

## Batteries Alt Energy Talk

>> I will be talking tonight a bit about electric cars and not just batteries. Good Batteries have developed often in response to the needs of electric cars.

So we will start with some history.

Thomas Davenport is credited with building the first EV In 1834.

Problem was that no rechargeable or secondary cells as they are sometimes called existed.

>> In 1859 Gaston Planté invented the Lead acid battery the first practical rechargeable battery

>> About 1860 onwards small numbers to 1890's where they out sold Petrol&Diesel ten to one.

### [Ferdinand Porsche](#)

At the 1900 Paris Auto show Ferdinand Porsche yes that porsche turned up in one of his Mixte Hybrids.

[Porsche 2wd](#) The standard model used two hub motors and had a top speed of 67 kph. This was an absolute sensation. The car was twice as fast as virtually anything else there. [Porsche racer](#) He won many races with this car and hundreds were built. [Porsche 4wd](#) In 1903 a four wheel drive model was finally built with a top speed of 110 kph. If it had been built just eighteen months earlier it would have held the world land speed record. The cars used a very common platform at the time of a series hybrid. These required no clutch or gearbox, and also ran a much smaller engine than their petrol cousins and so were far far easier to crank start.

The success of these hybrids shows that Lead-acid

batteries are quite capable of being used in a hybrid car. Porsche's patents were sold to Mercedes who decided not to produce any hybrids though the Lohner-Porsches were selling well.

>> Around the same time as this in Sweden the first Nickel-Cadmium cells and Nickel Iron cells were produced.

Also in 1900 the French company BGS set a range benchmark of 180miles on one charge. This kind of figure was often produced through design very different to today's cars with upto 60% of the total weight of the car as batteries.

### [Detroit electric](#)

Electric cars were especially popular amongst women, even Henry Ford's wife drove one. Their cleanliness and simplicity of operation was very appealing. I am sure the same can apply in the modern world.

One Detroit electric managed to achieve more than 340km on a lead acid battery, though many sold used Edison's version of the nickel iron battery. One of these detroits now resides in Jay Leno's garage and still runs on its original nickel-iron cells.

1960's The next major change in electric car format came with VRLA. This made the batteries safer, more durable, and most importantly less maintenance through less water use.

### [Henney kilowatt](#)

In England a few dozen Henney kilowatts were produced. They were converted Renault dauphines. They had a top speed of 60mph and could travel 60 miles on a charge. It

used a series wound DC motor and this is significant as most home built electric cars today use the same layout and technology with similar results. Though the controllers are now smaller and far more advanced.

### Renault metro

In 1977 three Renault Metros joined President Carter's inauguration parade. I include this simply because Obama was not the first to do this though I very much congratulate him for doing so.

### TEVan

The product of battery development in the mid-80's Nickel-Iron batteries with Eagle-Picher were developed with automatic watering systems and 55Wh/kg. More modern examples go to 80Wh/kg used the latest sintered plate techniques.

### GM EV1

Much was achieved through the California clean-air act which forced the introduction of electric cars. General motors produced the EV1 - showing that Lead-acid batteries can be the basis of a practical electric car. [Ford ranger](#) It also powered the pickup trucks of the Ford Ranger and Chevy S10, many of which are still working hard today. [Nissan Altra](#) Nissan produced the Altra with lithium batteries, and even though these were the more dangerous Lithium Cobalt Chemistry. The car was suitably constrained and they experienced no fires with this car.

[AFS prototype](#) On the other hand a series hybrid uses the thermal engine more intelligently and simply. 200mpg can easily be achieved and careful design could reach 300mpg. The AFS Trinity prototype gets 250mpg. Also electric only operation is possible so renewable power from hydro, wind and solar can be accessed.

Now let's talk specifically about batteries.

### [Volta cell](#)

We want four factors in our car battery-

- to do the job - enough power and energy  
safety - thermal runaway - toxicity of materials - good  
charge characteristics. - use of large industrial cell is  
absolutely necessary.

price - batteries where possible need to be made from  
common element materials and must be easy to  
manufacture

longevity - cycles float time and able to recharge from flat

By these criteria many battery types fail.

NiMH - the fire cracker battery. They are quite inefficient at high rates of charge and discharge, leading to heating and thermal runaway from 55-70°C. Manufacturers appear afraid to mention the true value.

Vanadium - various easily formed compounds are as toxic as the same compounds of Mercury. This is of concern as the highly corrosive electrolyte is fully exchanged with each charging cycle.

Molten salt batteries- such as Sodium sulfur and Sodium nickel chloride (zebra). Zebra live at 270°C to 350 much

energy is wasted. The car must reach a power point at least once a day. Otherwise the battery cools and thermally cycling the battery to room temperature is very damaging. Also reports from test cars say the cabin is uncomfortably warm as much heat still escapes the thermos which houses the battery. NaS are worse as they live at a higher temperature and caused fires in the prototypes built by BMW.

Silver based batteries are promising but too expensive and often short life of 100 or so cycles.

### Large-format-cell

Lithium ion

Let's stop talking about lithium ion batteries and mention the proper chemistry as some are bad and some much better.

LiCoO are the laptop batteries - short life - very bad charge characteristics and thermal runaway caused by self-heating.

A bit safer are

LiMnO<sub>2</sub> they last longer - deliver better power - Now Manganese is cheaper than Co still self-heat to some degree. Their thermal runaway of 270°C is significantly higher than LiCoO 160°C

Easily the most promising Lithium is

LiFePO<sub>4</sub> thermal safe over 400°C appears to have no self-heating. Power is limited to about 2C unless the carbon electrode is specially treated - so far we are taking A123's word on this as they are claiming to produced batteries easily capable of over 10C. Historically high power batteries often lose their high power after a 100 cycles or

so but still live a normal cycle life at an average power rate. So testing will show the truth here.

The major limitation comes from the birth of this battery at the university of texas in 1995 - LTC bought the patent and makes the substrate for the electrodes. Only a limited number of companies have licenses to produce these batteries. Thundersky and other chinese brands are not amongst them. To sell a car powered by these chinese batteries would leave one in a very bad legal position. Saft has indicated that at high production numbers of these could be priced as low as \$150 per kWh. So although prices are high now this will drop with time.

Battery management is very necessary with all Lithium batteries to manage the fact that they withstand charge abuse very poorly, and can also go out of balance with their neighbours. The systems available reflect the money spent and expertise employed. If corners are cut the battery will not survive the warranty period.

Another issue to be careful of is dangerous electrolytes - some contain  $\text{CCl}_4$  and other carcinogens - some explode on contact with water-this was in the MSDS for the 2007 Thundersky model.

Safe alternatives are available but proper enquires need to be made, even though battery manufacturers are often reluctant to provide this information.

There are 2 big benefits to Lithium Iron phosphate technology. Lightness and efficiency. They are about quarter the weight of Lead-acid and half the weight of Nickel Cadmium.

For efficiency it is fair to rate them 10-20% better than any

common rival.

The easiest battery option is Lead acid

GM's EV1 proved a practical car can be built - but the battery weight was 594kg for a 100 mile range. Today's technology now 20 years later could achieve a similar result for about 400kg.

NiCd - about twice the energy density of lead acid.

[Hoppecke fibre](#) Modern versions last through 3000 cycles for a 25 year lifespan. They have maximum discharge values upto 20C and store double the energy of a lead-acid battery. The great feat they also perform is that they can recover after being run flat, and are highly resistant to charge abuse. They also do not require complex battery management systems. Also the use of new fibre or sintered electrodes mean this battery no longer suffers from memory effects.

Off the shelf Saft batteries have 55 Wh/kg and upto 80Wh/kg is possible. They say the next season of batteries will be 65Wh/kg. They also have the advantage of sagging under load much less than Lead-acid. So a car with these batteries would be much better at climbing hills. Also remember that all of the energy of the battery is available not just 80%. Also there is no heavy battery management to add. These batteries are low power between 100-200 Wh/kg, but Saft's type sth or stx batteries for hybrids offer 350W/kg in power but energy drops back to 35Wh/kg. Hoppecke's fibre electrode batteries offer similar energy but more power at above 600W/kg. These are probably the only current commercial battery you can flatten and

with a proven long life. They do suffer in efficiency being about 20% below  $\text{LiFePO}_4$

NiFe - When invented in 1902 the energy and power was low. They were much further developed 1980's energy density was doubled to over 50wh/kg. Their limited power mattered then as DC motors were the go - now PMM's and their high torque mean this battery should get a new life. They are the king for withstanding charge abuse and other maltreatment. The electrolyte can completely dry and the battery can still be recovered. However compared to  $\text{LiFePO}_4$  they are about 35% less efficient. They do require automatic water systems due to their water consumption, but these systems have been well developed.

Only one manufacturer in China- the American distributor charges \$1000 per kWh though the studies in the 80's showed production in good numbers should lead to price below \$150 per kWh

Metal-air - still in development some chemistries look good but Zinc and Aluminium clearly don't work. Their energy density is better than Lithium, ranging from 140 Wh/kg to over 500. They can have long life, and are strongly resistant to charge abuse. The negatives are lack of efficiency and water use - they are very similar to NiCds.

In short I would recommend if you need a robust battery right now then choose NiCds.

Some Carbon-based capacitors will be coming soon. They are currently in the 25Wh/kg range.

The world of energy storage is ever changing and the future lies in high energy density capacitors which were demonstrated at Los Alamos Lab almost a decade ago. They were tested to store ten times the energy of a lead acid battery and recharge through 2.7 million cycles. Also many battery chemistries exist which are highly classified due to military use. A healthy electric car market could bring these to the public market.

### **Large format cells**

Thundersky yes \$600

China Batteries yes - also known as foxx lithium \$500

Epoch by electrovaya yes \$2000

Axeon europe yes \$unknown probably OEM only

Phostech Lithium - direct company of LTC - 10 to 20C discharge - not available yet

A123 small high power \$1200 large-format developed and only available in chev volt

Phet small \$1100

Leoindustries actually small cells \$2000