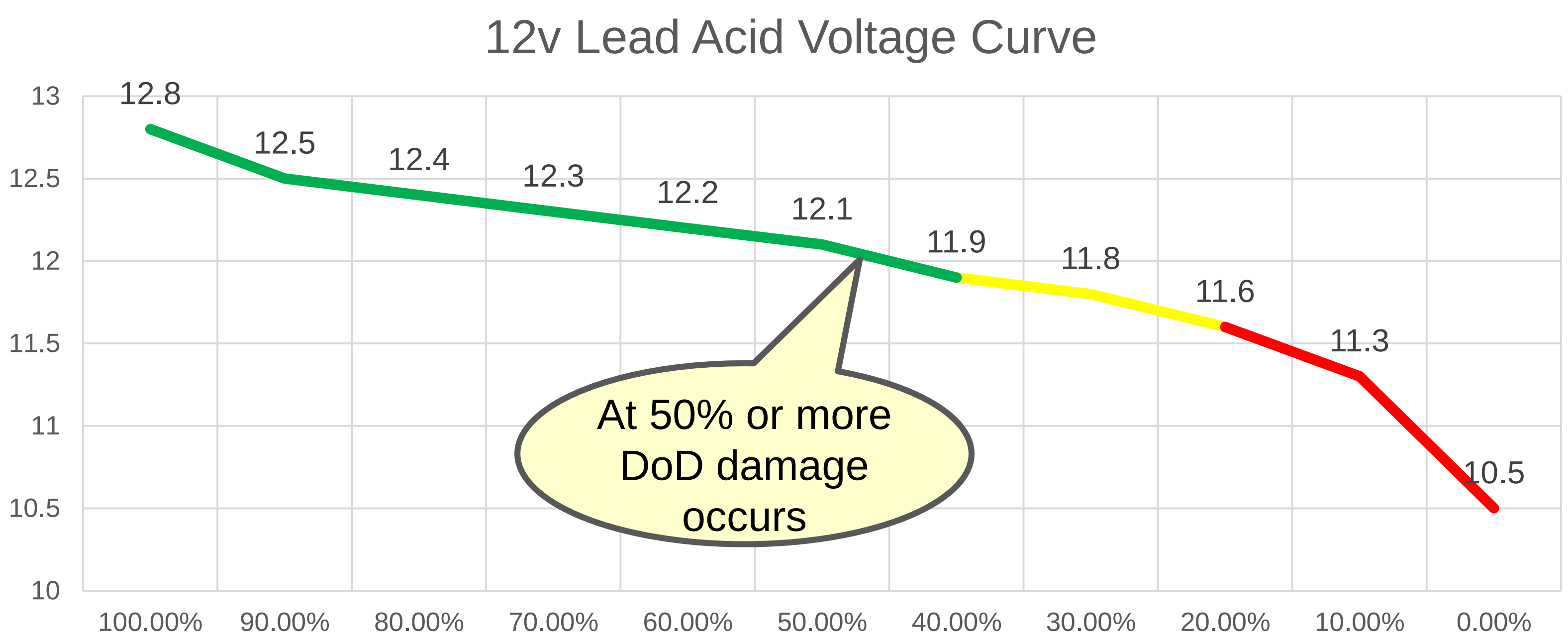
TEST RESULTS



Batteries

➢ True Capacity – Lead Acid Batteries

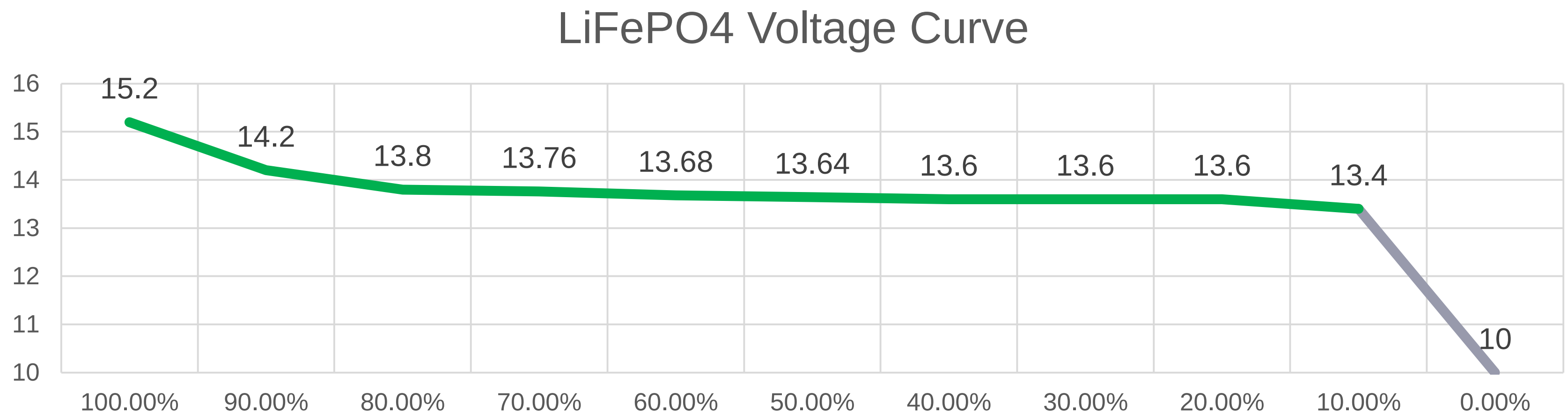
- Avoid discharging below 75% (12.4vdc) on a regular basis to ensure maximum life
- At 50% depth of discharge, batteries will experience some degree of permanent damage; This should be the maximum discharge level
- When calculating available amp hours, take the rated amp hours and half it
- Typical deep cycle lead acid batteries are rated for 550 cycles to 50% discharge



Batteries

➢ True Capacity – LiFePO4

- LiFePO4 batteries can be drawn down to under 10% with no damage and can be recharged to near full capacity
- They can safely provide a very large number of amps in a short amount of time (i.e. a high C rating)
- Because LiFePO4 batteries can be drawn down to below 10%, the true Ah available in a LiFePO4 battery is much higher than that of an equivalent Lead Acid battery
- Beware of LiFePO4 batteries with an amp hour rating stated as “PbEq” which means “Lead Acid Equivalent”. A LiFePO4 30ah PbEq battery is really a 15 to 20 amp hour (or less) battery
- LiFePO4 batteries can be recharged thousands of times



Batteries

- **Adding more capacity**
  - You can increase the capacity of your battery bank by adding more batteries

Batteries

➢ **Adding more capacity**

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- Batteries should be the same voltage and amp hours and if at all possible the same age

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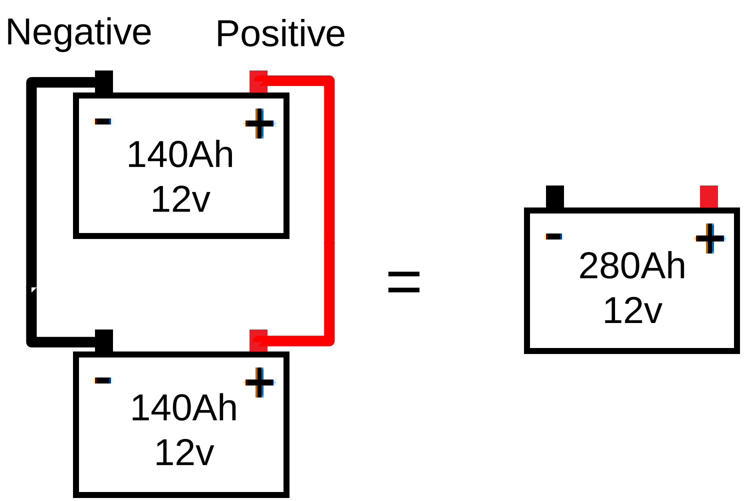
  - Batteries would be connected in parallel (positive to positive, negative to negative)



Parallel Wiring

Batteries

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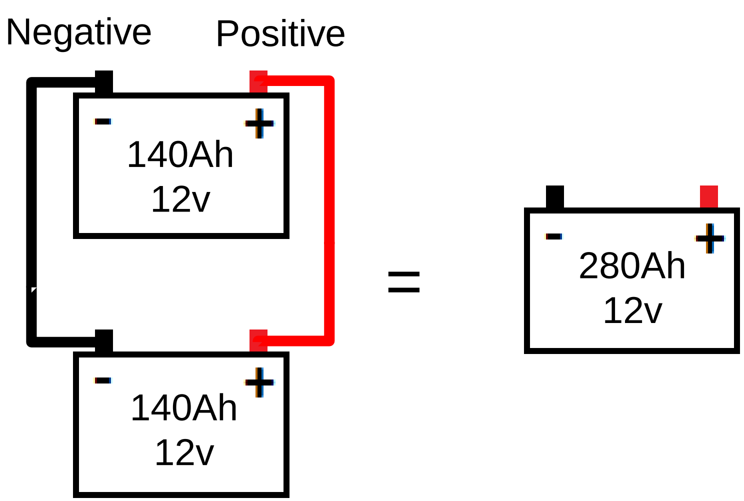
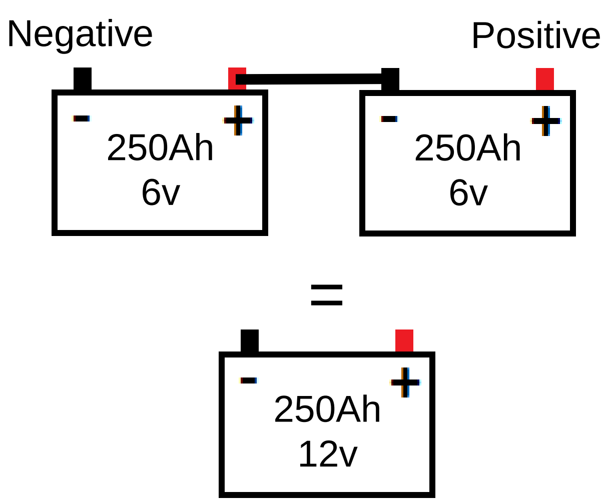


Parallel Wiring



Series Wiring

- 2 Batteries connected in parallel doubles the amp hours
- 2 Batteries connected in series doubles the voltage

Batteries

- **Lead Acid – Car Batteries**
  - Not recommended
  - Designed for starting, not cycling
  - Can be used in an emergency
  - Expected battery life = 3 to 12 months depending on how it is maintained*

*Source: https://www.solar-electric.com/learning-center/batteries-and-charging/deep-cycle-battery-faq.html

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Batteries

➢ **Lead Acid – Flooded Deep Cycle**

- Thicker lead plates
- Requires venting
- Need to monitor the water level and refill as necessary
- Prices vary depending on Ah’s and quality
- Expected battery life = 4 to 8 years depending on how it is maintained*

*Source: https://www.solar-electric.com/learning-center/batteries-and-charging/deep-cycle-battery-faq.html

Batteries

➢ Lead Acid – Golf Cart Batteries

- Typically six volt, so you need to purchase them in pairs and connect them in series to get 12vdc
- Requires venting
- Need to monitor the water level and refill as necessary
- Relatively inexpensive per Ah
- Expected battery life = 2 to 7 years depending on how it is maintained*

*Source: https://www.solar-electric.com/learning-center/batteries-and-charging/deep-cycle-battery-faq.html

Batteries

- **Lead Acid - Absorbent Glass Mat (AGM) / Sealed Lead Acid**
  - Sealed, so venting and adding water is not needed
  - Can be installed in any position
  - Deep cycle
  - Most expensive of Lead Acid type batteries
  - Expected battery life = 4 to 8 years depending on how it is maintained*

*Source: https://www.solar-electric.com/learning-center/batteries-and-charging/deep-cycle-battery-faq.html

Batteries

➢ Lithium Iron Phosphate (LiFePO4)

- Safe (punch a hole in one and they won't catch fire)
- Over charge/discharge protection with built-in battery management system (BMS)… will not explode
- Can be discharged below 10% and will recharge back to 100%
- Thousands of discharge/recharge cycles
- Be careful of how the manufacturer rates them (PbEQ)
- Although more expensive than lead acid batteries, over their life, they pay for themselves with more cycles and higher useful capacity
- Need to use a charger designed for this chemistry to ensure balancing

Photovoltaic (Solar) Panels

- **Sunlight hitting the Earth in one hour is enough to power the entire world for a year**
- **In the 1870s, William Adams and Richard Day discovered that the Sun's energy creates electricity when passed through selenium**
- **In the 1950s, Bell Labs scientist discovered that silicon cells generated 5x more energy than selenium and through experimentation, developed a cell that generated 50x more energy than selenium**
- **Today, some super-thin PV cells are over 300x more efficient than the first selenium cells**

Photovoltaic (Solar) Panels

- **Monocrystalline**
- **Polycrystalline**
- **Foldable (Thin Film, Copper indium gallium selenide [CIGS])**
- **Hybrid – Bendable Monocrystalline**

Photovoltaic (Solar) Panels

- **Monocrystalline**
  - More expensive
  - Smaller footprint and less weight per watt
  - Most efficient (~25%)
  - Work best when pointed directly at the sun
  - Shading a single cell could reduce output by 35 to 50%
  - Shading by a bare branch could reduce output by 25%

Photovoltaic (Solar) Panels

- **Polycrystalline**
  - Less expensive
  - Larger footprint and more weight per watt
  - Less efficient (~20%)
  - Work best when pointed directly at the sun
  - Shading a single cell could reduce output by 35 to 50%
  - Shading by a bare branch could reduce output by 25%

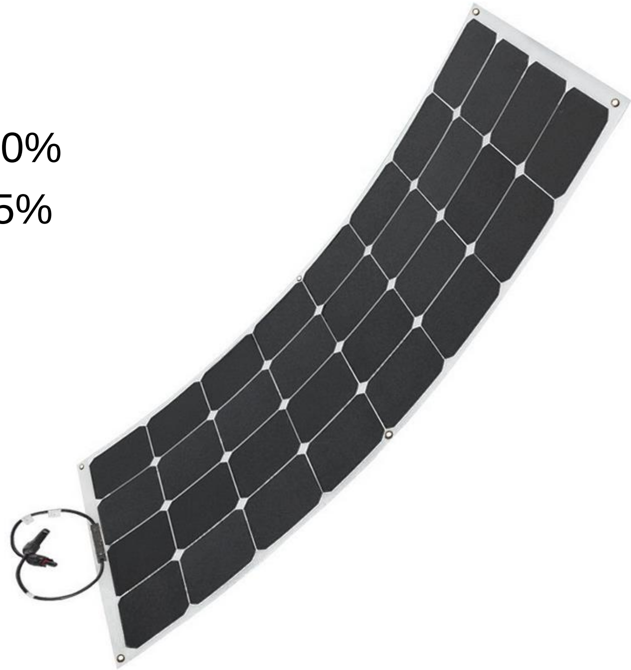
Photovoltaic (Solar) Panels

- **Foldable (Thin Film, Copper indium gallium selenide [CIGS])**
  - Most expensive
  - Larger footprint, but lighter weight per watt
  - Super lightweight
  - Least efficient (~14%)
  - Don't have to be pointed directly at the sun
  - Work well in partial shade

Photovoltaic (Solar) Panels

➢ Hybrid – Bendable Solar Panels

- More expensive than traditional panels, but less expensive than folding panels
- Monocrystalline
- Build on a plastic substrate with no aluminum frame, nor tempered glass
- Can be bent to some degree, but not folded
- Very lightweight
- Most efficient (~25%)
- Not as durable as traditional panels
- Work best when pointed directly at the sun
- Shading a single cell could reduce output by 35 to 50%
- Shading by a bare branch could reduce output by 25%



Photovoltaic (Solar) Panels

- **Larger (24v +) Solar Panels**
  - For non-portable use, are usually the best price per watt (typically under $1 per watt)
  - Can be found in 24v, 36v, 48v and higher output
  - Good value for powering your shack and/or a few moderate sized appliances during power outages
  - Work best when pointed directly at the sun
  - Shading a single cell will reduce output by 35 to 50%
  - Shading by a bare branch will reduce output by 25%

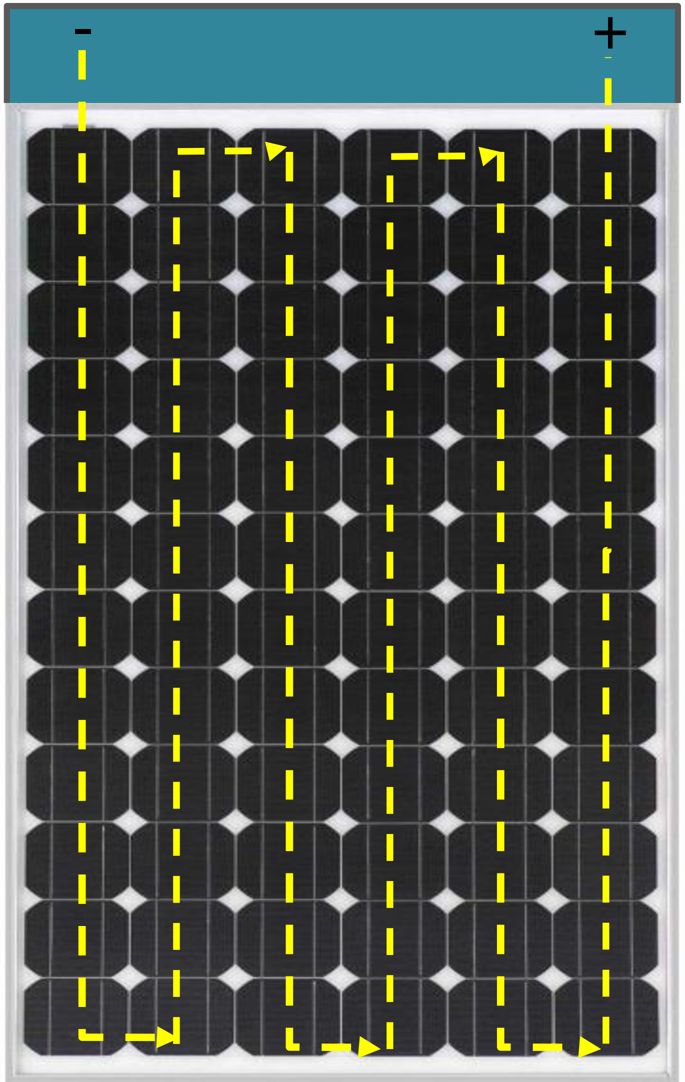


Photovoltaic (Solar) Panels

Why are most panels so impacted by a small amount of shading?

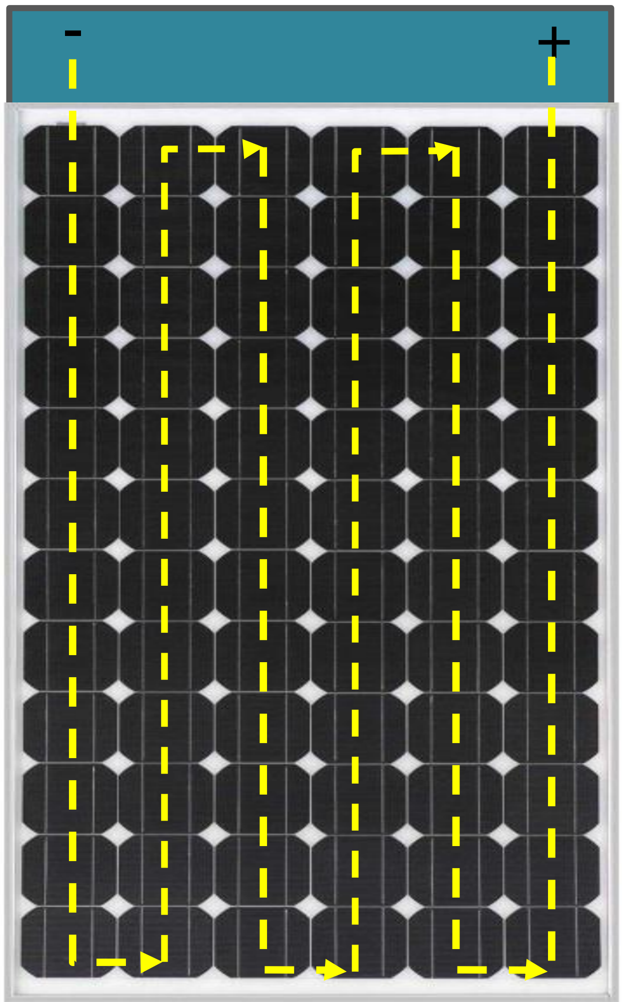
Photovoltaic (Solar) Panels

Let’s take a look at how solar cells are connected…



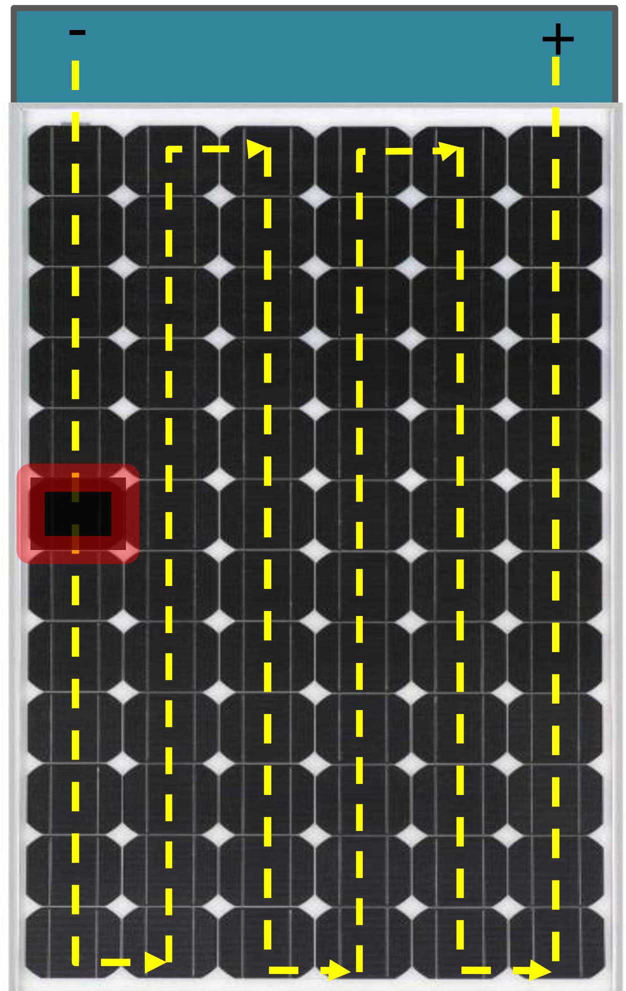
Photovoltaic (Solar) Panels

Like batteries in a flashlight, individual solar cells are connected in series



Photovoltaic (Solar) Panels

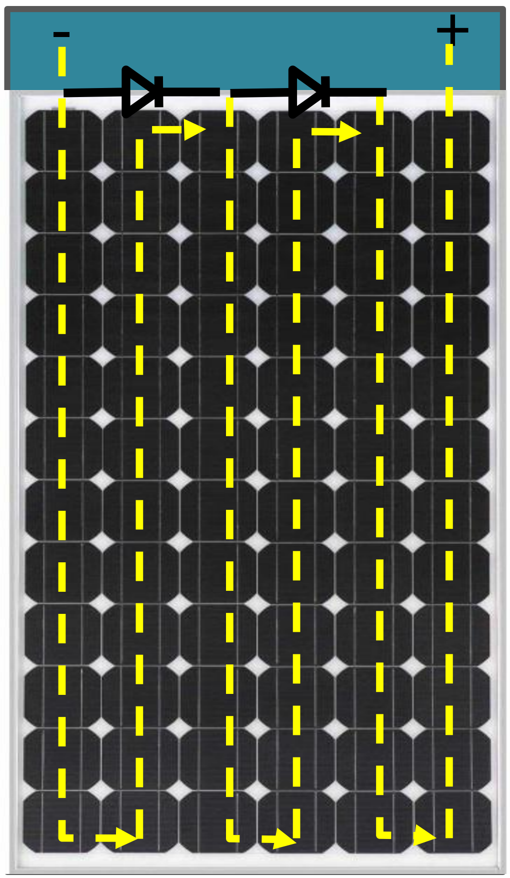
Think of shading like a flashlight with three new cells and one old one. Current flows from high to low, so in the same way that the old battery becomes a drain on the others, the shaded solar cell becomes a consumer of electricity, not a producer and begins to generate heat



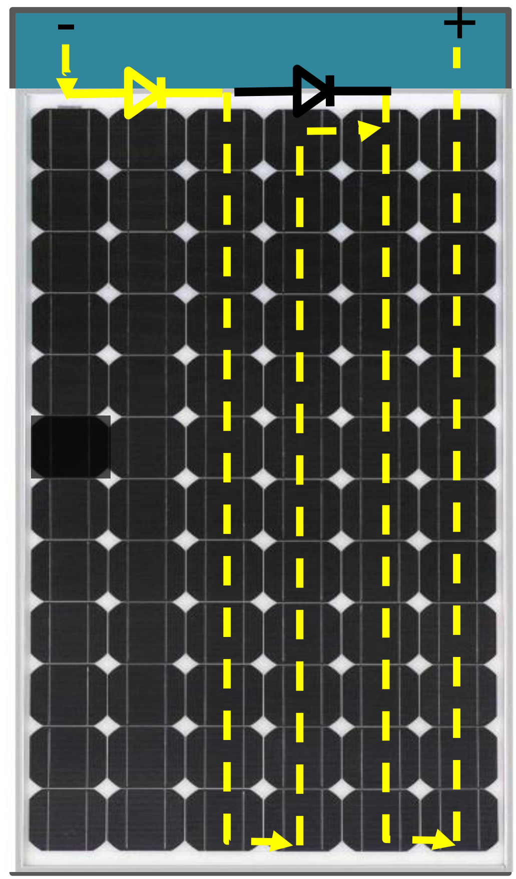
Photovoltaic (Solar) Panels

To prevent this, by-pass diodes are wired in parallel with the solar cells and become a lower resistance path around the shaded cells

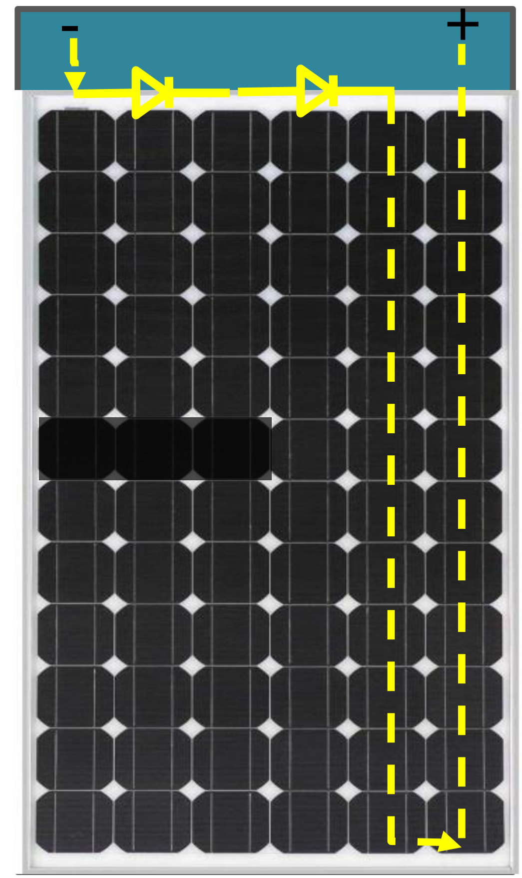
No Shading



One Cell Shaded



Three Cells Shaded



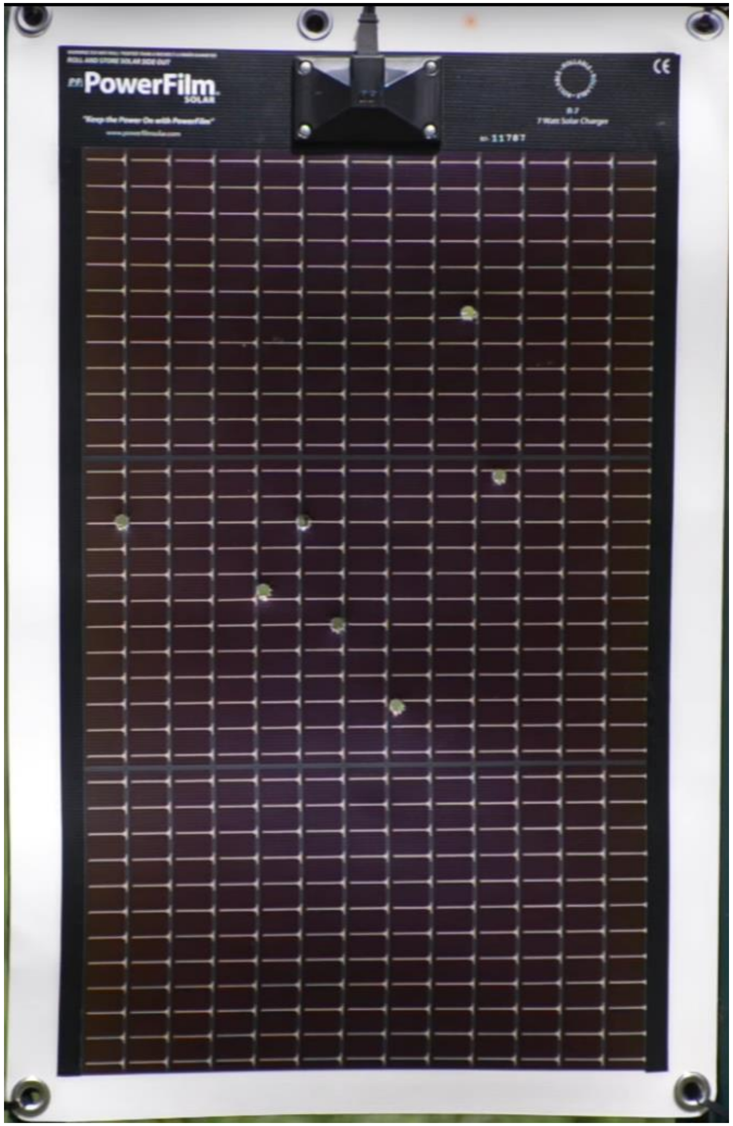
Photovoltaic (Solar) Panels

PowerFilm "panels" are wired differently so that shading or damaging a single cell or series of cells only reduces the output by the percentage that is covered

Photovoltaic (Solar) Panels

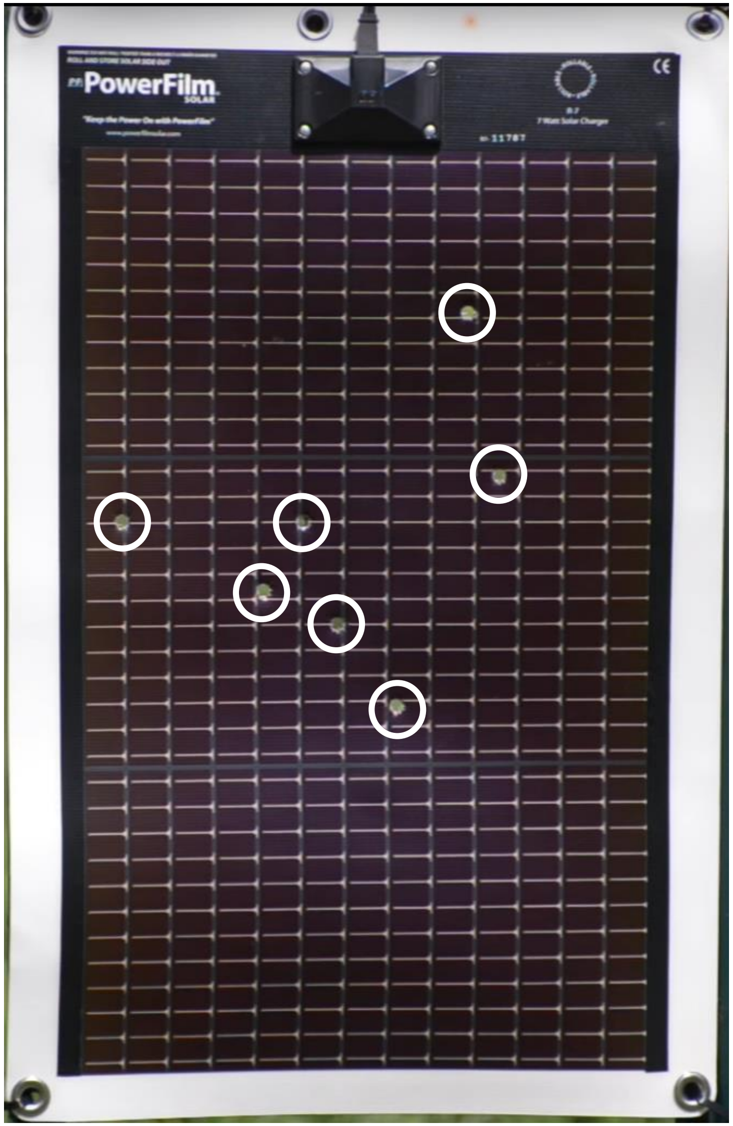
Shading a single set of cells only reduces the output by 5%

Photovoltaic (Solar) Panels



Shooting holes in the panel…

Photovoltaic (Solar) Panels



…only resulted in a loss of less than 20%

Photovoltaic (Solar) Panels

Standard Test Conditions (STC)

RENOGY
THE FUTURE OF CLEAN ENERGY

Address: 2775 E. Philadelphia St.,
Ontario, CA, 91761
Tel: 800-330-8678
Fax: 888-543-1164
Web: www.renogy.com

Module Type:	RNG-100D
Max Power at STC (P_{max})	100 W
Open-Circuit Voltage (V_{oc})	22.5 V
Optimum Operating Voltage (V_{mp})	18.9 V
Optimum Operating Current (I_{mp})	5.29 A
Short-Circuit Current (I_{sc})	5.75 A
Temp Coefficient of P_{max}	-0.44%/ºC
Temp Coefficient of V_{oc}	-0.30%/ºC
Temp Coefficient of I_{sc}	0.04%/ºC
Max System Voltage	600VDC (UL)
Max Series Fuse Rating	15 A
Fire Rating	Class C
Weight	7.5kgs / 16.5lbs
Dimensions	1195x541x35mm / 47x21.3x1.4in
STC	Irradiance 1000 W/m², T = 25ºC, AM=1.5

Address: 2775 E. Philadelphia St.,
Ontario, CA, 91761
Tel: 800-330-8678
Fax: 888-543-1164
Web: www.renogy.com

Module Type:	RNG-100P
Max Power at STC (P_{max})	100 W
Open-Circuit Voltage (V_{oc})	22.4 V
Short-Circuit Current (I_{sc})	5.92 A
Optimum Operating Voltage (V_{mp})	17.8 V
Optimum Operating Current (I_{mp})	5.62 A
Temp Coefficient of P_{max}	-0.44%/ºC
Temp Coefficient of V_{oc}	-0.30%/ºC
Temp Coefficient of I_{sc}	0.04%/ºC
Max System Voltage	600VDC (UL)
Max Series Fuse Size Rating	15 A
Fire Rating	Class C
Weight	7.5kgs / 16.5lbs
Dimensions	1010x680x35mm / 39.7x26.7x1.4in
STC	Irradiance 1000 W/m², T = 25ºC, AM=1.5

WARNING: This module produces electricity when exposed to light.
Please follow all applicable electrical safety precautions.
Only qualified personnel should install or perform maintenance work on these modules.
Beware of dangerously high DC voltages when connecting modules.
Do not damage or scratch the rear surface of the module.
Follow your battery manufacturer's recommendation.

Module Application: Class A

Electrical parameters at STC

Nominal Power (P_{max})	235W	240W	2
Open Circuit Voltage (V_{OC})	37.5V	37.7V	3
Short Circuit Current (I_{SC})	8.48A	8.57A	8
Voltage at Nominal Power (V_{mp})	29.7V	29.9V	3
Current at Nominal Power (I_{mp})	7.92A	8.03A	8
Module Efficiency (%)	14.44	14.75	1

STC: Irradiance 1000W/m², Cell temperature 25°C, AM1.5

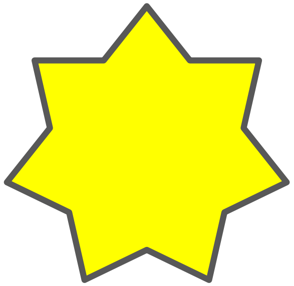
ELECTRICAL SPECIFICATIONS

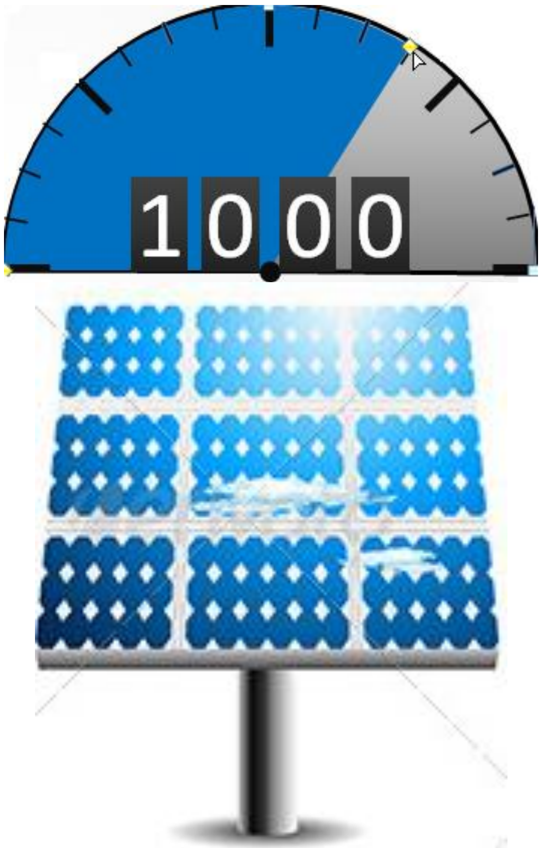
Electrical parameters at Standard Test Condition (STC)

Module Type			MSE290SE1J	MSE295SE1J	MSE300SE1J	MSE305SE1J	MSE310SE1J	MSE315SE1J	MSE320SE1J	MSE325SE1J	MSE330SE1J	MSE335SE1J
Power Output	Pmax	Wp	290	295	300	305	310	315	320	325	330	335
Tolerance			0~+3%									
Short-Circuit Current	Isc	A	8.84	8.87	8.90	8.93	9.96	8.99	9.12	9.13	9.14	9.15
Open Circuit Voltage	Voc	V	44.6	44.8	45.2	45.6	45.9	45.8	45.9	46.1	46.11	46.4
Rated Current	Imp	A	8.15	8.19	8.26	8.32	8.39	8.47	8.56	8.60	8.62	8.68
Rated Voltage	Vmp	V	36.1	36.3	36.6	36.9	37.0	37.2	37.4	37.8	38.5	38.9

Photovoltaic (Solar) Panels

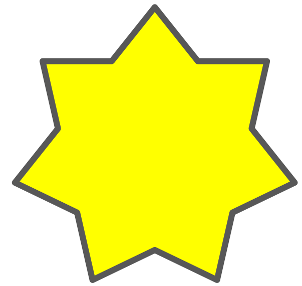
- **Irradiance 1000 Watts per Square Meter**

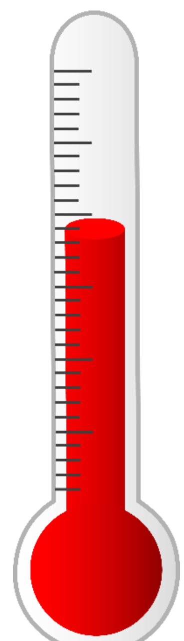




Photovoltaic (Solar) Panels

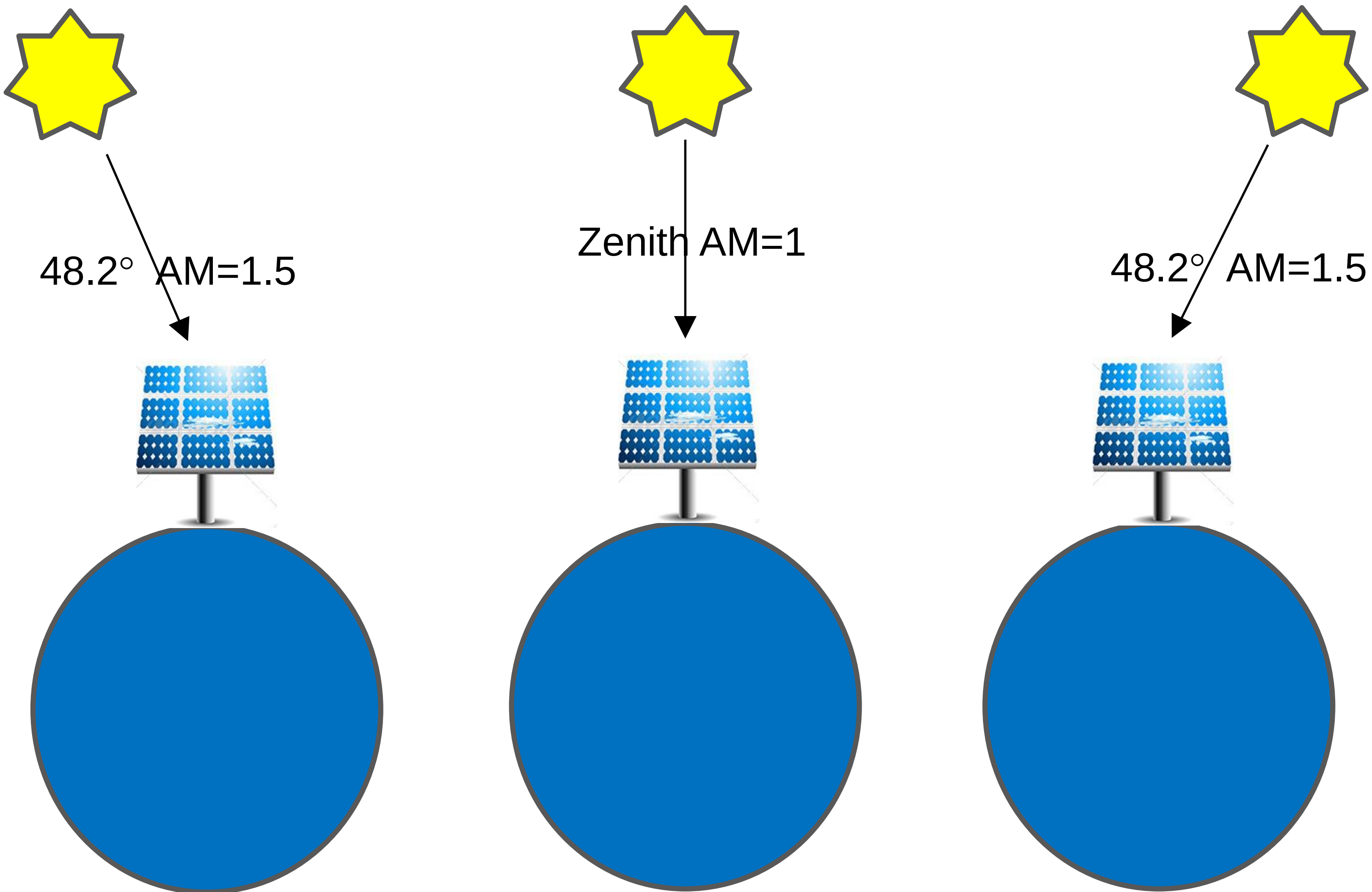
- **Temperature = 25° C / 77° F**





Photovoltaic (Solar) Panels

- **Air Mass (AM) = 1.5**



Testing Solar Panels - Test Methodology

- **The test was conducted from 11:45 to 13:00 PDT on 07 August 2016 in Menlo Park, CA**
- **Non-foldable panels were tilted and positioned for optimal sunlight. Foldable panels were laid out flat on the ground**
- **The panels were tested using the West Mountain Radio Computerized Battery Analyzer (CBA) IV and the included software V2.4**
  - The "Test Type" was set to "Power Profile", with a "Cutoff Voltage" of 12v
  - Test conditions were clear, 73° F with a light breeze

PV Panel
Renogy RNG-50DL 12v monocrystalline lightweight panel
Renogy RNG-100DB 12v monocrystalline bendable panel
Renogy RNG-100D 12v monocrystalline panel
Goal Zero Boulder 30M 12v monocrystalline x 4 panels
PowerFilm FM16-7200 12v thin film foldable panel

Testing the Solar Panels

Renogy RNG-50DL 12v monocrystalline lightweight panel †

Rated Watts	Tested Watts	% of Rated	Weight*	Weight/ Watt	Price**	Price/ Watt
50	37.98	75.96%	2.68	0.07	$139.99	$3.69

*Listed in Lbs. Weight is as listed by the manufacturer
**Typical Internet price
† Panel no longer available from Renogy - Possible replacement HQST 50 watt 12v monocrystalline flexible panel @ $109.99 for a price per watt of $2.90

Testing the Solar Panels

Renogy RNG-100DB 12v monocrystalline bendable panel ††

Rated Watts	Tested Watts	% of Rated	Weight*	Weight/ Watt	Price**	Price/ Watt
100	85.79	85.79%	4.00	0.05	$219.99	$2.56

*Listed in Lbs. Weight is as listed by the manufacturer
**Typical Internet price
†† Panel no longer available from Renogy - Possible replacement HQST 100 watt 12v monochrystalline flexible panel @ $189.99 for a price per watt of $2.21

Testing the Solar Panels

Renogy RNG-100D 12v monocrystalline panel

Rated Watts	Tested Watts	% of Rated	Weight*	Weight/ Watt	Price**	Price/ Watt
100	88.7	88.70%	16.50	0.19	$139.31	$1.57

*Listed in Lbs. Weight is as listed by the manufacturer
**Typical Internet price
Amazon recently had these on-sale for $109.99 for a price per watt of $1.24

Testing the Solar Panels

Goal Zero Boulder 30M 12v monocrystalline x 4 panels

Rated Watts	Tested Watts	% of Rated	Weight*	Weight/ Watt	Price**	Price/ Watt
120	90.96	75.80%	26.00	0.29	$799.96	$8.79

*Listed in Lbs. Weight is as listed by the manufacturer
**Typical Internet price
Additional Items Used as part of the test:
8 Panel Quick Clips, Tripod, Cases $408.65 for a Price Per Watt $13.29

Testing the Solar Panels

PowerFilm FM16-7200 12v thin film foldable panel

Rated Watts	Tested Watts	% of Rated	Weight*	Weight/ Watt	Price**	Price/ Watt
120	96.19	80.16%	6.50	0.07	$1,212.00	$12.60

*Listed in Lbs. Weight is as listed by the manufacturer

**Typical Internet price

Testing the Solar Panels – The Results

PV Panel	Rated Watts	Tested Watts	% of Rated	Weight*	Weight / Watt	Price**	Price/ Watt
Renogy RNG-50DL 12v monocrystalline lightweight panel †	50	37.98	75.96%	2.68	0.07	$139.99	$3.69
Renogy RNG-100DB 12v monocrystalline bendable panel ††	100	85.79	85.79%	4.00	0.05	$219.99	$2.56
Renogy RNG-100D 12v monocrystalline panel	100	88.7	88.70%	16.50	0.19	$139.31	$1.57
Goal Zero Boulder 30M 12v monocrystalline x 4 panels	120	90.96	75.80%	26.00	0.29	$799.96	$8.79
PowerFilm FM16-7200 12v thin film foldable panel	120	96.19	80.16%	6.50	0.07	$1,212.00	$12.60

Best Portability per Watt

Best Weight per Watt

Best Price Per Watt

Rachel Kinoshita – KK6DAC

† Panel no longer available from Renogy - Possible replacement HQST 50 watt 12v monocrystalline flexible panel ($99)

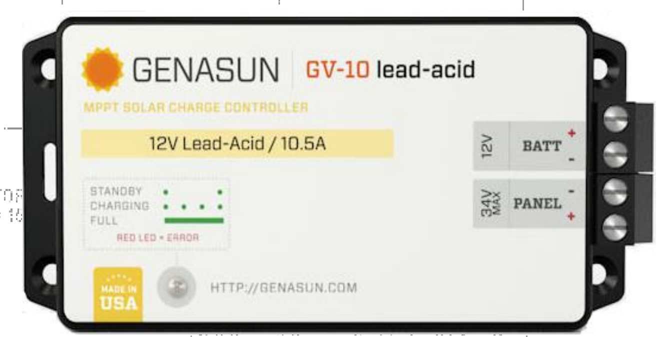
†† Panel no longer available from Renogy - Possible replacement HQST 100 watt 12v monocrystalline flexible panel ($179.99)

Charge Controllers

- **What is a Charge Controller and why do I need one?**
  - Think of a charge controller like a battery charger…it regulates the current and voltage as it charges the battery
  - A 12v solar panel typically puts out 22vdc to 23vdc open circuit (i.e. no load) and 17vdc to 19vdc under load
- **Can I hook my 12v solar panel directly to my 12v battery?**
  - You can, but you will likely damage your battery (especially SLA & AGM)
  - Output from the solar panel is unregulated

18v

8.3a



14.2v

10a

Charge Controllers

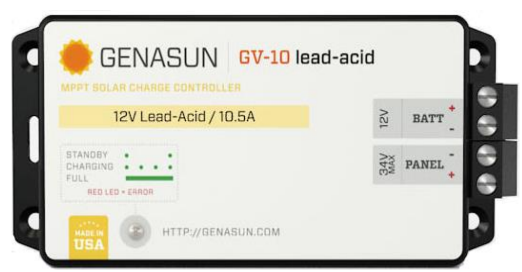
- **A good charge controller will provide 3-stage charging for lead acid batteries**
  - **Bulk** – Constant Current (or close to it) – Charge to about 80% of battery capacity. Unlike a 3-stage AC battery chargers, a solar charge controller can't guarantee constant wattage input. Thus during Bulk, it's not necessarily Constant Current
  - **Absorption-** Constant Voltage (high voltage / lower current) and slowly reduce the current until the battery is nearly full
  - **Float** – Voltage decreased to battery maximum (13.5 / 13.7), trickle current
- **Different types of batteries such as AGM, Gel, Flooded, LiFePO4 require different charging profiles**
  - Some charge controllers are fixed for one type of battery
  - Some charge controllers have settings for a few battery types
  - Some charge controllers can be programmed with any value to match any battery
  - Make sure the charge controller you choose matches your battery, otherwise you may damage your battery

Charge Controllers

- **Maximum Power Point Tracking (MPPT)**
- **Pulse Width Modulation (PWM)**
- **Cheap Controllers**

PWM

Cheap



MPPT

Charge Controllers

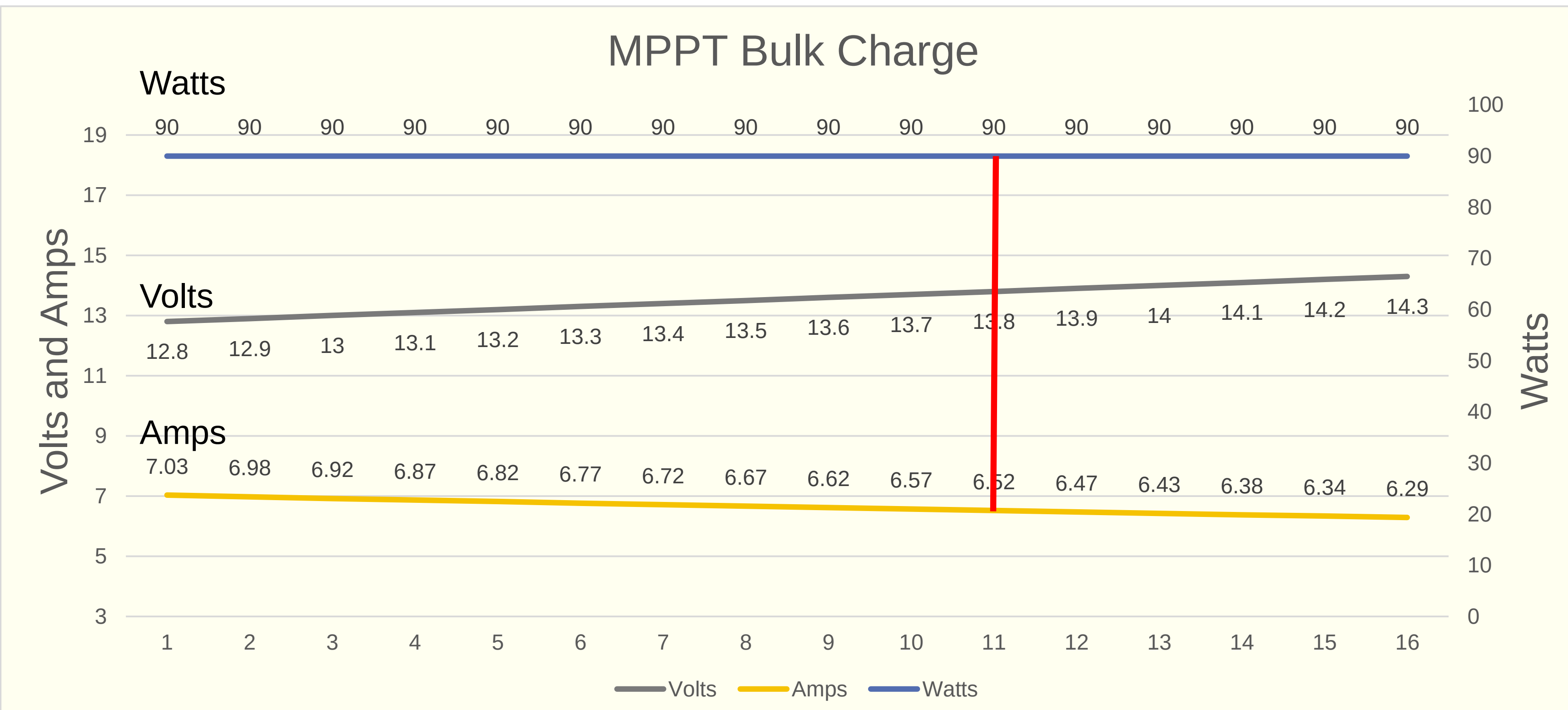
➢ Maximum Power Point Tracking (MPPT)

- More expensive
- Required when PV panel voltage is significantly higher than the battery (i.e. 24 or 36v panels and a 12v battery bank)
- Converts excess PV voltage into more amps
- During the Bulk phase, the controller takes the input wattage and outputs the optimum battery voltage and the maximum current
- During the Absorption phase, the controller pulses on and off many times per second. As the battery resistance increases, the length of the "on" pulse decreases

Charge Controllers

➢ **Maximum Power Point Tracking (MPPT)**

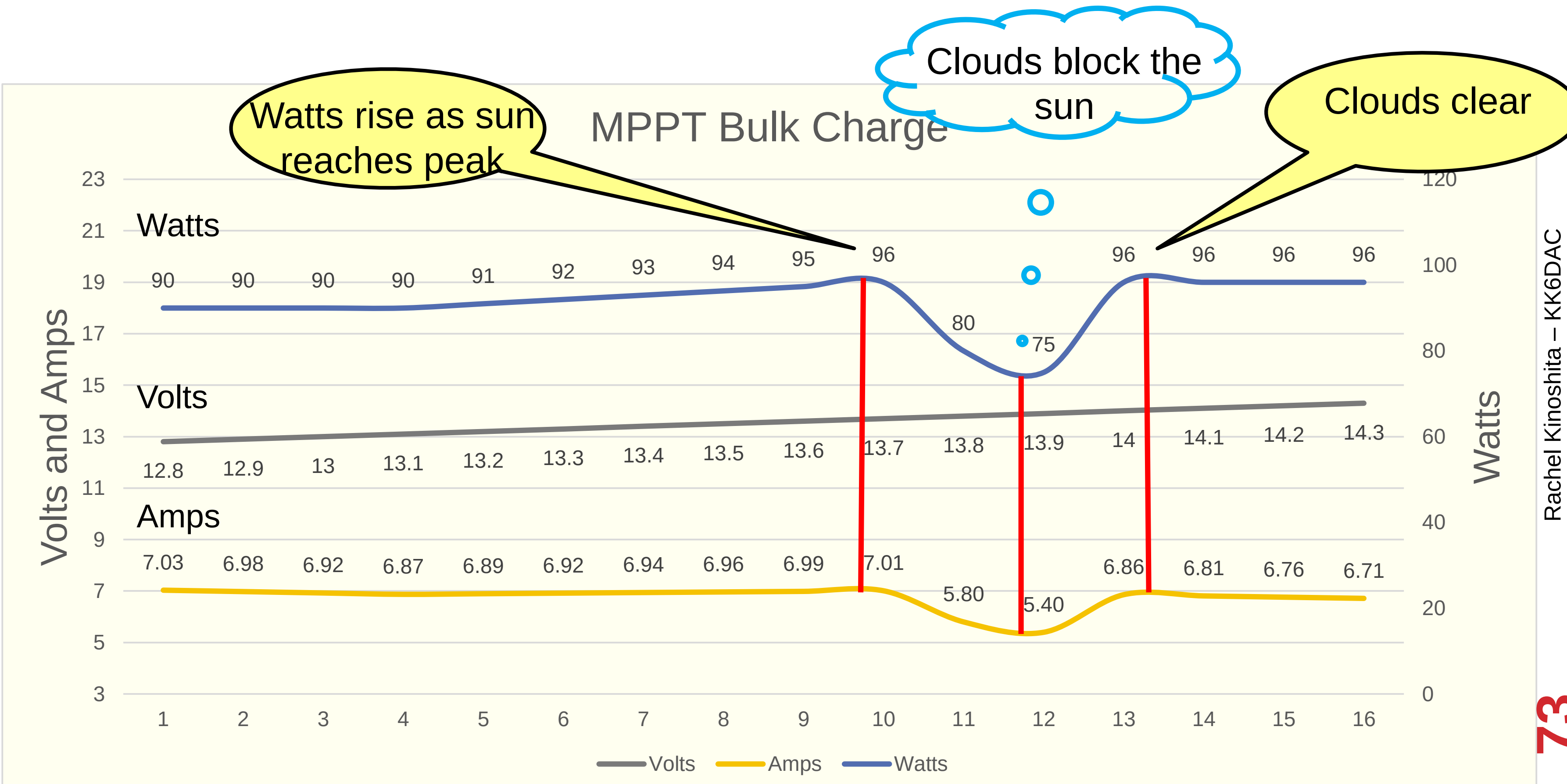
- For example, a 12vdc solar panel is producing 17vdc @ 5.3 amps (17 * 5.3 = 90 watts) with an initial battery voltage of 12.8v. An MPPT charge controller would, for example, charge the battery at 13.8vdc @ 6.5 amps (13.8 * 6.5 = 90 watts)



Charge Controllers

➢ Maximum Power Point Tracking (MPPT)

- In this example, the output from the PV panel starts to go up as the sun rises in the sky. However, a cloud comes through and partially blocks the sun, dropping the output wattage. As the cloud moves out of the way, the output climbs back to 96 watts



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Charge Controllers

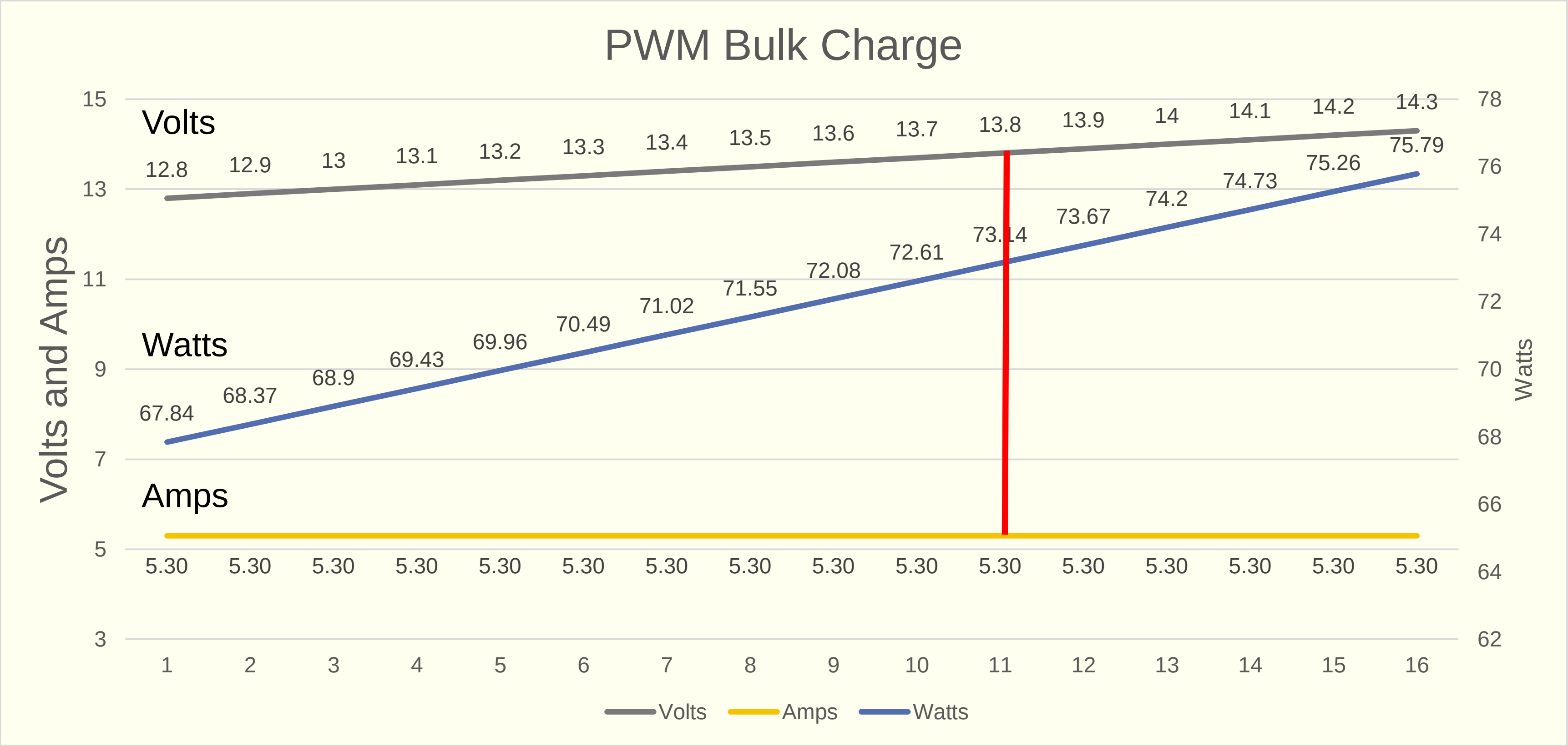
➢ Pulse Width Modulation (PWM)

- Less expensive
- Works well when PV panel and battery voltages are closely matched
- Reduces PV input voltage to the battery voltage
- During the Bulk phase, the controller is basically a connector between the PV panel and the battery. Current is constant. Voltage increases as the resistance increases.
- During the Absorption phase, the controller pulses on and off many times per second. As the battery resistance increases, the length of the “on” pulse decreases
- Uses pulses to charge the battery
- Emit more EMI and RFI


Charge Controllers

➢ Pulse Width Modulation (PWM)

- Using the same example, a 12vdc solar panel is producing 17vdc @ 5.3 amps (17 * 5.3 = 90 watts). A PWM charge controller would charge the battery at 13.8vdc @ 5.3 amps (13.8 * 5.3 = 73 watts)



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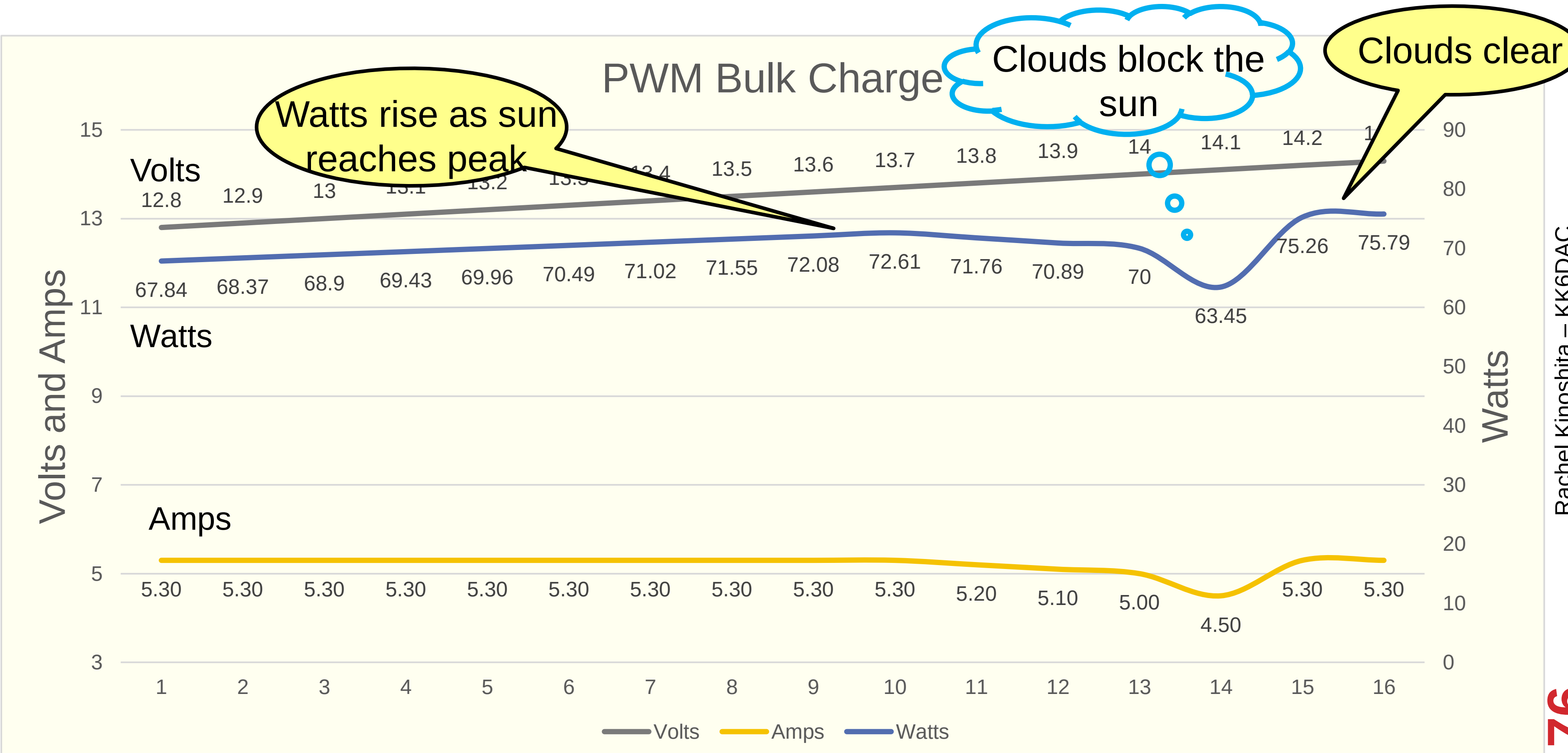
Charge Controllers

➢ **Pulse Width Modulation (PWM)**

- In this example, the output from the PV panel starts to go up as the sun rises in the sky. However, a cloud comes through and partially blocks the sun, dropping the output wattage. As the cloud moves out of the way, the watts increase.



Charge Controllers

➢ Cheap Controllers

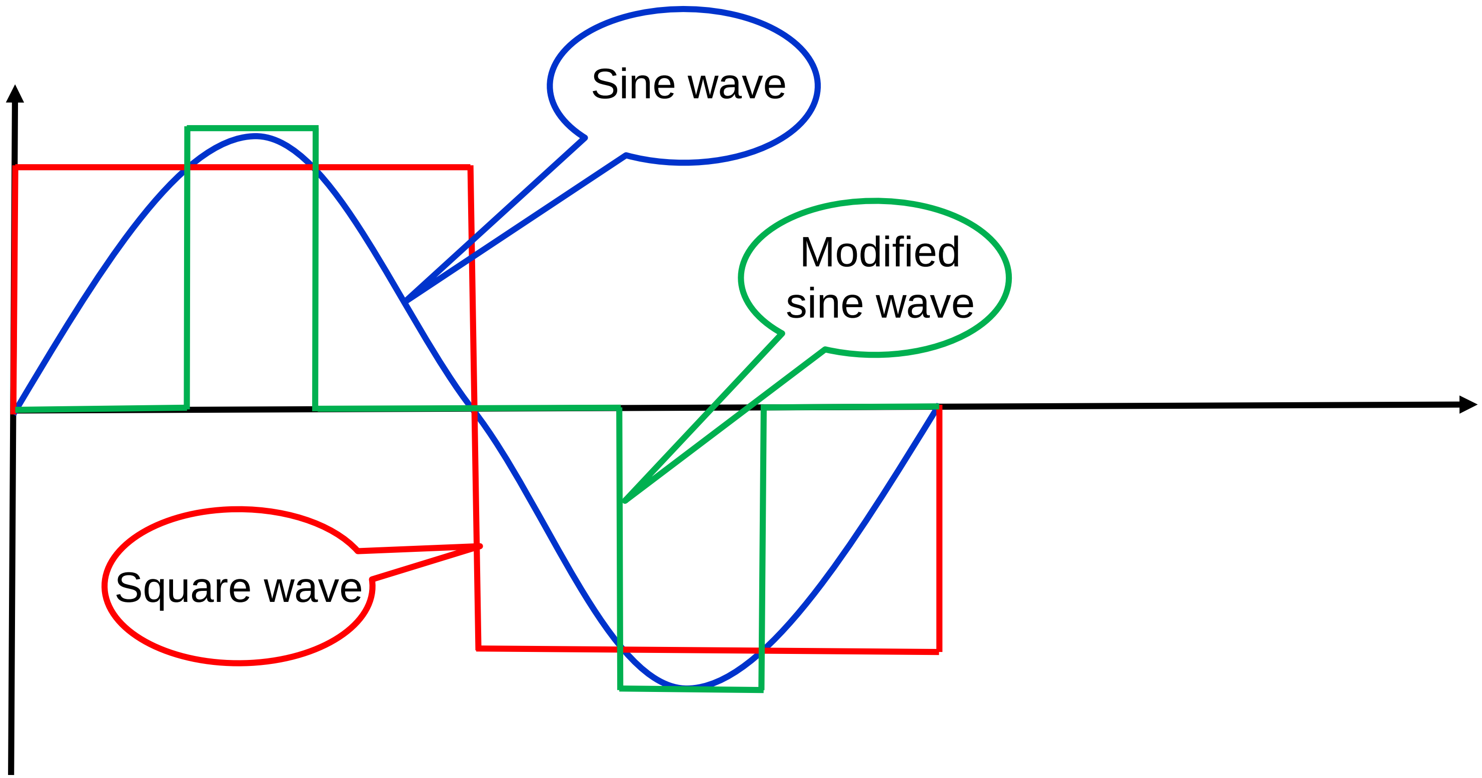
- Very inexpensive
- On / Off charging
- Unknown charging algorithm
- Most are designed for a single charging algorithm
- Could damage your batteries
- Avoid

Inverters

- **Converts Direct Current (DC) to Alternating Current (AC)**
  - DC is the form of electricity that comes from batteries
  - AC is the form of electricity delivered to your house
- **Expect at least a 10% loss due to conversion**
- **Tend to generate Radio Frequency Interference (RFI)**
- **Typical consumer inverters use 12vdc to 48vdc input**
- **Output voltage and frequency for US inverters are typically 120vac at 60 Hz**
- **Available in a wide range of output power**
- **Different types of output waveform**
  - Square wave
  - Sine wave
  - Modified sine wave

Inverters

- **Different types of output waveform**
  - Square Wave
  - Sine Wave
  - Modified Sine Wave



Inverters

➢ **Pure Sine Wave**

- More expensive, but prices have come down significantly
- Outputs a pure sine wave just like grid power
- Safe for delicate electronics
- Not as efficient, requires more input for the same output
- High surge capacity enables them to have much higher peaks than rated capacity

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Inverters

➢ Modified Sine Wave

- Inexpensive
- Output is a square wave approximation of sine wave
- Emit more EMI and RFI
    - https://www.solar-electric.com/learning-center/general-solar-information/reducing-electromagnetic-interference-pv-systems.html
- Safe for many electronics like TVs and computers
- Motor driven devices such as refrigerators and drills don’t like modified sine waves
- Microwaves, fluorescent lights and clocks don’t like modified sine waves
- May damage delicate electronic devices

Components That I Like

- **Batteries**
  - **Bioenno Power LiFePO4 Batteries**
    - **Lightweight, high energy density**
    - **Great customer service**
    - **Available at HRO (save $ on shipping)**
    - **National Sales Manager, Kevin (KI6DHQ) is a ham**
- **Solar Panels**
- **Charge Controllers**
- **Inverters**

Components That I Like

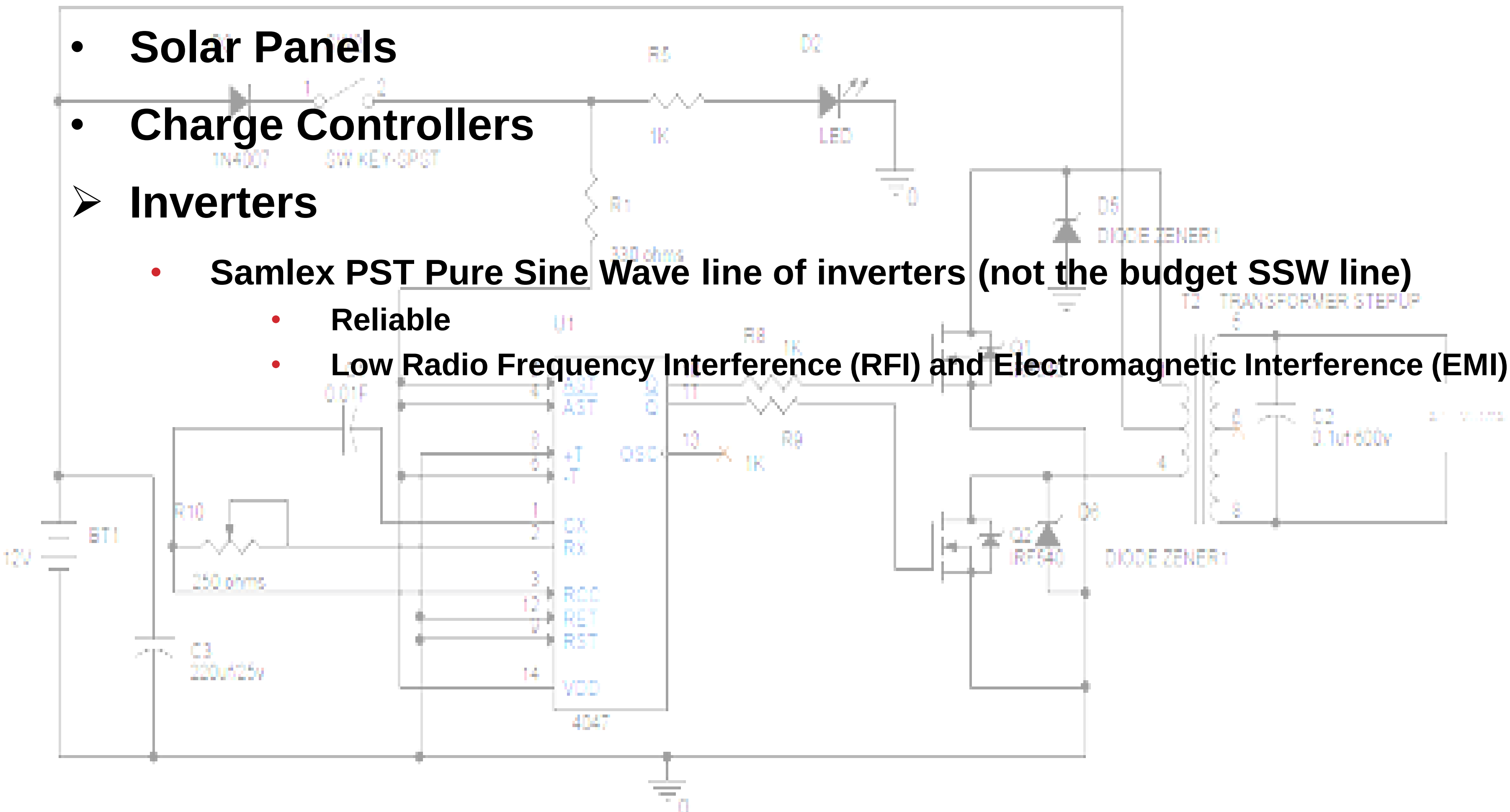
- **Batteries**
- **Solar Panels**
  - **Renogy 100w Rigid Solar Panels**
    - **Reliable and well constructed**
    - **Good value**
    - **Excellent customer service**
  - **PowerFilm Solar**
    - **Lightweight, fold up into a very small package**
    - **Unique design**
    - **Great for Field Day**
- **Charge Controllers**
- **Inverters**

Components That I Like

- **Batteries**
- **Solar Panels**
- **Charge Controllers**
  - **Genasun GV-10 MPPT**
    - **Maximum Power Point Tracking**
    - **Very reliable**
    - **RF quiet**
    - **Models designed specifically for Lithium batteries**
    - **Lightweight and easily portable**
  - **Testing Victron Energy 75/15 and 100/30 MPPT**
    - **Maximum Power Point Tracking**
    - **Appear to be well built**
    - **Higher input/output than Genasun**
    - **Cool Bluetooth interface**
  - **Outback MPPT 60a+ Charge Controllers**
    - **Maximum Power Point Tracking**
    - **Well built**
    - **Menu is a little quirky**
- **Inverters**

Components That I Like

- **Batteries**
- **Solar Panels**
- **Charge Controllers**
- ➢ **Inverters**
  - **Samlex PST Pure Sine Wave line of inverters (not the budget SSW line)**
    - **Reliable**
    - **Low Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI)**



Evaluating Your Needs

- **Determine the watts used by each device that you plan to use**
- **Determine how much time per day it takes to charge that device or how much time per day that you will be using it**
- **Calculate how many days per week you will be using that device**
- **Multiply the Qty * Watts * Hours * (use per week / 7), then total it all up**
- **Calculate the Amp hours by dividing by the volts of your battery bank (i.e. 12v)**

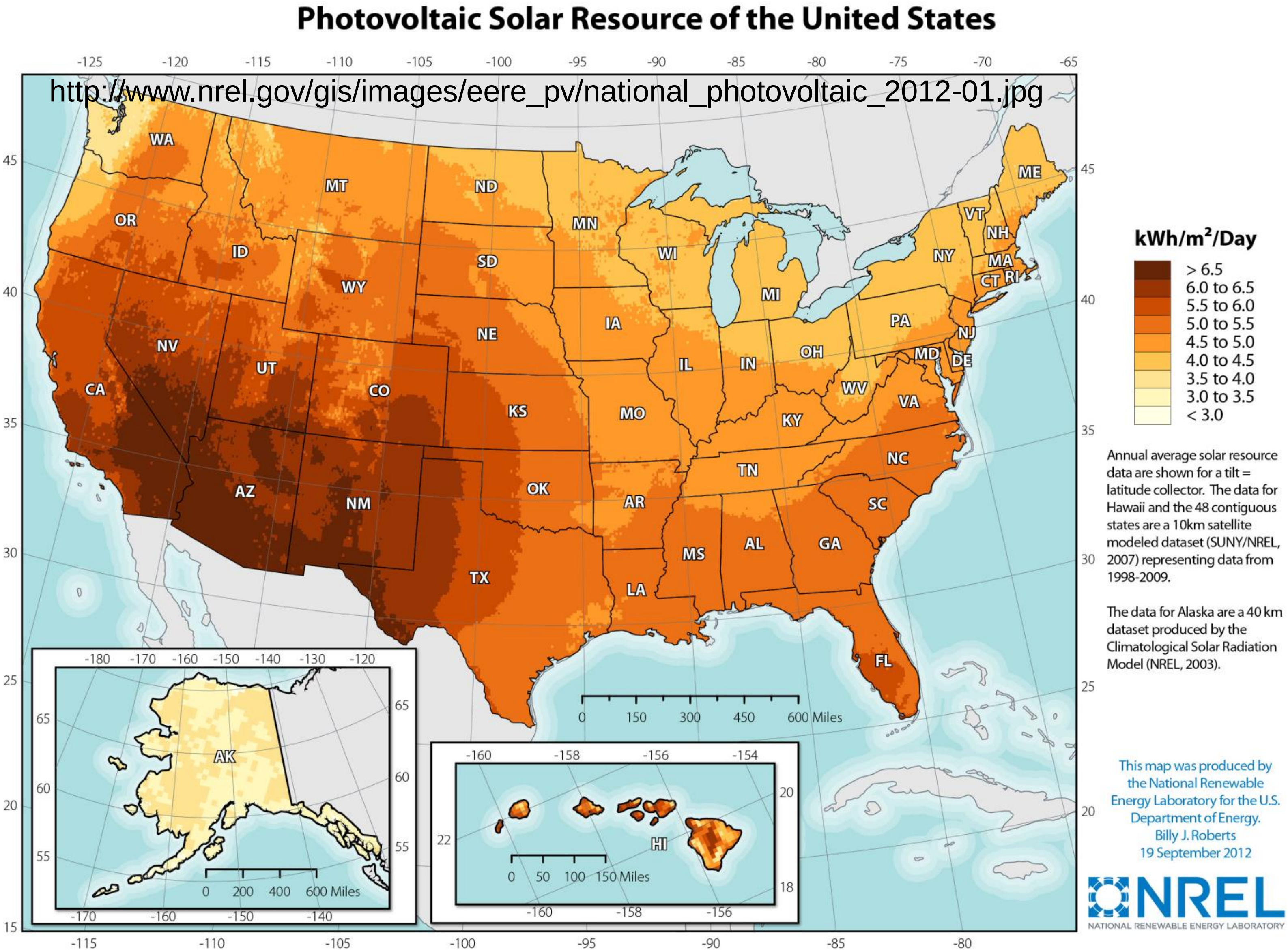
Qty	Device	Volts	Amps	Watts	Hours	Days/Week	Watt hours
	Yaesu FT60r Standard Charger	12	0.2	2.4	10	3	0.0
	Yaesu FT60r Rapid Charger	12	0.9	10.8	1.5	3	0.0
	Yaesu FT1D/2D Rapid Charger with FNB-101LI Battery	12	0.5	6	2.5	3	0.0
1	Yaesu FT1D/2D Rapid Charger with FNB-102LI Battery	12	0.5	6	4	3	10.3
	Engle MT80 Fridge / Freezer @ 41° F, amb temp 77° F			7.2	24	7	0.0
	Engle MT80 Fridge / Freezer @ -4° F, amb temp 77° F			30			
1	Battery Charger	12	3	36	3	1	15.4
4	LED Lights			10	3	7	120.0
1	Mobile Phone Charger			6	2	7	12.0
1	Laptop Charger			45	2	1	12.9
1	LCD HDTV 24"			30	1	7	30.0
	Total						380.2
	Ah @ 12v						31.3

Sizing Your Batteries

- **Let's start by sizing our battery requirements**
- **In our scenario, we plan to use 380.2 watt hours or 31.3 amp hours at 12vdc**
- **Lead acid batteries should not be drawn down below 50%, so we need at least a 63.4 Ah lead acid battery**
- **LiFePO4 batteries can be drawn down to 10%, so we need at least a 35.2 Ah LiFePO4 battery**
- **If you need to use an inverter, you must factor in a 10% loss converting from DC to AC**
- **Of course, not every day is sunny, so we also have to compensate for rainy and overcast days when very little solar power is generated**

Battery Type	Projected Usage	Max Battery Discharge	Min Battery Required	Inverter Loss	Min Battery with Inverter	Max days w/o Sun	Required Ah	Required Ah (w/Inverter)
Lead Acid	31.3	50%	63	10%	70	2	127	141
LiFePO4	31.3	90%	35	10%	39	2	70	78

Sizing Your Solar Panels



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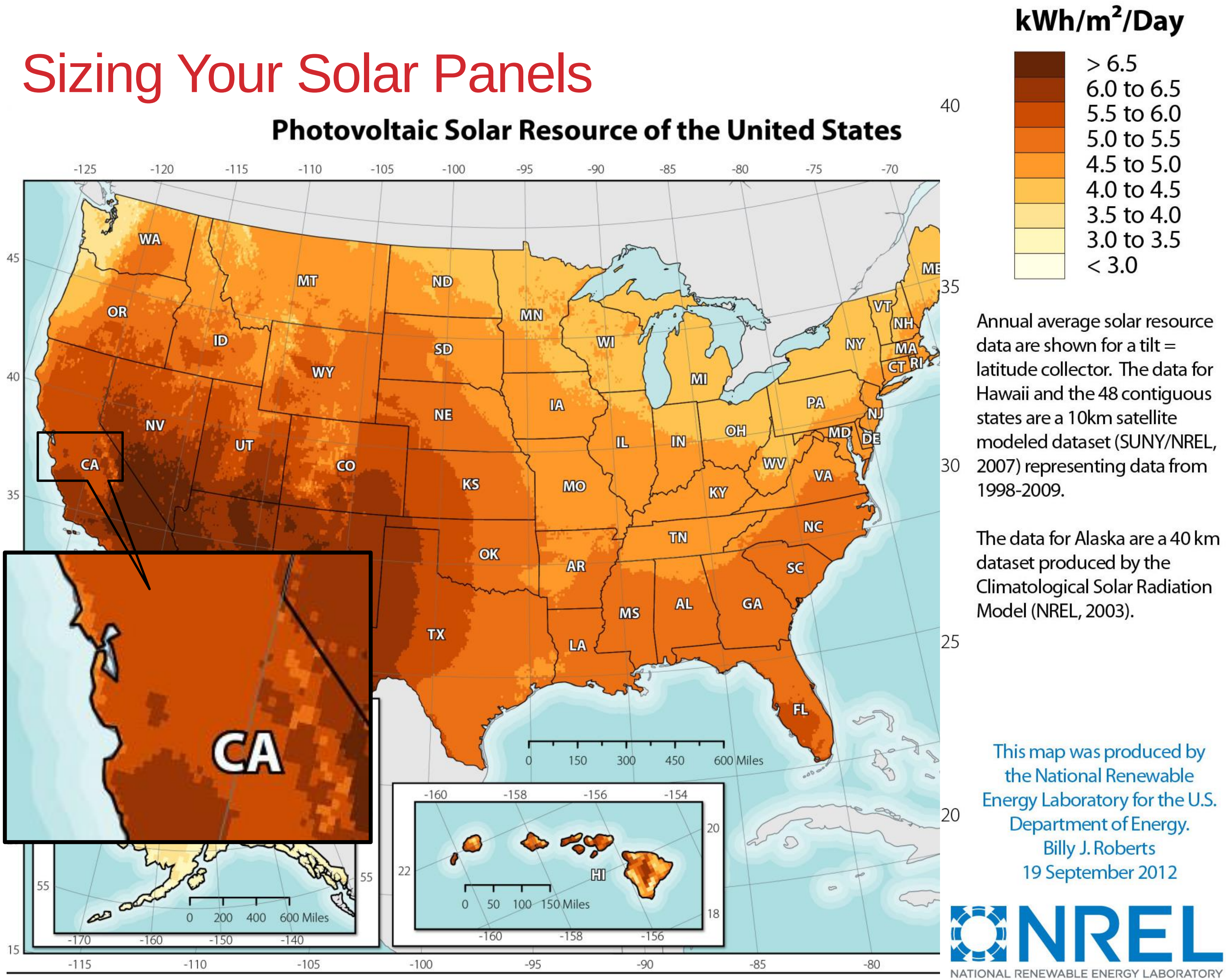
Sizing Your Solar Panels



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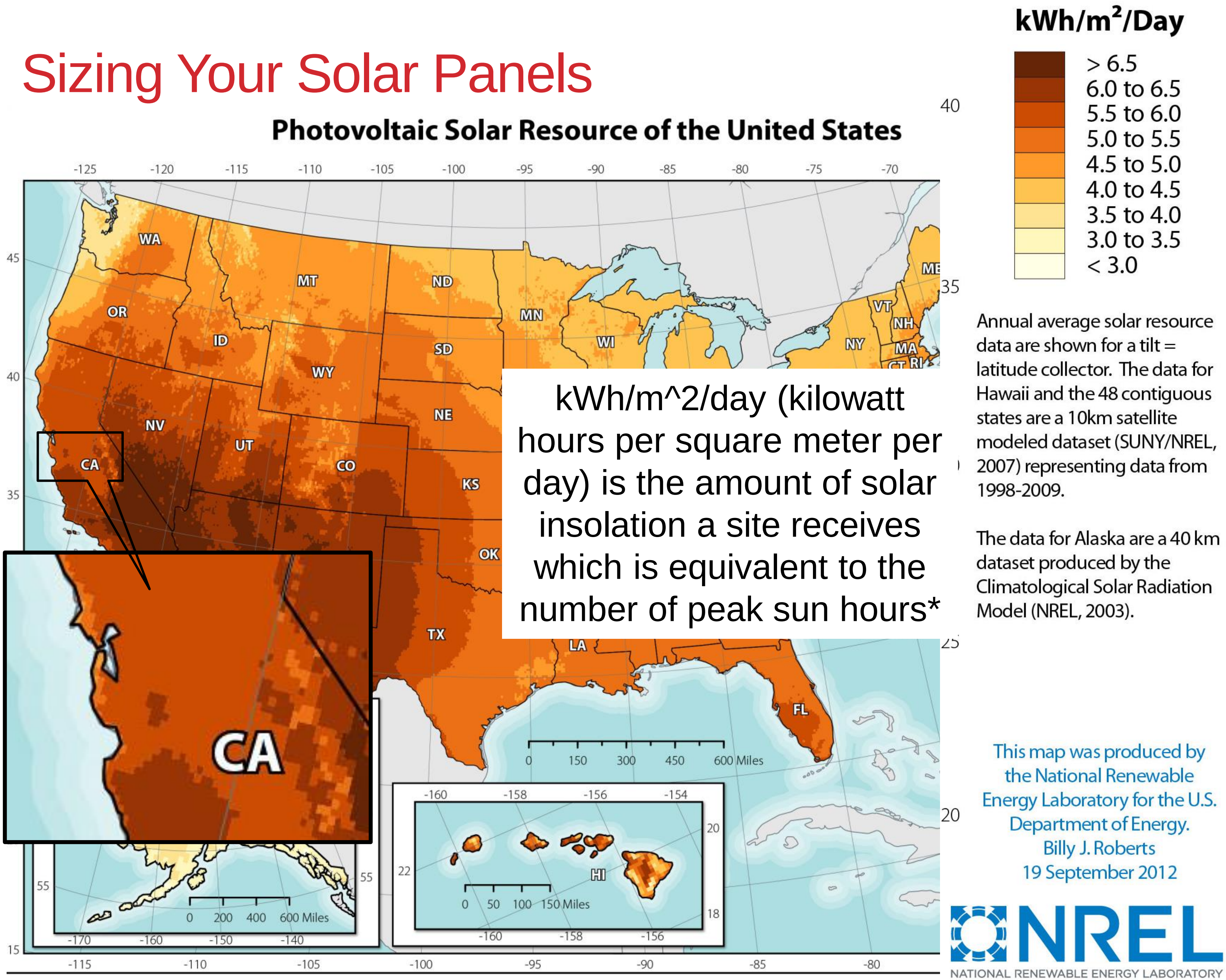
Sizing Your Solar Panels



kWh/m^2/day (kilowatt hours per square meter per day) is the amount of solar insolation a site receives which is equivalent to the number of peak sun hours*

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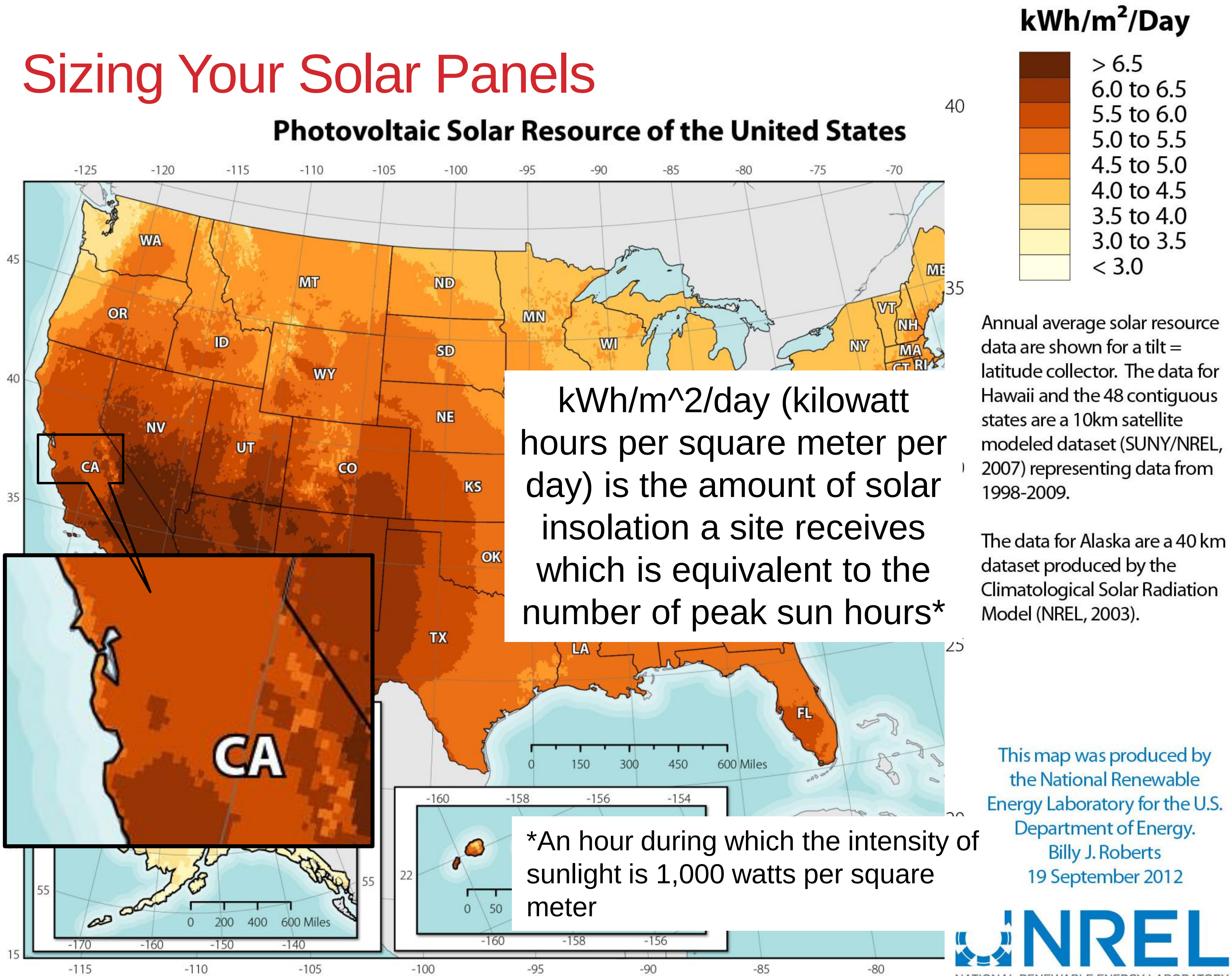
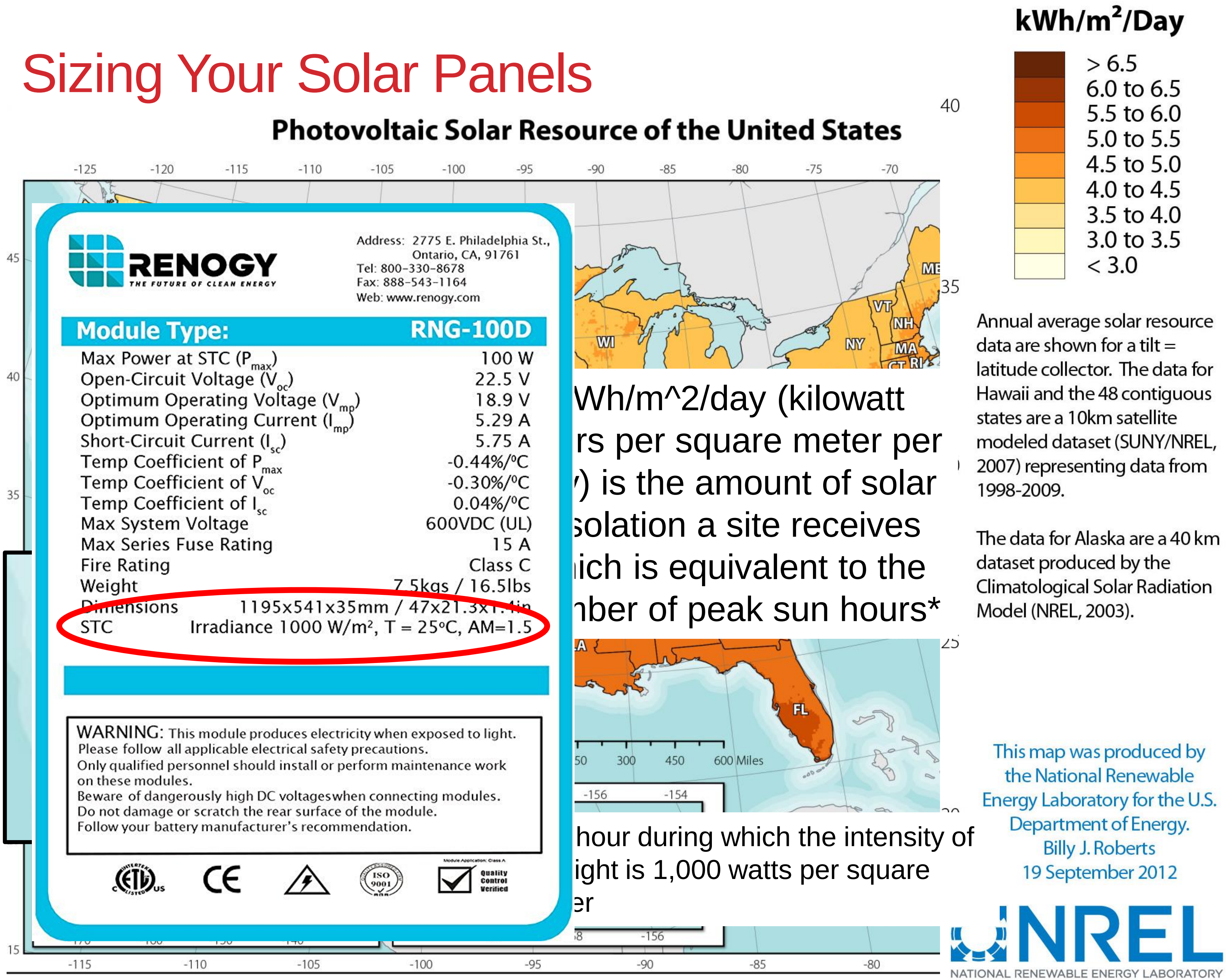
Sizing Your Solar Panels



kWh/m^2/day (kilowatt hours per square meter per day) is the amount of solar insolation a site receives which is equivalent to the number of peak sun hours*

*An hour during which the intensity of sunlight is 1,000 watts per square meter

Sizing Your Solar Panels



Wh/m^2/day (kilowatt rs per square meter per) is the amount of solar solation a site receives ich is equivalent to the nber of peak sun hours*

hour during which the intensity of ight is 1,000 watts per square er

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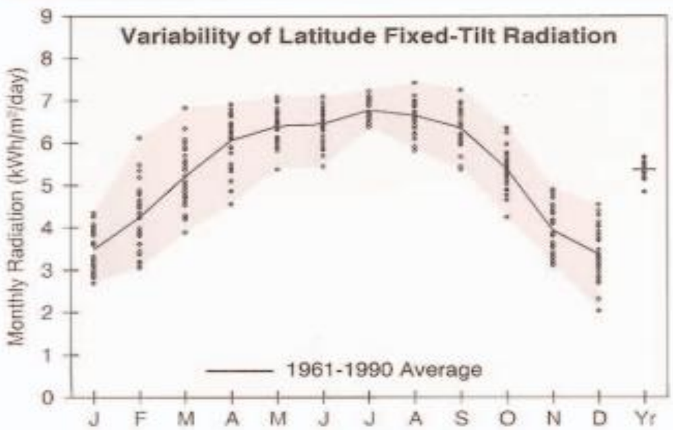
Sizing Your Solar Panels



San Francisco, CA

WBAN NO. 23234

LATITUDE: 37.62° N
LONGITUDE: 122.38° W
ELEVATION: 5 meters
MEAN PRESSURE: 1017 millibars

STATION TYPE: Secondary

http://rredc.nrel.gov/solar/pubs/redbook/PDFs/CA.PDF

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	2.2	3.0	4.2	5.7	6.7	7.2	7.3	6.5	5.4	3.9	2.5	2.0	4.7
	Min/Max	1.8/2.5	2.3/3.9	3.3/5.3	4.4/6.4	5.7/7.4	6.1/7.9	6.9/7.9	5.7/7.3	4.7/6.0	3.2/4.4	2.1/2.9	1.4/2.4	4.4/4.9
Latitude -15	Average	3.1	3.9	5.0	6.2	6.8	7.0	7.3	6.9	6.2	5.0	3.5	2.9	5.3
	Min/Max	2.4/3.8	2.9/5.5	3.8/6.5	4.7/7.0	5.7/7.5	5.9/7.7	6.9/7.8	6.0/7.7	5.3/7.1	4.0/5.8	2.8/4.3	1.9/3.9	4.9/5.6
Latitude	Average	3.5	4.2	5.2	6.1	6.4	6.5	6.8	6.7	6.4	5.4	3.9	3.4	5.4
	Min/Max	2.7/4.3	3.1/6.1	3.9/6.8	4.6/6.9	5.4/7.1	5.4/7.1	6.4/7.2	5.8/7.4	5.4/7.3	4.3/6.4	3.1/4.9	2.0/4.6	4.9/5.7
Latitude +15	Average	3.7	4.4	5.1	5.6	5.7	5.6	5.9	6.1	6.1	5.5	4.1	3.6	5.1
	Min/Max	2.8/4.7	3.1/6.4	3.8/6.8	4.2/6.4	4.8/6.3	4.7/6.1	5.6/6.3	5.3/6.7	5.2/7.0	4.3/6.5	3.2/5.2	2.1/5.0	4.6/5.5
90	Average	3.3	3.6	3.7	3.4	2.8	2.5	2.7	3.3	4.1	4.3	3.6	3.3	3.4
	Min/Max	2.5/4.2	2.4/5.4	2.7/4.9	2.6/3.8	2.5/3.0	2.3/2.6	2.6/2.8	3.0/3.6	3.5/4.7	3.4/5.2	2.8/4.6	1.9/4.7	2.9/3.7

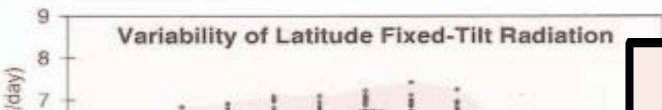
Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	3.0	4.1	5.7	7.6	8.8	9.3	9.7	8.7	7.4	5.5	3.5	2.8	6.3
	Min/Max	2.3/3.7	2.8/6.0	4.1/7.7	5.6/8.9	7.0/10.1	7.5/10.8	9.0/10.7	7.4/10.2	6.2/8.8	4.3/6.5	2.8/4.4	1.7/3.8	5.7/6.7
Latitude -15	Average	3.7	4.7	6.3	8.0	8.9	9.2	9.7	9.0	8.1	6.3	4.3	3.5	6.8
	Min/Max	2.8/4.6	3.3/7.1	4.5/8.6	5.8/9.4	7.1/10.3	7.4/10.7	9.0/10.8	7.7/10.6	6.7/9.6	4.8/7.6	3.3/5.4	2.0/4.8	6.1/7.2
Latitude	Average	4.0	5.0	6.5	8.0	8.7	8.9	9.4	8.8	8.2	6.6	4.6	3.9	6.9
	Min/Max	3.0/5.1	3.4/7.6	4.6/8.9	5.7/9.4	6.8/10.0	7.1/10.3	8.7/10.4	7.5/10.4	6.8/9.7	5.1/8.0	3.5/5.9	2.2/5.4	6.1/7.3
Latitude +15	Average	4.2	5.1	6.4	7.7	8.1	8.2	8.7	8.4	8.0	6.7	4.8	4.1	6.7
	Min/Max	3.1/5.4	3.4/7.8	4.5/8.8	5.5/9.0	6.4/9.4	6.6/9.6	8.1/9.7	7.1/9.9	6.6/9.5	5.1/8.1	3.6/6.1	2.3/5.7	5.9/7.1

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9%

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
2-Axis	Average	4.2	5.1	6.5	8.1	9.0	9.4	9.9	9.0	8.2	6.7	4.8	4.1	7.1
	Min/Max	3.1/5.4	3.4/7.8	4.6/8.9	5.8/9.5	7.2/10.4	7.6/11.0	9.2/11.0	7.7/10.6	6.8/9.7	5.1/8.1	3.7/6.2	2.3/5.8	6.3/7.5

Sizing Your Solar Panels



San Francisco, CA

WBAN NO. 23234

7.3
6.9/7.9

Solar Radiation for Flat-Plate Collec[...]h at a Fixed Tilt (kWh/m²/day), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	[illegible]	[illegible]	[illegible]	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average Min/Max	2.2 1.8/2.5	3.0 2.3/3.9	4.2 3.3/5.3	[illegible] 4.4/6.4	[illegible] 5.7/7.4	7.2 6.1/7.9	7.3 6.9/7.9	6.5 5.7/7.3	5.4 4.7/6[illegible]	[illegible]	[illegible]	2.0 1.4/2.4	4.7 4.4/4.9
Latitude -15	Average Min/Max	3.1 2.4/3.8	3.9 2.9/5.5	5.0 3.8/6.5	6.2 4.7/7.0	6.8 5.7/7.5	7.0 5.9/7.7	7.3 6.9/7.8	6.9 6.0/7.7	6.2 5.3/7[illegible]	[illegible]	[illegible]	2.9 1.9/3.9	5.3 4.9/5.6
Latitude	Average Min/Max	3.5 2.7/4.3	4.2 3.1/6.1	5.2 3.9/6.8	6.1 4.6/6.9	6.4 5.4/7.1	6.5 5.4/7.1	6.8 6.4/7.2	6.7 5.8/7.4	6.4 5.4/7.3	[illegible] 4.3/6.4	[illegible] 3.1/4.9	3.4 2.0/4.6	5.4 4.9/5.7
Latitude +15	Average Min/Max	3.7 2.8/4.7	4.4 3.1/6.4	5.1 3.8/6.8	5.6 4.2/6.4	5.7 4.8/6.3	5.6 4.7/6.1	5.9 5.6/6.3	6.1 5.3/6.7	6.1 5.2/7.0	5.5 4.3/6.5	4.1 3.2/5.2	3.6 2.1/5.0	5.1 4.6/5.5
90	Average Min/Max	3.3 2.5/4.2	3.6 2.4/5.4	3.7 2.7/4.9	3.4 2.6/3.8	2.8 2.5/3.0	2.5 2.3/2.6	2.7 2.6/2.8	3.3 3.0/3.6	4.1 3.5/4.7	4.3 3.4/5.2	3.6 2.8/4.6	3.3 1.9/4.7	3.4 2.9/3.7

3.6
2.1/5.0

Solar Radiation for 1-Axis Tracking Flat-Plate Collectors with a North-South Axis (kWh/m²/day), Uncertainty ±9%

Axis Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average Min/Max	3.0 2.3/3.7	4.1 2.8/6.0	5.7 4.1/7.7	7.6 [illegible]	8.8 [illegible]	9.3 [illegible]	9.7 9.0/10.7	8.7 7.4/10.2	7.4 6.2/8.8	5.5 4.3/6.5	3.5 2.8/4.4	2.8 1.7/3.8	6.3 5.7/6.7
Latitude -15	Average Min/Max	3.7 2.8/4.6	4.7 3.3/7.1	6.3 4.5/8.6	[illegible]	[illegible]	[illegible] [illegible]/10.7	9.7 9.0/10.8	9.0 7.7/10.6	8.1 6.7/9.6	6.3 4.8/7.6	4.3 3.3/5.4	3.5 2.0/4.8	6.8 6.1/7.2
Latitude	Average Min/Max	4.0 3.0/5.1	5.0 3.4/7.6	6.5 4.6/8.9	[illegible]	[illegible]	[illegible] [illegible]/10.3	9.4 8.7/10.4	8.8 7.5/10.4	8.2 6.8/9.7	6.6 5.1/8.0	4.6 3.5/5.9	3.9 2.2/5.4	6.9 6.1/7.3
Latitude +15	Average Min/Max	4.2 3.1/5.4	5.1 3.4/7.8	6.4 4.5/8.8	7.7 5.5/9.0	8.1 6.4/9.4	8.2 6.6/9.6	8.7 8.1/9.7	8.4 7.1/9.9	8.0 6.6/9.5	6.7 5.1/8.1	4.8 3.6/[illegible]	4.1 2.3/5.7	6.7 5.9/7.1

9.7
9.0/10.7

Latitude	Average Min/Max	4.0 3.0/5.1	5.0 3.4/7.6	6.5 4.6/8.9	8.0 5.7/9.4	8.7 6.8/10.0	8.9 7.1/10.3	9.4 8.7/10.4	8.8 7.5/10.4	8.2 6.8/9.7	6.6 5.1/8.0	[illegible]
Latitude +15	Average Min/Max	4.2 3.1/5.4	5.1 3.4/7.8	6.4 4.5/8.8	7.7 5.5/9.0	8.1 6.4/9.4	8.2 6.6/9.6	8.7 8.1/9.7	8.4 7.1/9.9	8.0 6.6/9.5	6.7 5.1/8.1	[illegible]

Solar Radiation for 2-Axis Tracking Flat-Plate Collectors (kWh/m²/day), Uncertainty ±9[...]

Tracker		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	N[...]	[illegible]	[illegible]
2-Axis	Average Min/Max	4.2 3.1/5.4	5.1 3.4/7.8	6.5 4.6/8.9	8.1 5.8/9.5	9.0 7.2/10.4	9.4 7.6/11.0	9.9 9.2/11.0	9.0 7.7/10.6	8.2 6.8/9.7	6.7 5.1/8.1	4.8 3.7/6.2	4.1 2.3/5.8	7.1 6.3/7.5

4.1
2.3/5.7

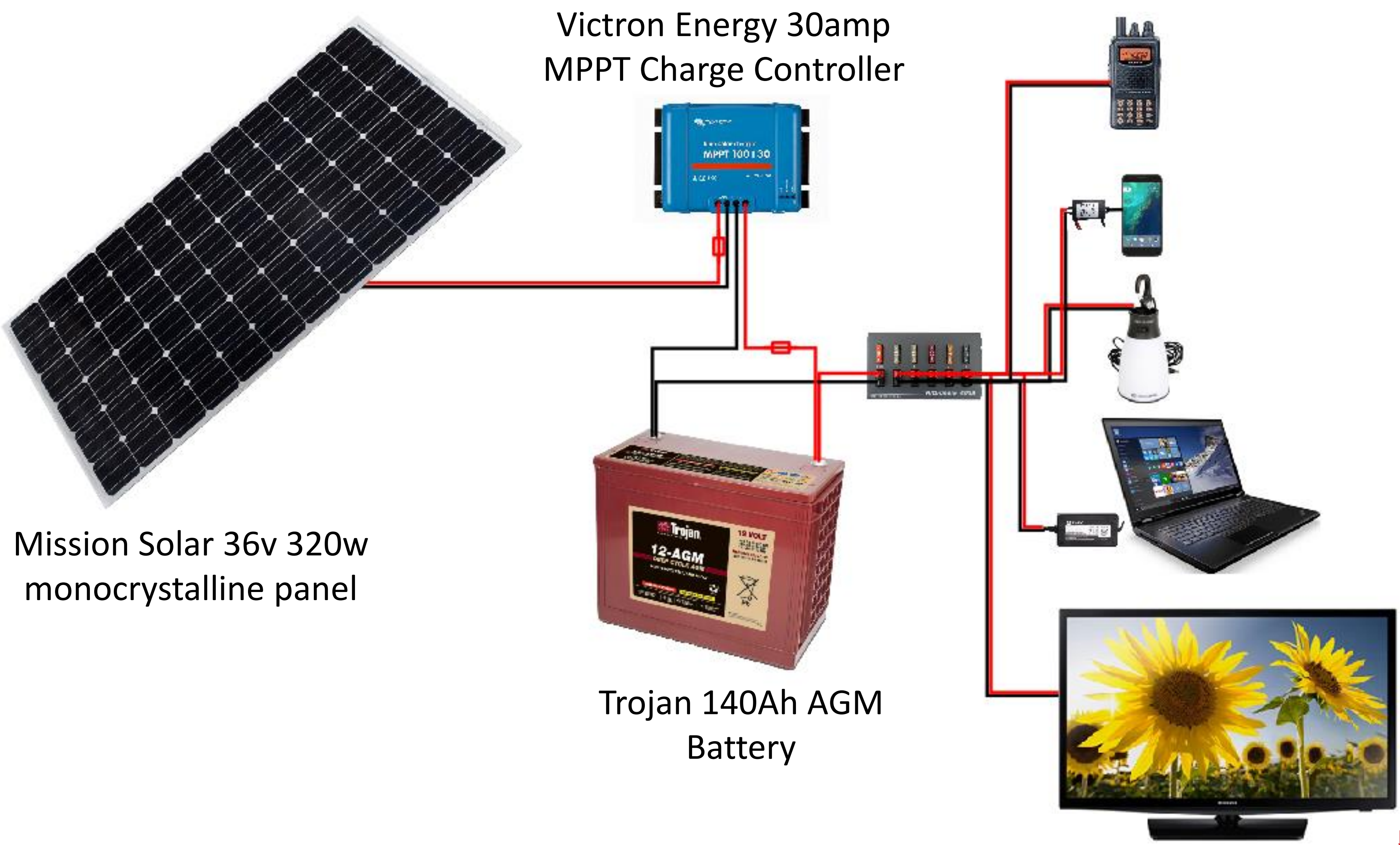
Sizing Your Solar Panels

- **We plan to consume 380.2 watt hours**
- **In the Bay Area, our peak sun hours vary between 7.3 in the summer and 3.6 in the winter**
- **Solar panels provide their rated output under ideal conditions, so we will use assume 70% to 80% as their actual output**
- **In this scenario we would need 132 watts of solar panels to ensure we generate enough power during the winter months**
- **We need to factor in overcast days, so we double this to 264 watts**

6DAC

		Spring Peak Sun Hours	Summer Peak Sun Hours	Autumn Peak Sun Hours	Winter Peak Sun Hours
Solar Panel Rated Output	Solar Panel Actual Output	6.2	7.3	5.5	3.6
100w	80	496	584	440	288
132w	105.6	654.72	770.88	580.8	380.16
200w	160	992	1168	880	576
300w	240	1488	1752	1320	864
400w	320	1984	2336	1760	1152

Evaluating Your Needs



What Does it Cost?

264 Watt Solar, 150Ah AGM Lead Acid Battery

Qty	Desc	Price	Total
1	Mission Solar 36v 320w monocrystalline panel	$150.00	$150.00
1	8 AWG Solar Cables with MC4 connectors	$47.00	$47.00
1	Victron Energy 30amp MPPT Charge Controller	$202.00	$202.00
1	Misc wires, connectors and fuses	$30.00	$30.00
1	150Ah AGM sealed lead acid battery	$300.00	$300.00
	Total		$729.00

264 Watt Solar, 80Ah LiFePO4 Battery

Qty	Desc	Price	Total
1	Mission Solar 36v, 320w monocrystalline panel	$150.00	$150.00
1	8 AWG Solar Cables with MC4 connectors	$47.00	$47.00
1	Victron Energy 30amp MPPT Charge Controller	$202.00	$202.00
1	Misc wires, connectors and fuses	$30.00	$30.00
1	80Ah Bioenno LiFePO4	$750.00	$750.00
	Total		$1,179.00

Evaluating Your Needs

- **If we eliminate the Laptop and TV from the usage table, we can reduce our watt hours to 175.7 and 14.64Ah @ 12vdc**

Qty	Device	Volts	Amps	Watts	Hours	Days/Week	Watt hours
	Yaesu FT60r Standard Charger	12	0.2	2.4	10	3	0.0
	Yaesu FT60r Rapid Charger	12	0.9	10.8	1.5	3	0.0
	Yaesu FT1D/2D Rapid Charger with FNB-101LI Battery	12	0.5	6	2.5	3	0.0
1	Yaesu FT1D/2D Rapid Charger with FNB-102LI Battery	12	0.5	6	4	3	10.3
	Engle MT80 Fridge / Freezer @ 41° F, amb temp 77° F			7.2	24	7	0.0
	Engle MT80 Fridge / Freezer @ -4° F, amb temp 77° F			30			
	Battery Charger	12	3	36	3	1	0.0
2	LED Lights			10	3	7	6.0
1	Mobile Phone Charger			6	2	7	0.0
	Laptop Charger			45	2	1	0.0
	LCD HDTV 24"			30	1	7	30.0
	Total						82.3
	Ah @ 12v						6.9

Evaluating Your Needs

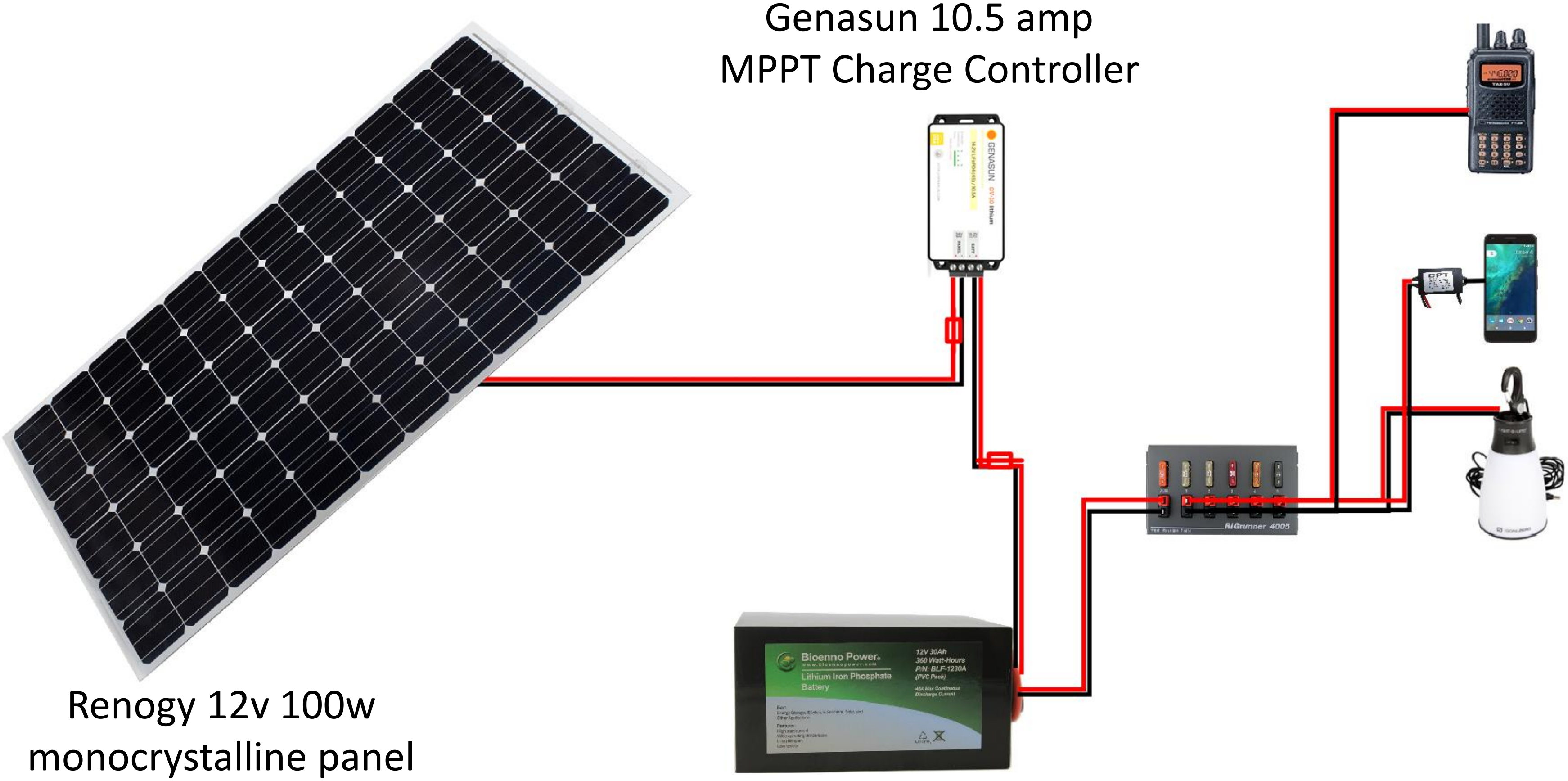
- **Reducing our battery requirements to 55Ah for Lead Acid and 30Ah for LiFePO4**
- **This reduces our solar requirements to a 100w panel**

Battery Type	Projected Usage	Max Battery Discharge	Min Battery Required	Inverter Loss	Min Battery with Inverter	Max days w/o Sun	Required Ah	Required Ah (w/Inverter)
Lead Acid	7	50%	14	10%	15	2	41	46
LiFePO4	7	90%	8	10%	8	2	23	25

		Spring Peak Sun Hours*	Summer Peak Sun Hours*	Autumn Peak Sun Hours*	Winter Peak Sun Hours*	Average Peak Sun Hours	PV Watts
Solar Panel Rated Output	Solar Panel Actual Output	6.04	7.12	5.31	3.79	5.565	
29	22	131	155	115	82	121	87

- KK6DAC

What Does it Cost?



Rachel Kinoshita – KK6DAC

What Does it Cost?

100 Watt Solar, 55Ah AGM Lead Acid Battery

Qty	Desc	Price	Total
1	Renogy 100w 12v monocrystalline solar panel	$125.00	$125.00
1	8 AWG Solar Cables with MC4 connectors	$47.00	$47.00
1	Genasun GV-10 10amp MPPT Charge Controller	$109.00	$109.00
1	Misc wires, connectors and fuses	$30.00	$30.00
1	55Ah AGM sealed lead acid battery	$125.00	$125.00
	Total		$436.00

100 Watt Solar, 30Ah LiFePO4 Battery

Qty	Desc	Price	Total
1	Renogy 100w 12v monocrystalline solar panel	$125.00	$125.00
1	8 AWG Solar Cables with MC4 connectors	$47.00	$47.00
1	Genasun GV-10 10amp MPPT Charge Controller	$159.00	$159.00
1	Misc wires, connectors and fuses	$30.00	$30.00
1	30Ah Bioenno LiFePO4	$280.00	$280.00
	Total		$641.00

Using Solar in Emergency Communications

- **Menlo Fire purchased the CERT trailer to provide a platform for communications during an emergency or disaster**
- **The trailer has been outfitted with amateur radios, computers, monitors, a generator, antennas and other accessories necessary to operate**
- **The current configuration requires manual charging of the battery on a regular basis to prevent battery damage**
- **Generators require fuel, regular oil changes and have moving parts which can fail**
- **In a disaster, gasoline for the generator may become a scare resource**
- **Configuring the trailer to run stand-alone with only batteries and PV panels will ensure independent operations during a disaster**

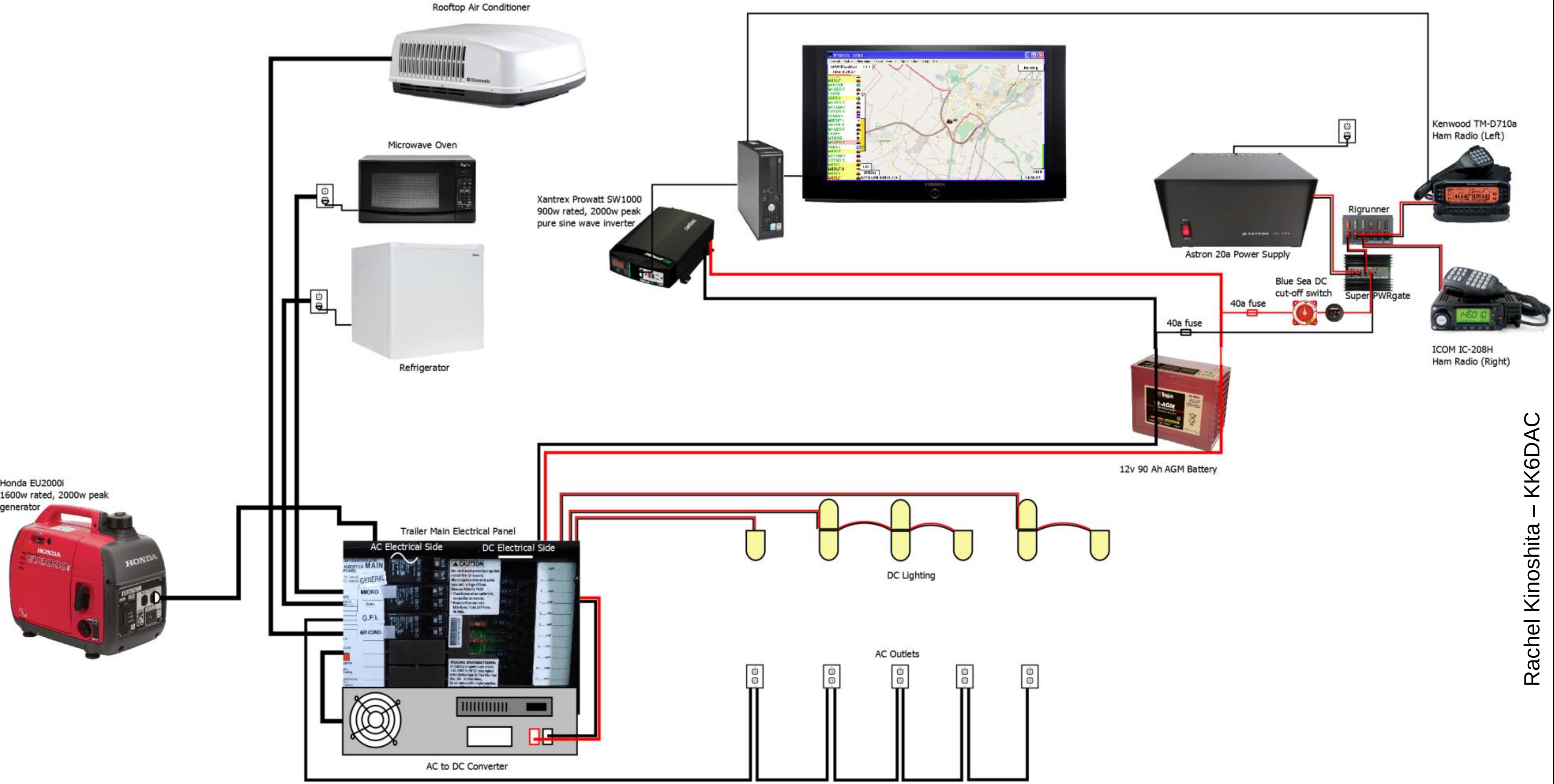
Menlo Park CERT Communications Trailer

Rachel Kinoshita –

Menlo Park CERT Communications Trailer

Rachel Kinoshita – KK6DAC

Menlo Park CERT Communications Trailer



Rachel Kinoshita – KK6DAC

Menlo Park - Proposed System

- **Batteries will automatically be maintained**
- **Trailer will always be ready to be deployed**
- **Provides sufficient power to run radios, computers and lights for an extended period of time**
- **Reduces or removes dependency on gasoline or propane generator**
- **Designed for growth**

Menlo Park - Proposed System

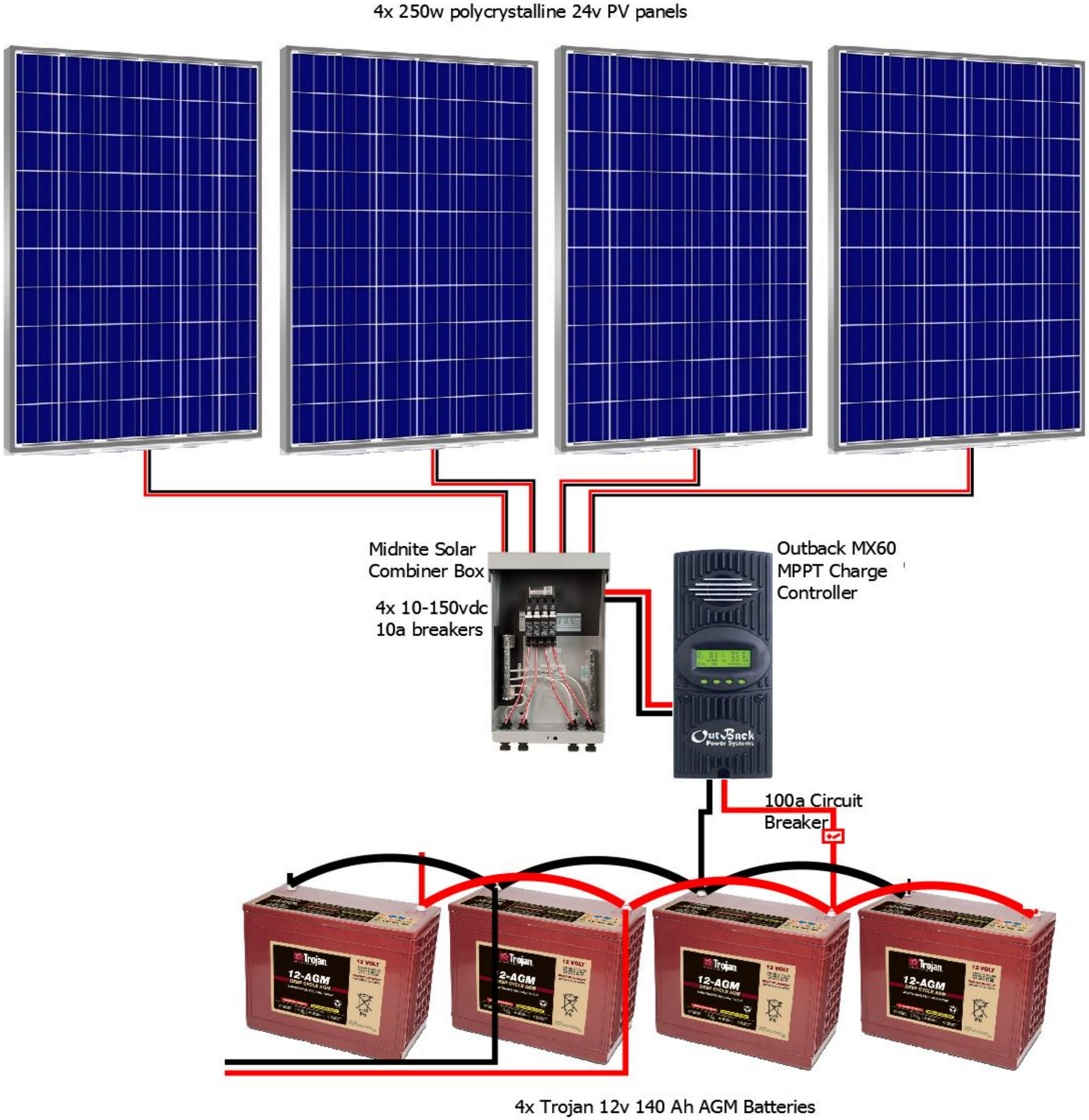
60A solar
Charge Controller

6 slot solar
Combiner box

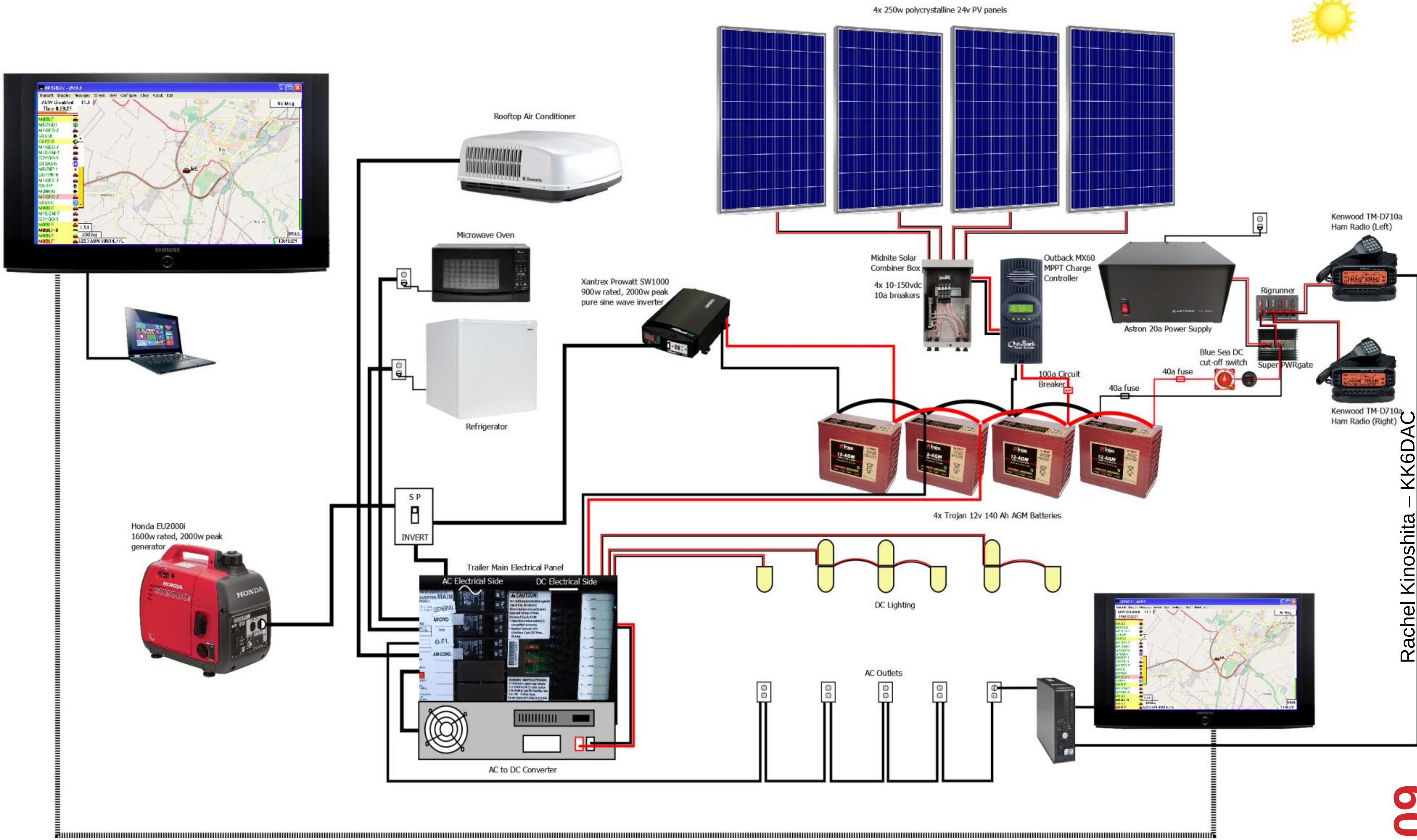
4x 250w PV Panels

4x 140ah AGM Batteries

Menlo Park – Completed System



Menlo Park CERT Communications Trailer



Rachel Kinoshita – KK6DAC

Menlo Park - Proposed System

Qty	Desc	Price	Total
4	Trojan 12v 140ah AGM Battery	$420.00	$1,680.00
4	Amerisolar 250w 24v PV panel	$170.00	$680.00
2	Solarline 50' cables with MC4 connectors	$44.00	$88.00
4	Aluminum Z bracket kit	$9.00	$36.00
1	Outback FX60 12-48v MPPT Charge Controller	$602.00	$602.00
1	Midnite Solar MNPV6 Combiner Box	$95.00	$95.00
4	Midnite 150VDC MNEPV DIN Mount Breaker	$16.00	$64.00
1	Misc wire and connectors	$200.00	$200.00
1	Lab bolts and sealant	$40.00	$40.00
1	Shipping	$400.00	$400.00
	Total		$3,885.00

Solar Conclusion

- **Good for both short and long-term emergencies**
- **Initial costs are higher, but the only fuel it requires is the sun**
- **No moving parts to break or wear out**
- **No noise, no exhaust fumes**
- **Need sufficient battery reserves to run overnight or for overcast/rainy days**
- **Nearly maintenance free**

Questions