

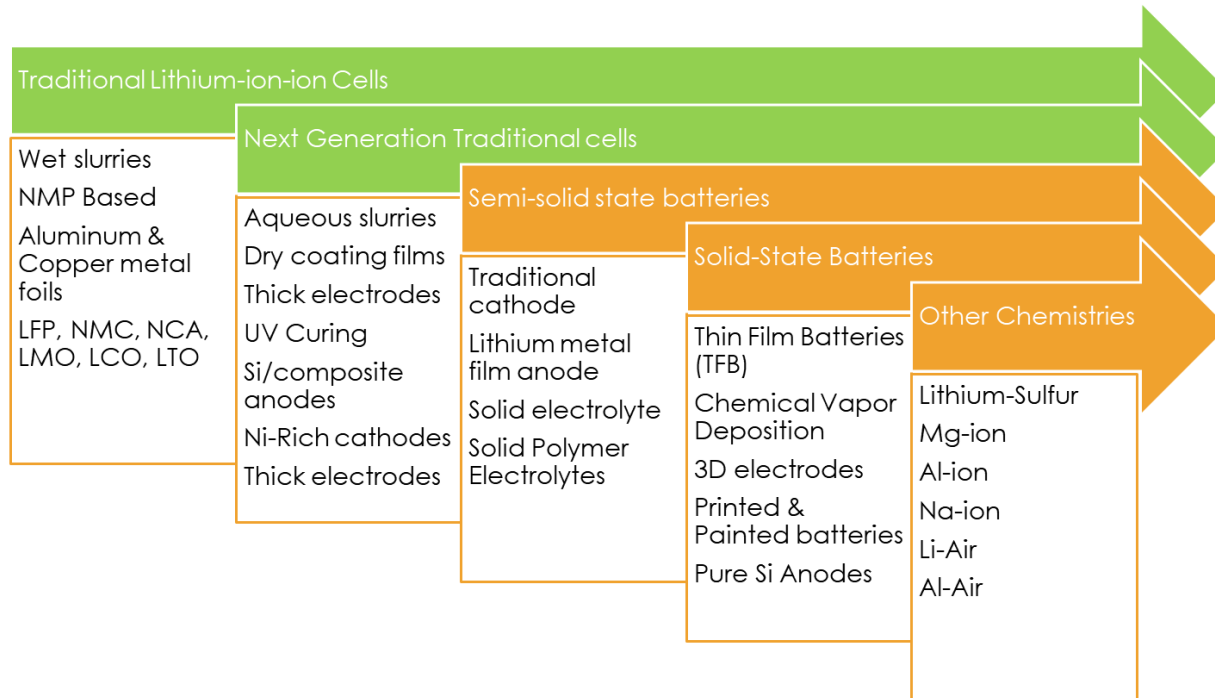


Can Lead Acid Batteries Maintain Their Market Share ...Among New Technology Entrants?

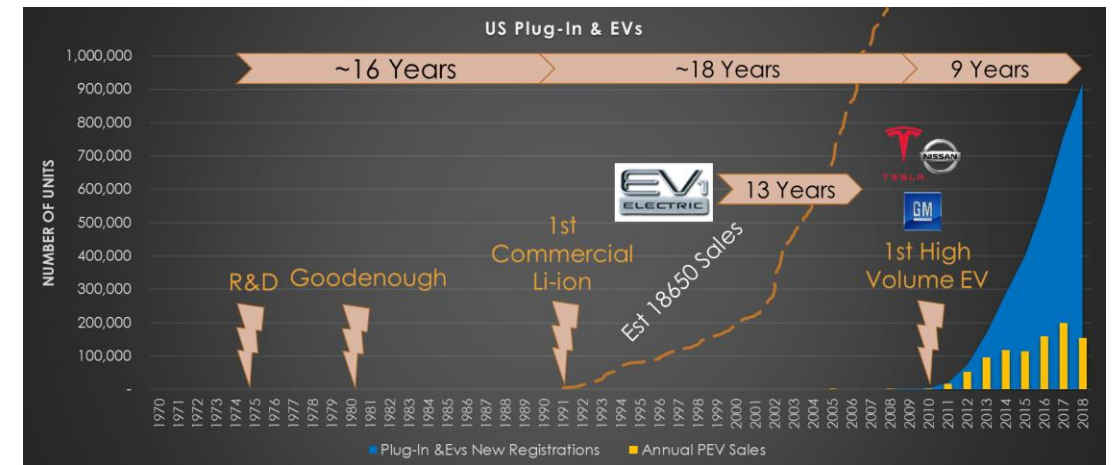
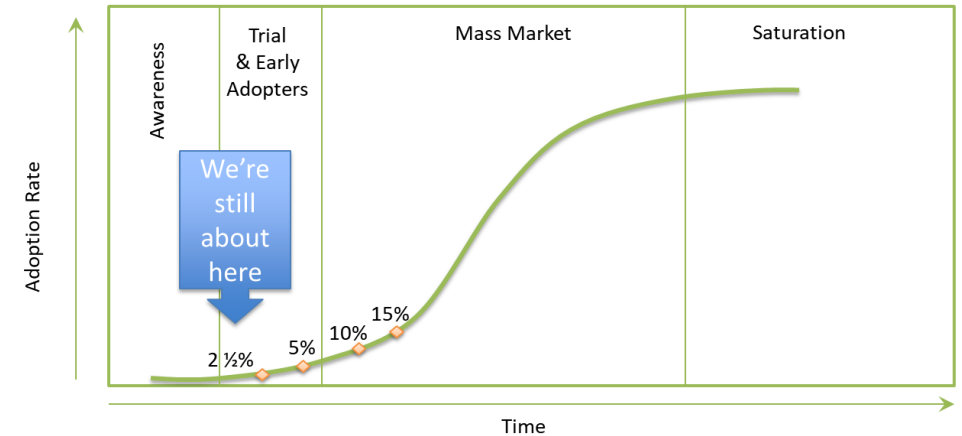
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Dr John Warner
Wednesday, March 13, 2019

New Technologies Emerging Fast But Take Time to be Adopted



- Lithium-Sulfur
- Solid-State / Lithium Metal
- Aluminum-Ion



From first lab work to 1M cumulative production EVs took lithium-ion 43 years

Other Chemistries that May Compete with Lead Acid

- Bi-Polar Cells
- Other Chemistries
 - Nickel Zinc
 - Nickel Iron
 - Zinc
- Air Batteries
 - Zinc
 - Nickel
- Flow Batteries



Bi-Polar Cells



Flow Battery



Nickel-Iron



Zinc-Air

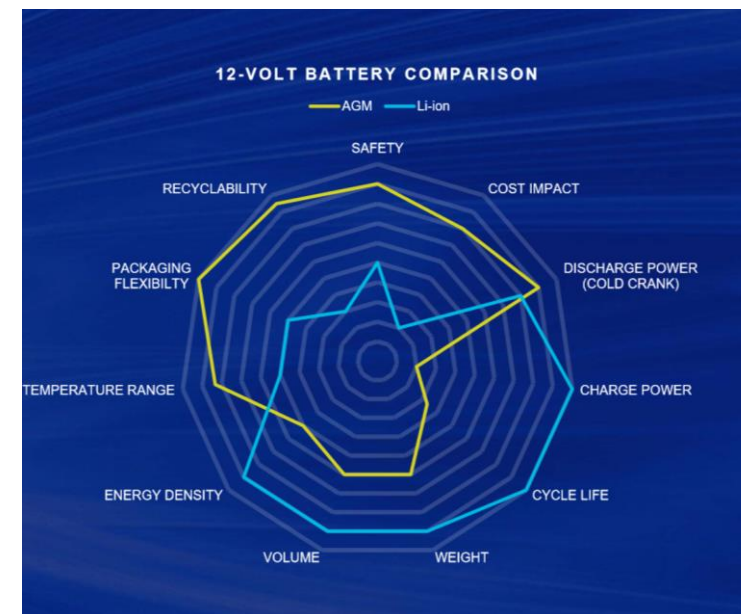


Nickel-Zinc

Lead Acid and Lithium-Ion Meet Very Different Needs

12V Micro-Hybrids & Stop/Start

- Lead acid – Advanced PbA and AGM
- 12V platforms are going to be almost universal with lead acid/advanced lead acid stop/start in North America within the next five years



48V Stop/Start & Mild Hybrids

- 48V and above hybrids moving towards other battery chemistries
- Higher power and energy demands drive towards Li-type solutions and away from lead acid

	Lead Acid	Lithium-ion	
Chemistry Descriptor	PbA / LAB	LTO	LFP
Specific Energy (Wh/kg)	30-40	60-80	90-120
Energy Density (Wh/L)	60-70	170-230	190-300
Specific Power (W/kg)	60-180	1,000	4,000
Power Density (W/L)	100	2,000	10,000
Nominal Voltage (per cell)	2.0V	2.3V	3.3V
Cycle Life	300-800	>15,000+	5,000-6,000
Self-Discharge (% per month)	3-5% (AGM 1-3%)	2-10%	<1%
Operating temperature range	-20°C to +50°C	-30°C to +75°C	-20°C to +60°C
Maintenance	3-6 months	None	None

EU Ban on Lead is Delayed...

...but is not dead

- ▶ April 2006:
 - ▶ “The Committee of the Regions (CoR) today called on the European Commission to seek a near-total ban on the use of mercury, lead and cadmium in household batteries.”
- ▶ November 2016
 - ▶ “ECHA rejected all claims and included four types of lead product [lead monoxide, lead tetroxide, pentalead tetraoxide sulphate and tetralead trioxide sulphate] used in batteries for inclusion in the Annex XIV.”
- ▶ June 2018
 - ▶ “A decision announced by the European Chemicals Agency on 27 June to add lead metal to the EU REACH candidate list of substances requiring authorisation flies in the face of the battery action plan unveiled just weeks ago by the EU Commission”
- ▶ February 28, 2019:
 - ▶ “We understand the EC advises not to include the lead compounds on the REACH list and the member states will vote on this, probably in April,”
 - ▶ “... we think the decision has been made to postpone — but it's not a guarantee for ever — adding the compounds to the list”



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