Energy 2013
ITP / NYU / Feddersen

Batteries

Batteries

Electrochemical energy storage devices. How do they work?

http://www.youtube.com/watch?v=CJK2kwF6Am4

Same considerations apply as for any energy storage:

- Energy per unit volume and mass
- Power per unit volume and mass
- Efficiency – ratio of energy in to energy out

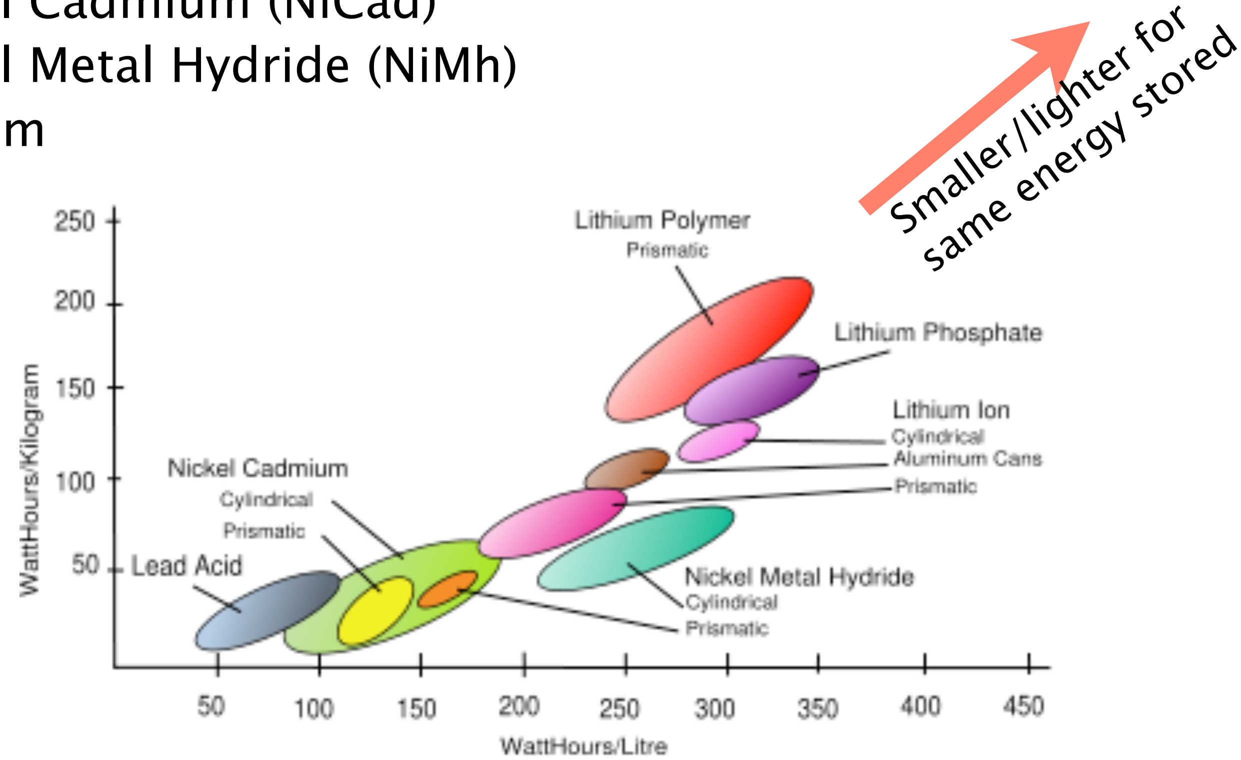
General battery concepts

- "Cell" refers to single electrochemical unit; "battery" to an array of cells.
- Voltage of a cell is intrinsic to chemistry involved; maximum current depends on amount of material (like PV).
- Cells can be arranged in parallel to increase maximum current.
- Cells can be arranged in series to increase voltage.
- "Primary" = non-rechargeable, "secondary" = rechargeable.
- Exceeding maximum or minimum cell voltage will damage the cell (potentially hazardously).

Chemistry - what is the battery made of?

Effects energy density, charging methods, safety considerations, etc. Some common types are:

- Lead acid
- Nickel Cadmium (NiCad)
- Nickel Metal Hydride (NiMh)
- Lithium



Capacity - how much can the battery hold?

Typically specified in **amp-hours** (or milliamp-hours), abbreviated Ah or mAh.

Can be roughly converted to joules by multiplying milliamps * 1 hour * nominal voltage.

Capacity – how much can the battery hold?

For example:

Battery in my phone specifies both milliamp-hours and capacity:

5.6 Wh

1500mAh @ 3.7V (typical Li-ion voltage)

1500mA * 3.7V * 1 hour = 19,980 Joules = 5.55 Wh

Capacity - how much can the battery hold?

Technical Detail:

Actual capacity depends on how fast the battery is discharged. Discharging a battery very quickly, or slowly, can reduce the realized capacity.

The capacity figure is given for 20-hour discharge rate (see C Rate, next slide).

For example:

A 12 volt battery (~14-10V during use) with a rated capacity of 10 amp-hours could average 12V while supplying 1/2 amp (500 mA) for 20 hours:

(12 volts) * (500 milliamperes) * (20 hours) = 432 000 joules

More about calculator.

C–Rate

Battery charge/discharge currents are typically given as a **ratio to total capacity** called the **C–Rate.**

For example, for a 750 mA–hour battery:

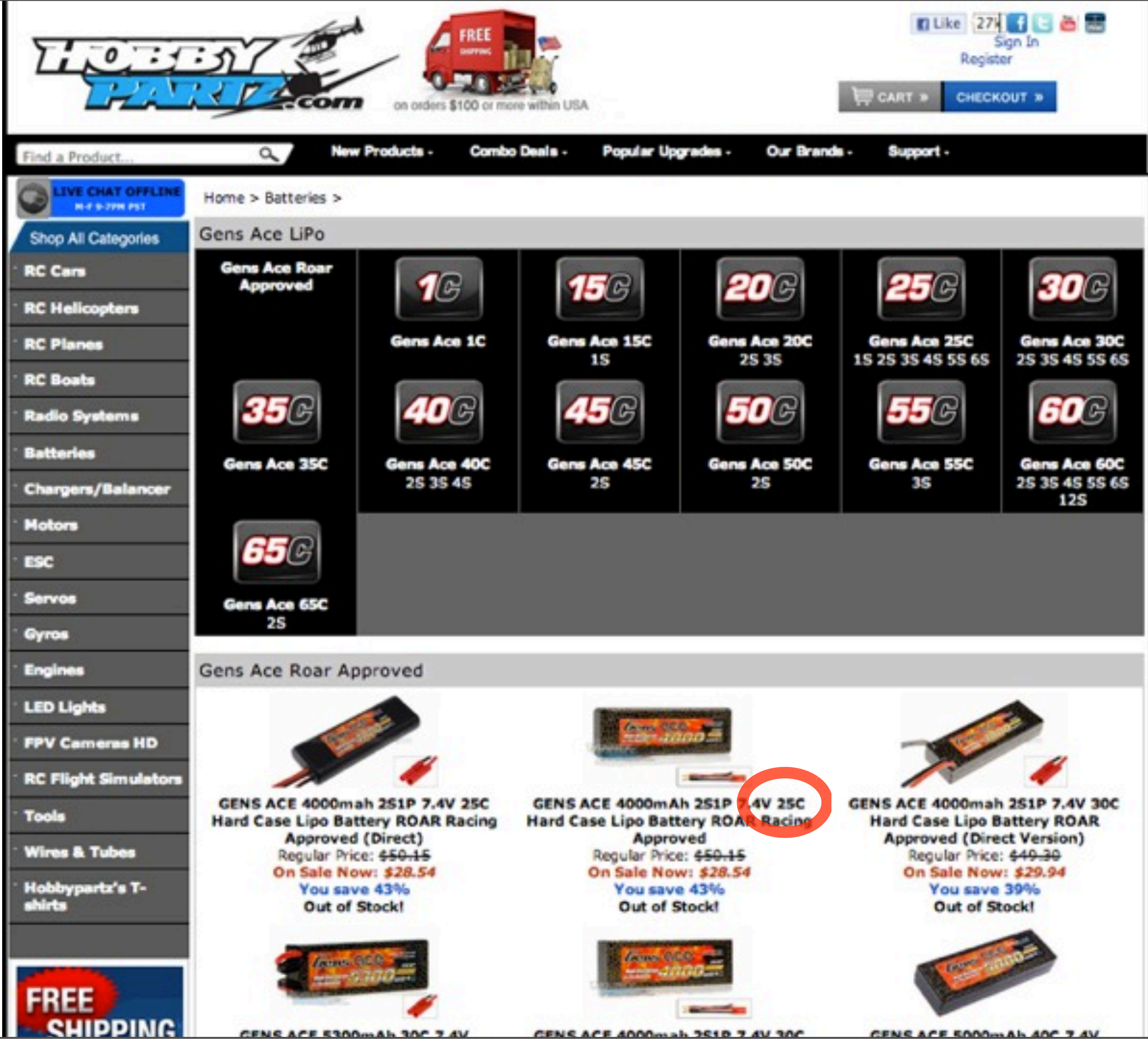
1C = 750mA

2C = 1500mA

.5C = 375 mA

A very important battery specification will be its **maximum safe discharge current**. This will vary widely depending on battery type.

As mentioned, the rated capacity of a battery is determined for its **C/20 (1/20 C) discharge rate**. Higher or lower rates of discharge may decrease realized capacity.

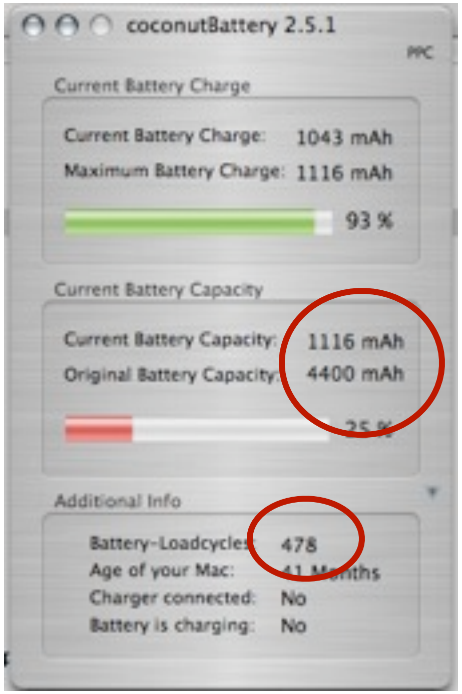


Thursday, March 28, 13

Other considerations:

Battery life – how many times a battery can be charged and discharged. Varies widely by type.

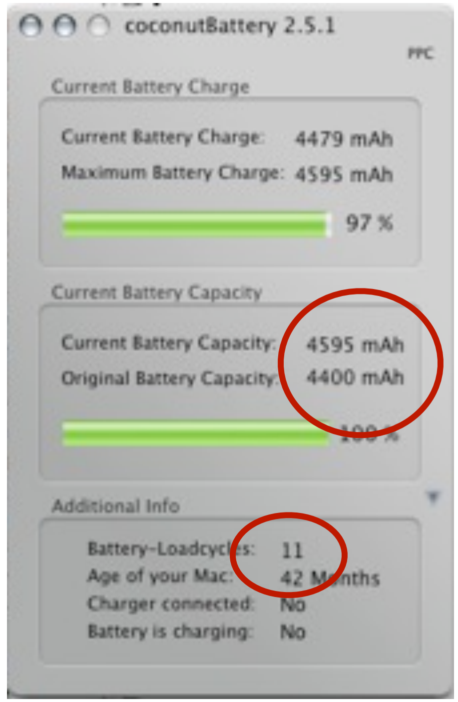
Depth of discharge – how deeply can it be discharged? Decreasing DOD increased life expectancy.



Old Battery

Capacity

Cycles



New Battery

Charging

Charging batteries can be very complex.

Doing it wrong can be dangerous!

Boeing Dreamliner

Charging – the hard (high performance) way

In order to maximize battery performance (most energy over longest time in smallest, lightest package) complex battery monitoring and charging circuits and algorithms are used.

They take into account:

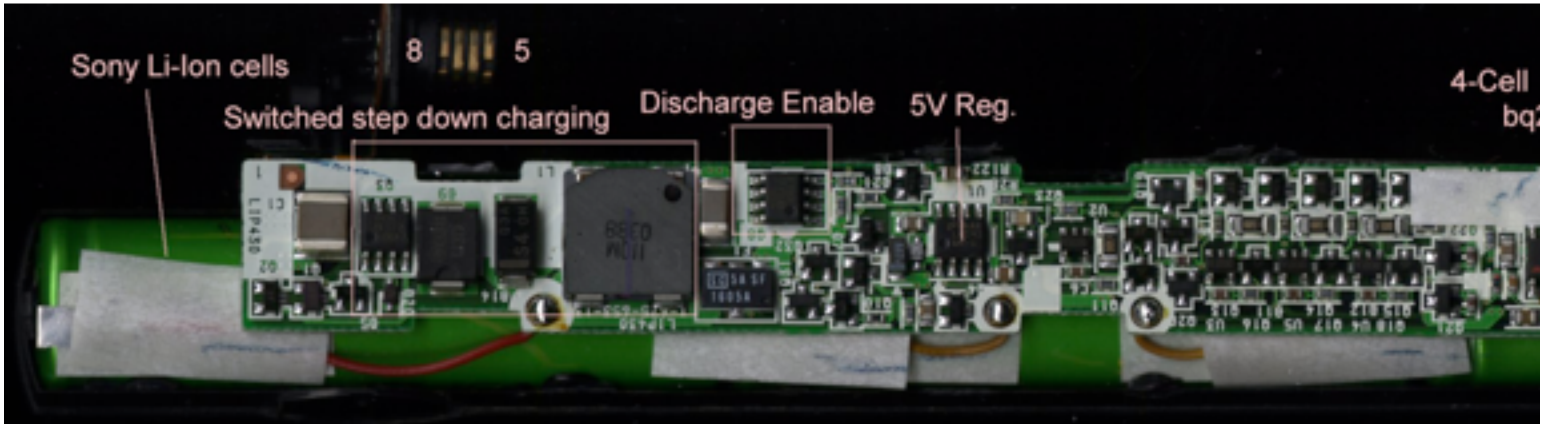
- Complete charge/discharge history of battery
- Temperature
- Battery age

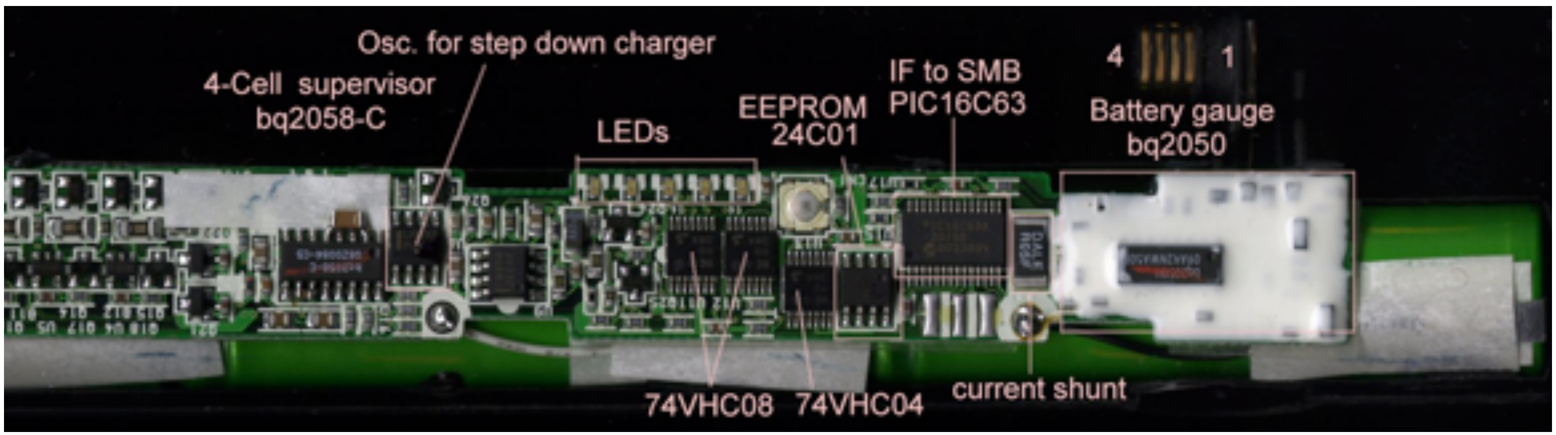
An advanced system typically uses a combination of constant current and/or constant voltage charge stages coupled with current, delta V, and/or delta T monitoring (changes in the rate of change of voltage or temperature). These will be tailored to the battery chemistry, number of cells, and other considerations.

Charging – the hard (high performance) way

Many manufacturers (Maxim, Analog Devices, etc) make dedicated battery ICs. (And publish whitepapers covering charging specifics)

The “Smart Battery” standard includes microcontrollers in the pack to communicate battery state to host device.





Charging – the easy (low performance) way

NiCad and NiMH batteries can be safely charged at C/10 (1/10C) at long periods of time (up to 15 hours).

Strategies for projects

Many off-the-shelf battery charging solutions are available that may be used in place of designing your own battery charger.

Small solar charge controllers are available for lead-acid and lithium batteries.

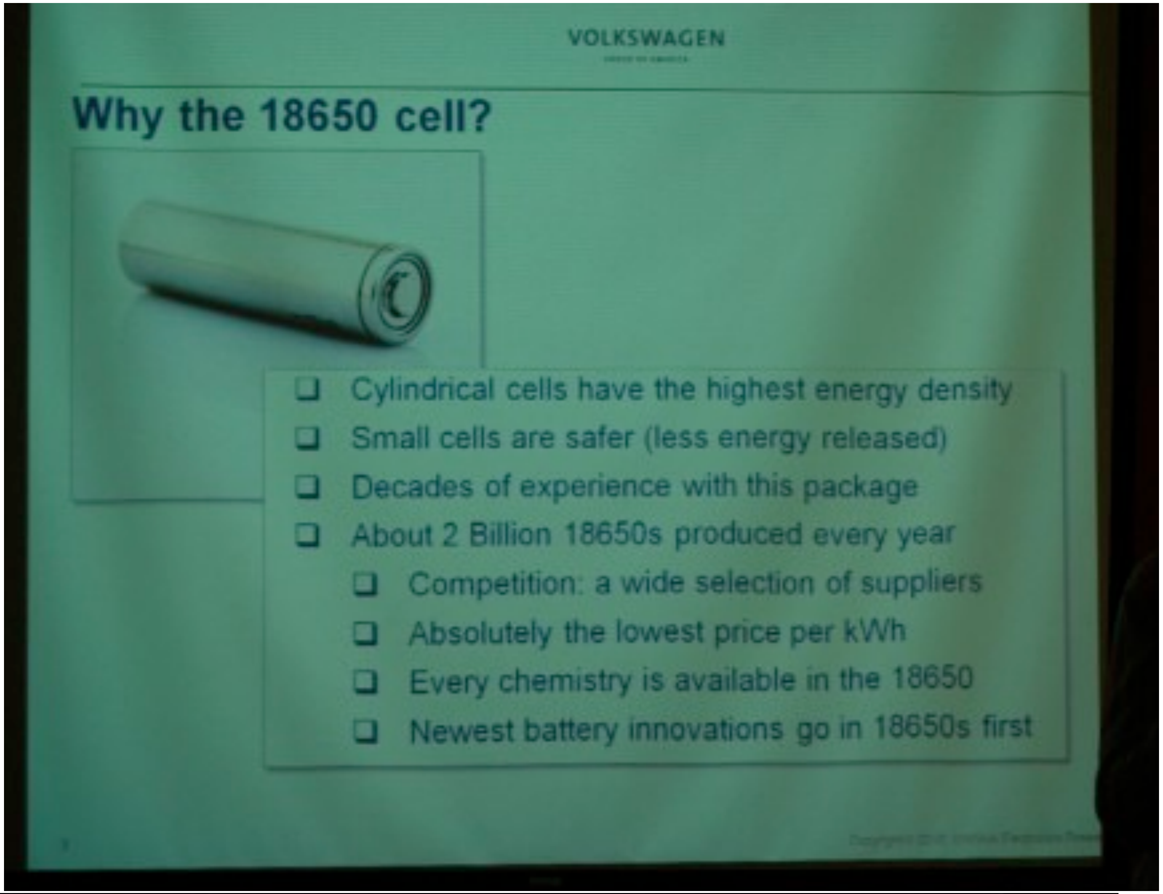
Ready-to-use lithium solar chargers are available (Solio, etc.)

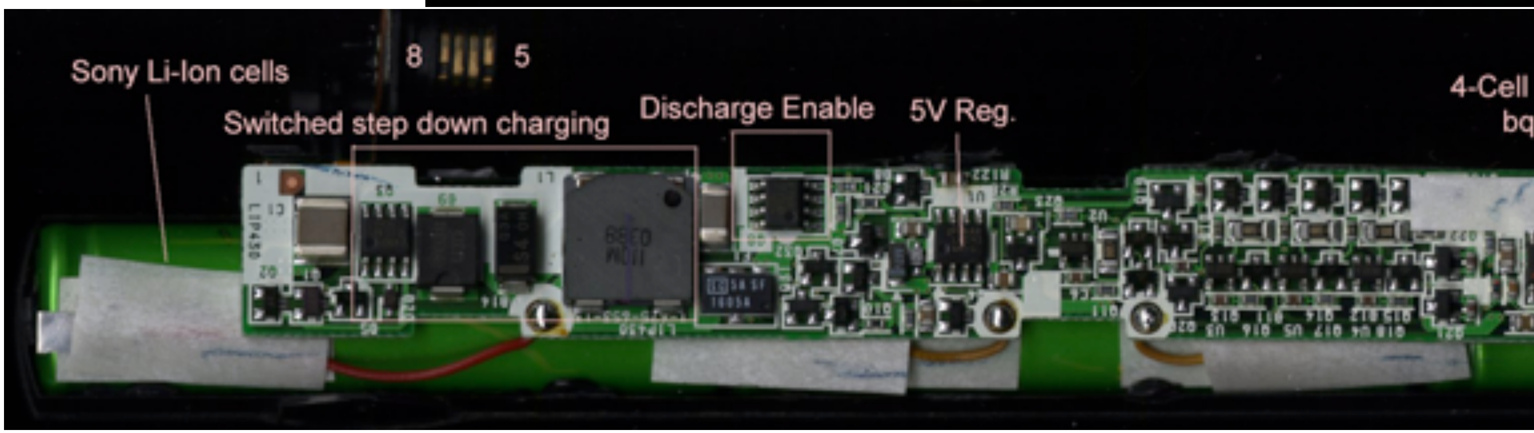
USB-powered chargers will work if you can provide up to 500 mA at 5 volts.

Etc…

18V Li-Ion battery, charger, and powerful variable speed motor ~$100

Tesla S


VOLKSWAGEN
Why the 18650 cell?
Cylindrical cells have the highest energy density
Small cells are safer (less energy released)
Decades of experience with this package
About 2 Billion 18650s produced every year
Competition: a wide selection of suppliers
Absolutely the lowest price per kWh
Every chemistry is available in the 18650
Newest battery innovations go in 18650s first


8
5
Sony Li-Ion cells
Switched step down charging
Discharge Enable
5V Reg.
4-Cell

Biggest trend: Vehicle-to-Grid storage

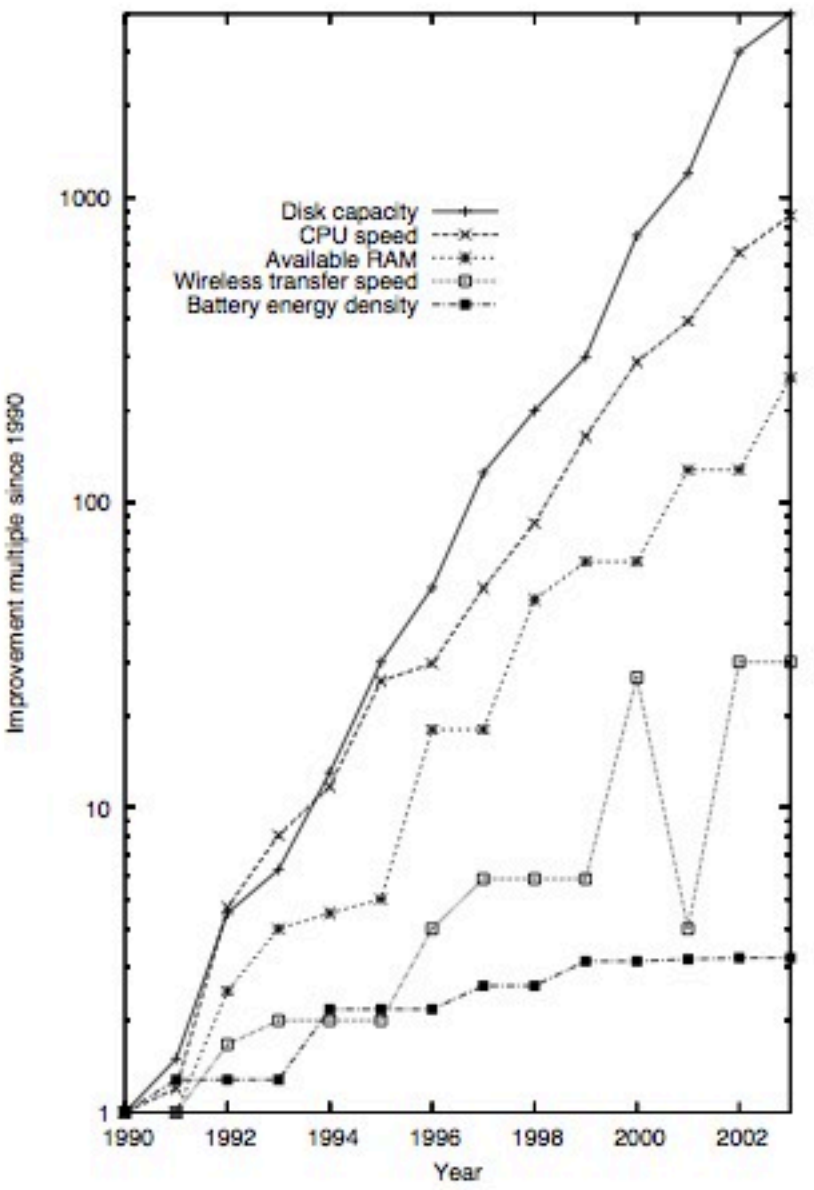
Wide-spread adoption of electric vehicles would be the first time the grid would have significant storage capacity.

Tesla S

Chevy Volt

Nissan Leaf

http://www.youtube.com/watch?v=y4P_ACPT5wA



“Don’t let anybody tell you batteries are going to get better. They can’t, it’s physically impossible.” Batteries are made of electrons on metal with oxygen in between; without a way to compress matter and make it more dense, battery store can’t improve, ever. What people can speak to is “power density” — but on the whole, batteries are “lousy, lousy, lousy, lousy.” We use fuels because they have lots of energy. We could use other energy sources, but when push comes to shove, we get a lot of energy out of fuels, because we can put electrons in tiny volumes of space.

Daniel Nocera interviewed in:
http://poptech.org/blog/daniel_nocera_on_personalized_energy