Solar Power and RV's

I'm adding these notes after the presentation and will to my best to fill in some of the blanks.

Introduction

- Full disclosure, I don't have solar panels on my RV. I have considered adding them.
- Retired electrical engineer.
- I've studied this topic, but not at great depth.
- My findings might not align with what you expect.
- The numbers are typical, but in the ballpark.
- Things are changing all the time.

Solar is very popular, but there are caveats. I think the message is we need to understand what we are trying to accomplish and then see if the available solutions fill the bill in an affordable and reliable way.

What I did not mention is that many believe that solar will meet all of their electrical needs.

Finally the situation looks different today than it did just a few years ago. We now have LED lights which make a huge difference. We also have LiFePO4 batteries which are much more affordable than they were a few years ago.

Electrical Hazards, High Voltage

- Be careful!
- Electricity is invisible but will act instantly under the right conditions.
- Electric Shock is a real danger and the amount of current required to put your heart into fibrillation is far lower than the circuit breakers in your rig.
- If you receive a severe shock, get medical attention, there can be delayed effects.

The message is one needs to be careful with electricity. Both the shock and physical hazards can catch you by surprise. Do a proper job and don't cut corners. Just because it appears to work is not sufficient.

Automotive seat belts are a great example. They do nothing until you have an accident and then they can make a huge difference in the outcome.

Electrical Hazards

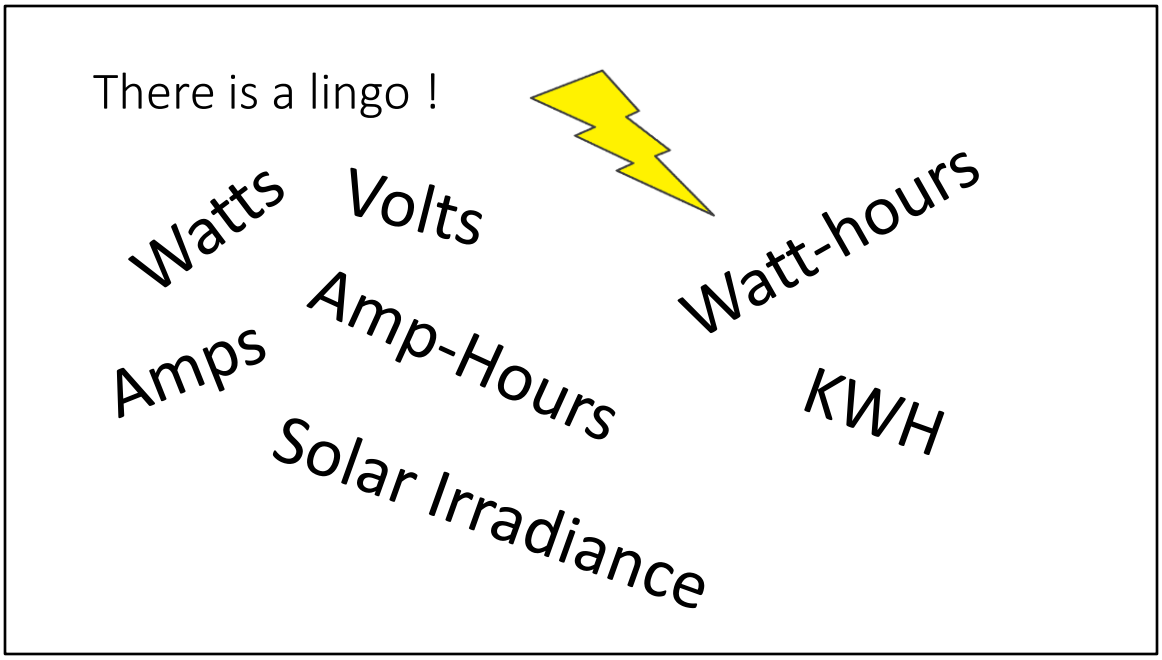
- With the low voltage circuits in the RV incredibly high currents are possible. A wedding ring can turn white hot in an instant and ruin your day!
- Be certain you understand what you are doing when working on electrical systems in your RV.
- There are multiple energy sources all interconnected. Lots of opportunities to get into trouble.
- Use proper wire size, current limiting devices & physical protection. Lots of shape edges and water!

Unrealistic Expectations

- The salespeople don't understand this either and really believe what they are telling you.
- Practice is usually less than theory. There are always factors not properly accounted for.
- Like car fuel economy, one rarely does as well as advertised.
- Yes, you can go off grid, but you will have to compromise.
- Solar is not "on demand power."
- There will be good days and/or good locations.

Again, understand the goals and see if it matches up with the proposed solution.

The two biggest challenges with solar are the it is not on-demand and you must have a place to store the energy. A gallon of gasoline is about 7 KWH of electricity from the generator. 7 KWH is more than the 600 amp-hours of batteries new Roadtrek have.



There is a lot of nomenclature. The important thing is to understand the difference between power and energy. Delivering power is one thing delivering it over a long period of time is something else. Making coffee is about the same power as running the AC but the energy is far greater for the AC even in a few hours.

Voltage

- Units: Volts, defined as electromotive force.
- By itself voltage can't do any useful work.
- DC or direct current is naturally produced by batteries and solar panels.
- AC or alternating current is what we get from the utility or Onan generator.
- Converting DC to AC is not free, you lose energy in the process.
- Just knowing the voltage does not tell you what is going on. It just tells you that there is the potential for current and work to be done.
- Easy to measure

Voltage is useful, but you need to know the current as well.

Current

- Units: Amps, defined as the movement of electrical charge.
- If current is flowing you are probably doing work, how much is another question.
- It takes both voltage and current to do work.
- You must “break” the circuit to measure current or use a clamp style meter to measure current.
- It is very easy to damage a conventional ammeter when making a measurement.
- Not all camp meters measure DC current.

If you have current flowing then you are probably doing work, and that work might be heat.

Power

- The rate of doing work, like rate of pay or miles per hour.
- Units: Watts, the product of voltage and the current.
- Power tells you that work is being done, but it takes time and power to do work.
- You can have very high power, but little or no work!
- Power is a “rate” of energy use or production. A 100-watt bulb run for 10 hours is 1000 watt-hours. A 10-watt bulb run for 100 hours is also 1000 watt-hours.
- The amount of power naturally varies over time.

Power is the rate, it takes time to do work.

Energy (Work)

- Units: Watt-hours or KWH. Watts x time = Watt-hours.
  1 KWH is 1000 Watt-hours.
- We don't use power constantly, so to compute energy use we have to measure the power over small intervals and then add up the values to get the energy usage. Your watt-hour meter at home does this.
- A high rate or power over a long period of time is high energy.
- A high rate over a short period of time is lower energy.
- You might not be able to deliver the power even for a short period of time.

Amp-Hours

- Essentially how long a battery will deliver a given current.
- For example, 100 amp-hour battery can in theory deliver 10 amps for 10 hours.
- Because the “voltage” is known, it’s a proxy for watt-hours.
- Multiply the amp-hours * the nominal voltage and you get watt-hours.
- AGM batteries can only be discharged to 50 % so the rating is effectively half. A 100 amp-hour battery has 50 available amp-hours.
- LiFePO4 batteries can be taken down to 30% or even lower. Like any battery, the more you cycle it the shorter the lifespan.

The big takeaway here is that amp-hours tell you about the stored energy, but the cost of getting it all in shortened battery life must be considered.

Solar Irradiance

- This is measured in watts / square meter.
- The sun puts out energy across the spectrum, but the usable energy is in the range of 400 to 700 nano-meters.
- On a sunny day in Phoenix, the energy available to convert into solar energy is about 1000 watts / square meter of area, or about 93 watts per square foot.
- Solar panels are about 25% efficient, so you can get about 21 watts per square foot.
- Panel orientation, shade, clouds, dirt and temperature will reduce the available energy production.

Good days and bad days. While you will get some power in the shade or on cloudy days, you won't get useable amounts.

The orientation of fixed solar panels is carefully considered. This is not the case when you park your RV.

Where are we using energy?

- Smoke, CO and Propane Detectors
- Gas Furnace and Water Heater Controls
- Lighting
- Computers
- Charging Phone
- TV
- Exhaust Fan
- C-pap Machine
- Microwave Oven
- Coffee Pot
- Induction Cooktop
- Toaster / Oven
- Hair Dryer
- Air Conditioner

There are lot of things which use electricity. Oddly enough most things are either high power or low power with few things in between.

Most things have labels, but you can easily measure power with a simple device called a Kill-o-watt available at home improvement stores. In the 20 to 30 dollar range.

How much Energy do These Things Require

- Detectors and controls are very low. Less than 5 watts. In 24 hours, that would be about 120 watt-hours or 0.120 KWH.
- With LED lights in my rig running all of them at once is only 24 watts. In 8 hours, that would be about 200 watt-hours or 0.200 KWH.
- The Exhaust fan on high runs about 24 watts. 8 hours at 24 watts is about the same as running all the lights.
- A c-pap machine requires between 50 and 90 watts. 8 hours at 90 watts is about 720 watt-hours. These vary greatly.

Low Power / Low Energy Devices

Device	Power Watts	Hrs/Day	Energy KWH/Day
Computer/TV	50	2 hrs	0.100
Cell Phone Charger	<5	8 hrs	< 0.040
Exhaust Fan Hi	18	8 hrs	0.216
4 Lights (18w each)	72	10 hrs	0.720
4 LED (1w each)	4	10 hrs	0.040

How much Energy (continued)

- Microwave Oven
  - A microwave oven of the size found in most Roadtrek's requires about 1200 watts. The oven power will be less. Microwave ovens have high inrush currents can be difficult for an inverter to start.
  - 20 minutes of cooking is about 400 watt-hours or 0.400 KWH.
- Induction Cooktop
  - These device can draw 1300 watts on high. About the same as the microwave so for example 10 minutes would be 0.217 KWH.
- Hair Dryer
  - 1280 watts so do the math. 10 minutes is about 0.240 KWH.

The inrush for the AC is well known, but I was unaware of how difficult it is to start a microwave using an inverter. It is of much shorter duration, but tough for an inverter to deal with.

How much Energy (continued)

- Coffee Pots vary, but generally are about 1000 watts, but only run for a few minutes. If your pot has a "warmer," then that adds to the consumption.
- Dometic A/C Cool-Cat 11.1 amps running 50-plus amps to start. 11.1 amps x 120 volts = 1320 watts.
- Run it for 4 hours. 4 x 5,280 watt-hours or 5.28KWH, 8 hours would be 10.5 KWH.
- The A/C, like the microwave has high inrush current. This is why your generator struggles a bit when you switch on the AC.

High Power Devices

Device	Power Watts	Hrs/Day	Energy KWH/Day
Coffee Pot	1025	6 min	0.103
Hair Dryer	1600	10 min	0.270
Microwave	1300	15 min	0.325
Toaster Oven	1500	30 min	0.750
A/C / Space heater	1400	8 hrs	11.2
Frig on DC	175	12	2.1

I really wanted to run the microwave, and this is quite reasonable with LiFePO4 batteries. A lot tougher with lead-acid.

Sources of Energy

- Park Power
  - Up to 3600 Watts with a 30-amp circuit. Way beyond your needs.
- Generator (Onan) 2800 Watts (11 gallons / day at full load.)
- Under-hood Generator (Some Roadtrek Models) In theory, 3400 Watts In practice a lot, less, 2000 watts? I don't know.
- Vehicle Alternator
  - 600 Watts (Limited at idle due to heating.)
  - Run the vehicle loads in addition to RV battery charging.

The alternator is limited to about 50 or 60 amps just due to the circuit breaker. They can get really hot at idle, so idling your vehicle to charge a LiFePO4 battery is tough on the alternator. I am still learning about this.

One issue that people see with LiFePO4 batteries and boats is that the battery may "switch" off once charged to avoid overcharging. This can damage the alternator. Not an issue with cars since there is a vehicle battery in the circuit.

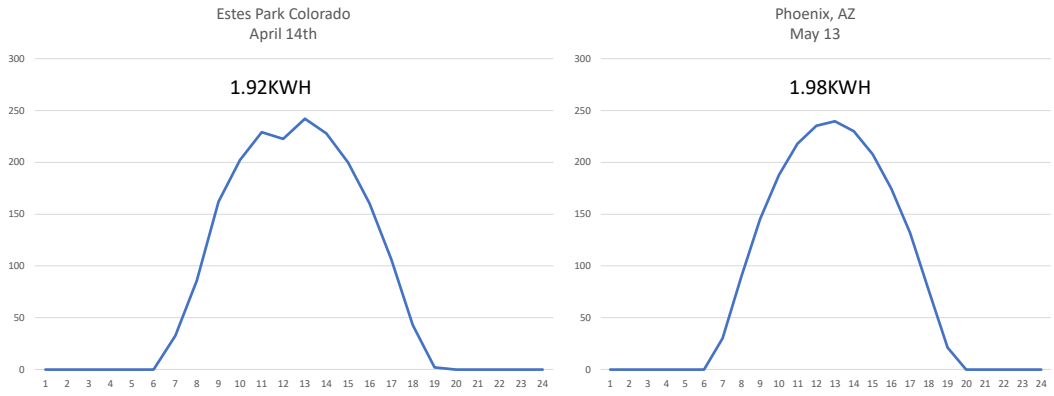
Solar Energy

- Recent Roadtrek's come with a 300-watt panel, and many have 600 watts or more. (Only so much roof area.)
- Because the sun does not shine all the time, I found some data for a location I like. Estes Park, CO.
- A 300 watt panel on the best day of the year in full sun, oriented flat will produce 242 watts max and generate 1920 watt-hours or 1.92KWH. Per day. A 600-watts would double the output.
- You can find the calculator here: https://pvwatts.nrel.gov/pvwatts.php
- To make use of this "free energy" you need to have a bucket to catch the energy you can't use immediately. Once the bucket is full, you can't save it.

The calculator is fun to play with. Of course these are just predictions, the weather is variable.

Typical Maximum Solar Output

This is in full sun without shade.
Most of us want a shady spot!



While solar is available all day, in truth the real output is restricted to a limited number of hours per day.

Energy Storage

- Lead Acid Batteries (Flooded, AGM & Gell)
  - Older Roadtrek's had 1 or 2 65 amp-hour batteries.
    Newer units have 2 100 amp-hour batteries.
    Remember 2 12-volt 100 amp-hour batteries is the same capacity as 2 6-volt 200 amp-hour batteries. Energy is amp-hours * voltage. (Don't forget you can't discharge all the way.)
- LiFePO4 Batteries
  - 100 amp-hour 12-volt batteries about becoming quite common in RV's. Newer Roadtrek's have 600 amp-hours of capacity which works out to about 5.4 KWH when you factor in the permitted depth of discharge.

Lead acid is more affordable, but the life cycle cost of LiFePO4 batteries is probably less. However they are not drop in replacements. They will work, but one needs to cautious.

Wasted or Lost Energy

- Once the battery is charged, excess solar energy is lost, there is no place save it.
- Conversion loss from DC to AC. 85 to 95 % Always specified under the best conditions.
- Rapid Consumption (Lead Acid) Runs down much faster under heavy load. While you could run a 100 amp-hour battery at 50 amps, it won't last very long and you will shorten the battery life.
- 20% is a petty good rule of thumb. If you have 200 amp-hours worth of batteries you could safely run at 40 amps for a while which is about 500 watts. Not really enough for that microwave, sorry!

Got to make hay when the sun shines!

LiFePO4 Battery Considerations

- LIFePO4 Batteries can demand excessive current from your alternator. You could easily overheat the alternator. A properly designed system is required to avoid this. Don't just drop in a battery without considering the load on the alternator.
- Appropriate battery charger required.
- All LiFePO4 batteries will or should have a battery management system which prevents over discharge and overcharging. Sometimes they will prevent below freezing charging, but not all.
- Unlike the Li-ion batteries in your phones and lap-tops LIFePO4 batteries are much safer.

LiFePO4 Battery Considerations (Continued)

- Charging a LiFePO4 freezing temperatures can damage the battery.
- Some batteries have “heaters” which keep batteries above freezing. However, leaving this on all winter without external power will run the battery down to the point of self-shutoff.
- The maximum charge rate is generally very high 100% of the amp-hour rating. In most cases you won’t be able to supply this level of current. I have encountered BMS systems which limit to 60 amps, so use caution.
- Likewise, the maximum discharge rate is also very high. You can go as high as 100 amp for a 100-amp-hour battery. Two 100-amp LiFePO4 batteries will let you run that microwave for a little while;-)

Why Solar Energy

Solar is great for keeping your batteries charged while you are not using your rig. So often RV owners find that they have a dead battery when coming out of storage. You do need sun however!

You can boondock longer but won't come close to being able to use those big devices with impunity. You might start out with a full charge in that 600-amp-hour pack, but you will quickly lose ground if you don't conserve.

People love solar and see it as an asset for their RV. Complete freedom to boondock probably another matter, but all things being equal, it's a plus at resale.

Interesting, fun, green all nice things, but not a panacea.

Recommendations

- Do your homework and be sure that you know the actual benefits of solar and if it will make a big difference.
- Invest in things which will help first. LED lighting and more battery capacity.
- With solar you will want battery capacity to catch the energy when it is available. LiFePO4 batteries are getting less expensive all the time.
- It's difficult to know if what you are buying is good. Do your homework. Amazon lists several 100 amp-hour batteries under $500.
- Remember you need to manage the charge rate from your alternator. There are a few ways to do this. The most common are battery isolation managers and DC to DC chargers.
- A proper charger is also required for LiFePO4 batteries.

Ask questions and make sure the proposed "solution" lines up with the system. There are lots of variables and it's easier not to think about it.


ANY
questions?