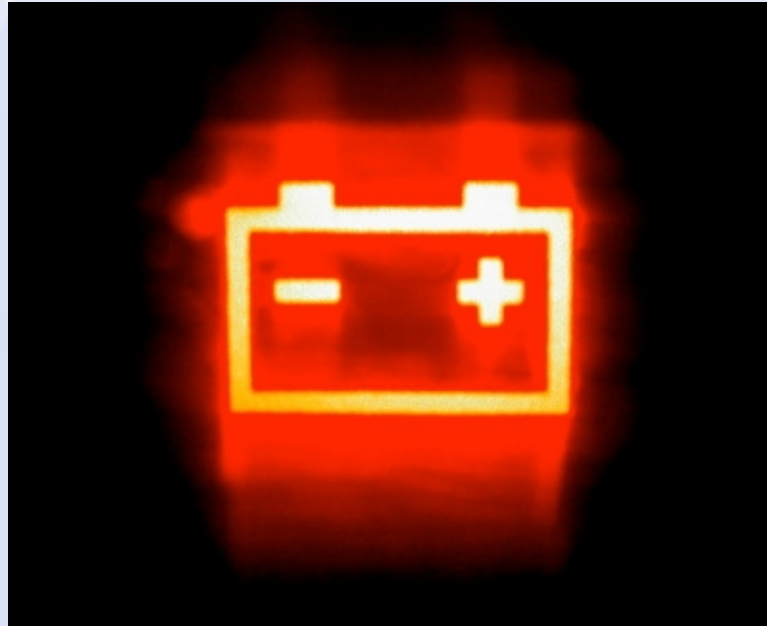




Welcome  
to the  
February 2010 meeting  
of the  
Australian Electric Vehicle Association  
(AEVA Adelaide)

# EV Battery Comparison



***Presenter: Eric Rodda***

***For AEVA Meeting: 23<sup>rd</sup> February 2010***



# EV Battery Comparison

## Battery Requirements for Typical Traction Applications

*Traction applications have traditionally been jobs for Lead Acid batteries but the limitations of Lead Acid batteries, together with the high cost of alternatives, have in turn limited the range of potential battery powered traction applications. A typical family car would need a battery capacity of about 40 KWh to provide a one way range of 200 miles and a 40 KWh Lead Acid battery weighs 1.5 tons.*

*continued...*

# EV Battery Comparison

## Battery Requirements for Typical Traction Applications

*The situation is changing however as new battery chemistries and supporting technologies have brought with them new technical and economic benefits making battery power viable for traction applications that were previously uneconomic or impractical. In particular, the use of light weight Nickel Metal Hydride and Lithium batteries instead of the heavy and bulky Lead Acid batteries has made practical electric vehicles and hybrid electric vehicles possible for the first time.*

*Courtesy: Woodbank Communications Ltd*

# EV Battery Comparison

## Electric Vehicle (EV) Battery Operating Requirements

*Large capacity batteries are required to achieve reasonable range.*

- The battery must be capable of regular deep discharge (80% DOD) operation*
- It is designed to maximise energy content and deliver full power even with deep discharge to ensure long range.*
- A range of capacities will be required to satisfy the needs of different sized vehicles and different usage patterns.*
- Must accept very high repetitive pulsed charging currents (greater than 5C) if regenerative braking required.*

Courtesy: Woodbank Communications Ltd *continued...*

# EV Battery Comparison

## Electric Vehicle (EV) Battery Operating Requirements(cont.)

- *Without regenerative braking, controlled charging conditions and lower charging rates are possible. (At least 2C desirable).*
- *Routinely receives a full charge.*
- *Often also reaches nearly full discharge.*
- *Fuel-gauging critical near "empty" point.*
- *Needs a Battery Management System (BMS).*
- *Needs thermal management.*
- *Typical voltage > 300 Volts.*
- *Typical capacity > 20 - 60 kWh.*
- *Typical discharge current up to C rate continuous and 3 C peak for short durations.*

*continued...*

*Courtesy: Woodbank Communications Ltd*

# EV Battery Comparison

## Electric Vehicle (EV) Battery Operating Requirements(cont.)

*Because these batteries are physically very large and heavy they need custom packaging to fit into the available space in the intended vehicle.*

*Likewise the design layout and weight distribution of the pack must be integrated with the chassis design so as not to upset the vehicle dynamics.*

*These mechanical requirements are particularly important for passenger cars.*

# EV Battery Comparison

**What are the different types of electric car batteries?**

*There are several different types of electric car batteries including:*

- **Lead-acid batteries**
- **Nickel metal hydride batteries**
- **Lithium-ion batteries**
- **Zinc-air batteries**
- **Molten salt batteries**

*Courtesy: [TheGreenCarWebsite.co.uk](http://TheGreenCarWebsite.co.uk)*



# EV Battery Comparison

**What are the different types of electric car batteries?**

## **Lead-acid batteries**

*The most widely available and the least expensive, electric cars that use lead-acid batteries usually have a range of 80 miles per charge.*

*There are concerns however, over their disposal. Lead-acid battery recycling is popular although an effective pollution control system is needed to reduce emissions.*

*Deep Cycle Types: - Flooded  
- Valve Regulated (VRLA) eg. AGM & Gel*

# EV Battery Comparison

What are the different types of electric car batteries?

## Lead-acid

*The most common type of battery that use lead-acid technology to charge.*

*There are many types of Lead-acid batteries, but they all produce pollution during charging.*

*Deep Cycle*



*electric cars  
100 miles per*

*disposal.  
effective  
\$.*

*M & Gel*

Courtesy: [TheGreenCarWebsite.co.uk](http://TheGreenCarWebsite.co.uk)

# EV Battery Comparison

**What are the different types of electric car batteries?**

## **Nickel metal hydride batteries**

*Abbreviated to 'NiMH' these have a higher energy density than lead-acid batteries and can deliver a range of up to 120 miles. The energy density for nickel metal hydride batteries is approximately 250kJ/kg and these batteries have been used in many all-electric plug-in vehicles including the Toyota RAV4 EV, General Motors EV1 and Honda EV Plus. They have also been used in hybrid vehicles including the Toyota Prius and the Honda Civic Hybrid. Generally they have a lower environmental impact than nickel-cadmium batteries due to the absence of the toxic cadmium. Most industrial nickel is also recycled due to its high value.*

*Courtesy: [TheGreenCarWebsite.co.uk](http://TheGreenCarWebsite.co.uk)*

# EV Battery Comparison

**What are the different types of electric car batteries?**

**Nickel metal hydride batteries**

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Courtesy: [TheGreenCarWebsite.co.uk](http://TheGreenCarWebsite.co.uk)



# EV Battery Comparison

**What are the different types of electric car batteries?**

## **Lithium-ion batteries**

*Lithium-ion batteries are widely preferred for electric car use due to their superior range per charge – at around 250-300 miles. They are also less expensive than nickel and they have a low discharge rate of approximately five per cent per month compared to 30 per cent per month from nickel-metal hydride batteries. To prolong the life of a lithium-ion battery, it should be charged early and often, they should never be depleted below their minimum voltage and they should be kept cool but not frozen.*

*Courtesy: [TheGreenCarWebsite.co.uk](http://TheGreenCarWebsite.co.uk)*

# EV Battery Comparison

What are the different types of electric car batteries?

## Lithium-ion batteries



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Courtesy: [TheGreenCarWebsite.co.uk](http://TheGreenCarWebsite.co.uk)

# EV Battery Comparison

**What are the different types of electric car batteries?**

*There are two other types of batteries that have been used for electric vehicles, but only rarely.*

*They are:*

## **Zinc-air batteries**

*Electro-chemical batteries powered by the oxidation of zinc with oxygen from the air. They are inexpensive, have high energy densities and are most commonly used in hearing aids.*

*continued...*

# EV Battery Comparison

**What are the different types of electric car batteries?**

*There are two other types of battery technology that have been used for electric vehicles, but they are not used much anymore.*

*They are:*

## **Zinc-air batteries**

*Electro-chemical batteries that use zinc with oxygen from the air. They have high energy densities and are used in hearing aids.*



*continued...*

Courtesy: [TheGreenCarWebsite.co.uk](http://TheGreenCarWebsite.co.uk)



# EV Battery Comparison

**What are the different types of electric car batteries?**

*and...*

## **Molten salt batteries**

*These use molten salt as an electrolyte. They are used in services that rely on high energy density and high power density, which is ideal for electric vehicles. However, they generally rely on operating temperatures between 400°C and 700°C which can make their usage prohibitive.*

*Courtesy: [TheGreenCarWebsite.co.uk](http://TheGreenCarWebsite.co.uk)*

# EV Battery Comparison

What are the different types of electric car batteries?

*and...*

**Molten salt**

*These use  
services that  
density, which  
generally run  
and 700°C*



*used in  
high power  
over, they  
run at 400°C*

Courtesy: [TheGreenCarWebsite.co.uk](http://TheGreenCarWebsite.co.uk)

# EV Battery Comparison

**Peukert's\* Law**, presented by the German scientist W. Peukert in 1897, expresses the **capacity** of a **lead-acid battery** in terms of the rate at which it is discharged.

As the rate increases, the battery's available capacity decreases. However, more commonly, manufacturers rate the capacity of a battery with reference to a discharge time.

\*Pronounced: POY KERT

*Courtesy: Wikipedia.org*

# EV Battery Comparison

## Peukert's Law ...cont

For an ideal battery, the Peukert constant  $k$  would equal one, in this case the actual capacity would be independent of the current. For a [lead-acid battery](#), the value of  $k$  is typically between 1.1 and 1.3 however. The Peukert constant varies according to the age of the battery generally increasing with age. Application at low discharge rates must take into account the battery self-drain current.

*Courtesy: Wikipedia.org*

# EV Battery Comparison

## Peukert's Law ...cont

The Peukert law becomes a key issue in a [battery electric vehicle](#) where batteries rated at 20 hour (or even 100 hour) discharges are used at much greater rates of about 1 hour.

*Courtesy: Wikipedia.org*

# EV Battery Comparison

## Peukert's Law ...cont

$$C_p = I^k t$$

where...

$C_p$  is the capacity in Ah (at 1 amp discharge)

$I$  is the discharge current expressed in Amps

$K$  is the Peukert constant

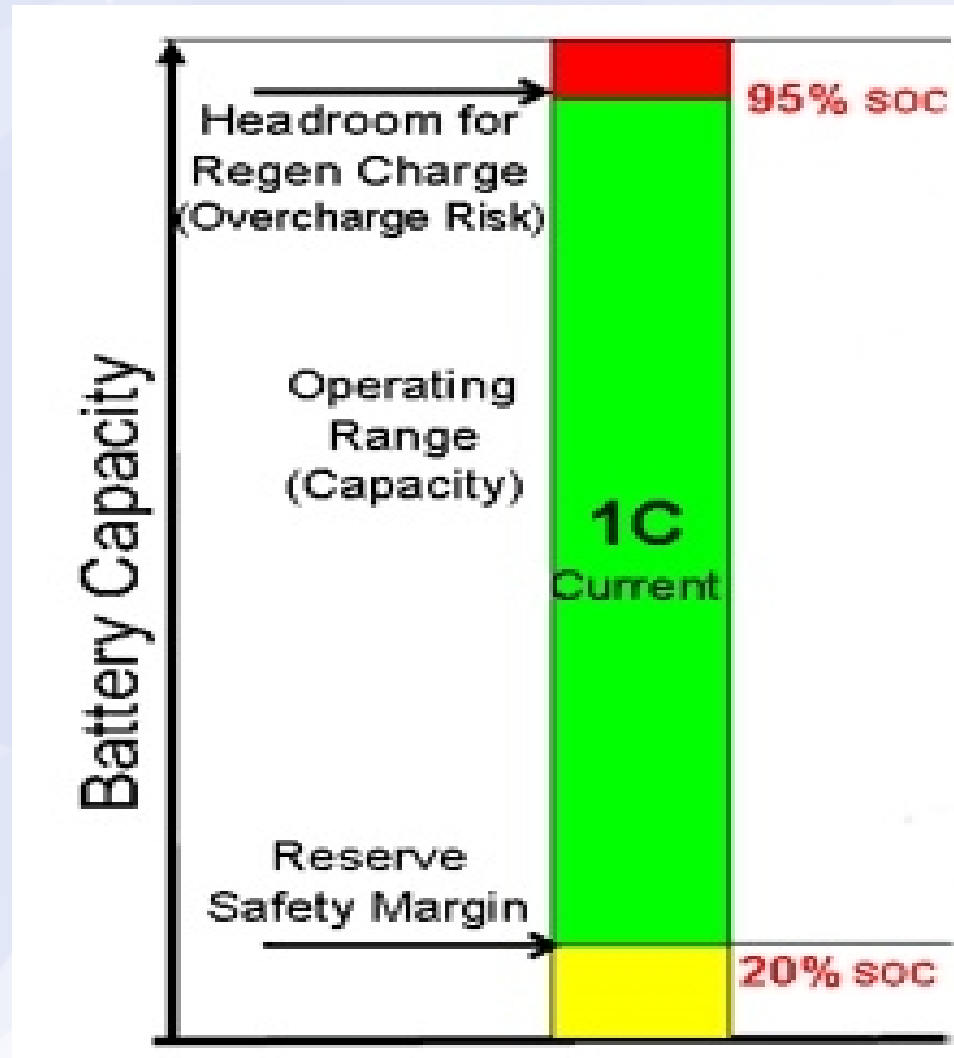
$t$  is the time of discharge in hours

*Courtesy: Wikipedia.org*

# EV Battery Comparison

Type	Voltage (V)	Energy density (MJ/kg)	Power (W/kg)	Charge/Discharge Efficiency (%)	Time durability (years)
Lead-acid	2.1	0.11-0.14	180	70-92	3
Ni-cadmium	1.2	0.14-0.22	150	70-90	N/A
NiMH	1.2	0.11-0.29	250-1,000	66	N/A
Lithium-ion	3.6	0.58	1,800	99.9	2-3
Lithium-poly	3.7	0.47-0.72	3,000+	99.8	N/A
Molten salt	N/A	N/A	150-220	N/A	8+

# EV Battery Comparison



Courtesy: [TheGreenCarWebsite.co.uk](http://TheGreenCarWebsite.co.uk)



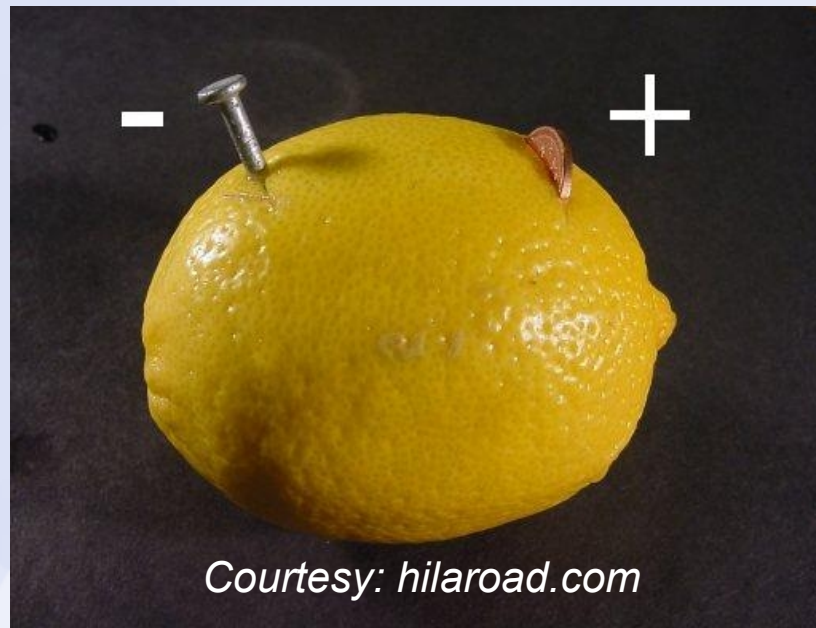
# EV Battery Comparison

	Chevy Volt	Mitsubishi MiEV	MiEV Sport	Tesla Roadster	Opel Flextreme	Aptera
<b>Estimated Production Date</b>	2010	2010	2010	2008	2010	2008
<b>Estimated Price</b>		30000		98000		26900 for EV, 29900 for Hybrid
<b>Estimated Initial Production</b>	60000	1000		650		
<b>Body Style</b>	4-5 Passenger Sedan	4 Passenger Sedan	2+2 Passenger Sedan	2 Passenger Roadster	3 Door Liftback	2 Door
<b>Vehicle Class</b>	Compact Car	Sub-Compact Car	Sub-Compact Car	Compact Car	Compact Car	Micro Car
<b>Battery Type</b>	Li-Ion	Li-Ion	Li-Ion	Li-Ion	Li-Ion	
<b>Peak Power</b>	130 - 140 kW	47 kW	87 kW	185 kW	120 kW	
<b>Continuous Power</b>	45 kW					19 kW
<b>Generator Power</b>	54 kW	n/a		n/a	53 kW	12 kW
<b>Recharge Time @ 110V</b>	6 - 6.5 hours	13+ hours	17 hours	3.5 hours	6 hours	
<b>0-60 time</b>	8 - 8.5 seconds			4 seconds		< 10 seconds
<b>Weight</b>	3140 pounds	2380 pounds		2700 pounds		850 pounds
<b>Full EV Range</b>	40 miles	99 miles	124 miles	245 miles	34.17 miles	120 miles
<b>Extended Range</b>	640 miles	n/a	n/a	n/a	444 miles	600 - 700 miles
<b>Peak Power / Weight Ratio</b>	34.6	19.7		68.5		

*Courtesy: V is for Voltage Forums*

# EV Battery Comparison

## Questions ...



*This Lemon Battery produces approx. 1 Volt*

