Southern Peninsula Emergency Communications System

Operating Off the Grid

Agenda

- **Evaluating Your Needs**
  - What equipment do you want to operate?
  - How long do you need to power this equipment?
  - When do you need to use this equipment?
- **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)
- **Putting it All Together**
  - What else is needed?
  - Using Solar in Emergency Communications

Evaluating Your Needs

- **What equipment do you need to operate?**
  - Ham radio
  - Lights
  - Radios
  - Mobile phones
  - Laptop computer
  - Television
  - Refrigerator
  - Microwave
  - Medical Devices (CPAP, oxygen, refrigeration for insulin)
- **How long do you need to power this equipment?**
- **When do you need to use this equipment?**

Evaluating Your Needs

- **What equipment do you need to operate?**
  - Ham radio
  - Lights
  - Radios
  - Mobile phones
  - Laptop computer
  - Television / Monitor
  - Refrigerator
- **How long do you need to power this equipment?**
  - 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
- **When do you need to use this equipment?**

Evaluating Your Needs

- **What equipment do you need to operate?**
  - Ham radio
  - Lights
  - Radios
  - Mobile phones
  - Laptop computer
  - Television / Monitor
  - Refrigerator
- **How long do you need to power this equipment?**
  - 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
- **When do you need to use this equipment?**
  - Around the clock or primarily during the day or night?
  - Year long or only during specific seasons?

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

- **You can also look at the label on the device itself which should indicate the power usage for that device. However, this is often less accurate.**

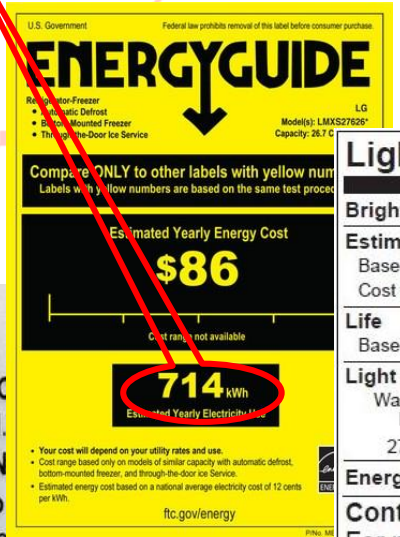
Fridge uses 714 kWh per year or 81.5w per hour

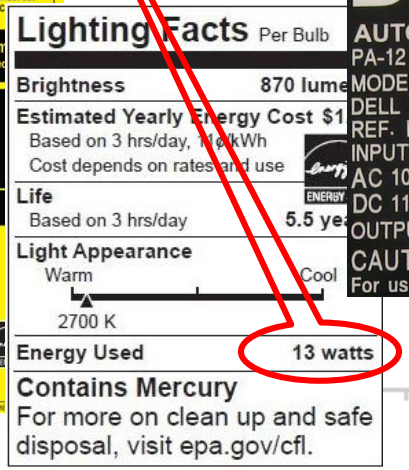
LED lightbulb uses 13w

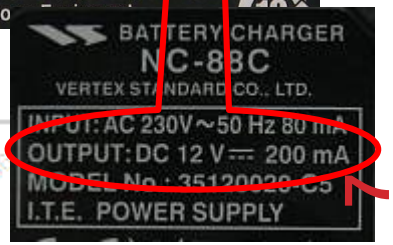
Laptop charger uses 65w

HT charger uses 2.4w

TV uses 35w







Rachel Kinoshita – KK6DAC

Evaluating Your Needs

Qty	Device	Volts	Amps	Watts	Hours	Days/Week	Watt hours
	Yaesu FT60r Standard Charger	12	0.2	2.4	10	3	0.0
0	Yaesu FT60r Rapid Charger	12	0.9	10.8	1.5	3	0.0
	Yaesu FT1D/2D Rapid Charger with FNB-101LI Battery 1100mAh	12	0.5	6	2.5	3	0.0
	Yaesu FT1D/2D Rapid Charger with FNB-102LI Battery 1800mAh	12	0.5	6	4	3	0.0
	Yaesu FT1D/2D Rapid Charger with FNB-14LI Battery 2200mAh	12	0.5	6	4	3	0.0
	Baofeng Charger with the Standard (1800 mAh) Battery	10	0.5	5	4	3	0.0
	Baofeng Charger with the Extended (3400 mAh) Battery	10	0.5	5	7	3	0.0
	Kenwood TH-D72 KSC-32 Rapid Charger with PB-45L battery	12	1.35	16.2	3	3	0.0
	Kenwood TH-D74 standard charger with KNB-74LW battery	12	0.65	7.8	5	3	0.0
	Kenwood TH-D74 standard charger with KNB-75LW battery	12	0.65	7.8	6	3	0.0
	Kenwood TH-D74 KSC-25LSK Rapid Charger with KNB-74LW battery	12	0.75	9	3	3	0.0
	Kenwood TH-D74 KSC-25LSK Rapid Charger with KNB-75LW battery	12	0.75	9	4	3	0.0
0	Mobile Radio (Net Control 5w)			11	4	7	0.0
	Mobile Radio (Net Control 10w)			16	4	7	0.0
	Mobile Radio (Net Control 25w)			26	4.8	7	0.0
	Mobile Radio (Net Control 50w)			46	4	7	0.0

▪
▪
▪

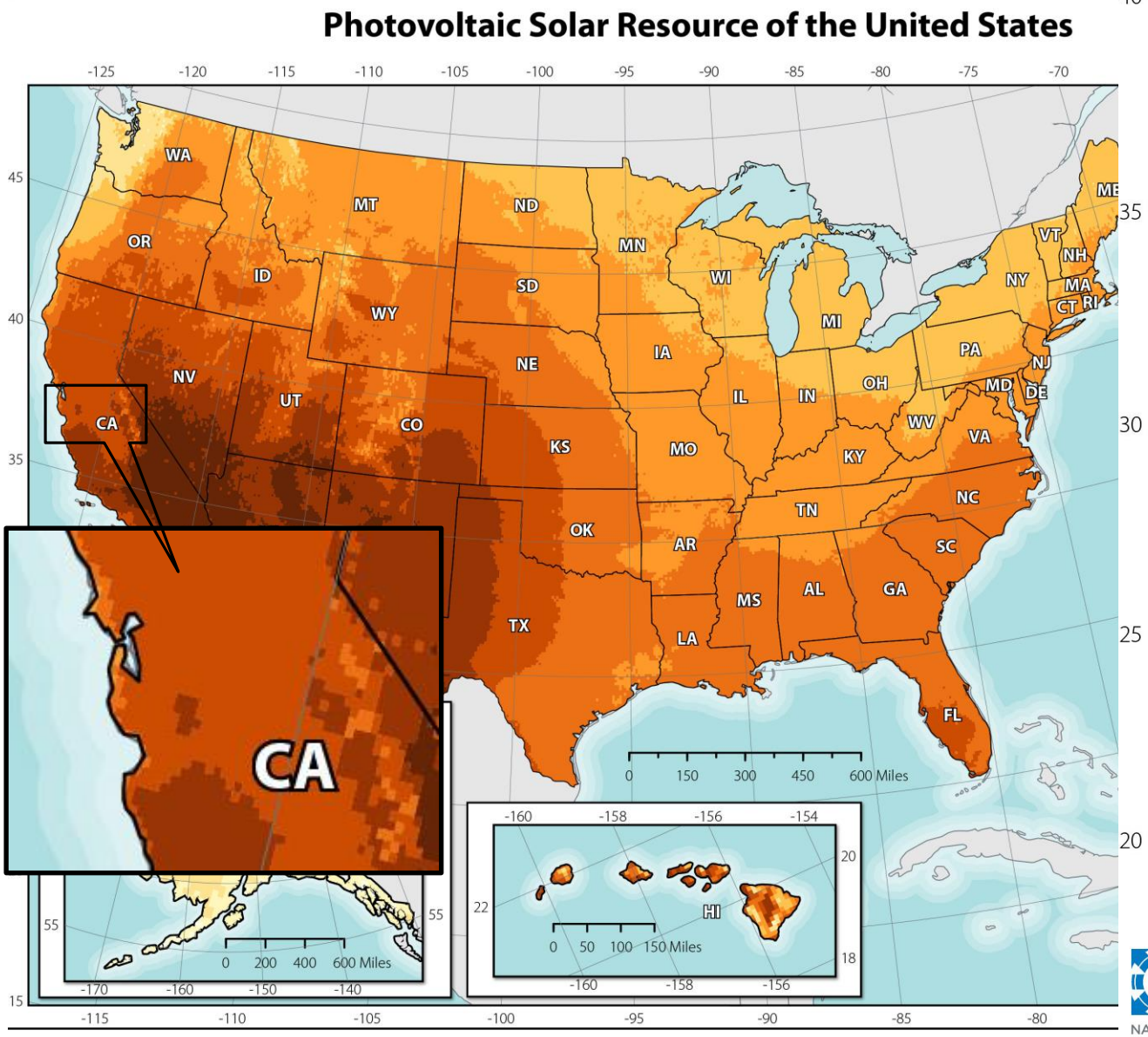
	Refrigerator 22 cu ft (2001-04 Energy Star Compliant)			63	24	7	0.0
	Refrigerator 22 cu ft (2004-08 Energy Star Compliant)			60	24	7	0.0
	Refrigerator 22 cu ft (2008-10 Energy Star Compliant)			57	24	7	0.0
	Refrigerator 22 cu ft (2011-14 CEE Tier 3)			40	24	7	0.0
	Motorola Repeater (Idle)	12	0.92	11.04	24	7	0.0
	Motorola Repeater (Xmit)	12	8.3	99.6	7.2	7	0.0
	Total						0.0
	Ah @ 12v						0.0

Evaluating Your Needs

Evaluating Your Needs

Qty	Device	Volts	Amps	Watts	Hours	Days/Week	Watt hours
	Yaesu FT60r Standard Charger	12	0.2	2.4	10	3	0.0
1	Yaesu FT60r Rapid Charger	12	0.9	10.8	1.5	3	6.9
	Mobile Radio (Net Control 5w)			11	4	7	0.0
	Mobile Radio (Net Control 10w)			16	4	7	0.0
1	Mobile Radio (Net Control 25w)			26	4.8	7	124.8
	Mobile Radio (Net Control 50w)			46	4	7	0.0
1	Engel MT35 Fridge / Freezer @ 41° F, amb temp 77° F - Fridge Mode			6	24	7	144.0
	Engel MT35 Fridge / Freezer @ -4° F, amb temp 77° F - Freezer Mode			27.72	24	7	0.0
1	LED Lights			10	3	7	30.0
1	Mobile Phone Charger			6	2	7	12.0
1	Laptop Charger			45	2	1	12.9
1	Samsung LCD HDTV 24"			35	3	7	105.0
	Total						**435.6**
	Ah @ 12v						**36.3**

Evaluating Your Needs



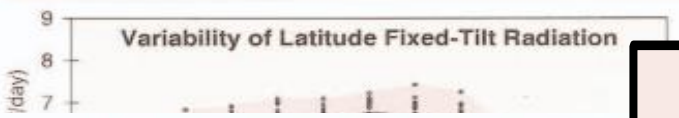
Annual average solar resource data are shown for a tilt = latitude collector. The data for Hawaii and the 48 contiguous states are a 10km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2009.

The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.
Billy J. Roberts
19 September 2012

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Evaluating Your Needs



San Francisco, CA

WBAN NO. 23234

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

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

7.3
6.9/7.9

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	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	…	…	…	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	…	…	…	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	…	…	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	…	…	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	…	…	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	2.3/5.7	5.9/7.1

9.7
9.0/10.7

4.1
2.3/5.7

Latitude	Average	4.0	5.0	6.5	8.0	8.7	8.9	9.4	8.8	8.2	6.6	4		
	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		
Latitude +15	Average	4.2	5.1	6.4	7.7	8.1	8.2	8.7	8.4	8.0	6.7	4		
	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		

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		
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

Evaluating Your Needs

					Peak Sun Hours			
City	State	Lat	Lon	Elev	Winter	Spring	Summer	Autumn
BARROW, AK	AK	71.3	-156.8	4	0.42	6.75	5.3	1.02
ARCATA, CA	CA	40.98	-124.1	69	3.72	6.52	7.11	5.06
BAKERSFIELD, CA	CA	35.42	-119.1	150	4.4	8.63	10.85	7.31
DAGGETT, CA	CA	34.87	-116.8	588	7.1	10.2	11.23	8.79
FRESNO, CA	CA	36.77	-119.7	100	4.04	8.82	10.86	7.13
LONG BEACH, CA	CA	33.82	-118.2	17	5.53	7.76	8.85	6.67
LOS ANGELES, CA	CA	33.93	-118.4	32	5.58	7.76	8.55	6.6
SACRAMENTO, CA	CA	38.52	-121.5	8	3.87	8.45	10.76	6.9
SAN DIEGO, CA	CA	32.73	-117.2	9	6.17	7.79	8.39	7.07
SAN FRANCISCO, CA	CA	37.62	-122.4	5	4.47	7.81	9.31	6.52

Evaluating Your Needs - Photovoltaic

	Total						435.6
	Ah @ 12v						36.3

					Peak Sun Hours					
City	State	Lat	Lon	Elev	Winter	Spring	Summer	Autumn	TZ Offset	DST
SAN FRANCISCO, CA	CA	37.62	-122.38	5	4.47	6.04	7.12	5.31	-8	1

Total Watt Hours	Winter Peak Sun Hour	PV Watts
435.6	4.47	97

PV Watts	Efficiency	Overcast Days	Overcast Production	Adjusted PV Watts
97	90%	2	75%	162

Evaluating Your Needs - Batteries

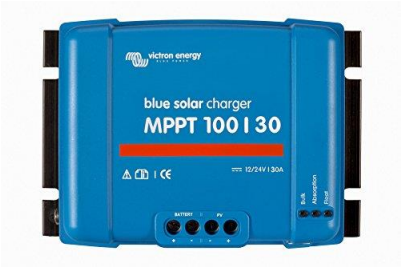
	Total						435.6
	Ah @ 12v						36.3

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	36	50%	73	10%	81	2	109	121
LiFePO4	36	90%	40	10%	45	2	61	67

Evaluating Your Needs

LiFePO4 Battery Option			
Qty	**Desc**	**Price**	**Total**
2	Renogy 100w 12v monocrystalline solar panel	$139.00	$278.00
1	Victron Energy BlueSolar 75/15 15amp MPPT Charge Controller	$99.00	$99.00
1	60Ah Bioenno LiFePO4 battery	$570.00	$570.00
1	Y branch MC4 Parallel connector	$8.00	$8.00
2	MC4 connector with inline 10a fuse (PV Panel -> Charge Controller)	$14.00	$28.00
1	12v Inline 20a breaker (Charge Controller -> Battery)	$13.00	$13.00
2	8 AWG Solar Cables with MC4 connectors	$47.00	$94.00
1	Misc wires and connectors	$50.00	$50.00
2	Small Adjustable PV Panel Mount	$47.00	$94.00
0		$0.00	$0.00
0		$0.00	$0.00
	Total		**$1,234.00**

Evaluating Your Needs



Batteries

- **Lead Acid**
  - Car batteries
  - Deep cycle batteries (Marine, Golf cart)
  - Sealed Lead Acid / Absorbent Glass Mat (AGM)
- **Lithium**
  - Lithium Iron Phosphate (LiFePO4) – 3.2v per cell nominal / 3.6v peak – 4 in series (4s) gives us 12.8v – 14.4v
  - Lithium Ion – 3.7v per cell nominal / 4.2v peak – 3s gives us 11.1 to 12.6 while 4s gives us14.8 – 16.8

12v Batteries

- **Why 12v batteries**
  - Mobile radios
  - Recharge HT radios, mobile phones, tablets, laptops, rechargeable batteries, lighting, television, etc
  - Easy to charge from solar or from your car
- **Lots of different size batteries available from small 7Ah sealed lead acid (SLA) to large 100+Ah absorbed glass mat (AGM)**
- **Different chemistries available include lead acid, lithium iron phosphate (LiFePO4), Lithium-Ion…you can even make a 12v battery from alkaline or NiMH batteries**
- **Amp Hour Measurement is typically at 20 hours**
  - Peukert Effect
  - As the discharge amps increase, the batteries available capacity decreases

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

Lead Acid

- Flooded (Automobile starter, Maintenance free, Deep cycle, Golf cart batteries)
  - Peukert constant = 1.6

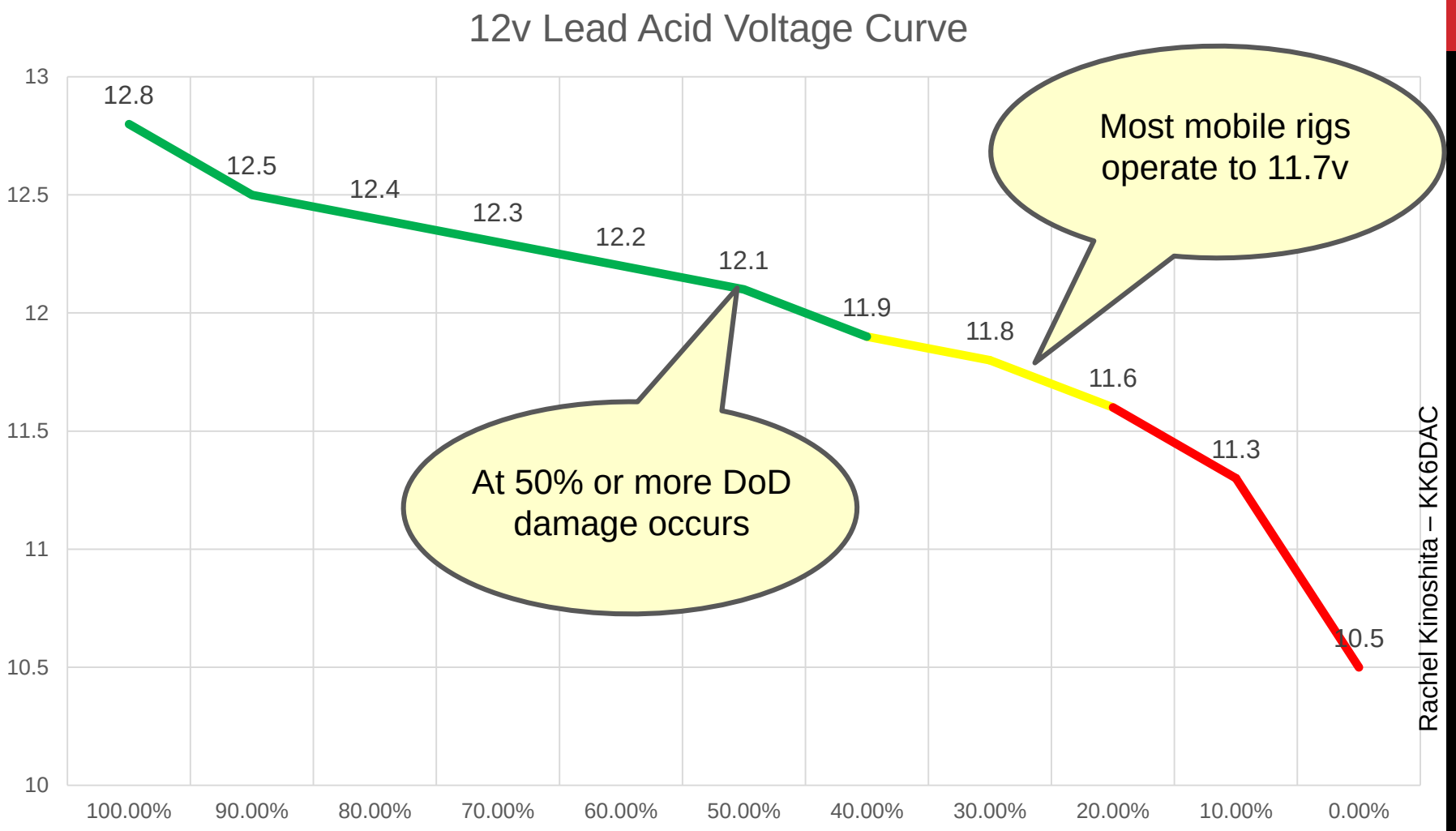
- Sealed Lead Acid
- Gel
  - Peukert constant = 1.25

- Absorbed Glass Matte (AGM)
  - Peukert constant = 1.15

Lead Acid

- **Pros**
  - Flooded (Automobile starter, Maintenance free, Deep cycle, Golf cart batteries)
    - Proven technology
    - Relatively inexpensive
  - Sealed/Gel
    - No outgassing
    - Can be installed in any position
  - Absorbed Glass Matte (AGM)
    - No outgassing
    - Can be installed in any position
    - Relatively long life (5+ years)
- **Cons**
  - Flooded
    - Heavy
    - Outgas
    - Spill hazard
  - Sealed/Gel
    - Heavy
  - AGM
    - Heavy
    - Expensive

Lead Acid



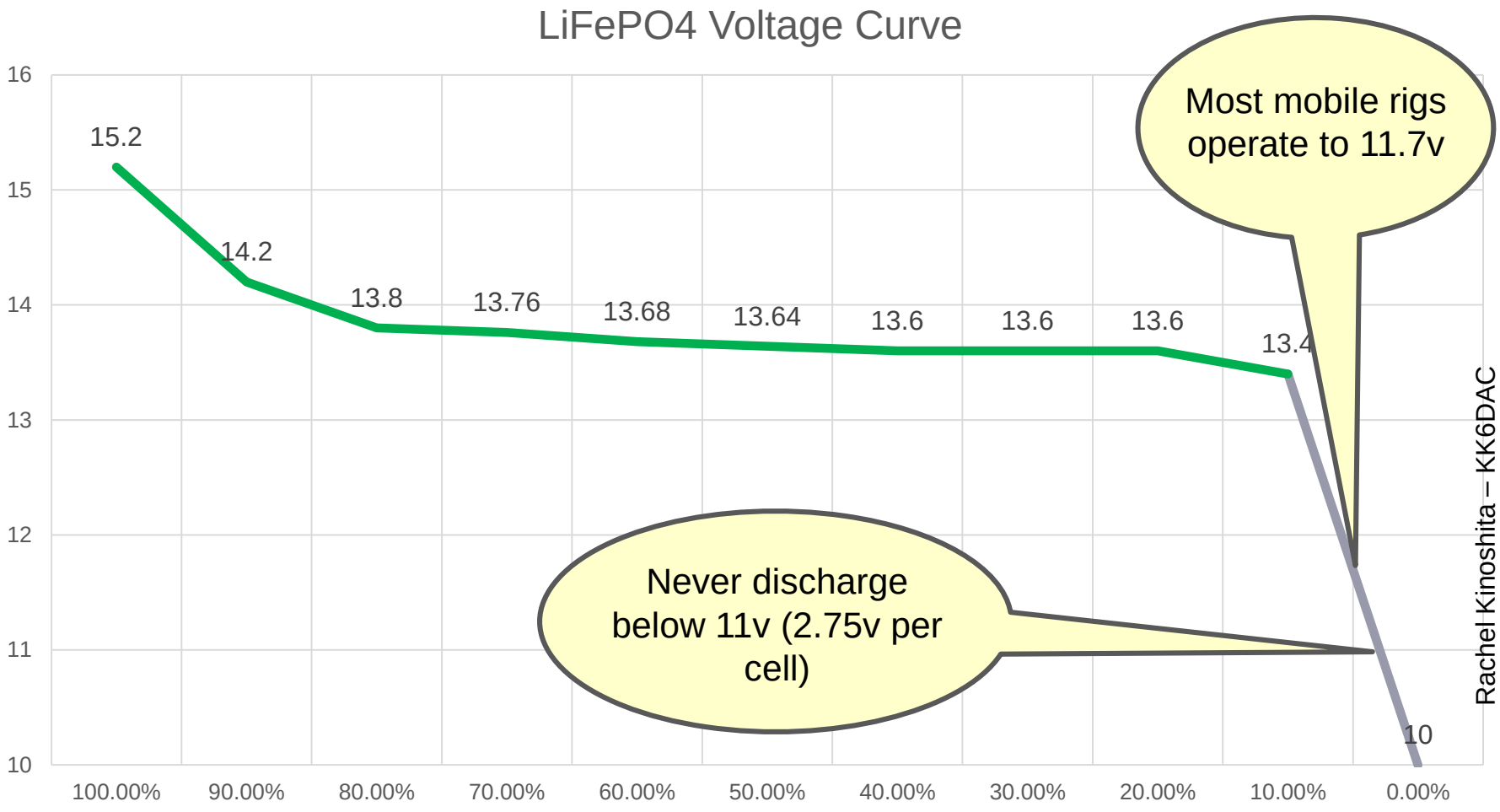
Rachel Kinoshita – KK6DAC

Lithium Iron Phosphate (LiFePO4)

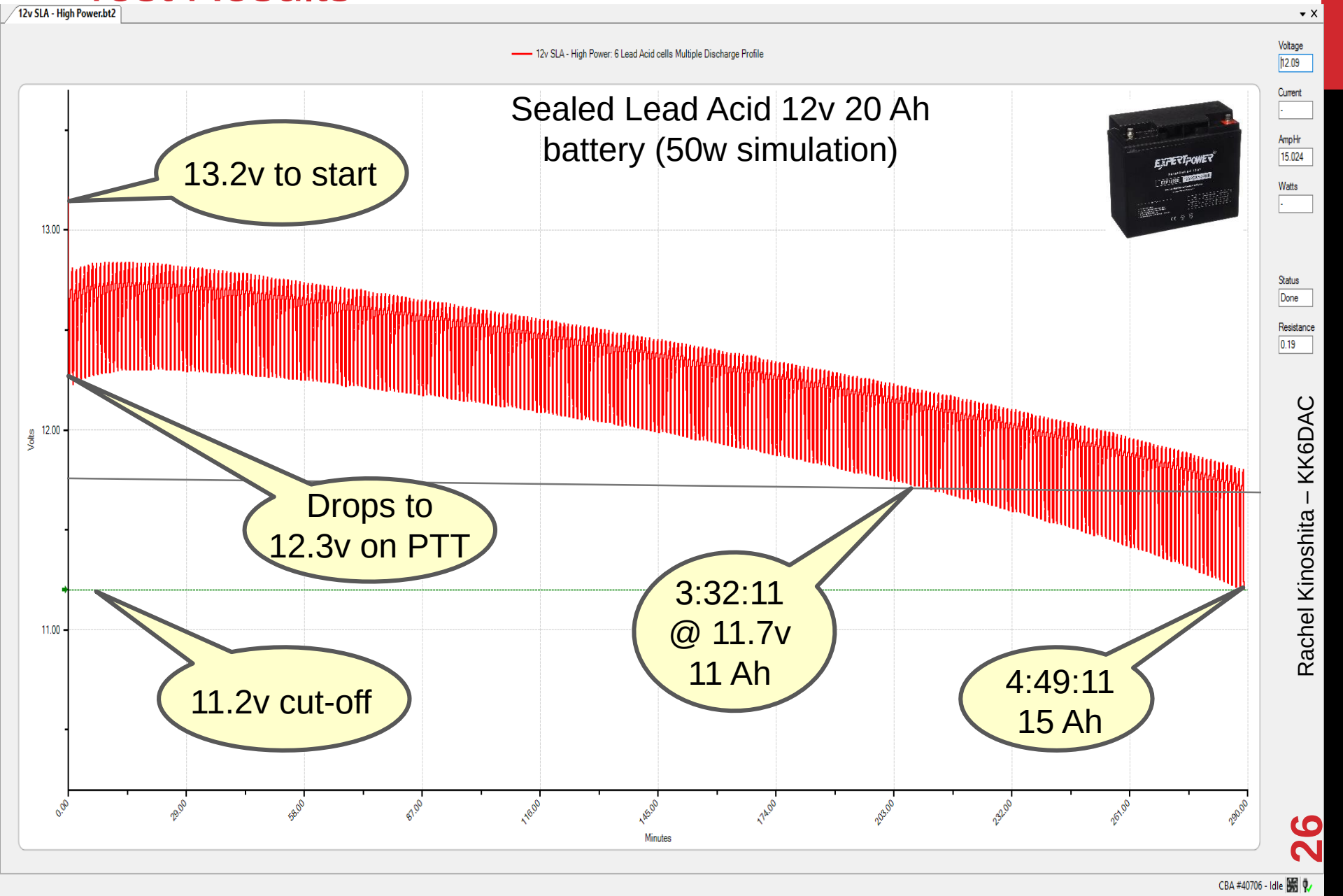
- **Pros**
  - Very low self-discharge
  - Relatively flat discharge curve
  - Can be recharged thousands of times
  - At 3.2vdc per cell, 4 cells in series (4s) has a nominal voltage of 12.8v and max voltage of 14.2v
  - Will not leak
  - No outgassing
  - High energy density
  - Can be charged with a power supply or charger set to 13.8v to 15.1v*
  - Unlike Li-Ion, LiFePO4 is very safe
  - Peukert constant = 1.01 or less
- **Cons**
  - Expensive

*With a Bioenno BMS. May also work with other LiFePO4 battery BMS

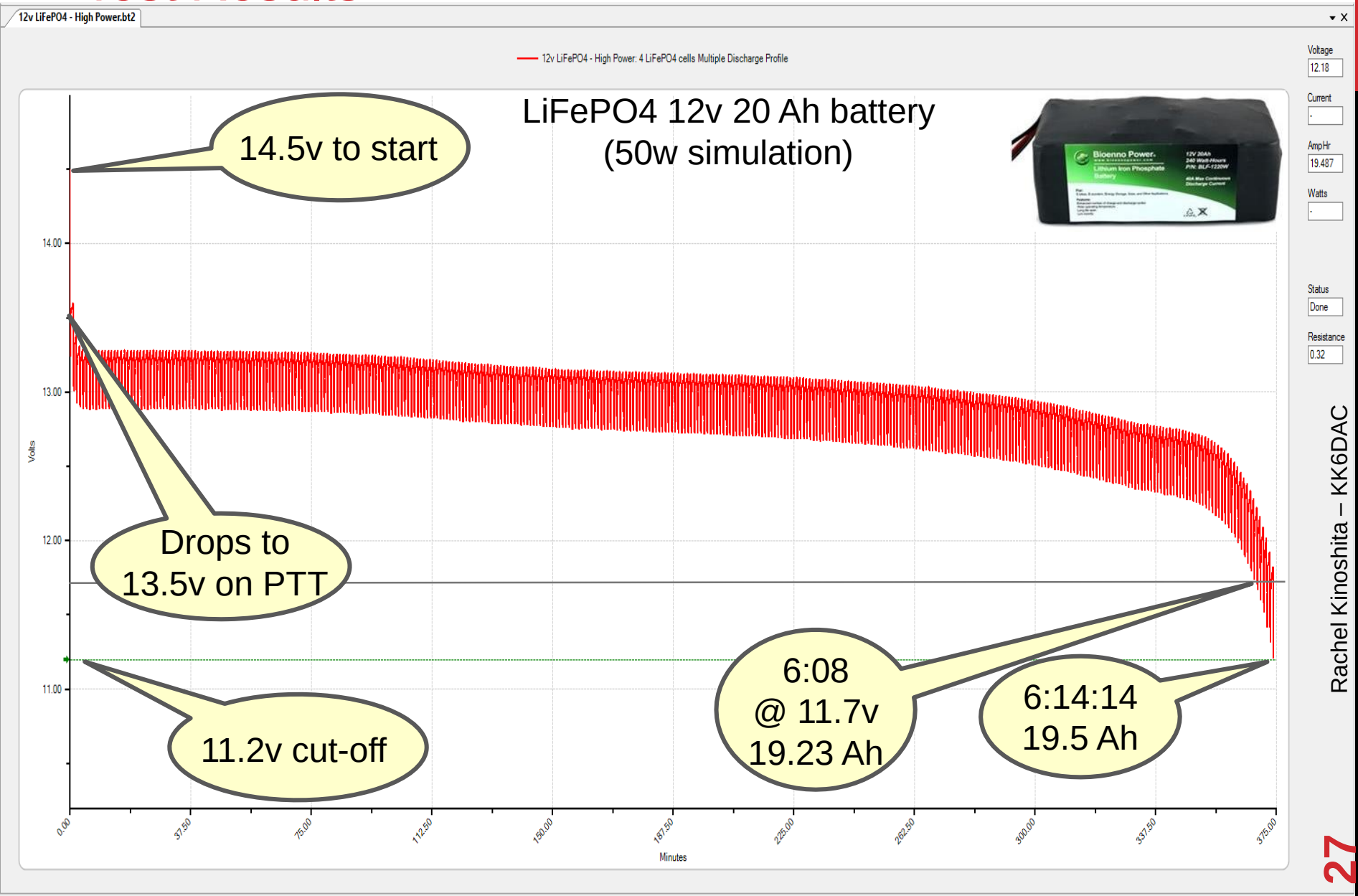
Lithium Iron Phosphate (LiFePO4)



Test Results



Test Results



Battery Recommendations

Bioenno Power LiFePO4
3 to 300Ah, 12 to 48v

Photovoltaic (Solar) Panels

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

Photovoltaic (Solar) Panels

➢ Monocrystalline

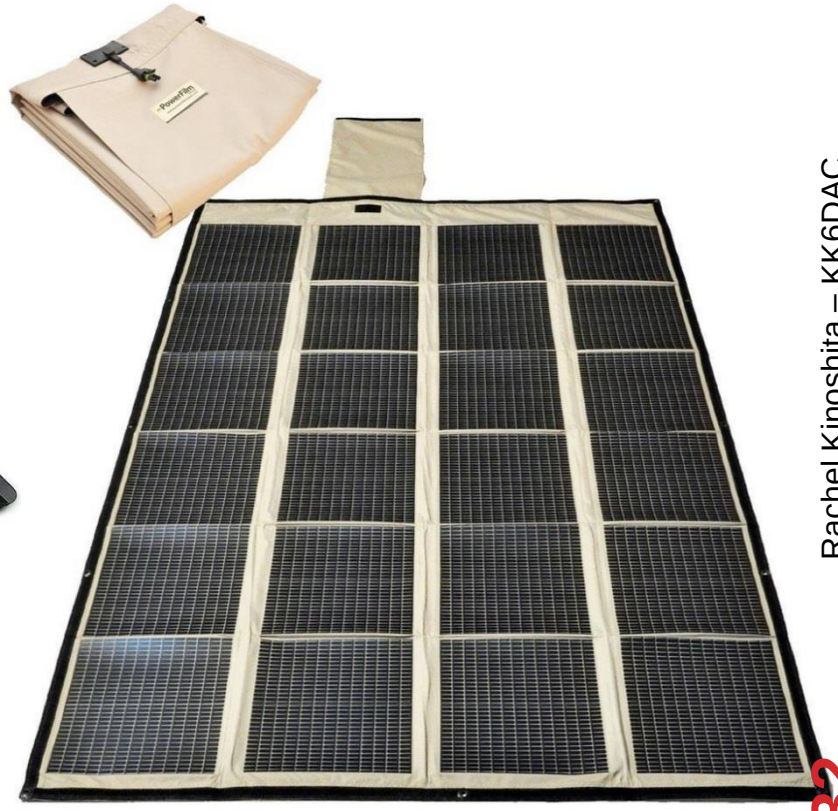
- More expensive
- Smaller footprint and less weight per watt
- Most efficient (~25%)
- Work best when pointed directly at the sun
- Shading a single cell could reduce output by 35 to 50%
- Shading by a bare branch could reduce output by 25%

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

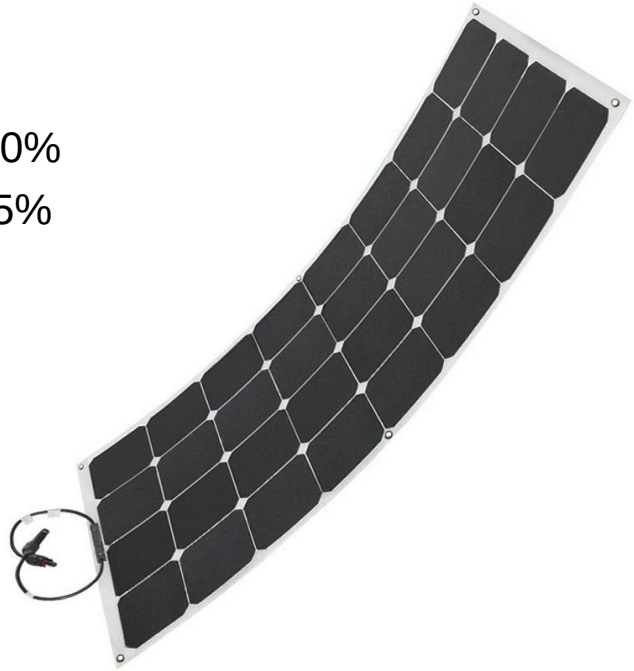
- **Foldable (Thin Film, Copper indium gallium selenide [CIGS])**
  - Most expensive
  - Larger footprint, but lighter weight per watt
  - Super lightweight
  - Least efficient (~14%)
  - Don’t have to be pointed directly at the sun
  - Work well in partial shade



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%

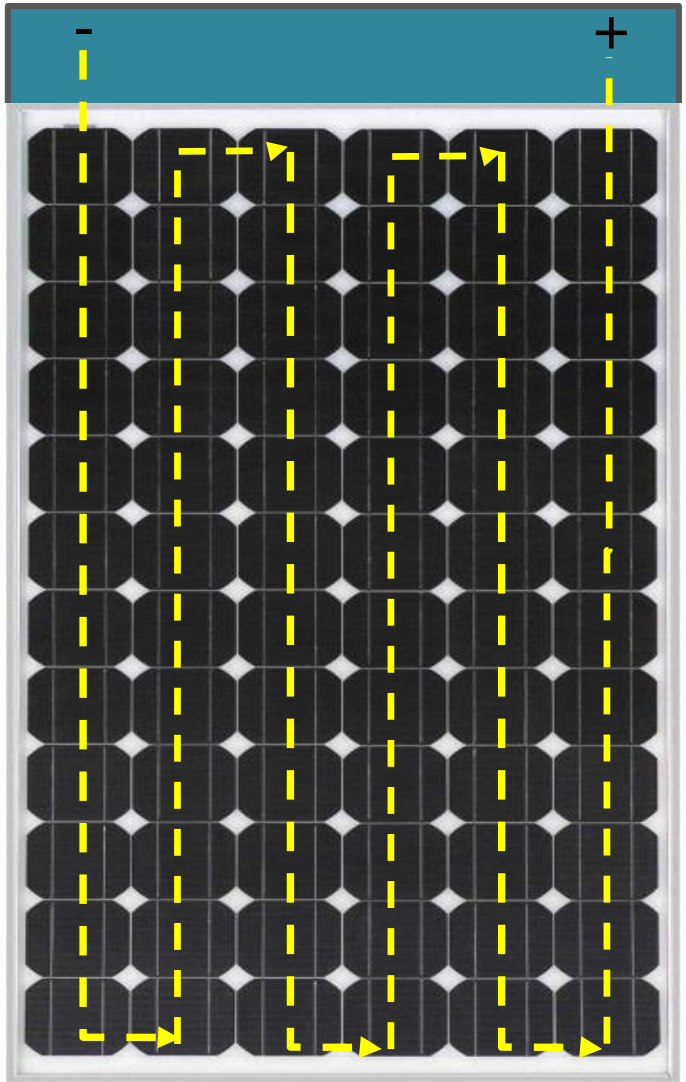


Photovoltaic (Solar) Panels

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

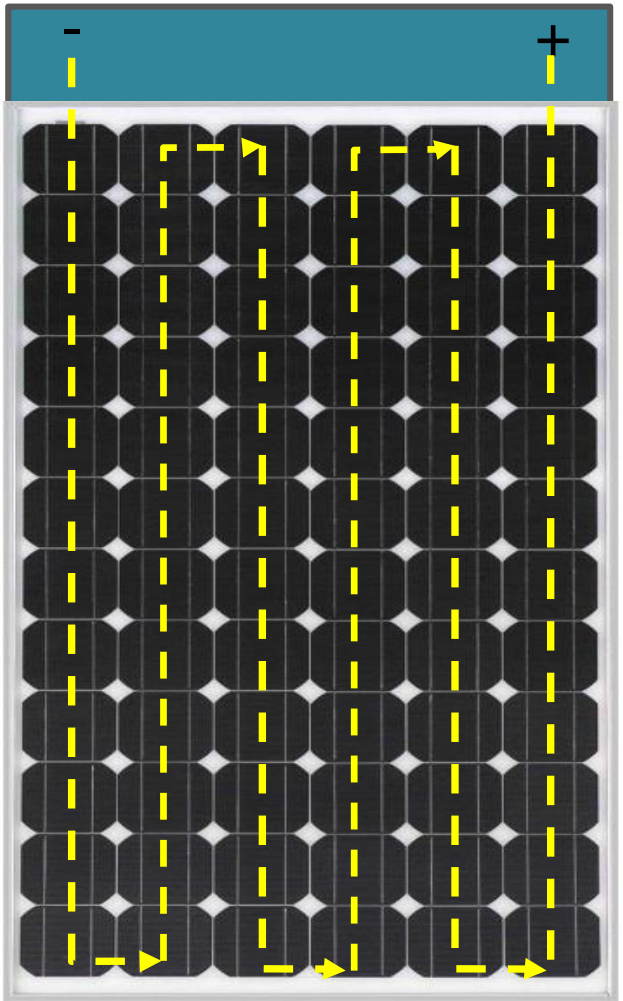
Photovoltaic (Solar) Panels

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



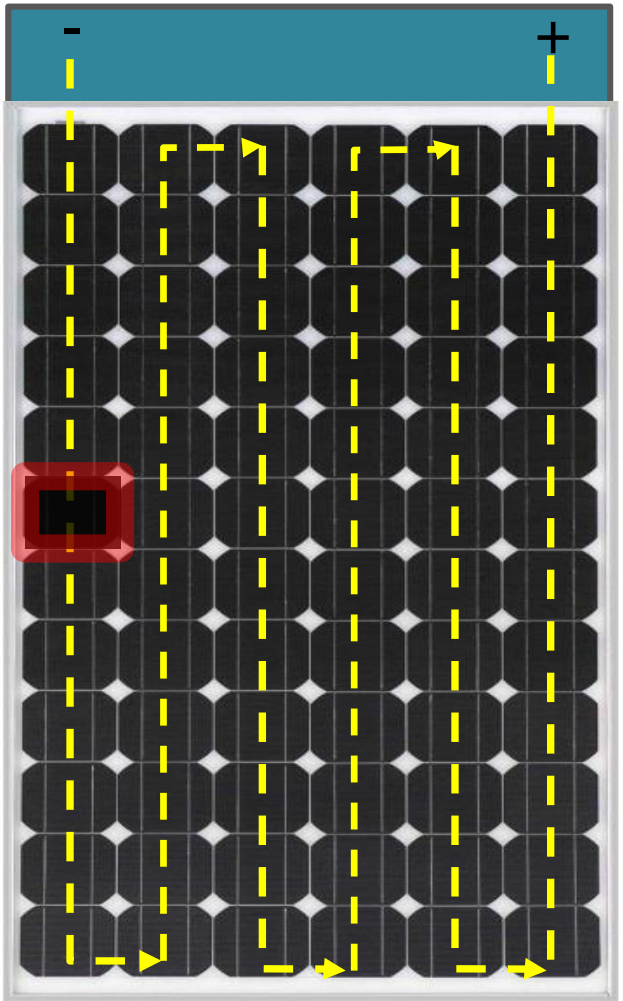
Photovoltaic (Solar) Panels

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



Photovoltaic (Solar) Panels

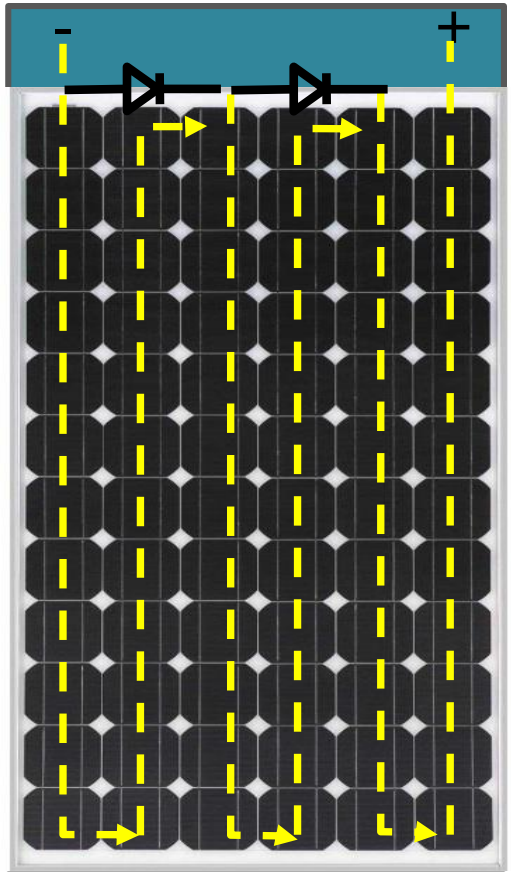
Think of shading like a flashlight with three new cells and one old one. Current flows from high to low, so in the same way that the old battery becomes a drain on the others, the shaded solar cell becomes a consumer of electricity, not a producer and begins to generate heat



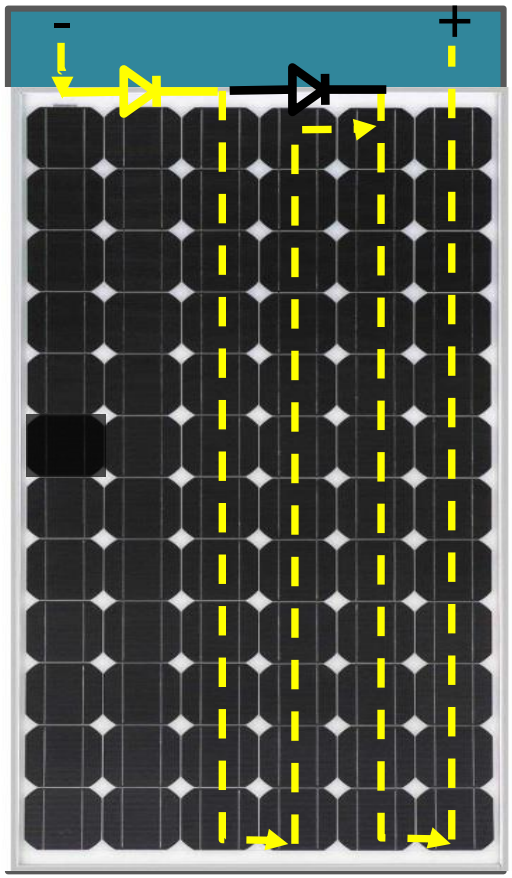
Photovoltaic (Solar) Panels

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

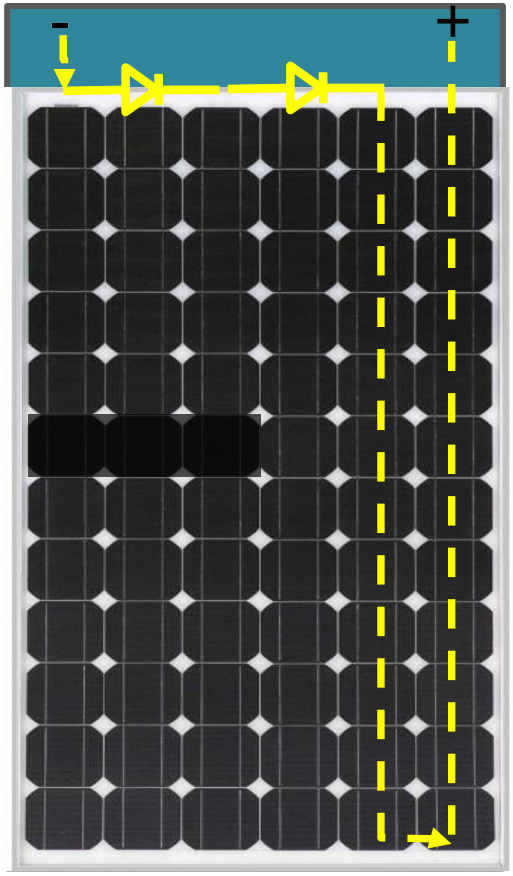
No Shading



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

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%/°C
Temp Coefficient of V_{oc}	-0.30%/°C
Temp Coefficient of I_{sc}	0.04%/°C
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 = 25°C, 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%/°C
Temp Coefficient of V_{oc}	-0.30%/°C
Temp Coefficient of I_{sc}	0.04%/°C
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 = 25°C, 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 voltageswhen 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

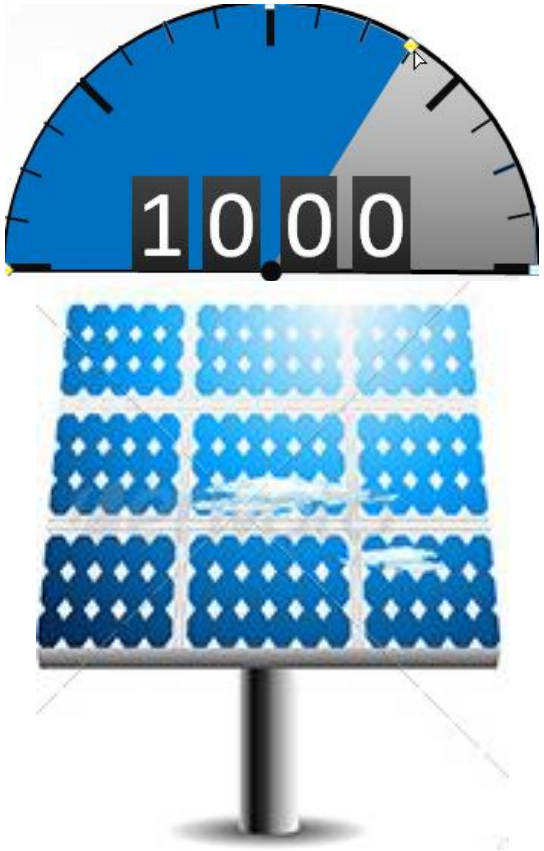
ELECTRICAL SPECIFICATIONS

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

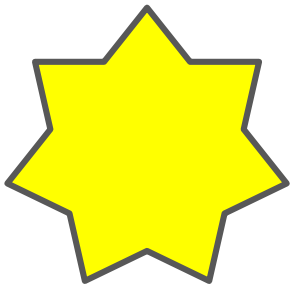
Photovoltaic (Solar) Panels

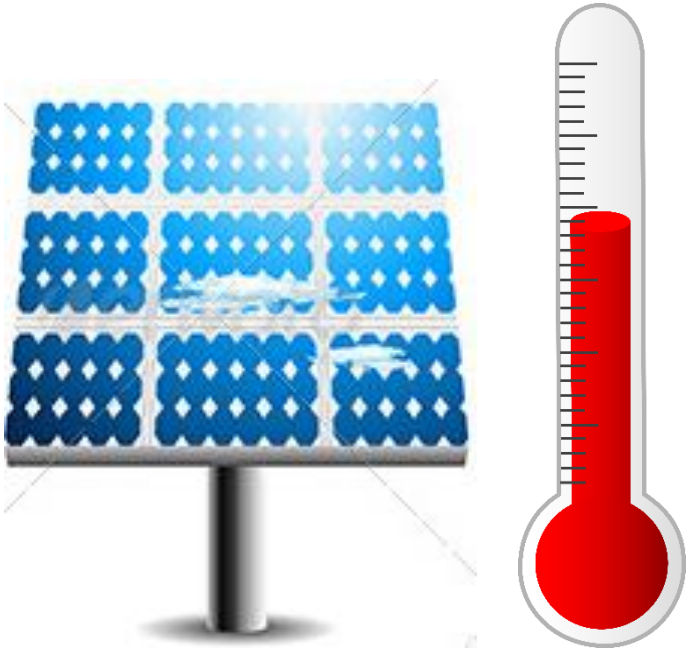
- **Irradiance 1000 Watts per Square Meter**



Photovoltaic (Solar) Panels

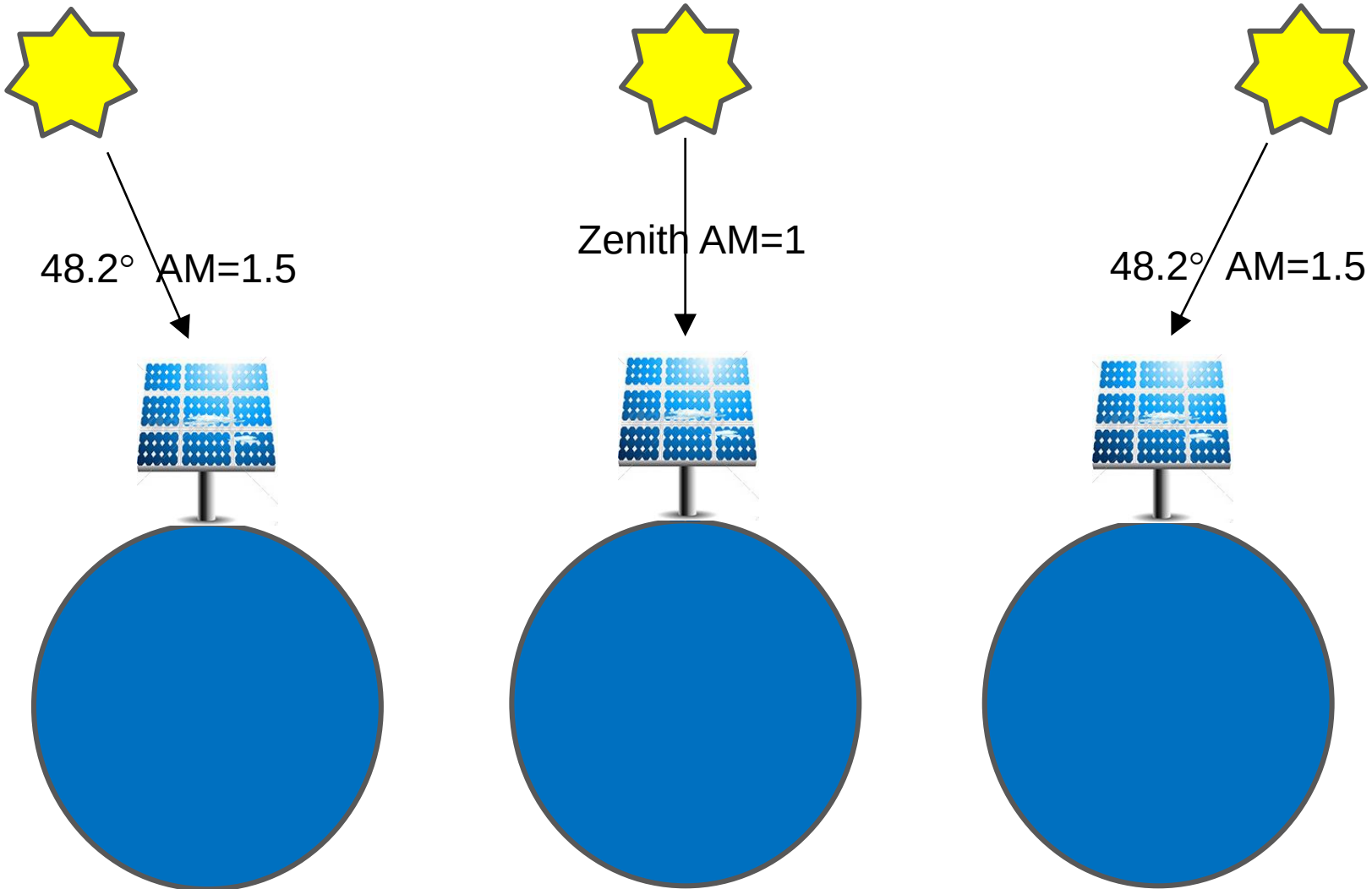
- **Temperature = 25° C / 77° F**





Photovoltaic (Solar) Panels

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

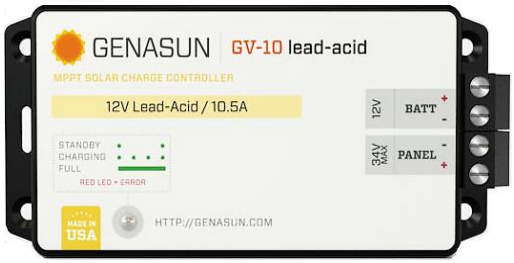


Photovoltaic (Solar) Panel Recommendations

- **Rigid Solar Panels – Renogy 100w, 12v monocrystalline**
- **Foldable Lightweight Panels – PowerFilm 12v**

Charge Controllers

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



MPPT

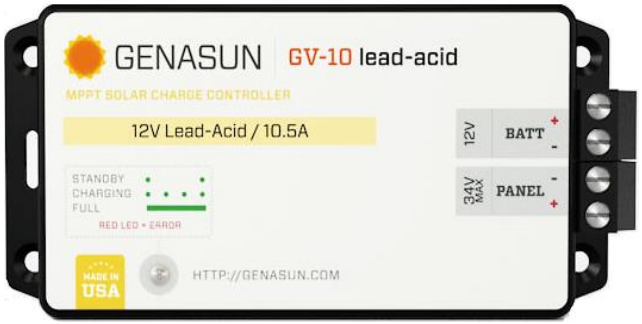
PWM

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

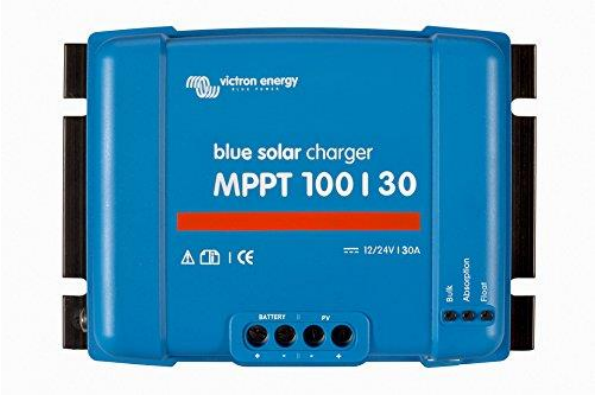
Charge Controllers

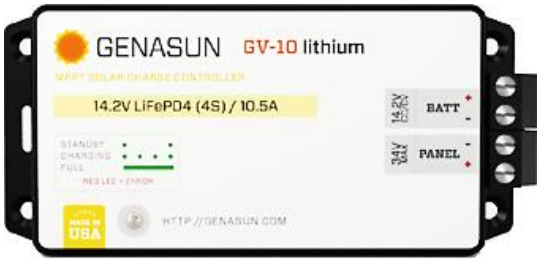
- **A good charge controller will provide 3-stage charging for lead acid batteries (and for flooded batteries, it may be a 4-stage)**
  - **Bulk** – Constant Current (or close to it) – Charge to about 80% of battery capacity. Unlike a 3-stage AC battery chargers, a solar charge controller can't guarantee 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
  - **Equalization** – A deliberate over-charge of the battery (typically 14.7v to 15v for a 12v battery). Often performed monthly to equalize the cells and de-sulfate the lead plates.
- **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)

- More expensive
- Required when PV panel voltage is significantly higher than the battery (i.e. 24v 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

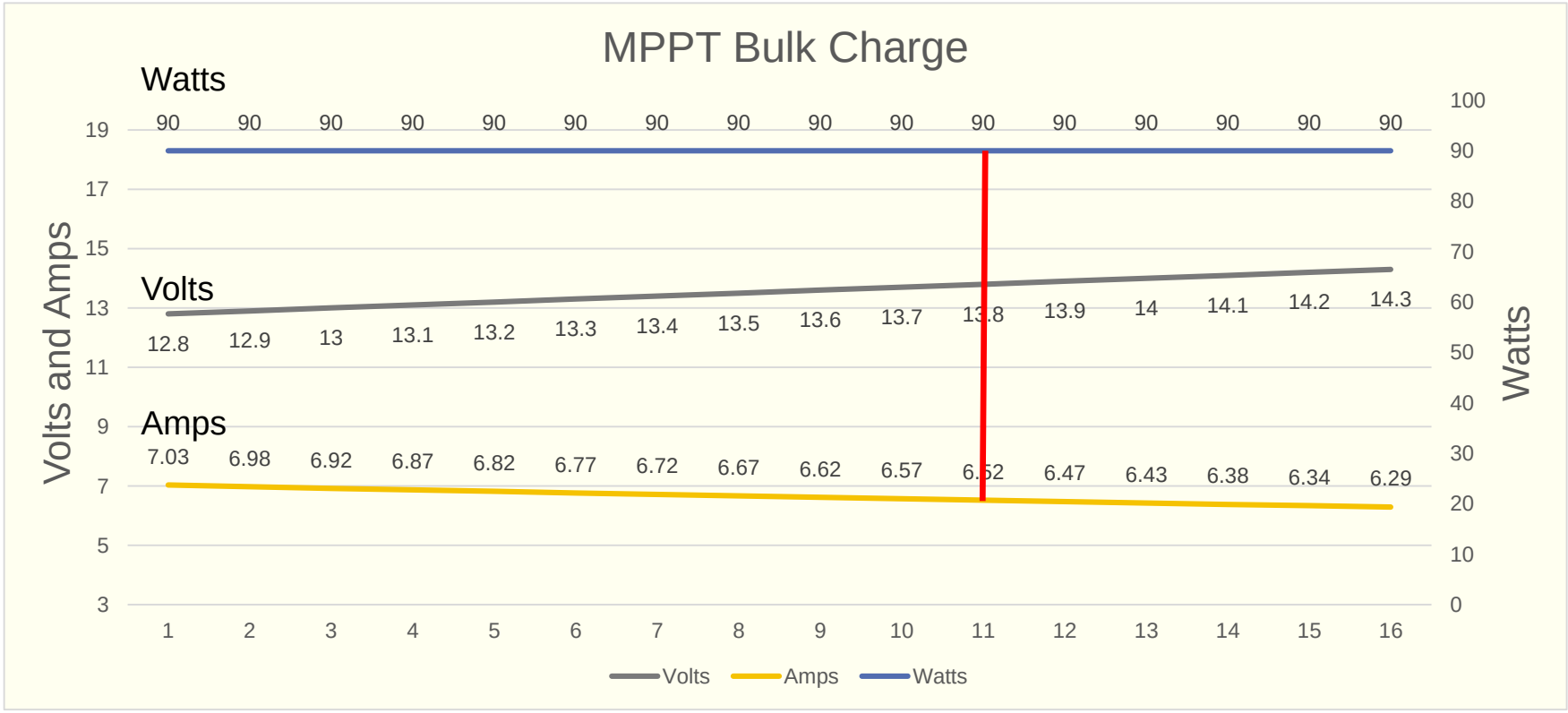




Charge Controllers

➢ 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

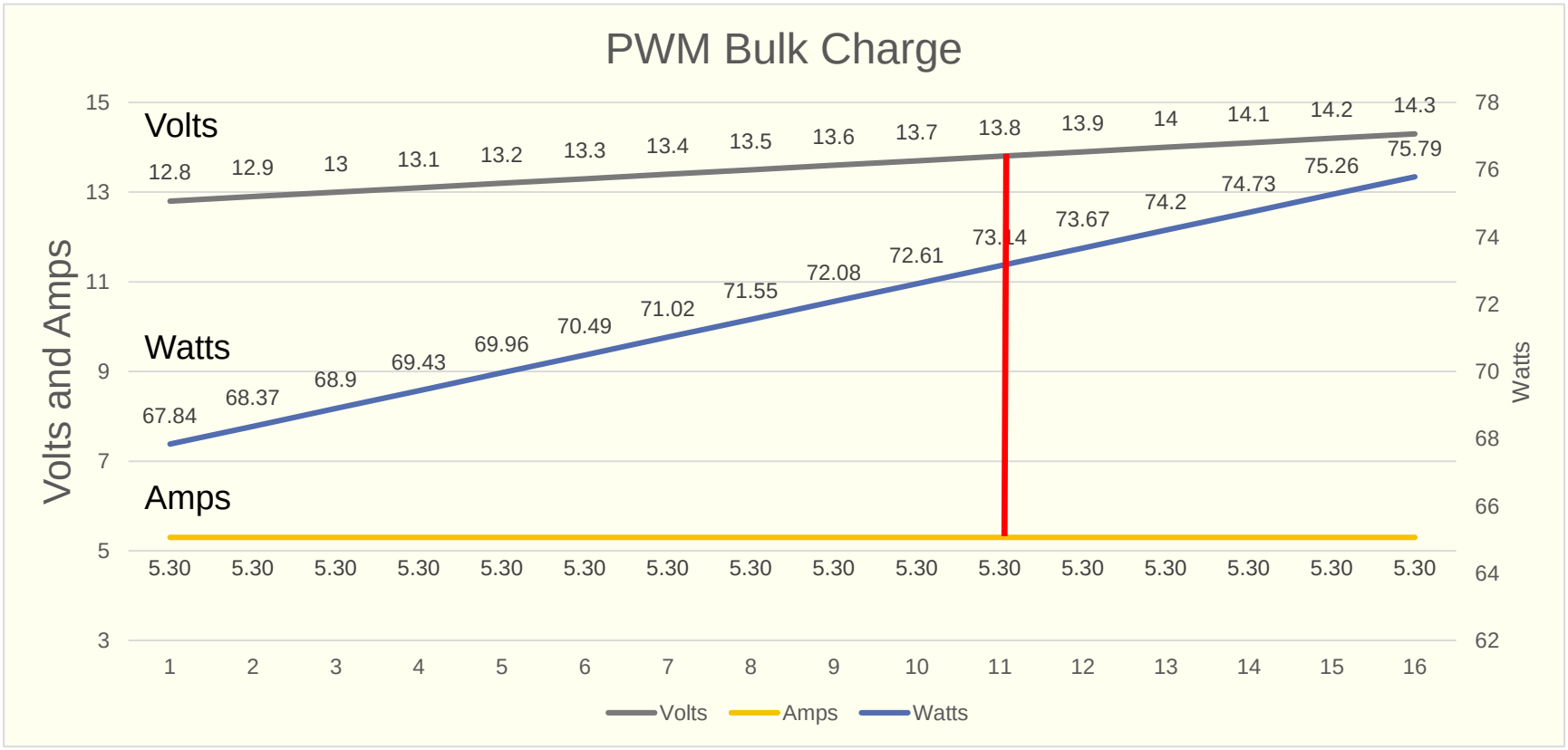
➢ Pulse Width Modulation (PWM)

- Less expensive
- PV panel and battery voltages **must** be 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)



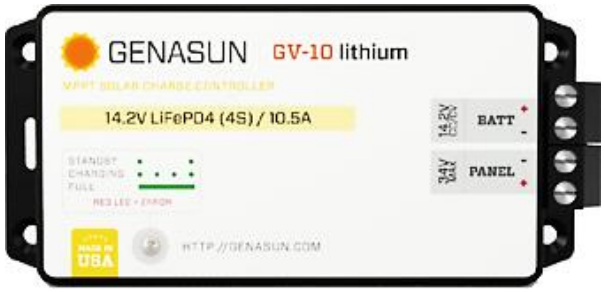
Charge Controller Recommendations

Genasun MPPT

- **Available for LiFePO4, Lead Acid and Lithium Ion batteries**
- **RFI Quiet**

Victron Energy MPPT Blue Series

- **Programmable**
- **Need chokes to reduce RFI**



Connecting the Components

Wires and Connectors

Connecting the Components

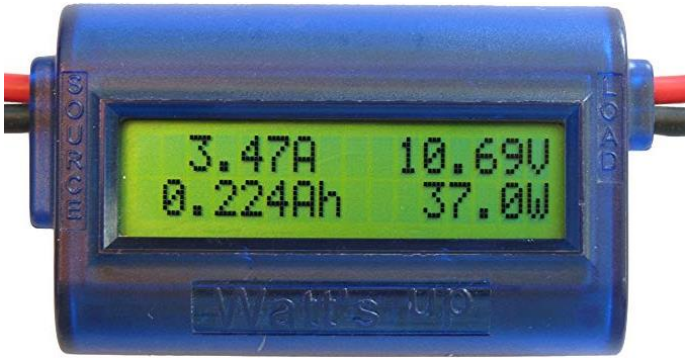
Fuses, Breakers and Wiring Blocks

Connecting the Components

12v Aux, USB and Powerpole Connectors

Connecting the Components

Meters and Monitors



Connecting the Components

Cases / Boxes

Low Voltage Disconnect

Switches and Continuous Duty Relays

Solar Tilt Mounts

Emergency Communications Off-Grid

- **Post Katrina, FEMA was left with more trailers than they knew what to do with**

Emergency Communications Off-Grid

- **The problem was exacerbated because many of the trailers had toxic levels of formaldehyde**

Emergency Communications Off-Grid

- **In late 2014 / early 2015 the Menlo Fire District acquired a surplus FEMA Katrina trailer**

Menlo Park CERT Communications Trailer

Menlo Park CERT Communications Trailer

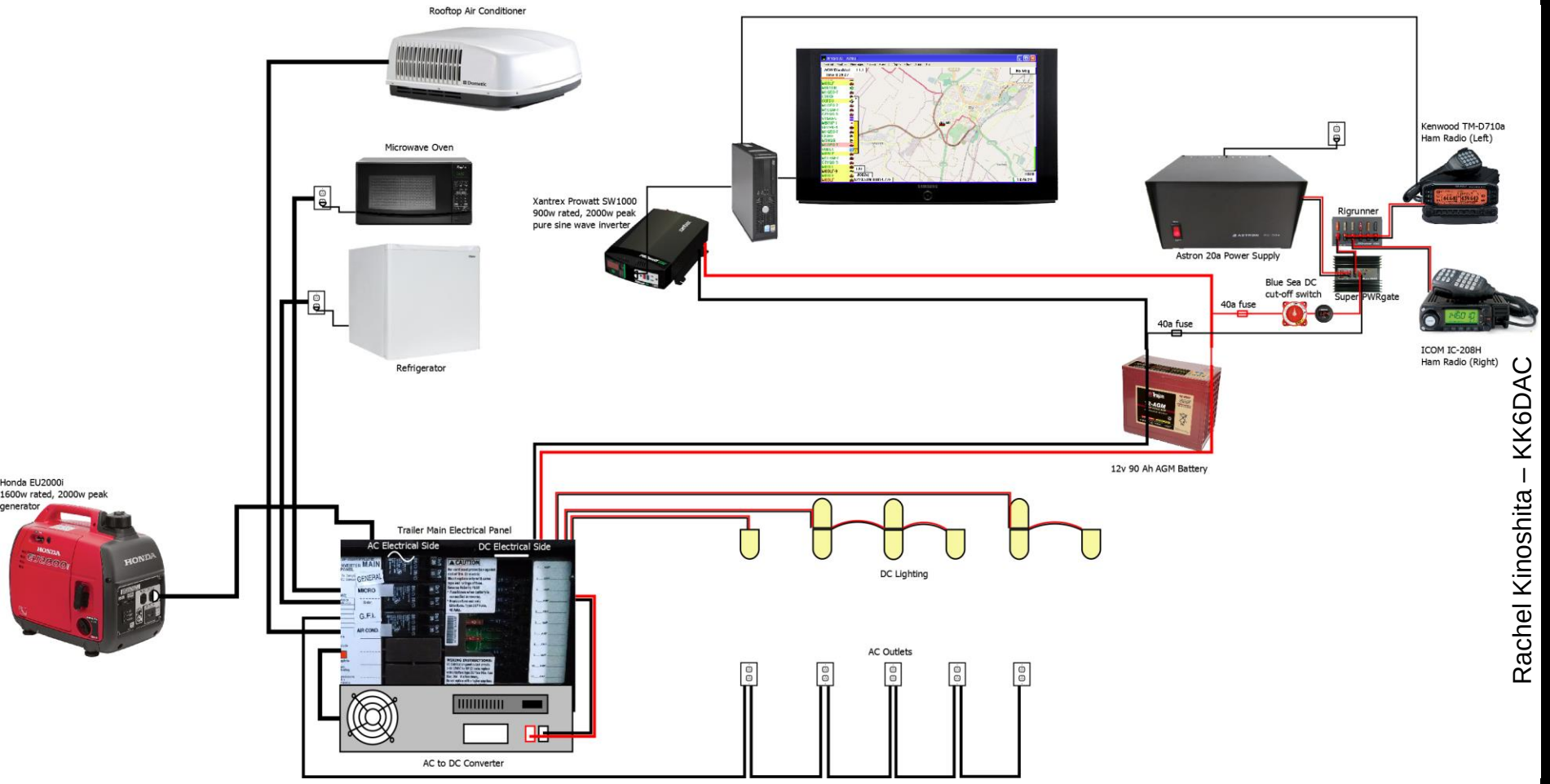
Menlo Park CERT Communications Trailer

Menlo Park CERT Communications Trailer

Menlo Park CERT Communications Trailer

- **Menlo Fire purchased the CERT trailer to provide a platform for communications during an emergency or disaster**
- **The trailer was outfitted with amateur radios, computers, monitors, a generator, antennas and other accessories necessary to operate**
- **In that configuration it required manual charging of the battery on a regular basis to prevent battery damage due to low voltage**
- **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 would ensure independent operations during a disaster**

Menlo Park CERT Communications Trailer



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

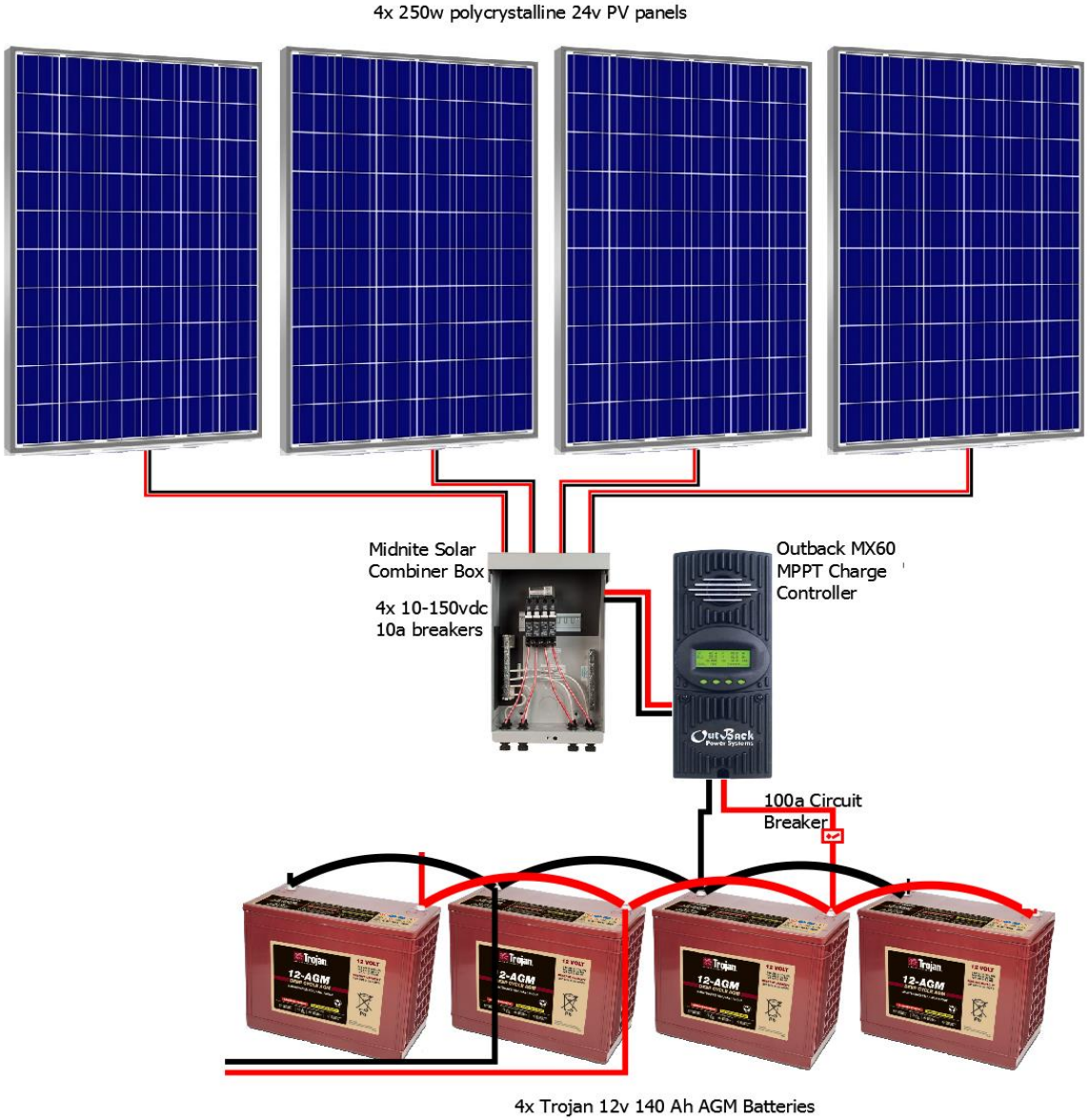
60A MPPT Solar Charge Controller

6 slot Solar Combiner box

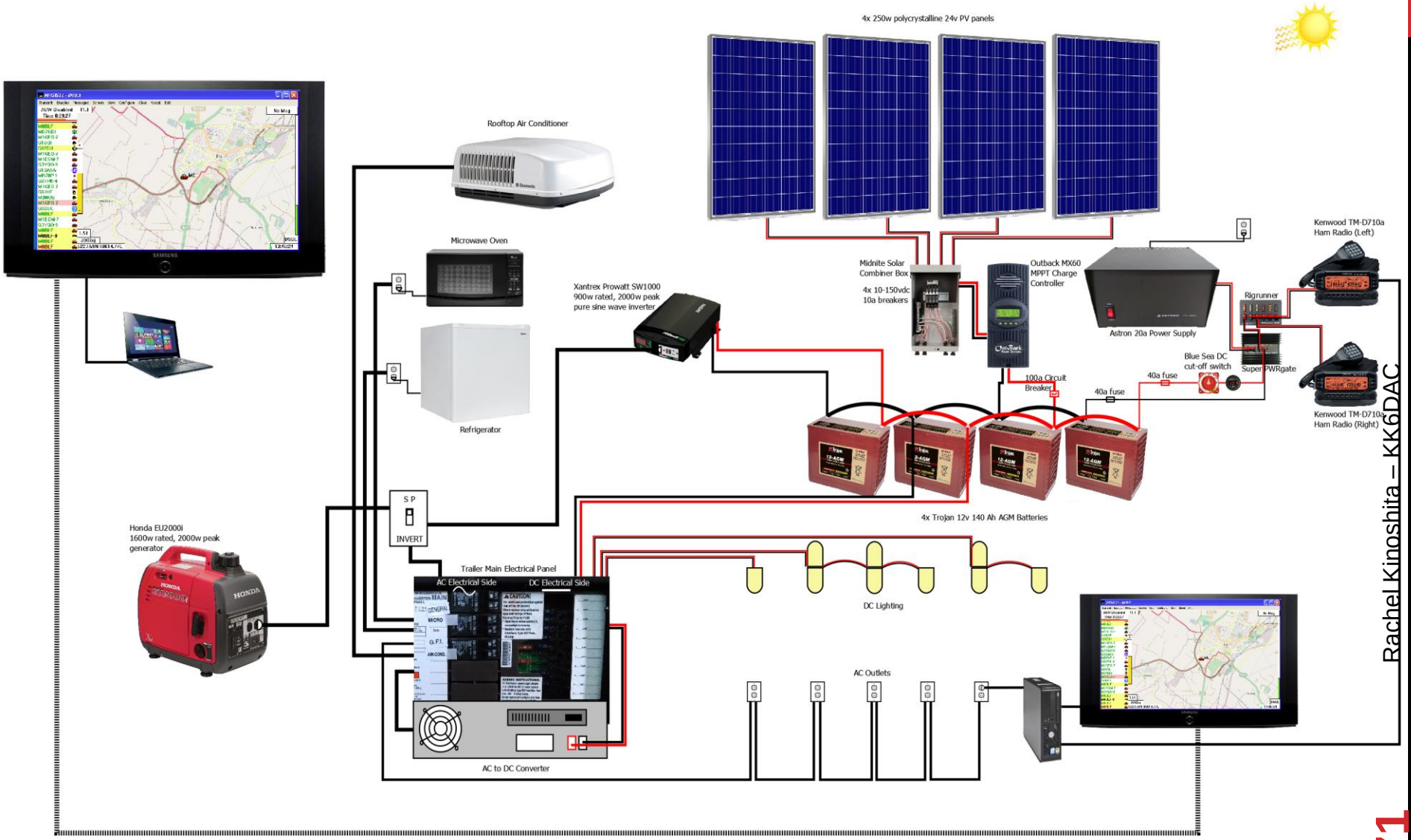
4x 250w PV Panels

4x 140Ah AGM Batteries

Menlo Park – Completed System

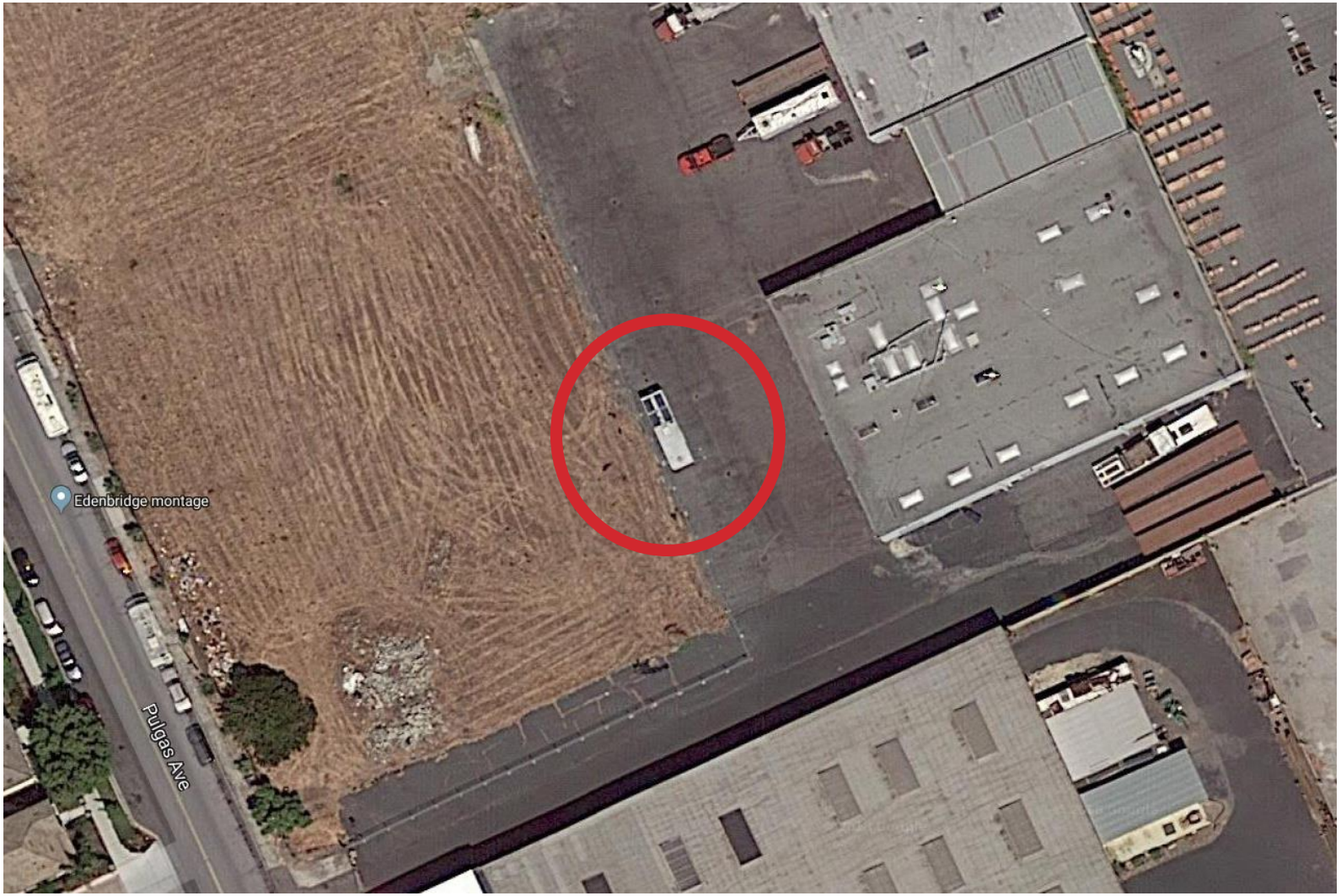


Menlo Park CERT Communications Trailer

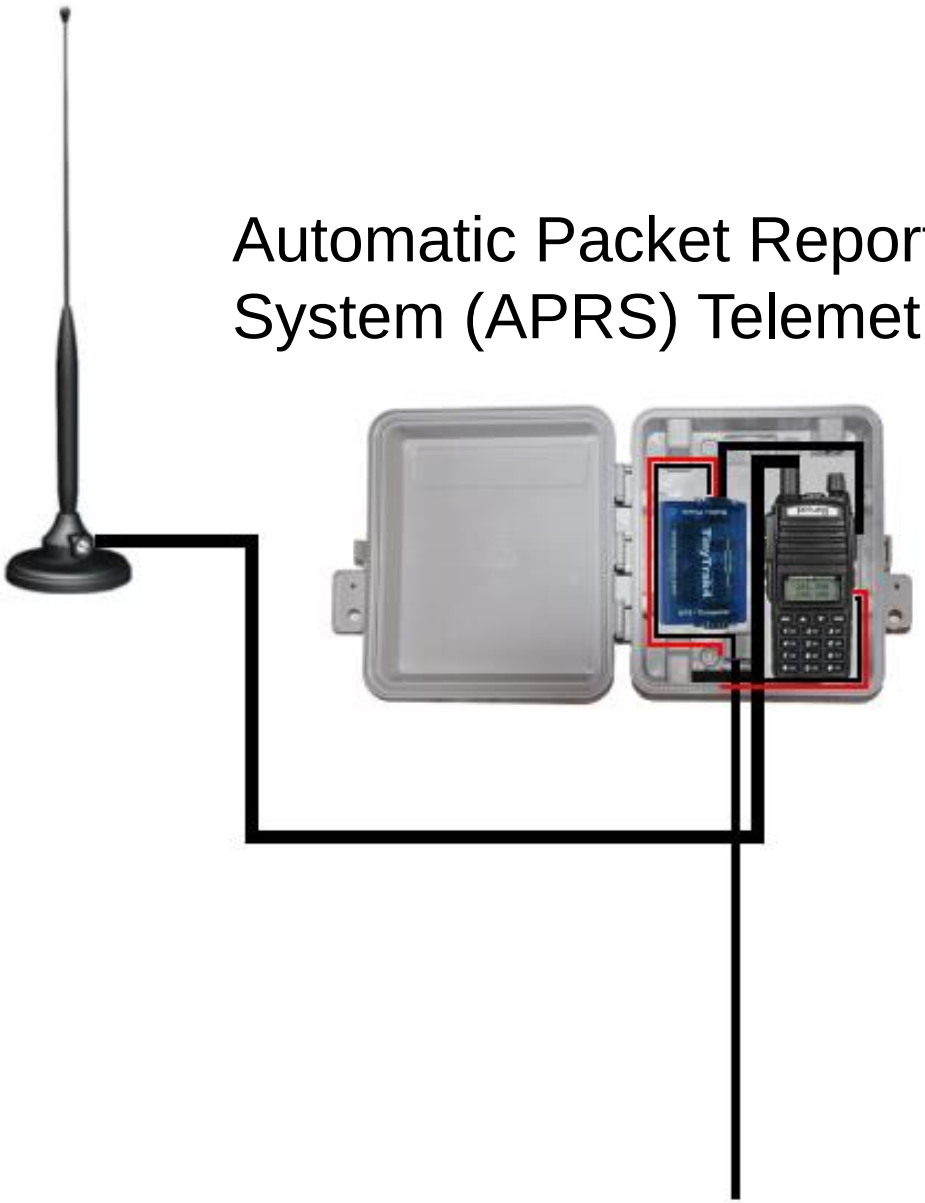


Rachel Kinoshita – KK6DAC

Menlo Park CERT Communications Trailer



Menlo Park CERT Communications Trailer



Automatic Packet Reporting System (APRS) Telemetry

Menlo Park CERT Communications Trailer

Callsign: KK6DAC-15 Search Clear **Completed generating statistics (took 0.015 s).**
Real-time page updates enabled.

Start date (YYYY-MM-DD HH:MM): 2017-10-04 23:27:15
End date (YYYY-MM-DD HH:MM): 2017-10-06 23:27:15

It is possible to search using wildcards (*?) after a prefix. Example: VK*

Telemetry from **KK6DAC-15** - info

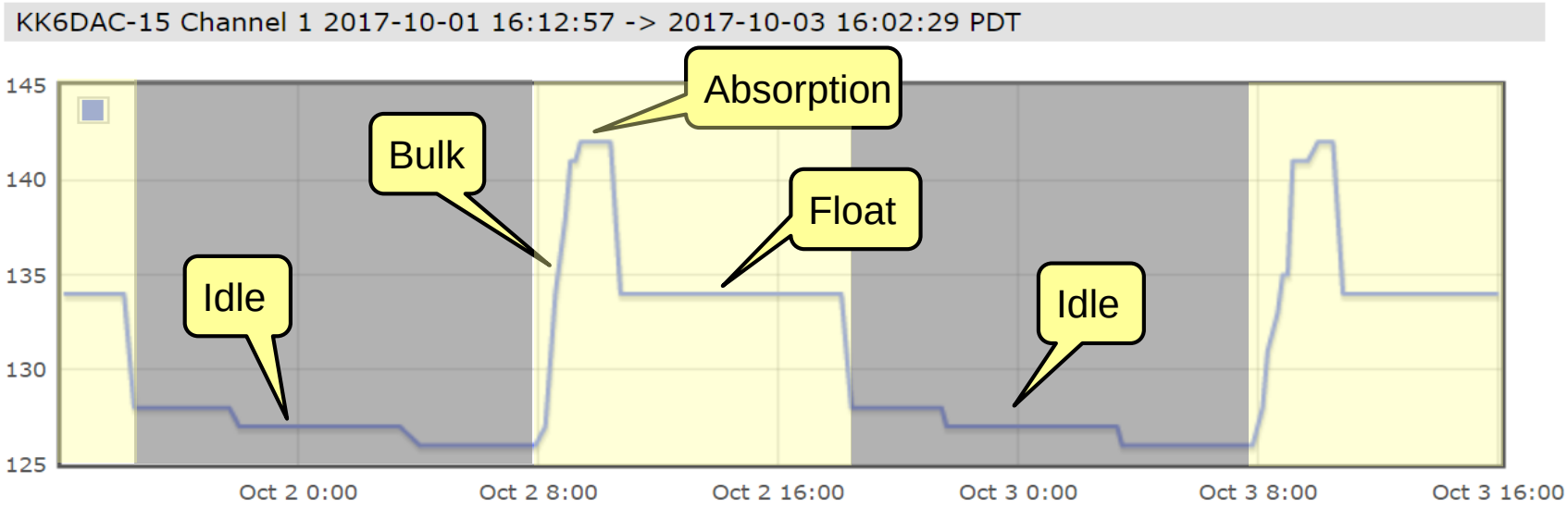
Comment: *Battery: 13.4V Temp: 77F*
Mic-E message: *Off duty*
Location: 37°28.69' N 122°08.98' W - locator CM87WL24AS - **show map** - **static map**
0.8 miles Northwest bearing 324° from East Palo Alto, San Mateo County, California, United States [?]
2.4 miles Northeast bearing 47° from Menlo Park, San Mateo County, California, United States
16.9 miles Northwest bearing 305° from San Jose, Santa Clara County, California, United States
25.2 miles Southeast bearing 144° from San Francisco, San Francisco County, California, United States
Last position: 2017-10-06 16:25:25 PDT (1m50s ago)
2017-10-06 16:25:25 PDT local time at East Palo Alto, United States [?]
Last telemetry: 2017-10-06 15:59:42 PDT (27m ago)
2017-10-06 15:59:42 PDT local time at East Palo Alto, United States [?]
Altitude: 33 ft
Values: Channel 1: 134 (TLM: 134 EQN: 0,1,0)
Channel 2: 76 (TLM: 76 EQN: 0,1,0)
Channel 3: 255 (TLM: 255 EQN: 0,1,0)
Channel 4: 91 (TLM: 91 EQN: 0,1,0)
Channel 5: 67 (TLM: 67 EQN: 0,1,0)
Bit sense: 1 2 3 4 5 6 7 8 (TLM: BITS: 11111111)

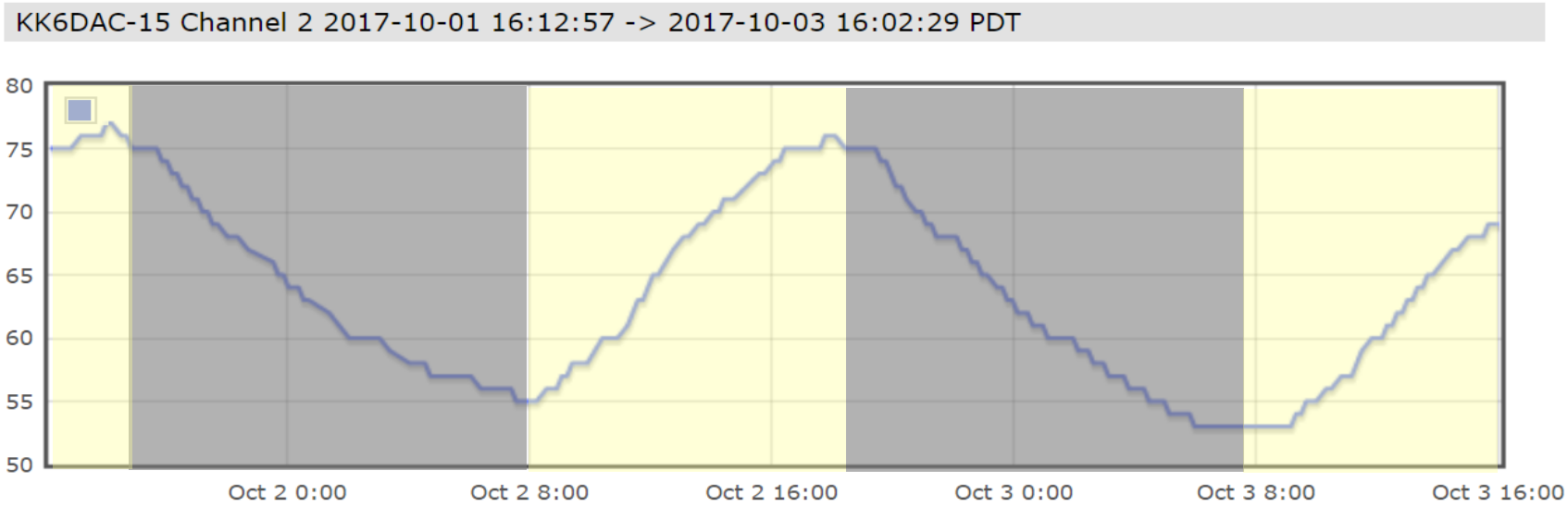
Telemetry history graphs for **KK6DAC-15**

[24 hours · 48 hours · week · month · year]

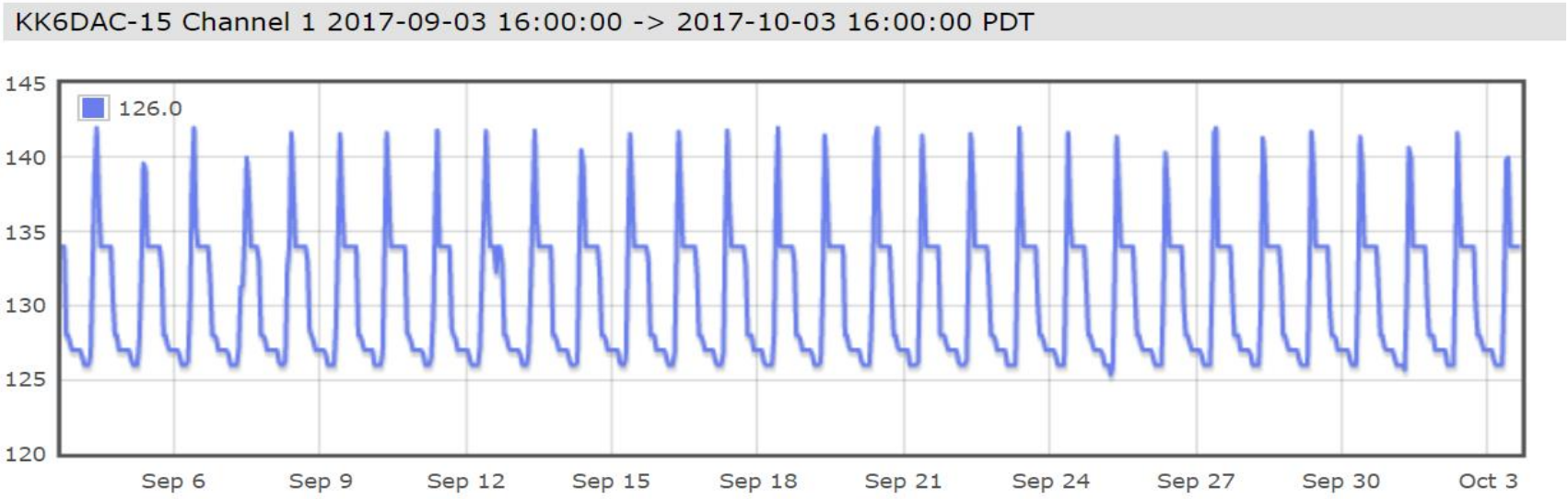
KK6DAC-15 Channel 1 2017-10-04 16:28:02 -> 2017-10-06 15:59:42 PDT

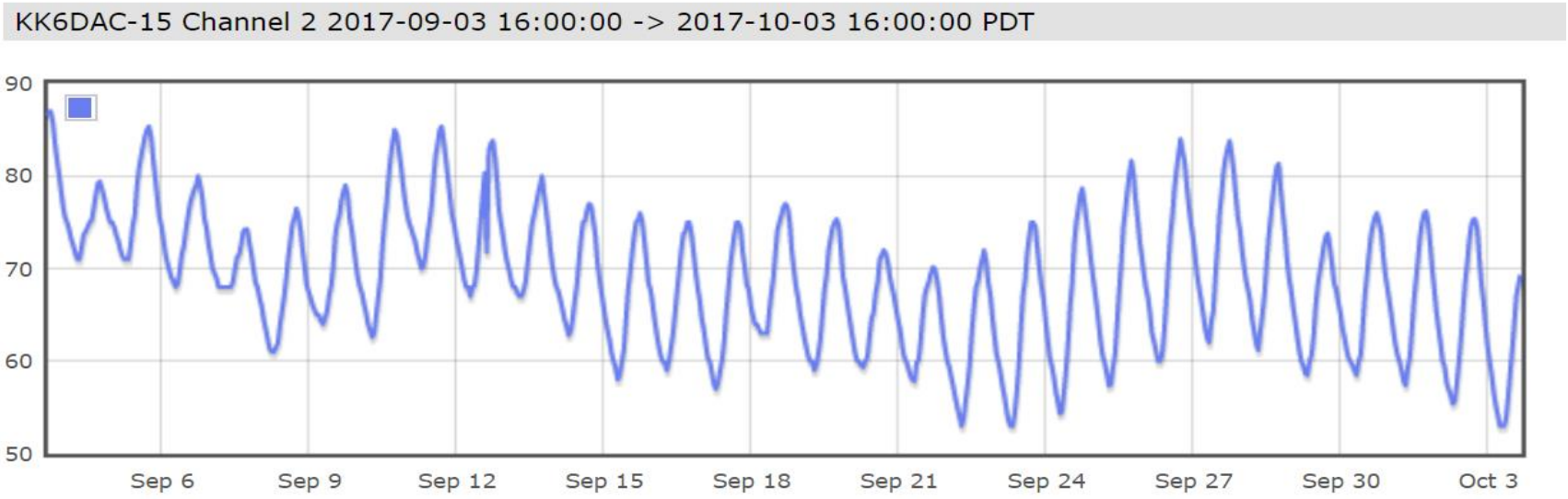
Menlo Park – 48 Hours of Collected Data



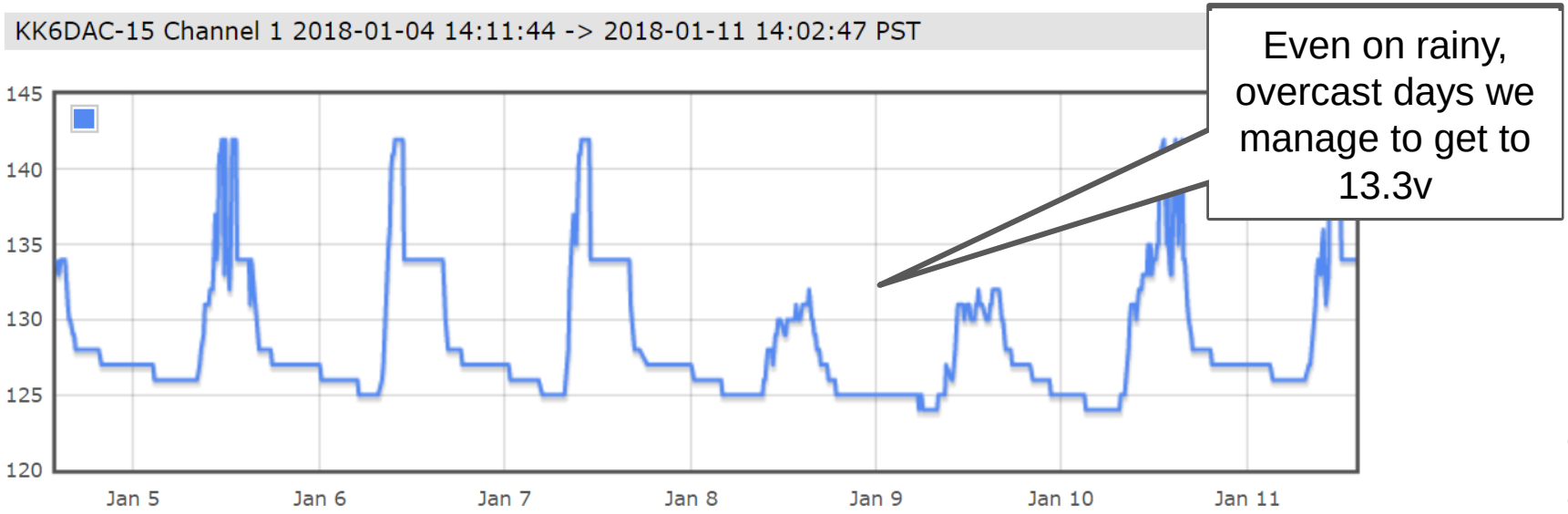


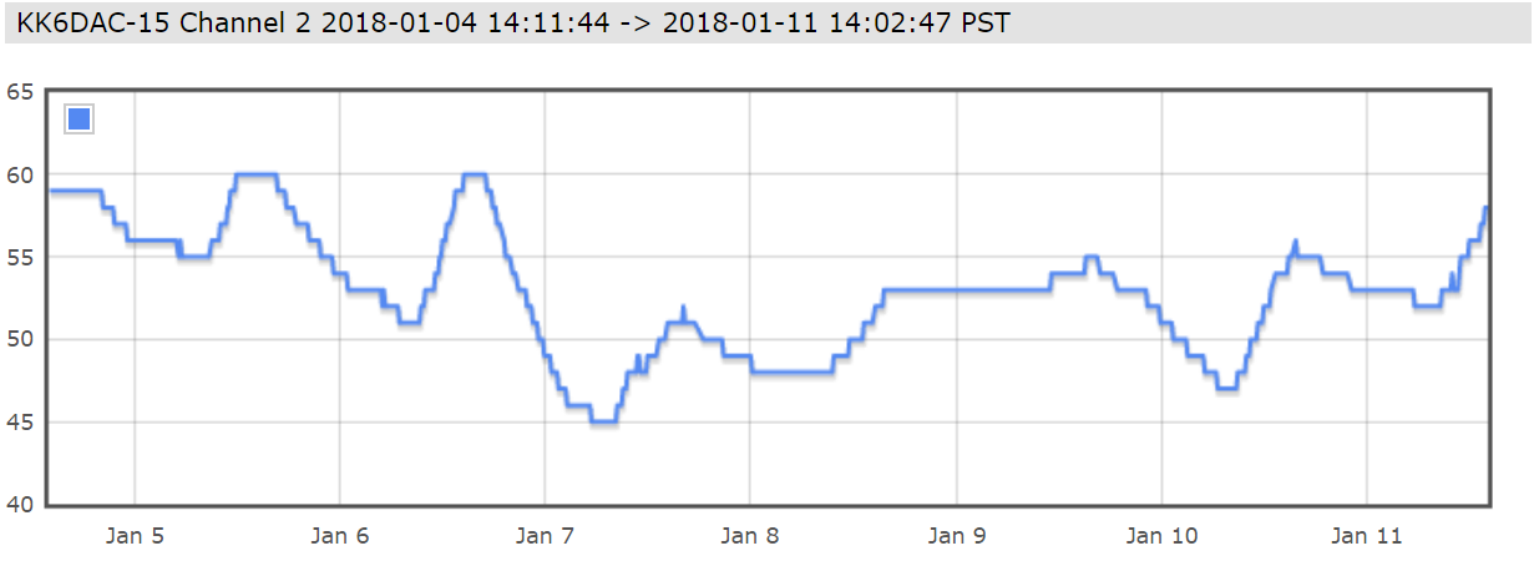
Menlo Park – 1 Month of Collected Data





Menlo Park – How Are We Doing this Winter?





Menlo Park CERT Communications Trailer

Menlo Park CERT Communications Trailer

EOC Stations

1F

Albuquerque DXA					
W5UR	700	2	7	3,696	NM
Parsippany OEM RACES Team					
NI2S	1,016	2	17	3,182	NNJ
Cottonwood Heights ARC					
W7RCH	424	2	20	2,540	UT
West Essex ARC					
W2EF	354	2	8	2,136	NNJ
WX5FWD Skywarn Team					
W5T	187	2	9	1,526	NTX
American Red Cross					
KY4RC	210	2	20	1,510	KY

A huge "thank you" to Frank Adams (N6YP) who was our Field Day Captain

Amargosa ARC					
N7A	153	2	8	1,496	NV
Montvale NJ EOC					
K2FJ	209	2	4	1,460	NNJ
Will Co. EMA Amateurs					
W9WIL	214	2	5	1,198	IL
Truro ARC					
VE1AO	282	2	22	1,168	MAR
Metro ARC Chicago					
W9L	198	2	25	1,126	IL
Fayette ARA					
K8FAY	350	2	4	1,050	OH
Dartmouth ARC					
VE1YO	196	2	1	1,034	MAR
Cedar Creek ARC					
K5CCL	147	2	29	944	NTX
El Segundo ARG					
WB6VMV	224	2	10	918	LAX
Menlo Park Fire CERT					
K6ATH	35	2	8	892	SCV
N5MI	189	2	10	746	WTX
Winchester & Clark Co. EOC					
AC4YD	184	2	3	718	KY
Meridian AmRad Op Lauderdale Emerg Mgmt Stn					

Menlo Park CERT – What Did it Cost?

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	Lag bolts and sealant	$40.00	$40.00
1	Shipping	$400.00	$400.00
	Total		$3,885.00

Field Day 2014

Questions

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