



Volta
Power Systems

Jack Johnson

What do you think of when you hear "Lithium Ion" ?



Rolls-Royce is skipping hybrids and going straight to electric cars

Sean Szymkowski, Motor Authority
Jul. 9, 2017, 12:00 PM 9,076

FACEBOOK LINKEDIN TWITTER EMAIL PRINT

It seems the industry's future propulsion method is sealed: electric cars will begin to take priority over the internal combustion engine.

The New York Times

Volvo, Betting on Electric, Moves to Phase Out Conventional Engines

By JACK EWING JULY 6, 2017

RELATED COVERAGE








- Tesla's First Mass-Market Car: How It Will Be Produced This Week
- Behind the Quiet State-by-State Race to Promote Electric Vehicles
- Intel's Chinese Answer to Tesla: Hope to Global Car Market
- At the Los Angeles Auto Show, Pioneers Its Digital Future

A Volvo plug-in hybrid at an auto show in Beijing in 2014. (Image courtesy of Volvo)

How to think about a Lithium ion battery pack.

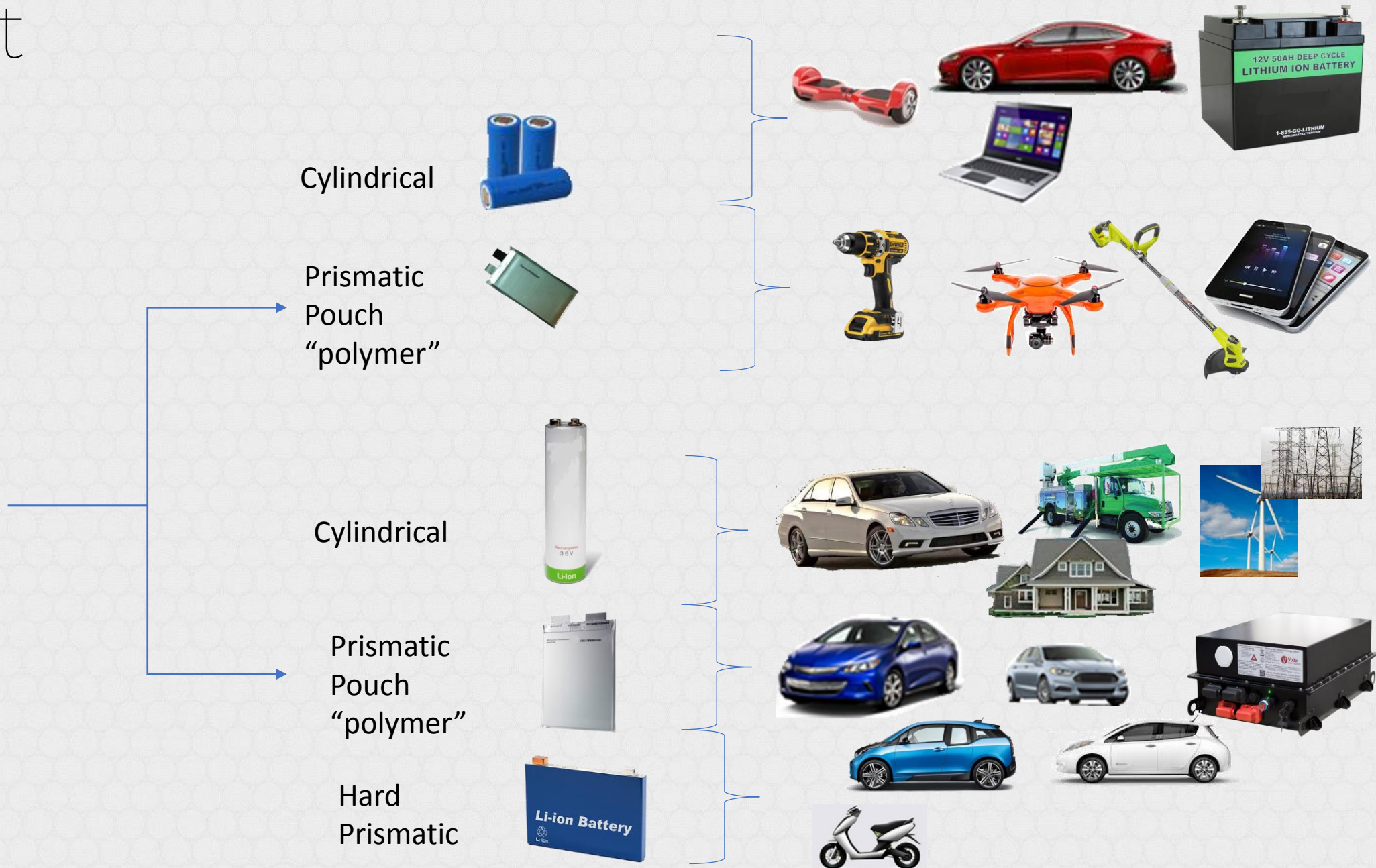
- The word “Lithium ion” **defines a process** not a chemistry.
- Using the word lithium ion in a sentence is kind of like using the word Fuel.

Seven Common types of lithium Ion

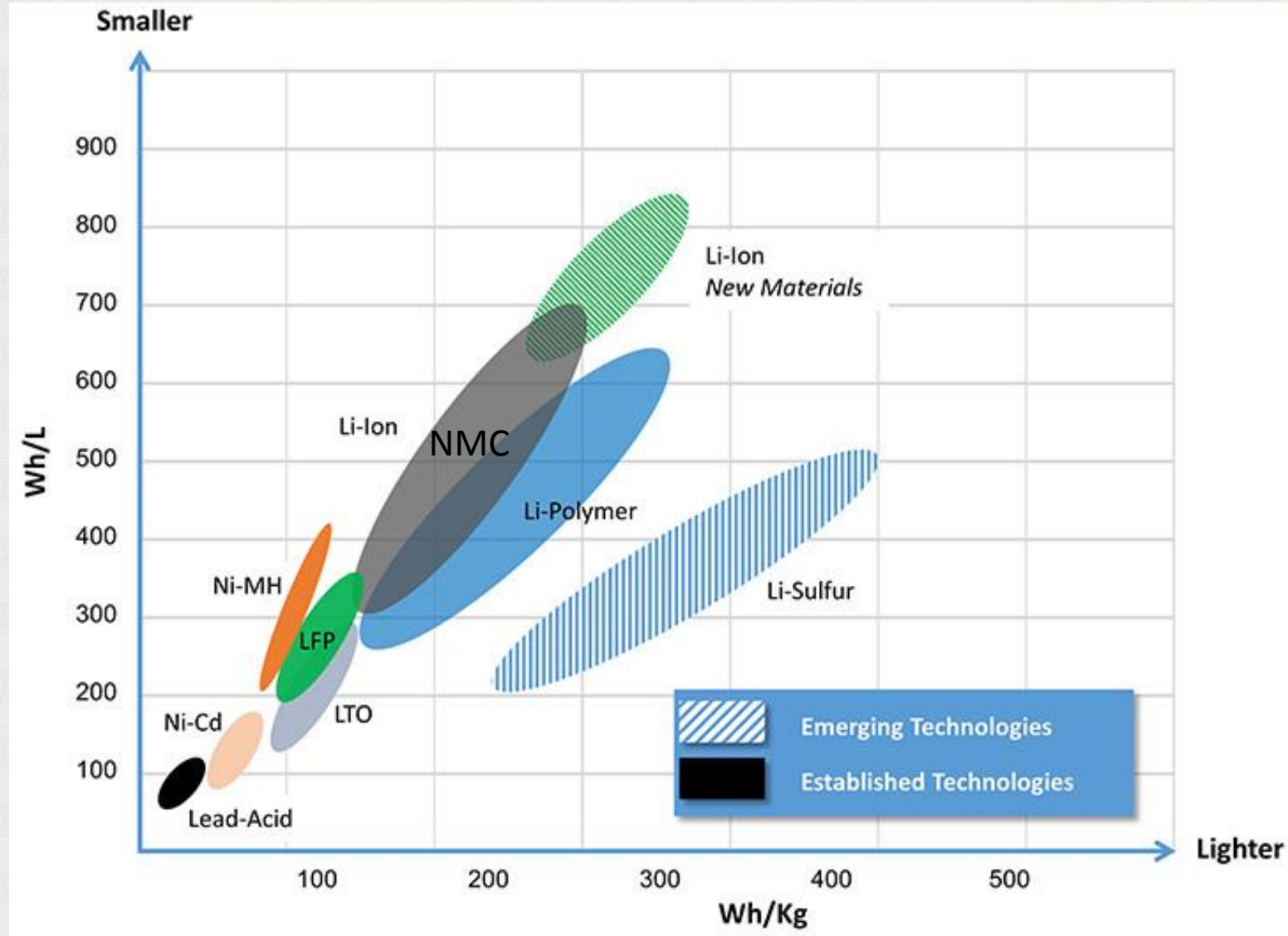
Chemistry	Where the chemistries are generally used
LiFePo “Lithium Iron Phosphate”	
NMC “Nickel Manganese Cobalt”	
NCA “Nickel Cobalt Aluminum”	
LTO “Lithium titanium Oxide”	
LMO “Lithium Manganese Oxide”	
LCO “Lithium Cobalt Oxide”	
NCO “Lithium Nickel Cobalt Oxide”	

Format

- Small
- Large



Chemistry Energy comparisons



How to think about a Lithium ion battery pack.

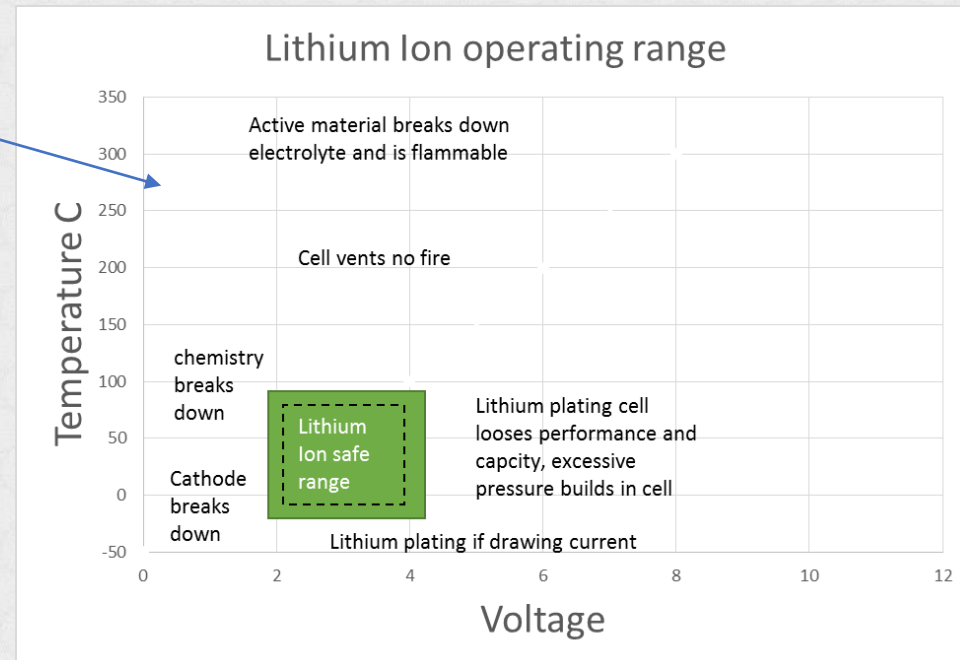
Similar to this



- Computer controlled
- Advanced sensors
- Process monitoring
- Thermal control
- Long life
- Powerful
- Designed to work



Not this



Recap

- Advanced Energy Systems are similar to Engines
- Lithium Ion doesn't mean one thing; Think AES “Advanced Energy Storage”
- Lithium ion Chemistries can be compared to different type of fuels
- Each lithium ion family has specific applications

Terminology

- Watt hrs/liter
- Watt hrs/kg
- kWh
- SOC “State of Charge”
- Over voltage
- Over Discharge
- CELL BALANCING
- FORMAT TYPE
- VENT VS. VENTING
- BMU – BATTERY MANAGEMENT SYSTEM
- USEABLE ENERGY & POWER

What is a kWh (kilowatt-Hour)?

Answer: It's the size of your storage container

$$100 \text{ Ah} \times 12\text{V} = 1.2 \text{ kWhrs}$$

$$100 \text{ Ah} \times 58\text{V} = 5.8 \text{ kWhrs}$$

$$100 \text{ Ah} \times 370\text{V} = 37 \text{ kWhrs}$$

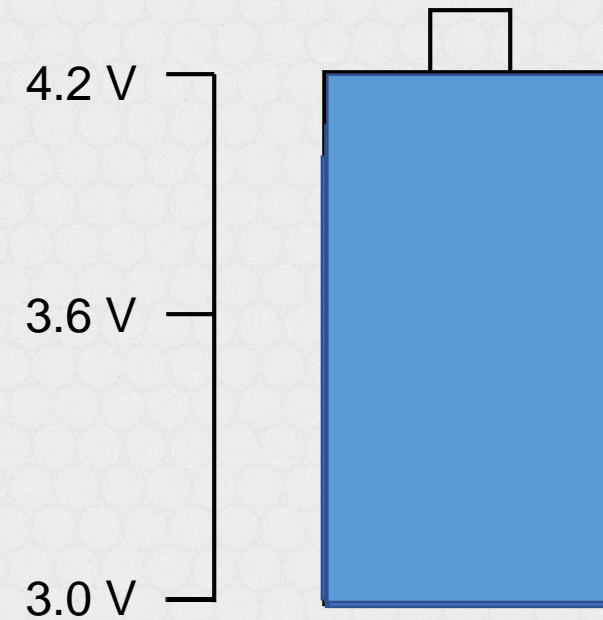
Amp hours do not describe total energy



Leaks represent devices, the bigger the device more is drained faster

Cycle

- One cycle is a full charge then full discharge and then full charge again



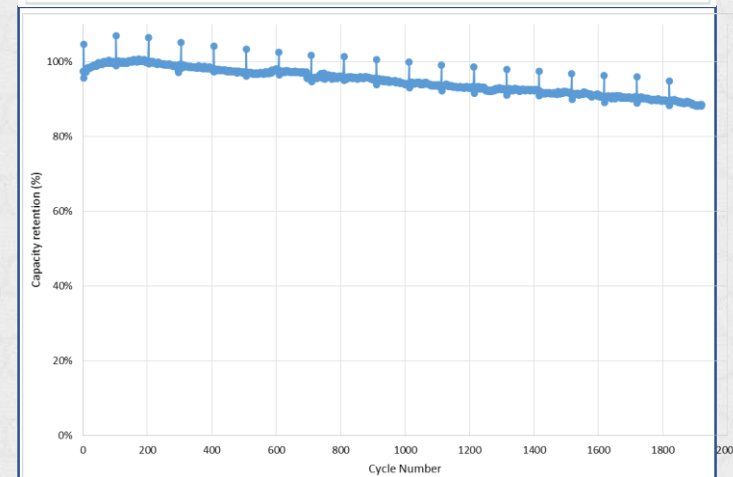
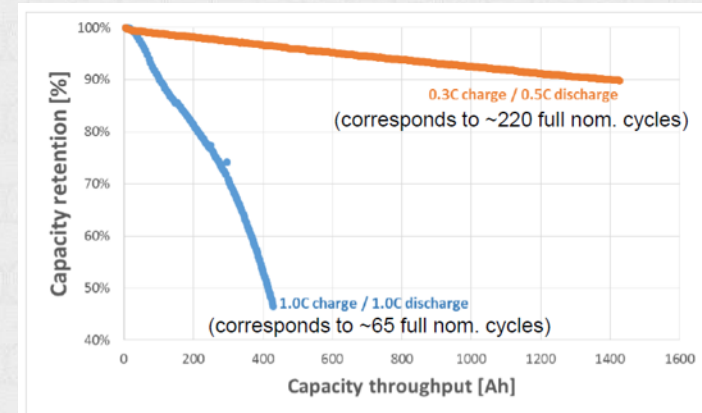
Cycle life

- Cycle life of a cell is different than cycle life of a system

Consumer products Cycle life 700 – 1000 or 3 years



Automotive cycle life 2,000-3,000 cycles over 10 years and still have 80% capacity remaining



POWER

- Power is: Volts X Amps

Example: Four 100 amphr lead acid batteries max discharge rate max = 120 amps (.3 C)



Total power 12 Volts x 100 Ahr x 4 = 4800 Whrs

Useable power = 4800 Whr x 50% = 2400 Whrs

$$\text{Runtime} = \frac{2800 \text{ W}}{2400 \text{ Whrs}} = 50 \text{ minutes}$$



2000 W



800 W

POWER

- Power is: Volts X Amps

$\frac{7745 \text{ Watt}}{12 \text{ Volts}}$

= 645 Amps

Not
feasible

2000 W



2000 W



6800 Watt = 10.3 Hp

2800 W



Total = 7745 W



800 W



145 W

POWER

- Power is: Volts X Amps

$$\frac{8890 \text{ W}}{58 \text{ Volts}} = \underline{\underline{153 \text{ Amps}}}$$

Almost 5 x reduction in amps!

50 amp Shore power = 12,000 W

2000 W



2000 W



2000 W



1800 W



800 W



145 W



145 W

POWER

- Power is: Volts X Amps

$$\frac{12,000 \text{ W}}{58 \text{ Volts}} = \underline{206 \text{ Amps}}$$

1/5th the amps!

50 amp Shore power = 12,000 W

Advanced Energy Systems let you take
Shore Power with you

2000 W



2000 W



2000 W



1800 W



800 W



145 W



145 W

Safety

Is Advanced energy system safe?

- Safety is a function of system design not just chemistry

- Is Gasoline Safe?
- Is Propane Safe?
- Is Diesel Safe?
- Is a Lead Acid battery safe?

All of these can be safe, but when operated or designed incorrectly they all have similar failure modes

Advanced Energy Systems are built to be safe.



4 common failure modes of lithium ion batteries

1. **Loose connections**: Connections that vibrate loose or are incorrectly torqued will create hot spots and arcing that can result in secondary materials catching fire.
2. **Overcharging**: All lithium chemistries are sensitivity to overcharging. An overcharge can happen by a poor control strategy like what happened to the Boeing 787, a failure in the BMU and human error.
3. **Over discharge**: When a lithium ion battery is allowed to go to low in energy the chemical process inside will scavenge copper from the electrode and begin plating it to the surface of the electrodes over time. If the control system doesn't prevent someone from charging a direct short within the battery will occur and you will have a failure like many of the hover boards did.
4. **Dendritic growth** from manufacturing process and time: A dendrite starts by creating small plating point from a small contaminant and it will grow until it puncture the separator and causes a short: Sony had this happen to them with LCO chemistry in the early 2000's



1



2



3



1st Layer: Cell

- Material quality
- Manufacturing capability
- Cell design safeties: IE rupture disks, vents
- Separator quality and function
- Electrolyte stability additive
- ISO and TS quality system to insure quality
- Aging and quality control strategy
- Testing data

2nd Layer: Module/cell assembly

- How are cells constrained
- What vibration and G testing are they designed for.
- What safety features are integrated
- What materials are used

3rd Layer: BMU

- Battery Management Unit, is an onboard computer like the engine controller for an engine. It continuously monitors the cells and provide control to insure the cells are maintained within operating parameters.
- What capabilities does it have?
 - Balancing
 - Shutdown capabilities
 - What does it do when things are not right?

7 Layers of Safety

4



4th Layer: Housing

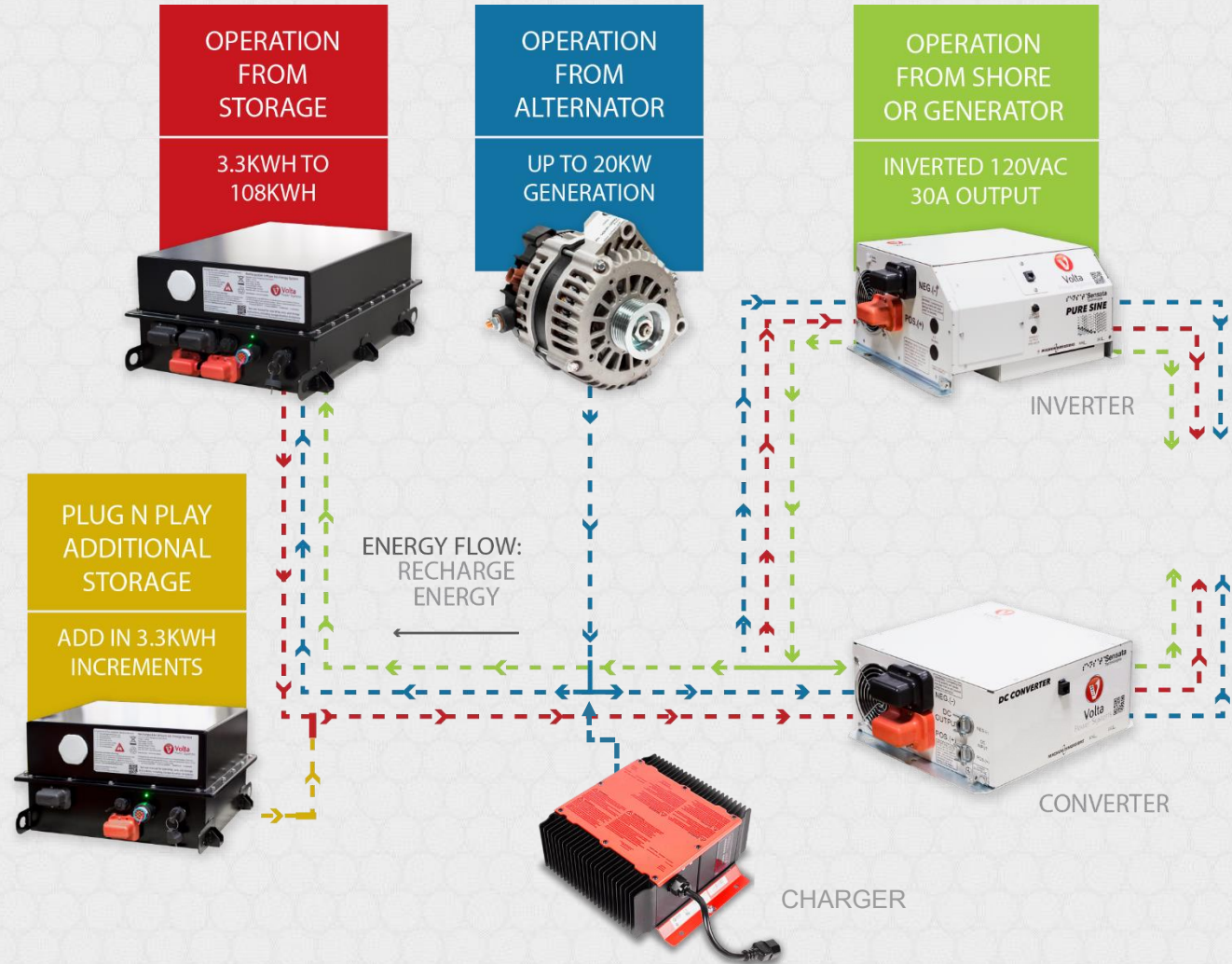
- World Class Construction
- No other product in the market provides the energy density, safety, performance, and cost in one complete package.
- Lesson's learned from automotive is integrated in this construction to insure a long life and in the case of a failure to contain the event within the case.

7 Layers of Safety

5

5th Layer: System Approach

Volta's patent pending solution provides automotive grade quality, safety and performance without the engineering, testing, and failure discovery costs associated with advanced energy technology.

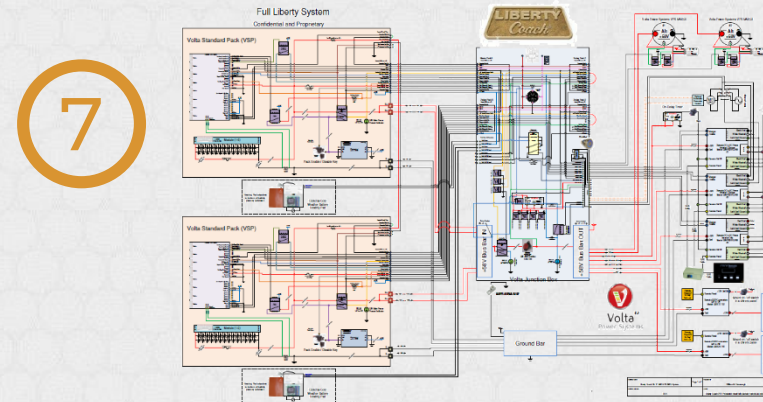


7 Layers of Safety



6th Layer: Main Contactor / Automatic Disconnect Connection

Each pack has the ability to shut power off mechanically if any adverse situation is observed by the BMU.



7th Layer: Partnership

Open communication and focus on customer integration requirements helps OEMs to optimize safety and cost on their side.



Capabilities



- **33,000 Whrs**
- **22,000 Watts of generation**
- **10,800Ws pure since 120V output**
- **20,000Ws starting surge**
- Runtime on a full charge up to 17 hours – with 1 AC running
- Recharge 4-6 hours depending on loads – 10X's faster than Pb
- No generator needed while driving

Storage Equivalent 2017 Liberty “useable energy”

Volta NMC 58V Packs



33,000 Watt hours

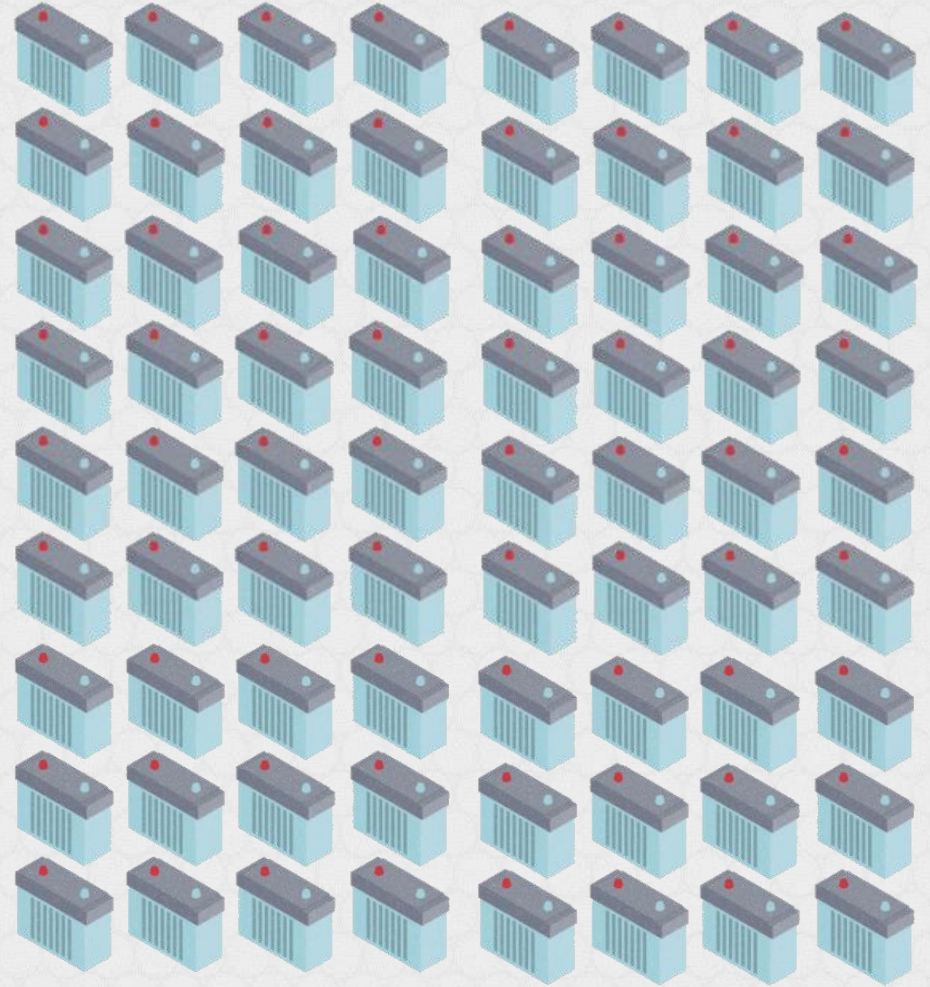
**Weight = 548 lbs
Volume = 9.5 ft³**

LFP 100AH 12V batteries



**Weight = 1,100 lbs
Volume = 22 ft³**

AGM Lead Acid group 31 batteries



**Weight = 4,968 lbs
Volume = 44 ft³**

Power Equivalent 2017 Liberty “useable energy”

Volta NMC 58V Packs



33,000 Watt hours

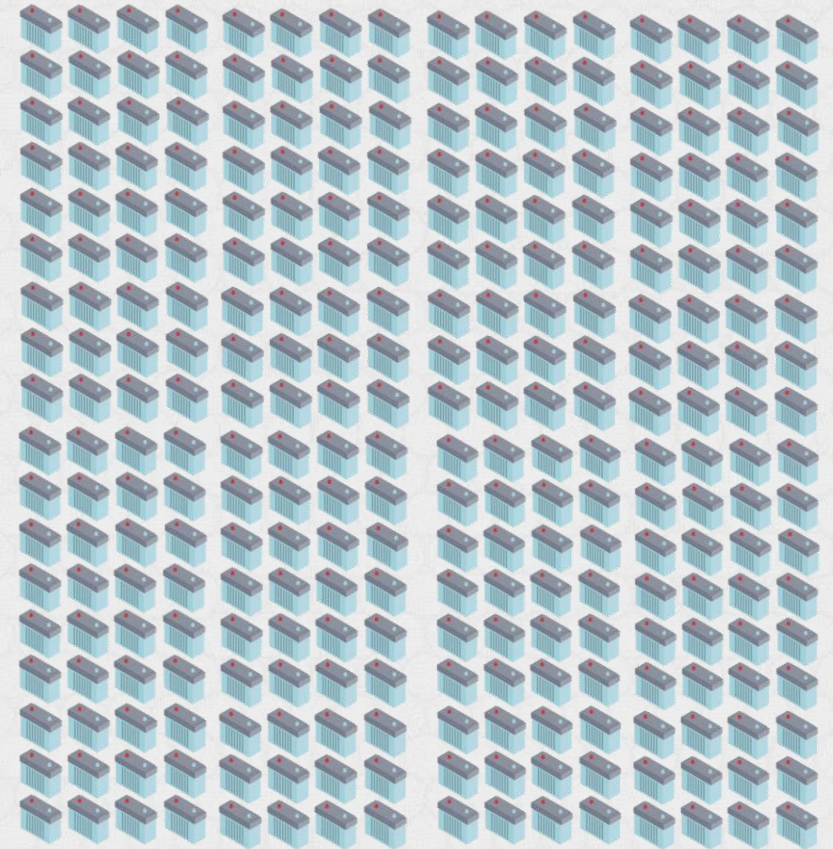
**Weight = 548 lbs
Volume = 9.5 ft³**

LFP 100AH 12V batteries



**Weight = 4,400 lbs
Volume = 88 ft³**

AGM Lead Acid group 31 batteries



**Weight = 19,800 lbs
Volume = 176 ft³**

What we learned

- Advanced Energy Storage (lithium ion) are like engines
- Lithium ion = What type?
- Lots of variation just like cars and trucks.
- Safety is a function of overall system design.
- Run time works like fuel consumption.
- They should last a lifetime.
- More voltage means more power – Makes shore power mobile



Volta
Power Systems