PORTABLE POWER FOR AMATEUR RADIO

PART 2: STORAGE BATTERIES

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Hey, we did say "PORTABLE", right?

PART 2 OF A SERIES: PORTABLE POWER FOR AMATEUR RADIO

1. Previously – How much power do you need? You established the operating goal and setting and computed the amount of capacity you intend to USE.
2. **TODAY**: Comparing different types of storage batteries. Taking the previous result and translating it into a battery selection. Focus on rechargeable and on radios OTHER than hand-held or QRP. (For HT's the manufacturer makes the call. For QRP there are almost infinite choices and many size/weight needs).

SAFETY – DON'T "ASSUME"

- High currents from large batteries can be very dangerous. 12V isn't 'safe'.
- Shorts can cause battery explosions and fires. Watches, rings, wires, TOOLS..
- Electrocution from 120/220V: Generators etc.
- Watch out for generators + rain.
- Protect batteries from physical damage.   Don't use damaged batteries.
- Pay attention to the warnings and ask a professional electrician if in doubt.
- If serious injury and death isn't enough, consider the equipment damage!
- Use these notes at your own risk! Follow manufacturer's guidance.

THE SHORT VERSION: Buy the LiFePo4 Battery?

1: Forget Li-Ion. Bad match to our 11.5-15.8V range and poor availability.

2: If you can't/won't lift the lead-acid battery, spend the money and get LiFePo4.

3: For 15-30 Ah <u>usable</u>, some savings on lead-acid. Get LiFePo4 even if you could lift a lead-acid. Plus, if you are 'in' for more than 3-5 years, it lasts twice as long.

4: For 40-50 <u>usable</u> Ah: You can save a bit up front on lead-acid. You'll lose the savings if you are in for more than 3-5 years and have to replace it. And, is it really feasible for you to carry around a battery this heavy (and DON'T crack that case with acids in it)? Lead-acid is OK for a fixed location backup or in an RV or vehicle.

5: For HUGE batteries (100-200 Ah usable etc.) LiFePo4 is expensive. But you'll have to buy a trailer or some wheels too for that lead-acid battery.

You can go home now! We'll see this slide again.

A FEW KEY TERMS:

- **CELL:** A single chemical unit comprising an Anode, Cathode and an electrolyte. For each different chemistry there is a typical cell voltage, and this can vary a great deal (1.2V for NiMH to 3.6V for Lithium Ion. Cell voltage varies with State of Charge but the degree of change is different for different chemistries. What we call an 'AA battery' is actually an AA size CELL.
- **BATTERY:** An assembly of multiple cells, usually connected in series to provide higher voltage. (A small 9V battery is a stack of six 1.5V alkaline cells). You cannot have 'part of a cell'. All alkaline batteries offer a voltage that is a multiple of the 1.5V cell voltage. Any lithium-ion battery offers a multiple of 3.6V. These 'steps' can be awkward for some purposes.

A FEW MORE KEY TERMS:

- **AMP-Hours (Ah):** A statement of capacity for a cell or battery of whatever voltage. Put simply, 10 Ah could mean 1 amp for 10 hours, or 10 amps for 1 hour, or 5 amps for 2 hours. In reality, higher discharge rates may deplete the battery a little faster than this. And any battery will have a maximum safe discharge current (Amps). Because cell voltage declines during discharge, you probably can't realize the full rated AH capacity of a cell or battery as the voltage will fall too low before you fully deplete the battery.
- **WATT-Hours (Wh):** This is a statement of the total ENERGY delivered. Unlike Ah, it takes the cell/battery voltage into account. Mathematically, the Wh will be the Ah times the battery or cell voltage. A 12 volt 20Ah battery is a 240 Wh battery. Intuitively it makes sense that a 12 volt 20Ah battery contains a lot more energy than a 3V 20Ah battery. (4 times as much, actually).

Most of our ham radio portable-ops concerns are at around 12V, so for simplicity most of our discussion will be in terms of Ah. Just multiply by 12 for Wh.

OK, 2 MORE TERMS YOU'LL BUMP INTO

- **DOD or Depth-of-Discharge.** % of the battery's capacity discharged. If we use up 80% of the capacity, that is 80% DOD.

- **SOC or State of Charge.** % of the battery's capacity that is presently remaining. Kind of the opposite of DOD. If we discharge to the 80% DOD in the example above, we could expect roughly a 20% SOC.

The End (of terms). (sort of).

BATTERY SPECS AND DIFFERENCE AREAS:

1. **Capacity** in Ah and the battery **voltage**. Or: Amount of energy stored (Wh).
2. **Voltage decline** during discharge. Affects 'available' capacity for ham use.
3. **Availability.** Ready-to-use, matching ham radio needs? (Or, must build your own)?
4. **DOD effect on lifetime** & future capacity.

   OR: **Maximum cycles** (charge/discharge) before large capacity loss.
5. **Expected years of life** even with light cycling.
6. **Max. discharge current** (short term and sustained limits). (Enough for radio?)
7. **Self Discharge** behavior. Is it 'ready to go'? Other storage concerns, maintenance.
8. **Safety**/Hazards.
9. **Complexity** of charging. Does it affect you?
10. **Weight, Volume**. Can you lift it – do you truly want to?
11. **Cost.** Up front cost? Total lifecycle cost?

FOCUS ON 3 CELL TYPES: VOLTAGE BEHAVIOR

Lead-Acid (Flooded, AGM, Gel): 2.1V nom. (1.8V - 2.2V). Voltage Declines fast.

- 6 cells = 12.6-12.8V nominal. (13.2V peak) (More when car alternator is charging).

Lithium Ion: 3.6V nom. (3V to 4.1V). Voltage Declines steadily. **Needs BMS.**

- 3.6V cell voltage VERY inconvenient for 12v radios. Limited availability ready-to-go.
  - 3 cells = 10.8V nom, TOO LOW! (12.3V peak but quickly declines).
  - 4 cells = 14.4V (but 16.4V peak is TOO HIGH – real radio damage risk).

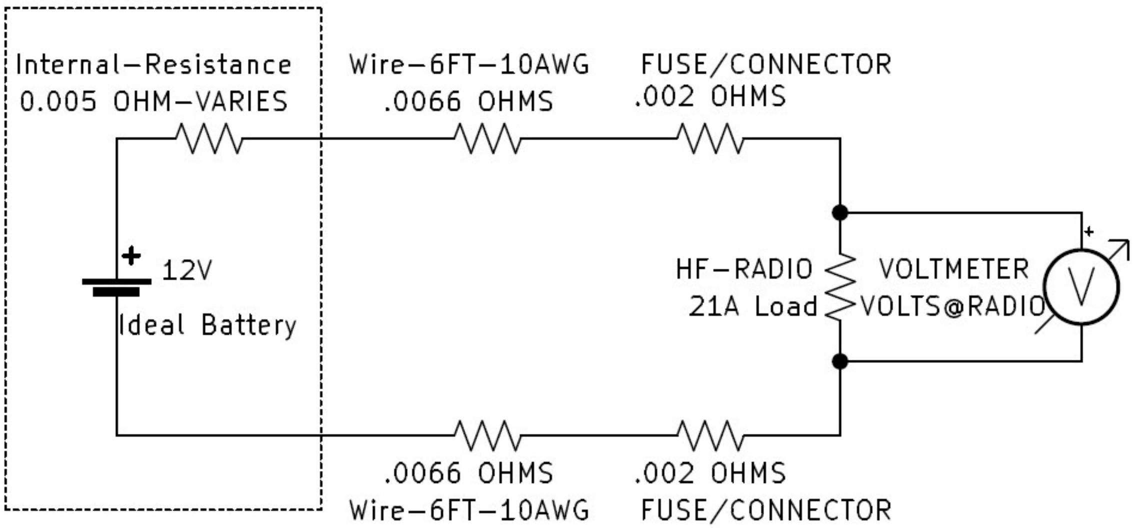
LiFePo4: 3.2V (2.7V - 3.3V). Little voltage change thru 85-90%. **BMS (included).**

- 4 cells = 12.8V nom. (13.2V peak). Matches radio specs, lots of usable capacity.

We are not seriously considering the following as not well suited for this purpose:

- Non-rechargeable dry cells and alkalines (1.5V): Prohibitive cost because one-time-use.
- Ni-Cd: Will cost more than LiFePo4, must probably build yourself from cells.
- NiMH (1.2V): Cost = or more than LiFePo4, lower performance, probably build yourself.
- Ni-Cd and NiMH CAN reasonably be considered for small QRP radio battery packs.

EQUIVALENT SERIES RESISTANCE, WIRING LOSSES



FULL BATTERY, 10AWG 6FT CABLE, 21AMPS, 2 X 25A ATO FUSES:
12.80V 12.70V 12.42V 12.33V

BUT IF YOU USE A LONGER 8 FOOT CABLE OF SKINNY 14AWG WIRE
12.80V 12.70V 11.92V 11.83V

OR USE A FAT 8AWG CABLE SHORTENED TO 4 FEET
12.80V 12.70V 12.58V 12.50V

Fully charged 20Ah LiFePo4
Note the limited voltage margin at radio, SO:

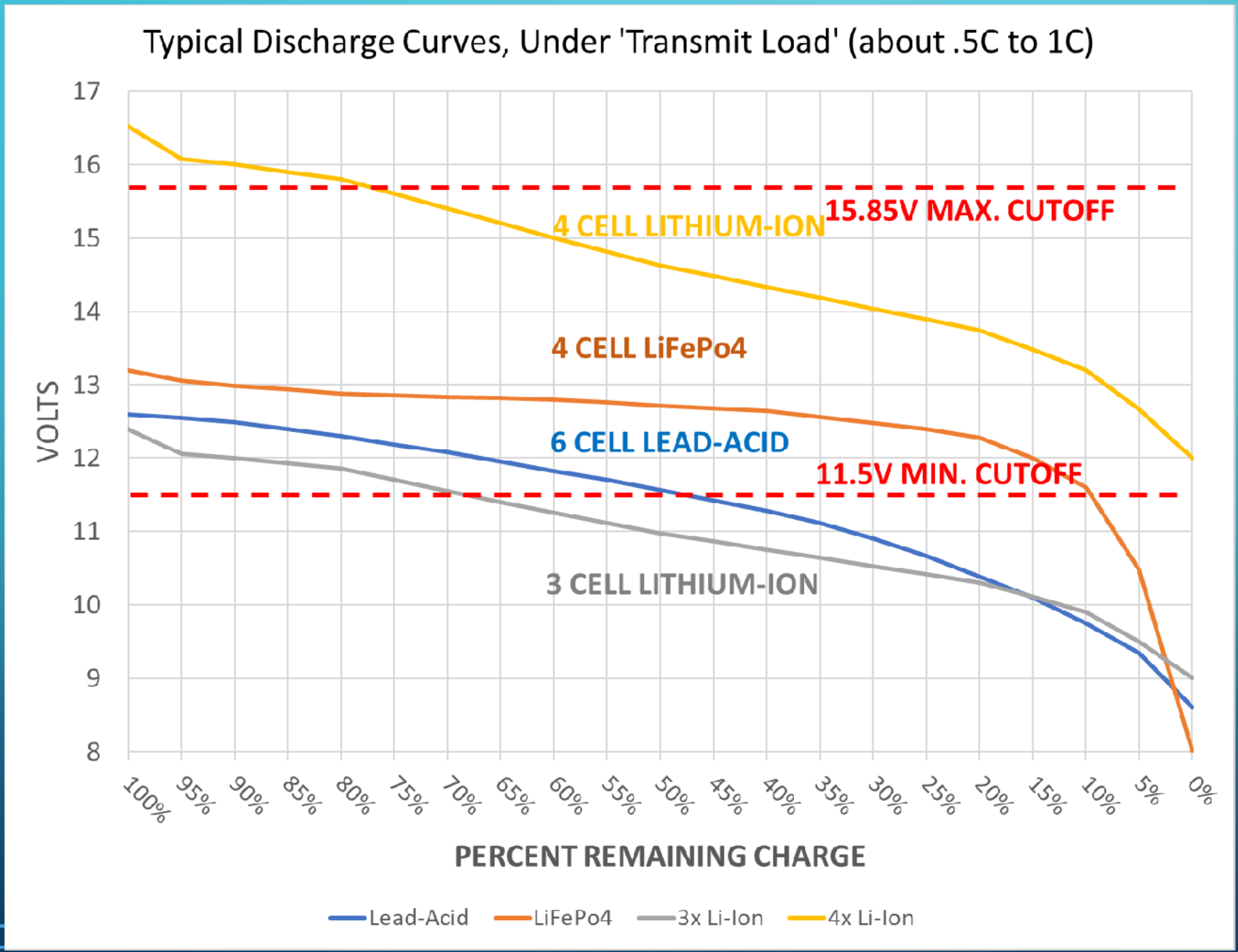
- MINIMIZE wire length
- Use LARGE AWG stranded wire.
- Inserting ‘charge counters’ etc. adds drop.

Example varies with battery, age, temp., etc. But the radio does NOT see the full no-load battery voltage, especially during high current TRANSMIT. (Unfortunately, just when needed).

Other battery types can have a lot more internal voltage drop – especially as they discharge. A 35Ah AGM Lead-Acid may start with 2-3 times as much resistance and considerably more as discharged.

BIG margin change with wire size & length.
Need 11.5V AT THE RADIO.

SOME DISCHARGE CURVES: (VARIES A LOT WITH BATTERY SIZE, BRAND, AGE, TEMPERATURE, ETC)



4 cell Li-Ion too 'hot' at 100% especially during RX (low load), and this could damage a radio.
But the 3 cell Li-Ion falls to a low voltage too soon. We can only use about 1/3 of it's capacity – less if allowing for wiring voltage drop?
Adding dc-dc converters like the MFJ-4416C ($200) to a Li-Ion pack to push up it's voltage will Increase cost past LiFePo4 level.

The lead-acid drops even faster during discharge, and we get low-volt problems after using only ½ of capacity. Also, it suffers greatly reduced cycle life – Even for 'deep discharge types – if discharged halfway. **So, if using lead-acid, buy 2X the Ah capacity you would buy for LiFePo4**

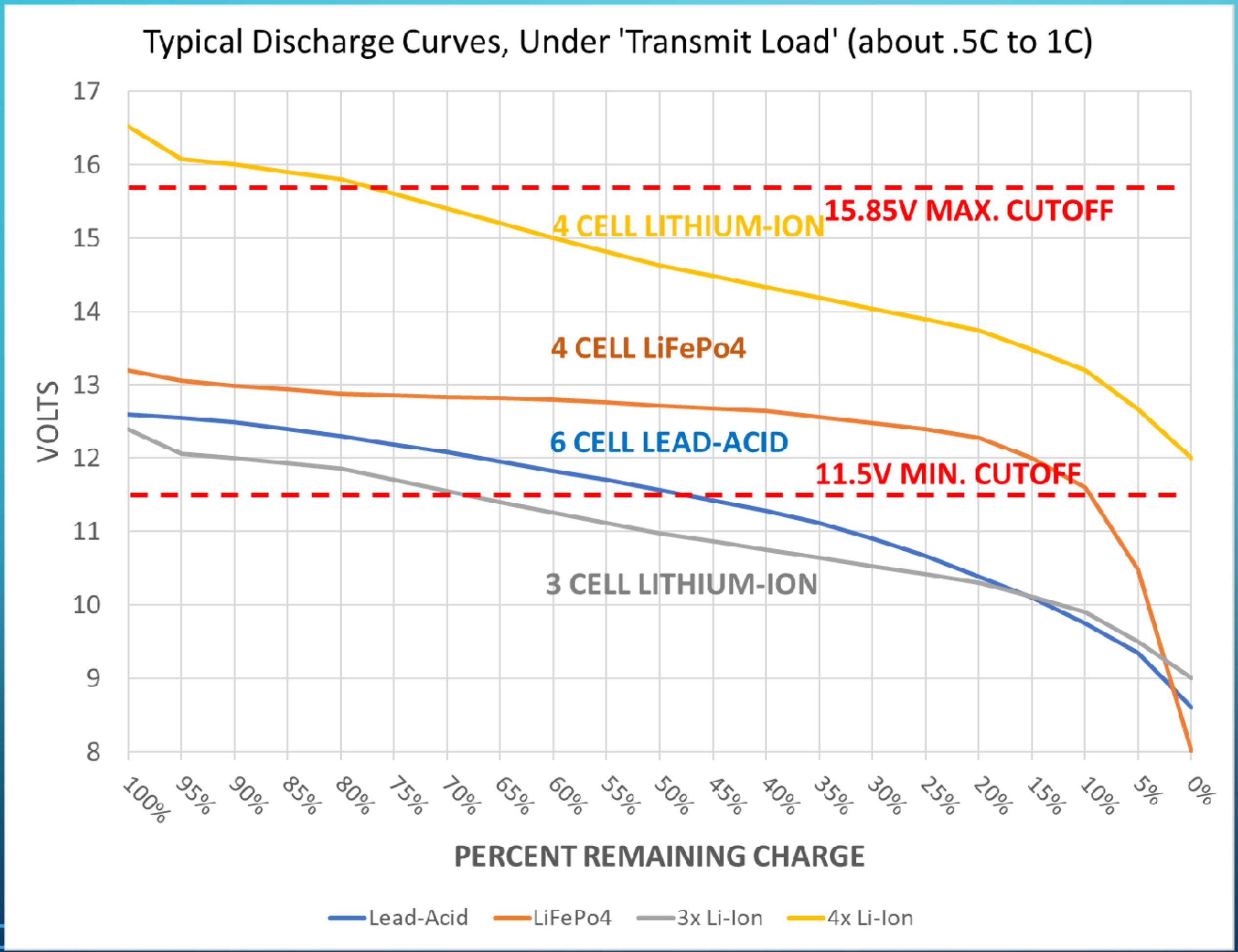
FOOTNOTE: WHY LI-ION'S IN MOST HT'S ARE FINE

- **Whole radio is designed around cell voltage of Li-Ion** (used to be NiCd or NiMH).
- Typically 2 Li-Ion cells for 7.2V nominal (or 7.4V as an advertising gimmick).
- **Radio LIKES anything from around 8.4V down to below 6V** as we discharge.
- Design makes best use of that range (But typically, RF power falls towards the end).

- The history of '12V' HF/VHF/UHF radios was built around the voltage range seen from the car's battery/alternator **system**: Perhaps 15V engine running/charging (from alternator, NOT battery). Less than 12V stopped w/ heavy transmitter load.
- Hence the typical 13.8V +/- 15% spec. for 'mobile' radios. (= 11.5 to 15.8V).

- When you use an HT in your car, a power adapter module (sometimes within radio) converts the voltage to something the radio's power system can use).

LOOK AT THE LIFEPO4 CURVE!



LiFePo4 is expensive BUT:

--Voltage curve much flatter and better placed for staying above 11.5V needed by most radios thru most of discharge. Also, some LiFePo4 vendors conservatively rate Ah capacity only to ~3V/cell, so you can use essentially 100% of the rated capacity before the radio gets down to around 11.5V

The LiFePo4 discharge curve is so flat that it is impossible to estimate the charge remaining (accurately). You CAN add a module to track charge usage, BUT these add voltage drop and make it harder to stay above 11.5V. Otherwise, this is a very easy battery to use in the field.

LIFETIME (# CYCLES AND AGE)

Batteries lose capacity after many discharge cycles. More when depth-of-discharge (DOD) is deep. Expect 20% or more capacity loss after:

- 300-500 cycles from a lead-acid deep-cycle type IF DOD IS LIMITED TO 50%.
- 400-800 cycles from a Li-Ion at around 80% DOD and not stored 'discharged'.
- 1500-4000+ cycles from LiFePo4 at 80% DOD (higher when rated Ah down to ~3V), and perhaps 1000+ cycles at 100% DOD depending on ratings.

Even when lightly used, batteries deteriorate over time. If cycle life is not exceeded, you might still expect to replace the battery within roughly:

- 3-5 years for lead-acid
- 5 years for Li-Ion
- 10+ or so for LiFePo4

… varying a lot with brand, use-history, storage conditions, etc.

SAFETY

Li-Ion and LiFePo4 both require some form of 'Battery Management System' (BMS). You must add this (PROPERLY) if you build your own battery from cells. LiFePo4 batteries from vendors like Bioenno have BMS built in. Without BMS, any of the lithium batteries can be damaged and increased safety risk. For lead acid systems, basic chargers can do the job. But ALWAYS fuse and handle carefully. Assuming BMS, expect:

- Lead-Acid: Moderately safe. Flooded types have more risk of spilling acid or out-gassing than pricier sealed types. Corrosion of surrounding electronics or tools is a risk, short circuits can cause violent explosions with a spray of acid. They are heavy.
- Li-Ion: Least safe of the 3. Mechanical damage, over-charging, using ancient or swelled batteries, short circuits or mfg. defects can cause explosions and/or fire.
- LiFePo4: Considered the safest. They are not prone to most of the Li-Ion risks and the fully integrated BMS systems tend to protect them (and you) from hazards like short circuits and any possibility of over-charging. BMS is more complicated and almost always within the battery itself and not in it's mating unit or load.

SELF DISCHARGE, STORAGE, MAINTENANCE

Even if left unused and disconnected, batteries self-discharge over time. Rates depend (a lot) on chemistry, history, SOC and storage conditions. Assuming room temperature and that the battery is FULLY disconnected, you can expect:

- Lead-Acid: ~3-20% per month.*
- Li-Ion: ~3-5% per month, depending on BMS design.**
- LiFePo4: ~3% per month.***

* Lead-Acid batteries are probably best kept on a trickle charger when stored for long periods. ('Battery Tender', etc). Keep in mind the risk of corrosion to electronics, connectors or tools stored near or with a lead-acid battery, especially within a battery box that traps gasses. For flooded types, regularly check and top up fluid level with distilled water.

** Li-Ion batteries are best long-term stored partially charged (50-70%).

*** For very best lifetime, when storing LiFePo4 batteries long term, Bioenno recommends charging to 100% then discharging to 50% before storing. They also recommend re-cycling this process every six months or so to ensure that charge is evenly distributed between the cells within the battery.

AVAILABILITY, CHARGING COMPLEXITY (EASE OF USE)

Available ready-to-use 'pack' suited to ham radio use? / Easy to charge?

- Lead-Acid: **YES/KINDA**. Deep cycle cells inexpensive and readily available in many sizes, and as the least expensive 'flooded' type as well as AGM and Gel types. Purchase chargers and battery tenders separately, but these are available. Overcharging = outgassing, damage, corrosion. Important that you match the charger and battery and use it properly, then easy.
- Lithium-Ion: **MAYBE NOT?/MAYBE** Large batteries are rare and, as noted, the voltage is awkward. You may have to build your own from cells -- and SOLID skill and attention to BMS/charging circuits is essential for safety. Selection of a matching charger requires similar attention ifyou build your own system. NOT RECOMMENDED as a beginner project.
- LiFePo4: **YES/YES**. Widely available, range of sizes & voltage well suited to ham radio. Sold with integrated BMS and matching charger. Complex charging technology INSIDE, but IF USING THE MATCHING CHARGER, charging is simple and safe for you.

MAXIMUM DISCHARGE CURRENT:

Your 100W HF radio probably needs 19-22A for full power transmit (key down CW or FT8 or FM – less for SSB). Any of these 3 battery types can supply this as long as you select a suitably large size.

- LiFePo4: Any 12V Bioenno LiFePo4 of 15Ah or larger should be fine, possibly even the 12Ah. Larger units give longer operating time.
- Li-Ion: We have other issues with Li-Ion, including availability in ready-to-use sizes. If building one, choose cells that can deliver the current.
- Lead-Acid. 20Ah or more should be OK (but you'll get less than 10Ah so only for a short time). Consider a larger size.

Use battery specs for the 'sustained' current demand.

WEIGHT AND SIZE, COST

- Lead-Acid   Heavy, Bulky.
  - **35Ah rated AGM SLA ~ 25 pounds, About 16Ah usable. Roughly $60-90 ($90-140 w/charger)**
  - 55Ah rated AGM SLA ~ 43 pounds, About 25Ah usable. Roughly $110-160 ($140-210 w/charger)
  - **105Ah rated Flooded – 58 pounds, about 50-55Ah usable. Roughly $180 (210-230 w/charger)**
  - Add cost of charger and/or battery tender, probably 30-50 dollars.   May need substantial 'carry case'.
- Lithium-Ion No ready examples in the 3 or 4 cell / 20Ah usable range?
  - Theoretically should be a little lighter and cheaper than LiFePo4. But adding DC-DC converters and the fact that a home-grown version may be less weight and cost efficient than a commercial-off-the-shelf solution means that it's probably a wash on weight and most likely costs MORE than LiFePo4..
- LiFePo4:
  - **15Ah, ~4.3 pounds, about 15Ah usable. $170 including charger**
  - 20 Ah, ~5.4 pounds, about 20Ah usable. $213 including charger
  - 30Ah, ~ 7.6 pounds, about 30Ah usable. $300 including charger
  - 40Ah, ~ 10.4 pounds, about 40Ah usable. $390 including charger
  - **50Ah, ~ 13.3 pounds, about 50Ah usable, $510 including charger**

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3: For 15-30 Ah usable, some savings on lead-acid. Consider LiFePo4 even if you could lift a lead-acid. Plus, if you are 'in' for more than 3-5 years, it lasts twice as long.

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5: For HUGE batteries (100-200 Ah usable etc.) LiFePo4 is expensive. But you'll have to buy a trailer or some wheels too for that lead-acid battery.

SIZE THE BATTERY

1. Refer to the calculations in Part 1 of this series to evaluate your need.
2. Remember that the provided calculator does NOT add much/any safety margin.
3. Add the 'extra' operating margin that makes sense to you, according to the criticality of success. If planning on solar recharging, remember it gets dark at night and efficiency is only high for the middle of the day. It's a Long Night on Field Day.
4. If buying a lot of LiFePo4 capacity, consider buying 2 units. This helps sove the problem of gauging what is left. When one exhausts, switch and charge the dead one. It also helps out in the unlikely event of a failure or damage.
5. Package the battery safely, protect it from mechanical, electrical or heat damage.

QUESTIONS?

THANK YOU!

PLEASE be careful.

And please advise me of any errors so that they can be corrected.