



RV SOLAR 101

Rick Lambert / Silver Lining Solar RV



Should I Invest in Solar?

Solar Power or Not?

- What is the point of having solar, and why would you want it?
- What does it do for you?
- How much can it do for you?
- What bits and pieces will you need to have a solar power system?
- Will it work with your own camper or RV?
- How much will it all cost?
- Is it worth the investment?

What is Solar?

What is solar for, what purpose does it serve?

- To charge one (or more) of your RV batteries with power from the sun
- By doing so, enhance and extend your camping experience

Improve Your Camping Experience

- To minimize or eliminate generator noise and fumes
- To reduce fuel consumption
- To give you a closer to nature lifestyle

Maintenance

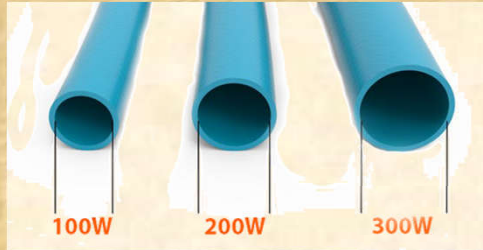
- To keep batteries charged while RV is in storage

**Ultimately, to give you the freedom to power whatever you need,
wherever you need it**

Why Have Solar?



The primary purpose of a solar energy system is to be the gas station that re-fills your tank!



Solar Panels

How big is your fuel tank?



Battery Group



Solar Controller



How fast do you use fuel?

Battery Monitor



Your Power Use

Camping as a Lifestyle??

How often do you camp?

- Do you camp 1x, 2x, 3x a year? More?

How long do you camp?

- Day trips, long weekends, extended trips?

Where do you like to camp?

- Do you prefer RV campgrounds with full services
- Are you a wilderness camper – dry-camping or “boondocking”
- Do you park in shaded areas or open ground?

How do you like to camp?

- Quiet solitude and close to nature?
- Some conveniences
- Where is the hot-tub?

Camping Style - Expectations

What are your needs and expectations?

- Just the basics: Lights, water pump and maybe phones and tablets?
- Do you run a CPAP or O² generator?
- Do you stay warm with furnace, cool with fans?

Are there other appliances you want to run?

- Television, coffee maker, Instant Pot[®] microwave, fans. (Hot tub?)
- Do you stay warm using a heater, furnace, or a fireplace?
- Do you have an RV fridge (runs on propane and battery) or...
- ...a residential fridge (runs on household AC)?
- Is running the Air Conditioner a necessity on hot days?
- Do you run a lot of lights inside and outside your camper (RV)?

SECTION 2: How do I start?

What basic components are involved?

- How do I select the correct components?

How much power do I use?

- Power Audit vs Battery Monitors
- DC vs AC – some background before auditing

How does the power I use related to battery types and sizing?

- How do I determine my daily consumption from my batteries?

How does my battery capacity relate to my solar panels?

- Should I go portable panels or roof mounted?
- If roof mounted, how do I get wires from my roof to my batteries?

What additional components do I need to run some luxuries?

- What is an inverter, do I need one?
- If so, what kind and how do I hook it up?

Where can I turn for help?

Primary Components

Key Components

- Batteries
- Solar Panels
- Solar Controller
- Wiring & Safety Devices



Primary Components

Battery/Batteries

- The fuel tank of your RV/solar power system

Solar Panels

- The gas station that delivers fuel to your system

Solar Charge Controller

- The fuel nozzle that regulates and controls the fuel as it fills the tank

Wiring & Safety Devices

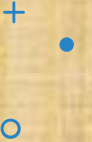
- Wires, fuses, breakers, switches and busbars that distribute power and protect you and your RV in case of short or faults

Choosing the correct wire for voltage, amperage and exposure to the sun are critical safety factors!

Don't Skip on Safety!



PLEASE DON'T CHEAPEN OUT ON SAFETY -- SOMEONE'S LIFE COULD DEPEND ON IT!



Step 1 – Power Audit

A POWER AUDIT examines and tabulates the devices you use, HOW you use them, HOW OFTEN you use them and HOW MUCH POWER that translates into

You do this by listing out all the items and devices in your RV that use electrical power and what type. This, in turn, determines:

- How many batteries you need
- How many solar panels you should plan to have to charge those batteries
- How fast you can charge your batteries
- If you will have a “RESERVE” for rainy days
- How large some of your system components will need to be in order to fit into that plan
- Where devices like the ice maker, coffee pot and TV come in

Step 1 – Power Audit

Different Electrical Systems in your RV

- 12 volts DC (batteries)
- 120 volts AC (SHORE power or HOUSE power)
- Solar Panels (will be DC, but a different voltage again)

Understanding this, we might realize it is difficult to compare Apples and Oranges when determining our electrical power requirements. So how can we understand the different forms of ELECTRICAL POWER we see in RV systems and establish a COMMON CURRENCY for them all. A POWER CURRENCY that aids us in sizing our battery systems and our solar panels?

First: A quick overview of DC and AC power and then some PIE to show how it all relates.

DC vs AC Power

DC or Direct Current

DC Power Sources include:

- Household batteries – Like your 9V smoke alarm, 1.5V flashlight, 6V camera or 12V car battery.
- Solar panels are also DC
- Positive is always Positive and Negative is always Negative

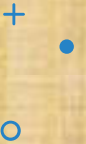
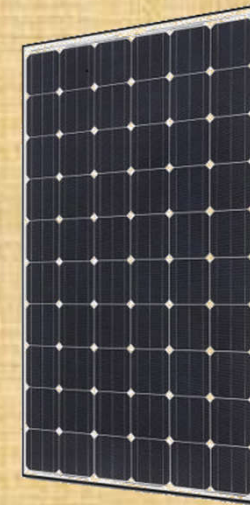
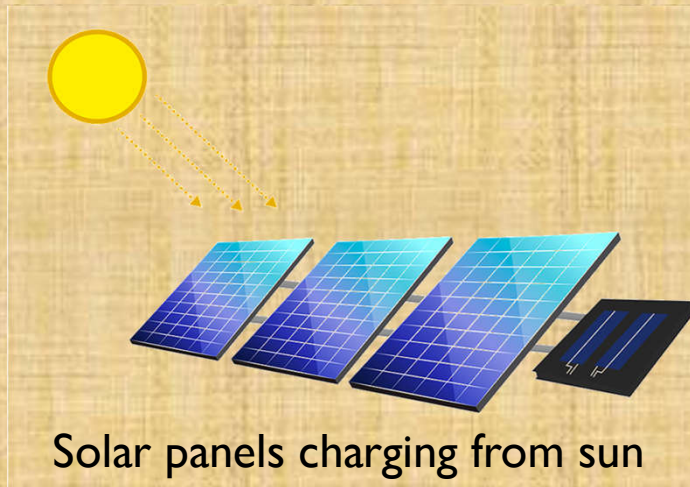
A Safety Note

RV batteries hold a lot of energy and DC power can be quite dangerous, even at low voltages, so caution is deserved!

Solar Panels can also be very dangerous as they run at even higher voltages!

Direct Current runs in one direction, and voltage does not change polarity over time.

Direct Current Sources



DC vs AC Power

AC or Alternating Current

AC Power Sources include:

- Typical household power
- Shore power from an RV pedestal
- An inverter/generator
- A battery power inverter

AC alternates direction, and the voltage polarity changes rapidly over time

Alternating Current Sources



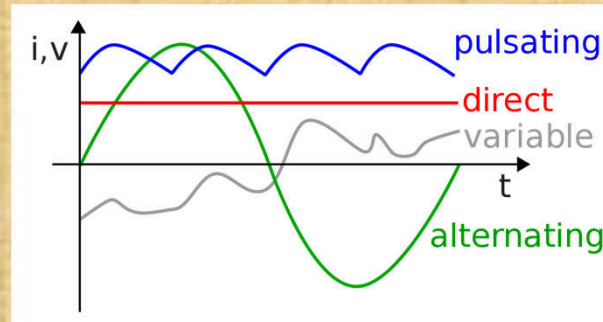
Hydroelectric Dam



AC Power Pole



Typical AC Outlet



AC vs DC (and other) currents



Typical 12V DC - 120V AC RV Inverter



Honda Inverter/Generator

Additional Components

Inverter

- Converts battery (12V/DC) power to household (120V/AC) power

Transfer Switch

- Senses when you an alternate power source and switches to that source (eg: generator, SHORE POWER, inverter)

Converter/Charger

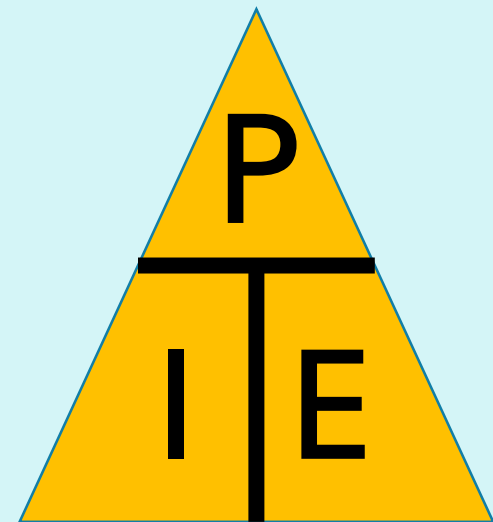
- This charges your RV batteries when plugged into shore power
- Converts household (120V/AC) power to battery (12V/DC) power
- (You probably already have one of these)
- May require upgrading if you change your batteries to Lithium

Shore Power is a nautical term referring to the standard AC (alternating current) power obtained from your home, or RV pedestal

Electrical Power and PIE

A common term for everything Power (P) is Watts (W)

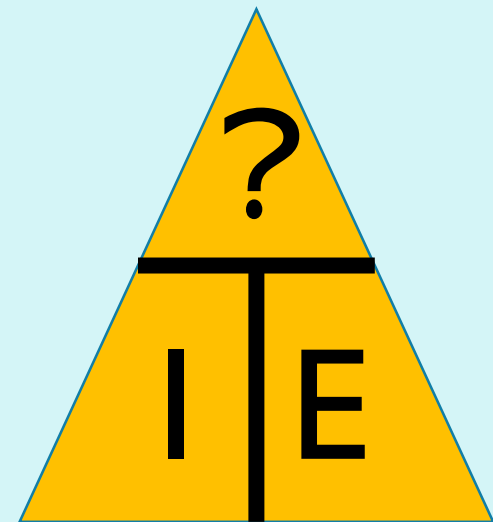
- $P=IE$
- Power (P in Watts) =
 - Current (I in Amps) x Voltage (E in Volts)



Basic Electronics (PIE)

If you know an AC appliance (vacuum cleaner) uses 120 volts and 8 amps, then it's power can be determined by using PIE.

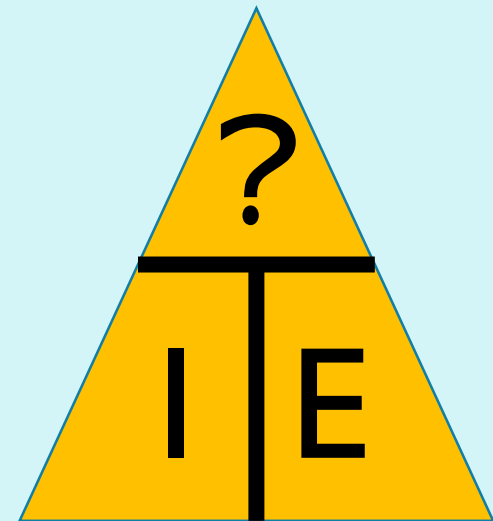
- $P=IE$
- Power (in watts) = 120 volts (E) x 8 amps (I)
 - = 120 x 8
- Power = 960 Watts



Basic Electronics (PIE)

Here is a DC example calculating the power in your battery. If you have a 12-volt battery with a 100-amp capacity:

- $P=IE$
- Power (in watts) = 12 volts (E) x 100 amps (I)
 - = 12 x 100
- Power = 1200 Watts



In a perfect world, your 1200-watt battery could run your 960-watt vacuum for $(1200/960) = 1.25$ hours.

How much power do I use?

12 Volt Devices	
Device	Amps
Aisle lights	0.50
Baggage compartment	0.50
Decorative wall lights	3.00
Dinette light	4.50
Fantastic fan	1.50
Furnace	12.00
Generator start	95.00
Levelling system*	95.00
LP detector	0.20
Map light	1.50
Porch light	1.50
Power awning	10.00
Refrigerator (on propane)	3.00
Phone charger	3.00
Antenna booster	1.00
Vanity light	0.50
Slides (each)*	25.00
Water pump	6.00
CPAP	7.00
Inverter (varies upon load)	

120 Volt Devices	
Device	Amps
Air Conditioner	18.0
Coffee Maker	12.5
Hair Dryer	15.0
Blue Ray Player	3.0
Microwave	12.0
Refrigerator (on AC)	6.0
Satellite Receiver	3.0
Television	3.0
Vacuum Cleaner	8.0
Juicer	5.0
Toaster Oven	12.0
Tool Charger	3.0
CPAP	2.5

Note:

Running 120-volt (AC) devices draws about 10x the current (in amps) from a battery¹

A television using 3 amps will consume 30 amps (360 watts) from your batteries – every hour!

A single 100Ah lithium battery (1280 watts) would be completely depleted in just over 3 hours

¹ – Not including inverter efficiency (typically 85-92%)

How much power do I use?

12 Volt Devices	
Device	Watts
Aisle lights	6
Baggage compartment	6
Decorative wall lights	36
Dinette light	54
Fantastic fan	18
Furnace	144
Generator start	1140
Levelling system*	1140
LP detector	24
Map light	18
Porch light	18
Power awning	120
Refrigerator (on propane)	36
Phone charger	36
Antenna booster	24
Vanity light	2
Slides (each)*	300
Water pump	84
CPAP	78
Inverter (varies upon load)	

120 Volt Devices	
Device	Watts
Air Conditioner	2160
Coffee Maker	1500
Hair Dryer	1800
Blue Ray Player	360
Microwave	1440
Refrigerator (on AC)	720
Satellite Receiver	360
Television	360
Vacuum Cleaner	960
Juicer	600
Toaster Oven	1440
Tool Charger	360
CPAP	300

Note:

Running 120-volt (AC) devices draws about 10x the current (in amps) from a battery¹

A television using 3 amps will consume 30 amps (360 watts) from your batteries – every hour!

A single 100Ah lithium battery (1280 watts) would be completely depleted in just over 3 hours

¹ – Not including inverter efficiency (typically 85-92%)

Power Audit Example 1:

12 Volt System / Devices							120 Volt System / Devices								
Qty	Device	Amps	Watts	Duration	Frequency	Watt/Hrs	Qty	Device	Amps	Watts	Duration	Frequency	Watt/Hrs		
1	Aisle lights	0.5	6.0	4.00	1.0	24.00	1	120" box fan	0.5	55.0	1.00	2.0	110.00		
1	Baggage compartment	0.5	6.0	0.08	1.0	0.48	1	140" HD LED TV	0.7	86.0	4.00	1.0	344.00		
1	Decorative wall lights	3.0	36.0	4.00	1.0	144.00	1	140" HD LED TV (standby)	0.0	1.0	20.00	1.0	20.00		
1	Dinette light	4.5	54.0	2.00	1.0	108.00	1	055" 4K LED TV	1.3	160.0	4.00	1.0	0.00		
1	Fantastic fan	1.5	18.0	1.00	2.0	36.00	1	055" 4K LED TV (standby)	0.0	2.0	20.00	1.0	0.00		
1	Furnace	12.0	144.0	0.08	40.0	460.80	1	Blender	7.5	900.0	0.02	1.0	18.00		
1	Generator start	95.0	1140.0	0.02	2.0	45.60	1	Coffee Pot	10.0	1200.0	0.50	1.0	600.00		
1	Levelling system*	95.0	1140.0	0.08	0.1	13.03	1	Hair Dryer	12.5	1500.0	0.07	1.0	105.00		
1	LP detector	0.2	2.4	24.00	1.0	57.60	1	Ice Maker	1.3	150.0	1.00	1.0	150.00		
1	Map light	1.5	18.0	0.03	2.0	1.08	1	Instant Pot (6qt)*	8.3	1000.0	0.50	0.3	166.67		
1	Porch light	1.5	18.0	4.00	1.0	72.00	1	Juicer	7.5	900.0	0.02	1.0	18.00		
1	Power awning	10.0	120.0	0.03	2.0	7.20	1	Kettle	12.5	1500.0	0.08	1.0	120.00		
1	Refrigerator (on propane)	3.0	36.0	0.08	72.0	207.36	1	Microwave	11.7	1400.0	0.08	2.0	224.00		
2	Phone Charger	3.0	36.0	8.00	1.0	576.00	0	Refrigerator (on AC)	5.1	610.0	24.00	1.0	0.00		
1	Antenna booster	1.0	0.1	8.00	1.0	0.96	1	Toaster Oven	12.5	1500.0	0.08	2.0	240.00		
1	Vanity light	0.5	6.0	8.00	1.0	48.00	1	Tool Chargers**	0.4	50.0	0.50	0.3	6.25		
3	Slides (each)*	25.0	300.0	0.02	0.1	2.57	1	Vacuum*	9.6	1150.0	0.08	0.3	30.67		
1	Water heater	6.0	72.0	0.08	40.0	230.40									
1	Water pump	7.0	84.0	0.05	32.0	134.40									
						Total Watts	2169.5							Total Watts	2152.58

*Based upon moving once every 7 days

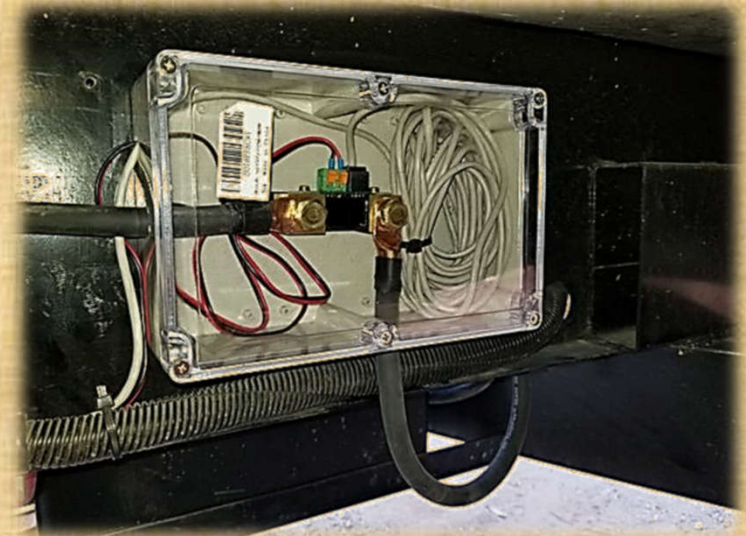
* Based upon using every 3 days
** Based upon using every 4 days

Grand Total Watts 4322.1

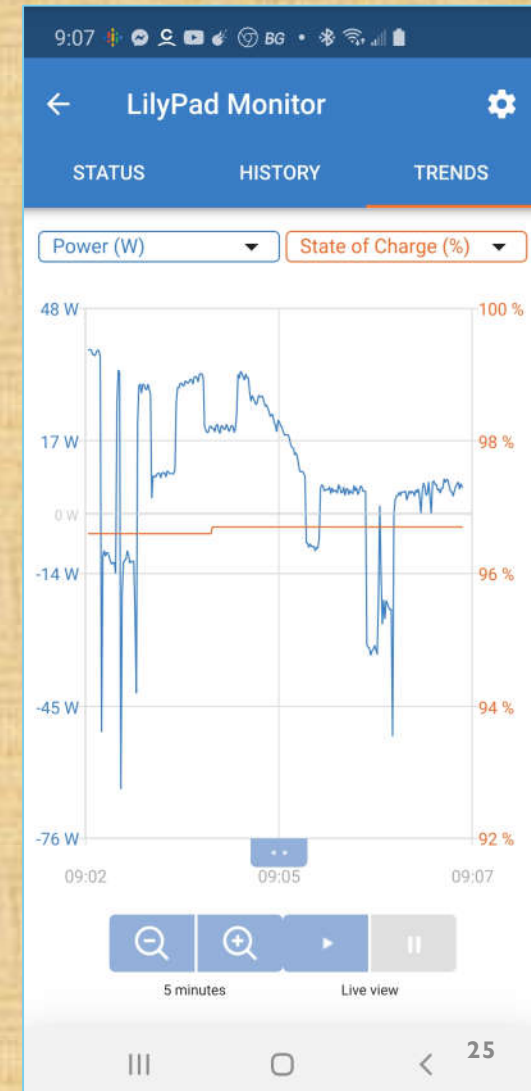
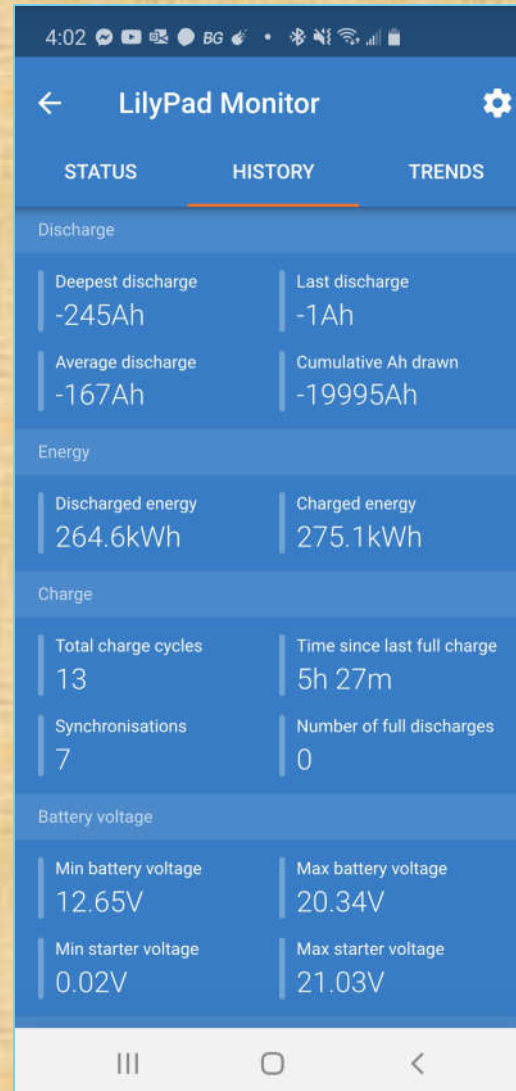
Battery Monitors

An easier & better way to determine your needs

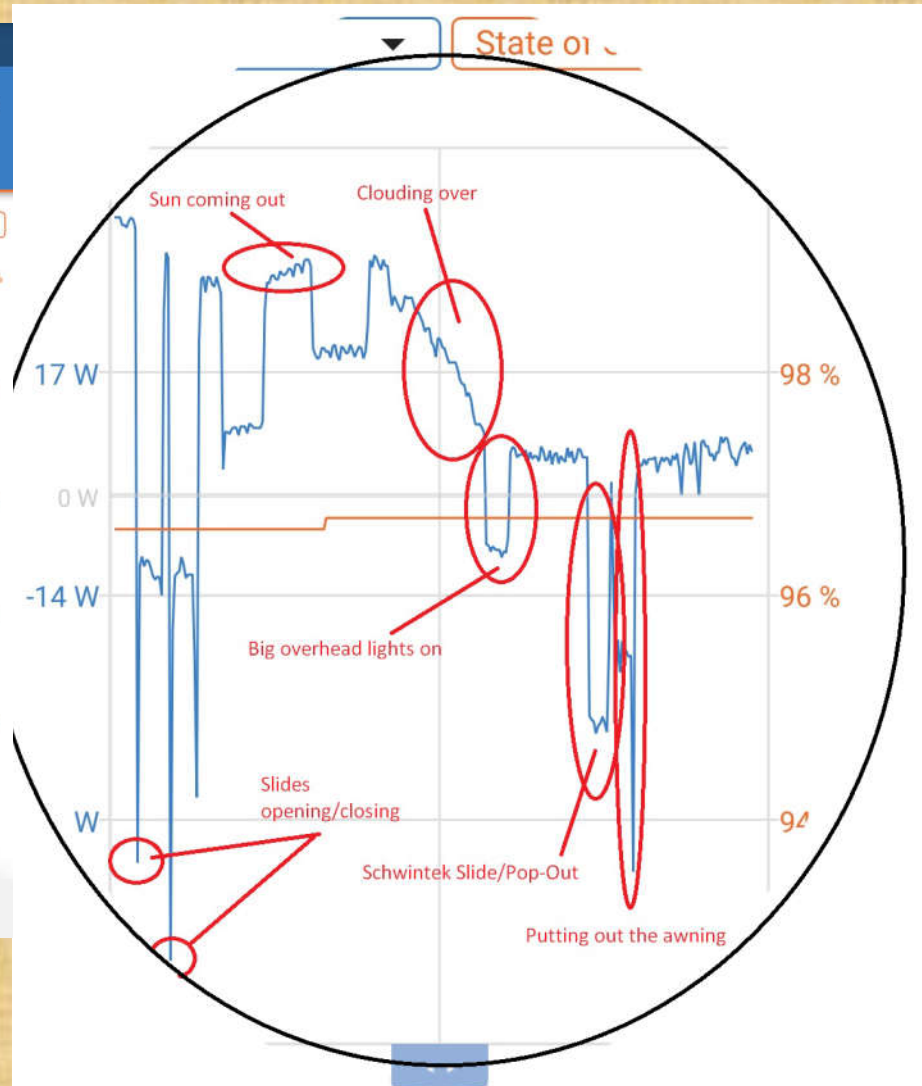
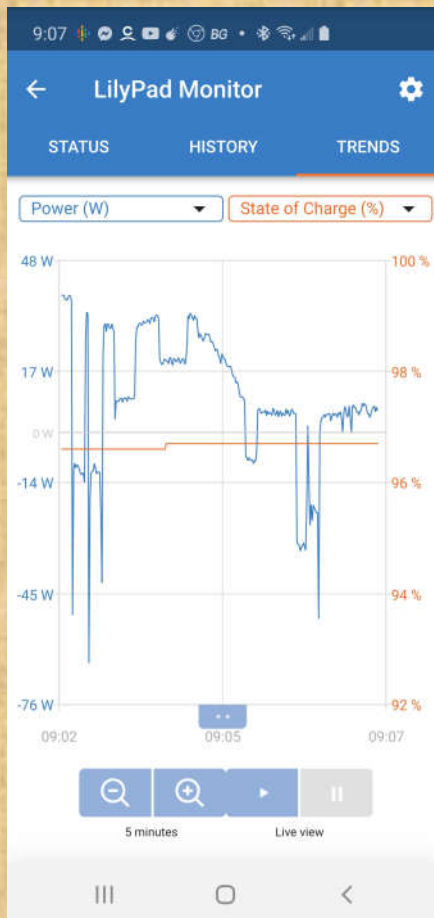
- Extremely accurate
- Measures watts/amps in and watts/amps out
- A common ground for AC and DC power use measurement



Battery Monitors



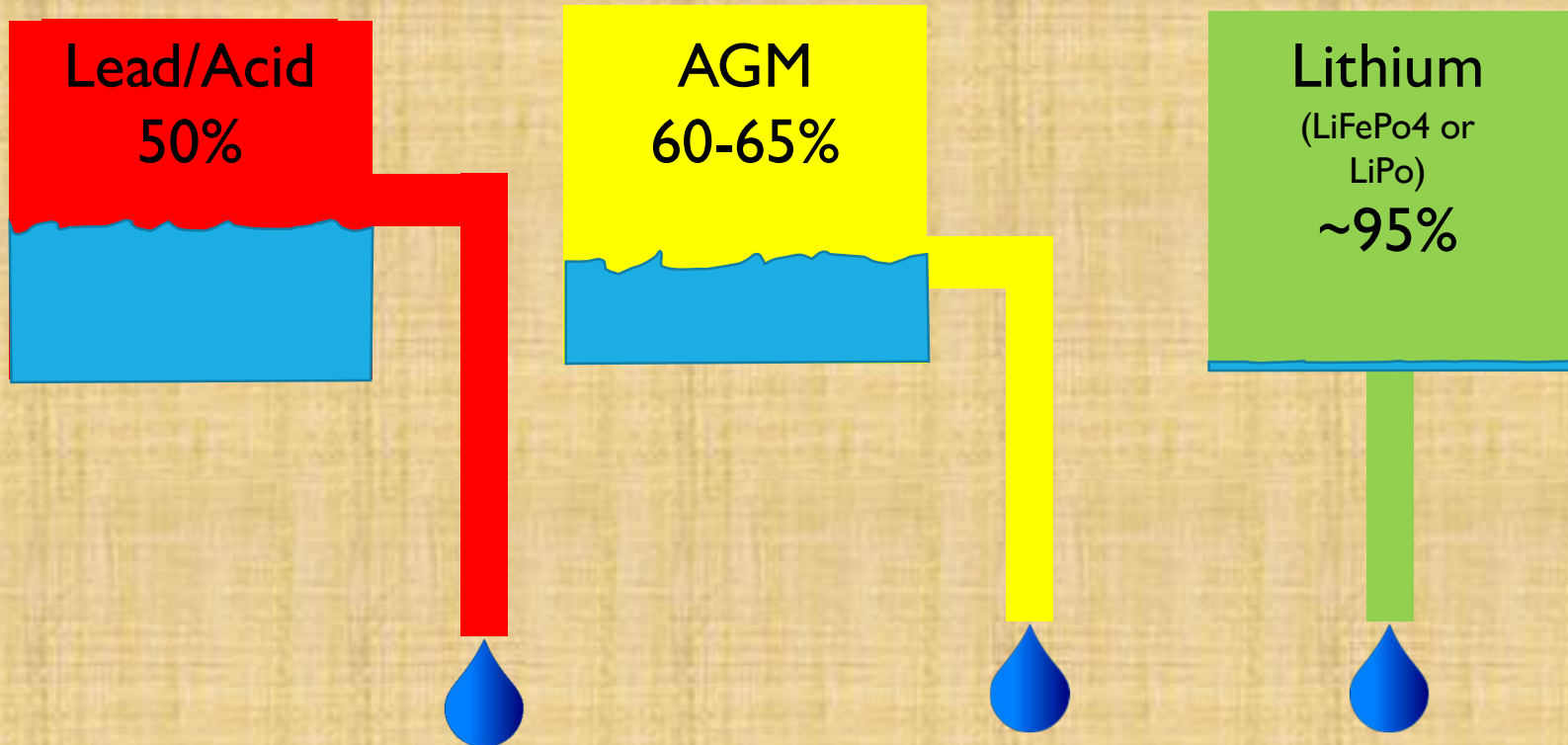
Battery Monitors



Step 2 – Batteries

- **How many batteries will I need?**
- **How do I account for those rainy days?**
- **What are the Pros/Cons of each type?**
- **What type of batteries are best for me?**
- **How and where should I install them?**

Step 2 – Power Capacity



Picture a battery as a fuel tank with the outlet at the minimum level you can discharge to. In other words, you can only tap so much power from each type of battery. Note: Most LiFePO₄'s can be discharged to almost 100% (Normally 95%)

Flooded Lead Acid (FLA)

Pros:

- Lowest cost battery – from \$90 - \$200 each
- Very common and therefore easy to find
- Most RV charging systems (ie: converter/chargers) are designed for these from the factory/dealer
- Tried and true – most service people are very familiar with these
- Typically, a one-year warranty

Cons:

- Only 40-50% of capacity can be safely used without affecting life
- Heavy: A single 12V RV/marine battery weighs over 50 pounds (Group 27 size)
- **MUST** be vented due to gases released during charging
- **MUST** be maintained with periodic checking of water levels
- Poor performance (charge/discharge) in cold weather due to 'slow' chemistry



Flooded Lead Acid (FLA)

Voltage	SOC*	Behavior	
>12.6	100	<i>Fully Charged</i>	<ul style="list-style-type: none"> • Voltages are approximate and can be influenced by temperature – and any potential load on the system • Voltage is best measured after a charge and battery has rested at least 60 minutes at a normal room temperature
12.5	90	Typical	
12.4	80	Operating	
12.3	70	Range	
12.2	60	<i>Lower</i>	
12.1	50	<i>End</i>	
12.0	50	<i>Of Range</i>	
11.9	40	Reduces	<ul style="list-style-type: none"> • Repeated discharges into this zone will reduce your battery life
11.8	30	Life	
11.6	20	Expectancy	
11.3	10	<i>Danger</i>	<ul style="list-style-type: none"> • Permanent damage if left in this SOC
10.5	0	<i>Wil Robinson!</i>	

*What is SOC?

- SOC refers to “State of Charge”, or at what ‘level’ the battery is currently at and referring to where it stands as to its (useable) capacity.

AGM (Absorbent Glass Mat)

Pros:

- No water to add - maintenance free (!!!!!)
- Spill proof design and unlikely to vent dangerous and explosive hydrogen gas
- Superior cold weather performance compared to standard FLA batteries
- Most RV charging systems (ie: converter/chargers) are capable of being configured to suit this type of battery
- Better capacity per amp/hr rating over FLA batteries (60-75%)
- More suitable to rough use environments (used in military)
- Most warranted for 1 to 2 years

Cons:

- Significantly more expensive than standard FLA battery
- Typically, a very heavy battery (70 pounds for Group 27 size)
- Sensitive to overcharging (an incorrect charger configuration can ruin them)
- Shorter cycle life than FLA or LiFePO4 (lithium) batteries



AGM (Absorbent Glass Mat)

Voltage	SOC	Behavior
13.0	100	<i>Fully Charged</i>
12.75	90	Typical Operating Range
12.5	80	
12.3	70	
12.15	60	
12.05	50	
11.95	40	Low End of safe range
11.81	30	
11.66	20	Damage and greatly reduced life expectancy!
11.51	10	
10.50	0	

- Voltages are approximate and can be influenced by temperature – and any potential load on the system
- Voltage is best measured after a charge and battery has rested at least 60 minutes at a normal room temperature

- AGM's tolerate this zone better than FLA

- Permanent damage if left in this SOC for any length of time – but may recover if quickly re-charged.

Lithium Iron Phosphate (LiFePO₄)

Pros:

- Very safe – no venting or spillage built-in battery safety mechanisms
- Intelligent – with an on-board Battery Management System (BMS)
- Completely maintenance free
- Will typically provide very close to full rate Ah capacity (90-105Ah)
- Much superior cold weather performance to FLA/AGM batteries
- Very light – typically between 28 and 35 pounds (vs 50-80 pounds)
- 3000 or more life cycles (some rated for over 5000 – leave them in your will)
- Most warranted for a minimum of 3 years (some are lifetime)
- Charges **VERY** fast, about ½ the time of FLA or 2/3 the time of AGM

Cons:

- Highest in initial cost of all battery chemistries listed here
- Some makes/models will require a charger/converter upgrade
- Not all solar controllers can be properly configured to use
- Did we mention they are expensive? However, over their lifespan, much cheaper

Permanent and catastrophic damage will occur if Lithium batteries are charged at temperatures below 0 degrees Celcius, 32 degrees Fahrenheit.

Lithium Iron Phosphate (LiFePO₄)

More about Lithium (LiPO's)

- Using voltage to calculate SOC is not advised
- Battery monitor and shunt most reliable method
- Lithium batteries **MUST NOT** be charged below freezing as permanent physical damage will occur due to “plating” of the electrodes
- Lithium batteries can still SUPPLY power below freezing
- Good lithium/LiFePO₄ batteries will not only have a BMS, but a low-temperature cut-off, or battery warming system to prevent taking a charge below freezing

You can still use power from LiPO's below freezing – you just can't charge them!



A Word About Battery Sizes

There are 4 or 5 commonly occurring battery sizes used in RV's and automobiles, generally the higher the number, the larger the physical size and power available

Battery Sizes				
Group	Length	Width	Height	Common Models and Uses
24	10.3	6.8	8.9	Small car battery Used in many late model, base model automobiles
27	12.1	6.8	8.9	Common 12V RV battery – stocked by most dealers
31	13.0	6.8	9.4	Another common RV battery BattleBorn lithium batteries are this size
GC2	10.3	7.1	11.2	A common deep cycle 6V “golf cart” battery Trojan T105's are this size (installed in pairs)
CAT/4D	21.0	8.1	9.4	Class “A” Motorhomes will often have a pair of these

6V, 12V or 24V Battery Banks

6V (volt) battery systems

- Batteries must be installed 2-in-a-series to supply the 12 volts common to most RV's. When batteries are connected in series, voltage is added ($6V+6V=12V$) but the current capacity (AmpHours) remains the same as the one individual 6V battery
- Biggest benefit: The deep-cycle golf-cart style batteries used have large current capacity (225+ Ah) due to their thick plates...which means...
- These batteries are heavy – a typical 2-battery system weighs almost 150 pounds

12V (volt) battery systems

- When connected in parallel, the voltage remains the same as the one individual 12V battery, but current increases
- Drawback: A group of 12V batteries typically has less current/power capacity as a group of 6V batteries
- A side benefit: If a single battery fails, it can be removed, and RV still maintain functional, albeit with reduced available power (watts).

24V (volt) battery systems

- 24-volt systems are not common, but gaining popularity
- Using higher voltage allows you to use lighter wiring
- A 'step-down' or 24V-12V converter is required to run most RV components such as stereos, lights, water pumps, furnaces etc..

Series & Parallel Battery Banks

bonus points for anyone who can see a design issue with 12V bank in Diagram 1

Figure 1

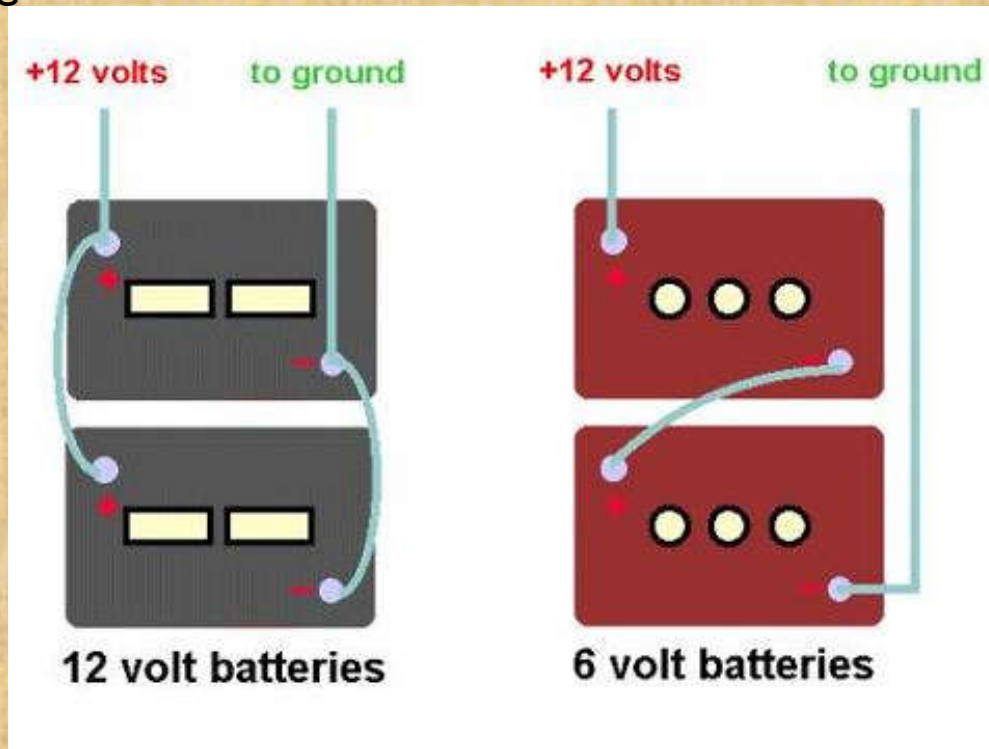


Figure 2

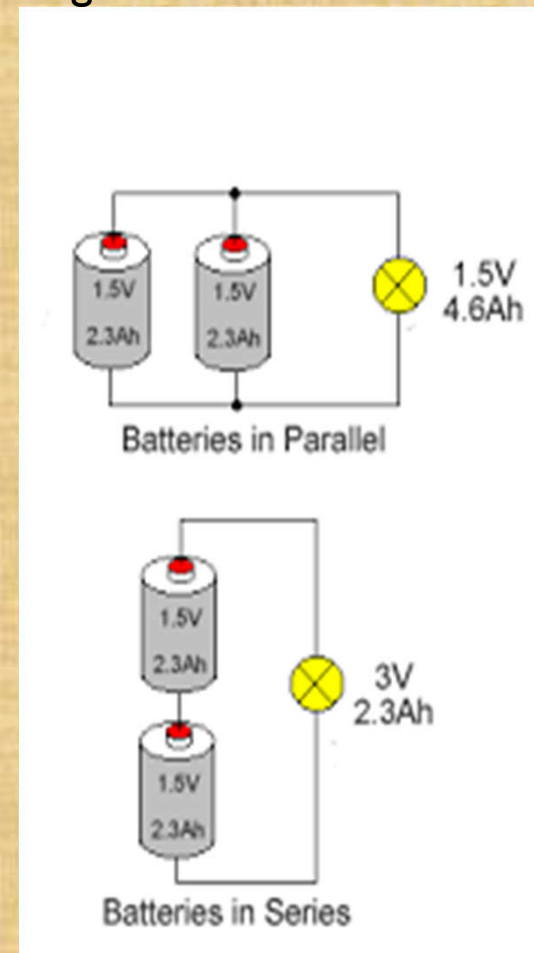


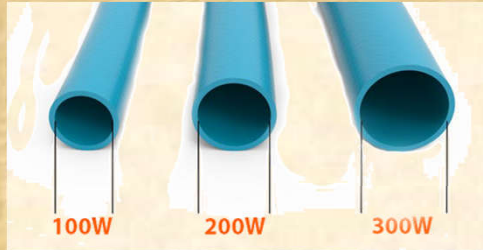
Figure 3



Step 3 – Solar Charging



The primary purpose of a solar energy system is to be the gas station that re-fills your tank!



Solar Panels

How big is your fuel tank?



Battery Group



Solar Controller

How fast do you use fuel?



Your Power Use

Battery Monitor



How empty do you let it get?

Power Audit - Example 2:

12Volt System / Devices							120Volt System / Devices						
Qty	Device	Amps	Watts	Duration	Frequency	Watt/Hrs	Qty	Device	Amps	Watts	Duration	Frequency	Watt/Hrs
1	Baggage compartment	0.5	6.0	0.08	1.0	0.48	1	120" box fan	2.0	240.0	1.00	2.0	480.00
1	Decorative wall lights	3.0	36.0	4.00	1.0	144.00	1	140" HD LED TV	0.7	84.0	4.00	1.0	336.00
1	Dinette light	4.5	54.0	2.00	1.0	108.00	1	140" HD LED TV (standby)	0.0	1.2	20.00	1.0	24.00
1	Fantastic fan	1.5	18.0	1.00	2.0	36.00	1	Blender	7.5	900.0	0.02	1.0	18.00
1	Furnace	12.0	144.0	0.08	40.0	460.80	1	Coffee Pot (brewing)	10.0	1200.0	0.20	1.0	240.00
1	LP detector	0.2	2.4	24.00	1.0	57.60	1	Coffee Pot (keep warm)	2.0	240.0	0.01	120.0	288.00
1	Map light	1.5	18.0	0.03	2.0	1.08	1	Popcorn Machine	1.0	500.0	0.20	1.0	100.00
1	Porch light	1.5	18.0	4.00	1.0	72.00	1	Juicer	7.5	900.0	0.02	1.0	18.00
1	Power awning	5.0	60.0	0.03	2.0	3.60	1	Kettle	12.5	1500.0	0.08	1.0	120.00
1	Refrigerator (on propane)	3.0	36.0	0.08	72.0	207.36	1	Microwave	11.7	1404.0	0.08	2.0	224.64
2	Phone Charger	3.0	36.0	8.00	1.0	576.00	1	Toaster Oven	12.5	1500.0	0.08	2.0	240.00
1	Antenna booster	1.0	0.1	8.00	1.0	0.96	1	Tool Chargers**	4.0	480.0	0.25	1.0	120.00
1	Vanity light	0.5	6.0	8.00	1.0	48.00			0.0		0.00	0.0	0.00
1	Water pump	7.0	84.0	0.05	32.0	134.40			0.0		0.00	0.0	0.00
Total 12V 1850.3 Watts							Total 120V 2208.64 Watts						
							Grand Total Watts 4058.9						

Battery Capacity

How many batteries do you need?

	Type	Battery Voltage	# of Batteries in 12V Group	Amps /Battery	Total Amps	Total Watts	Useable Watts	\$ each	\$ total	\$ per Watt	W/L
1	IS GC2-ECL-UTL	6V	2	225	225	2700	1350	190	380	.28	1/5
2	IS GC2-ECL-UTL	6V	4	225	450	5400	2700	190	760	.28	1/5
3	12V Deep Cycle	12V	1	105	105	1260	630	200	200	.32	1/3
4	12V Deep Cycle	12V	2	105	210	2520	1260	200	400	.32	1/3
5	12V AGM	12V	1	105	105	1260	756	340	340	.45	2/3
6	12V AGM	12V	2	105	210	2520	1512	340	680	.45	2/3
7	Lithium	12.8V	1	100	100	1280	1216	850	850	.66	3+/7+
8	Lithium	12.8V	2	100	200	2560	2432	850	1700	.66	3+/7+

Batteries Used:

- **1,2: Interstate: GC2-ECL-UTL / 6 Volt Golf Cart Battery**
- **3,4: Canadian Tire Deep Cycle / Group 31 Size**
- **5,6: Canadian Tire Nautilus Series / Group 31 Size**
- **7,8: Lynac True Series with cold weather protection / Group 27 Size**

W/L refers to the battery warranty and expected lifespan using optimal maintenance and charge/discharge procedures

How Many Panels???

How many panels do you need?

The number of panels you will need depends on the following:

- How many watts can each panel produce? (ie: size and efficiency)
- How many hours of each day will you have **productive*** sunshine?
- Angle of the sun? (latitude & time of year affect this)
- Are panels flat, tilted or portable?
- Is there typically cloud cover, shading by trees?
- What type of panel construction? Mono, poly, bypass diodes?
- How warm will your panels get? (cooler is better)

***productive – when sunlight is brightest and most direct during the day**

How Many Panels???

Method 1: Rule of Thumb Method

- At very minimum: *Two watts for every Amp/Hour of battery*
- Eg: A 100Ah battery would, at minimum, require 200 watts of panels

Using our own 4000-watt example from before, we calculate how many amps that would be and use the following calculation:

- $4000 \text{ watts} / 12 \text{ volts} = 350 \text{ amps}$
- Rule of thumb says 2 watts/amp.
- $2 * 350 = 700 \text{ watts of solar panels}$
- 3x 200-watt panels would produce 600 watts, or...
- 4x 200-watt panels would produce 800 watts.

This gives you a requirement of between three (3) and four (4) 200-watt panels.

*depending on battery type / chemistry

How Many Panels???

Method 2: Panel Efficiency Method

- This assumes panels typically are 65% efficient over the course of a day
- A single 100Ah battery @ 12V has 600-1200 watts of useable power*

Assuming 600 watts of power required to re-charge battery

- Assuming 5 hours of sun with 65% panel efficiency per single 200-watt panel
 - $5 \text{ hours} \times 65\% \times 200 \text{ watts} = \text{power production per day}$
 - $5 \times .65 \times 200 = 650 \text{ watts of power production per day}$
- The number of panels required:
= $600 \text{ watts (battery)} / 650 \text{ watts (of solar)} = .92 \text{ panels (rounded up to one panel)}$

One, 200-watt panel, with 5 hours of sun per day will recharge a single 12-volt battery

*depending on battery type / chemistry

How Many Panels???

Method 3: Solar Insolation Method

- Uses a value called the INSOLATION value
- INSOLATION VALUE refers to the amount of SOLAR POWER delivered to each specific geographic area
- You can find an INSOLATION VALUE for any month of the year
- Take the power you require via your POWER AUDIT and divide that by your INSOLATION VALUE
- That value becomes the size of your SOLAR PANEL or SOLAR ARRAY (group of panels)

SOLAR INSOLATION VALUES for your area can be found at many online resources

Several solar energy apps are available to do the same thing on both the Apple and Android platforms

How Many Panels???

How many panels do you need?

Quesnel			
Month	Watts Needed	Insolation	Array Size (watts)
Feb	4000	1.82	2198
May	4000	5.43	737
July	4000	5.73	698

Summerland			
Month	Watts Needed	Insolation	Array Size (watts)
Feb	4000	2.22	1802
May	4000	5.48	730
July	4000	6.36	629

Yuma, AZ			
Month	Watts Needed	Insolation	Array Size (watts)
Feb	4000	4.06	985
May	4000	7.41	540
July	4000	7	571

These values have NOT been temperature corrected

How Many Panels???

How many panels do you need?

Quesnel				
Month	Panel Size (w)	Insolation	watts/day	4 panels
Feb	200	1.82	364	1456
May	200	5.43	1086	4344
July	200	5.73	1146	4584

Summerland				
Month	Panel Size (w)	Insolation	watts/day	4 panels
Feb	200	2.22	444	1776
May	200	5.48	1096	4384
July	200	6.36	1272	5088

Yuma, AZ				
Month	Panel Size (w)	Insolation	watts/day	4 panels
Feb	200	4.06	812	3248
May	200	7.41	1482	5928
July	200	7	1400	5600

These values have NOT been temperature corrected

Final Word on Solar Panels

Discussing solar panels and their various attributes could almost be a presentation all by itself. There are lots of online resources available if you really want to dig in. So I am just going to cover the basics here.

- **Mono vs Poly**
- **Mounted vs Fixed**
- **Residential vs RV**
- **Flexible Panels**
- **Series vs Parallel**
- **Tilting your panels**
- **General Design and Electrical Specifications**

In Summary



Additional Components

Optional Components

- Inverter
- Transfer Switch
- Battery Monitor with Shunt
- Bluetooth Applications



Safety Components

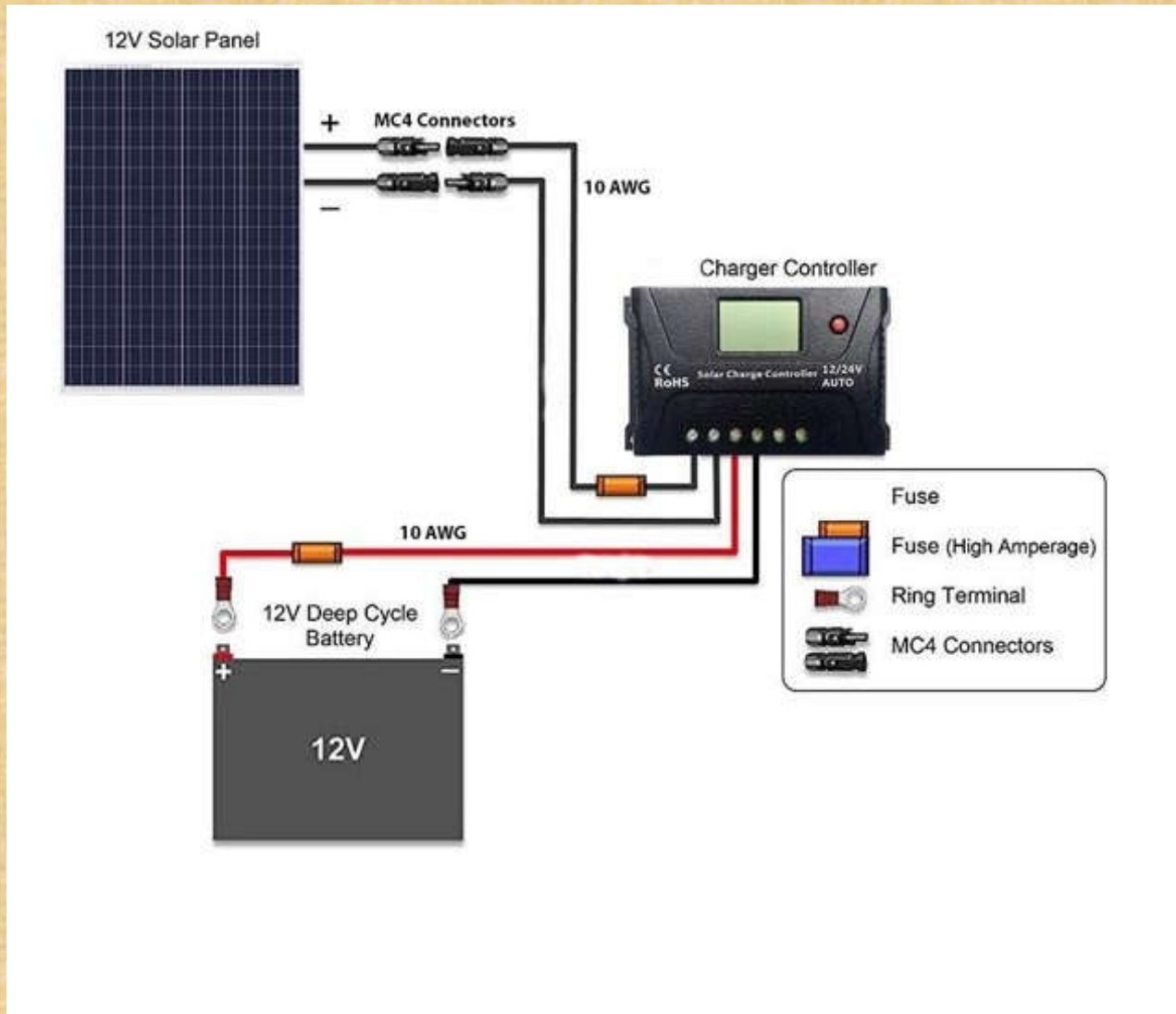
Wiring

- PV cable for panels to controller (sized for voltage and amperage)
- Appropriate gauge wire from controller to batteries
- Heavy gauge for batteries to inverter (if installed)

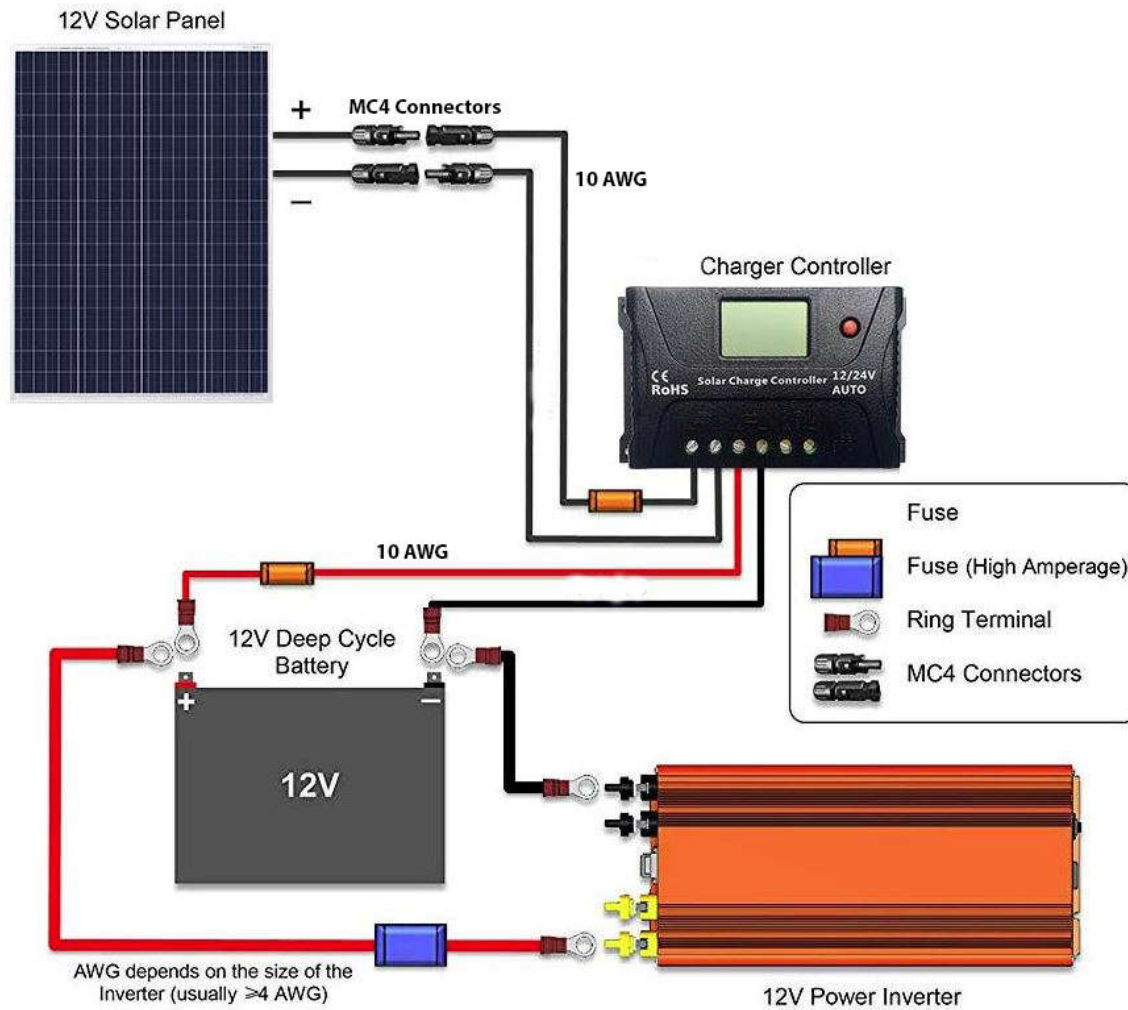
Safety Devices

- DC (NOT AC) circuit breakers and fuses on solar and controller side
- Fast acting fuses to protect inverter
- Circuit breakers for AC circuits and solar panel, DC circuits
- Temperature monitors for battery (for appropriate charging profile)
- Battery disconnect to turn off all battery power to system

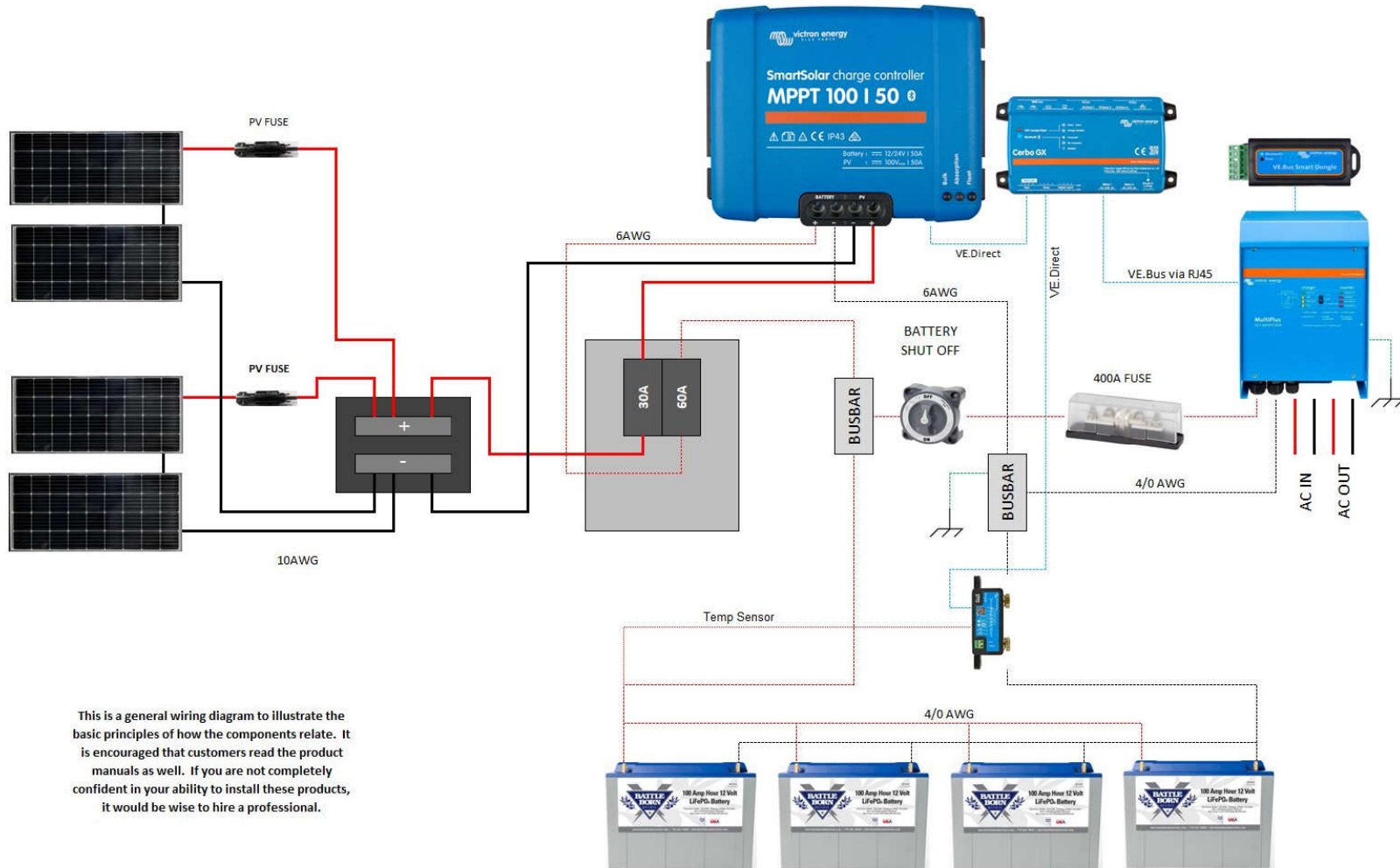
Minimalist Solar Setup



Basic Solar Setup + AC

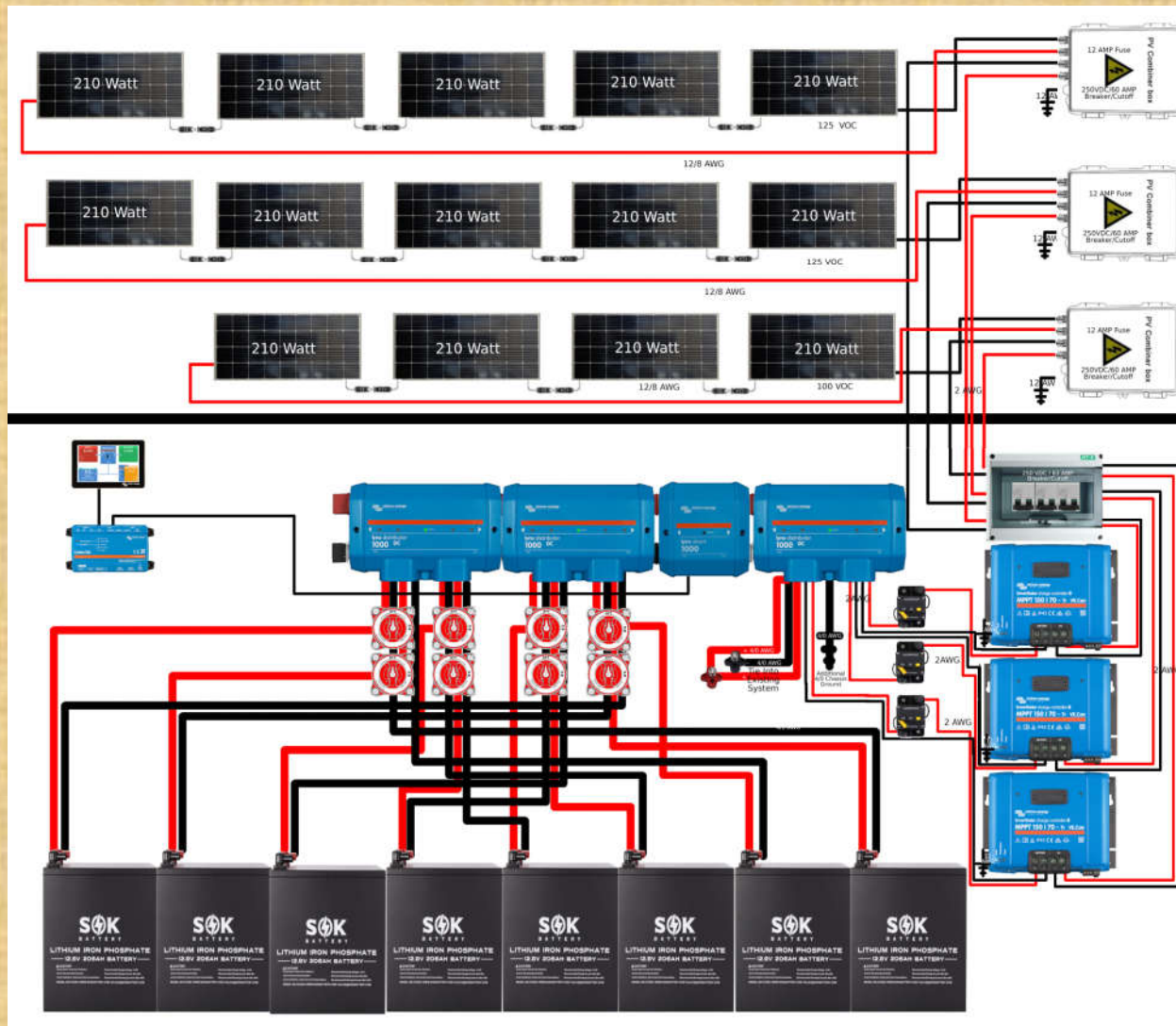


Intermediate Solar Setup



This is a general wiring diagram to illustrate the basic principles of how the components relate. It is encouraged that customers read the product manuals as well. If you are not completely confident in your ability to install these products, it would be wise to hire a professional.

Sky is the Limit!



What it Can Cost...

Component	Minimalist	Basic	Mid
Batteries	\$300 (Deep Cycle 12V)	\$500 (AGM)	\$900 (Lithium)
Panels	\$1.00 - \$2.00 / Watt		
Inverter	<\$150.00	\$300	\$2000+
Solar Controller	PWM / <\$100	MPPT \$200-\$300	\$400+
Wiring & Safety	<\$100	\$200	\$300

Some Brand Names

- **Safety Equipment and Wiring**

- Blue Sea Systems

- **Solar Controllers**

- BlueSky
- Midnight Solar
- Sunix
- GoPower
- Renogy
- Windy Nation
- Victron
- Outback

- **Inverters**

- GoPower
- Xantrex
- Victron
- Renogy
- Xantrex

- **Solar Panel Manufacturers**

- Canadian Solar

- **Batteries - Conventional**

- InterState
- Trojan

- **Batteries - LiPO**

- HUB Power (CA)
- BattleBorn (US)
- Lyncac (CA)
- LiON (US)
- SOC (CA)
- Renogy

Where to Get Help?

- YouTube
- Books
- Your RV manufacturer
- Your RV dealer
- Your RV friends
- Local College or Training Institute

Back to Me

My business, Silver Lining Solar, is specifically dedicated to the consulting and installation of solar products within the RV space.

I am a big solar enthusiast, and am more than happy to spread the word, so feel free to email me or call me anytime – even if it's just for free advice.

Thanks for your time and safe travels

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