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Website: gridmod.sandia.gov

Batteries and Energy Storage

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Batteries and Energy Storage – New Drivers

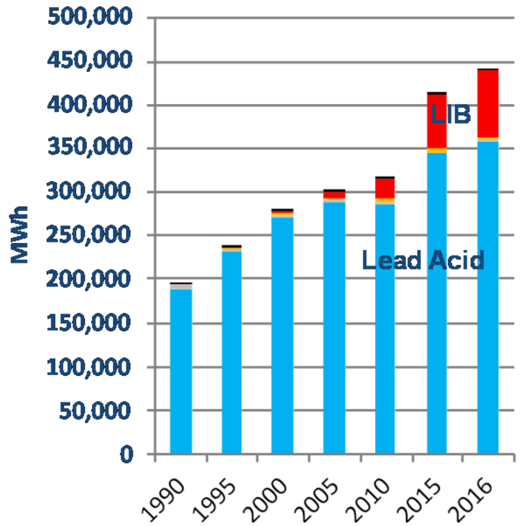
- Enabling electrification of transportation
  - Need batteries with higher energy and power densities
  - Continued improvements in cell costs, cycle life, safety and reliability
  - Lighter and faster recharge times

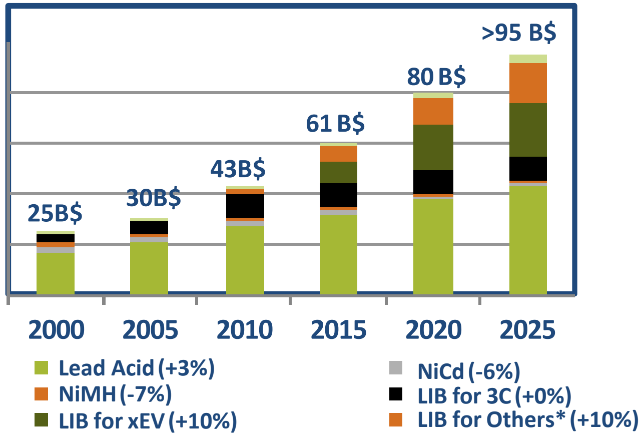
- Transformation of the electricity infrastructure
  - Aging grid infrastructure, energy storage can improve grid reliability and resiliency
  - Accommodating the growth of renewables and distributed generation
  - Large T&D infrastructure deferrals
  - Need lower costs, systems scalable from kWh to 100's of MWh
  - Long cycle life and low operating costs

Rechargeable Batteries – Industry Status

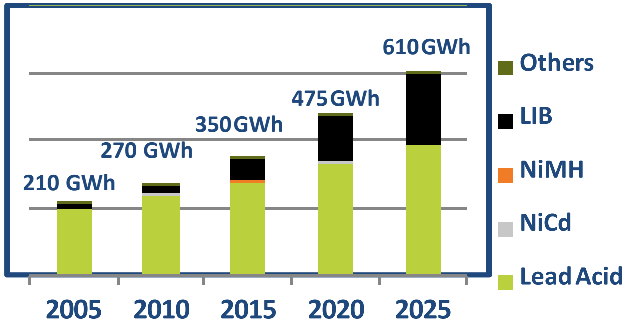
Mature Technologies				
	World Wide Capacity (GWh/y)	**Cost and Performance Improvements**	**Key Challenges for Energy Storage**	**Major Suppliers**
Lead Acid Batteries (LAB)	350	2%/year ((30 year data). $150/kWh	Cycle life. Advanced lead acid cycle life on par with EV grade LIB	JCI, GS Yuesa, EastPenn, EnerSys, Exide, Hagen, Amara Raja
Lithium Ion Batteries (LIB)	100	8%/year (20 year data). Cell level price reaching <$200/kWh	Cycle life for deep discharge. Safety. Thermal management	Samsung, LG Chem, Panasonic/Tesla, BYD, GS Yuesa, Lishen, JCI, Toshiba, ATL
Emerging Technologies				
NaS and NaNiCl	300 MWh	No economies of scale	High temperature chemistry. Safely, Cost	NGK, FIAMM
Flow Batteries	<200 MWh	Not fully mature. Potential for lower cost. $400/kWh. Reach $270/kWh	Not mature. Has not reached manufacturing scale.	Sumitomo, UET, Rongke Power, Gildenmeister
Alkaline chemistries (Na, Zn-MnO2,..)	<100 MWh	Not fully mature. Lowest cost BOM	Has not reached manufacturing scale.	UEP, Fluidic Energy

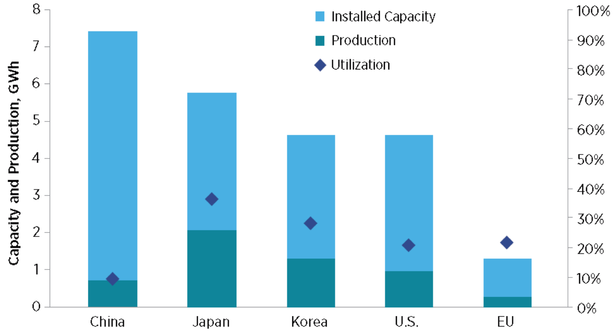
Manufacturing and Scale





Source: Avicenne, 2017



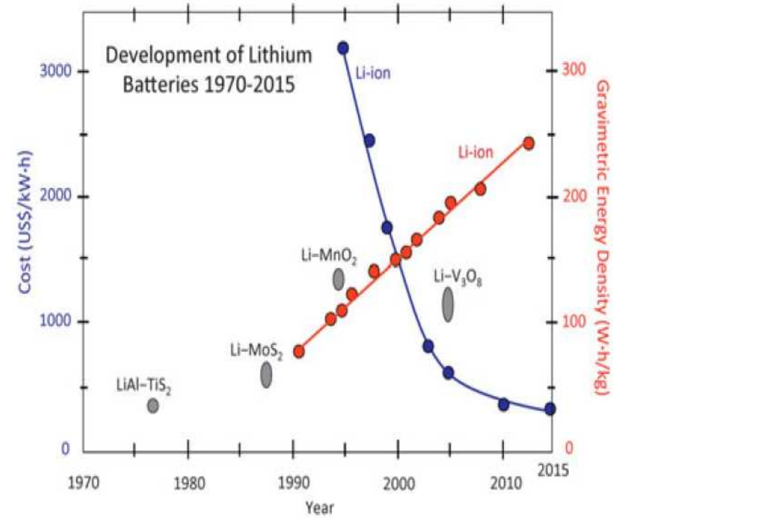


Source: D. Chang, et al, Automotive Li-ion Battery (LIB) Supply Chain and U.S. Competitive Considerations, NREL/PR--6A50--63354, June 2015

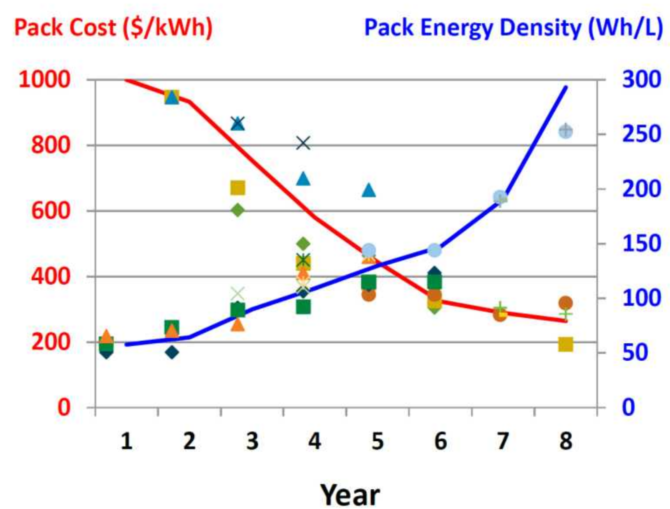
- Overcapacity in the large format LiB battery market. Factory utilization rates continue to be low. Continued consolidation in the EV LIB Battery business. Excess capacity driving the need for applications beyond EVs. Spillover into Grid applications.
- Lead acid batteries to continue to make improvements, business profitable

Lithium Ion Batteries

- First two generations driven by consumer electronics, newer chemistries geared for automotive applications
  - LiCoO2 continues be the dominant technology for consumer electronics
  - 2nd Generation Li-ion chemistries offering better performance, wider temp range, improved safety and lower cost
- Capacity improvements are incremental
  - 8% for LIB (1992-2007) and slowing; 2% for Lead acid
  - BOM is 80-85% of cell costs, scaling down materials cost difficult
  - Need significant improvement in electrolytes, membranes, anode and cathode materials
  - Engineering larger cells (>100 Ah) is not still economical
- Deep discharge cycle life issues for energy applications (1000 cycles for automotive)
- Safety and reliability continue to be significant concerns



Source: Crabtree, Kocs, Trahey, MRS Bulletin, Dec 2015



Source: David Howell, DOE VTO, 2017

Challenges to simultaneously achieve higher power and energy storage systems

- For aerospace and propulsion, how to engineer energy storage systems that are lighter, with high energy and high power capacities is the challenge.
- How do we manage the tradeoff between energy and power due to a combination of electrical, ionic, structural and chemical effects?
- How do we design materials to realize high energy and power simultaneously?
- How do we optimize power and energy at multiple length scales?
- How do we enable fast ion and electron transport without sacrificing energy density, while maintaining long life and safety? Or how to improve energy capacity without sacrificing safety and life?
- How to achieve high reversibility, with low capacity loss, and low over-potentials?
- How to achieve long term reliability, on par with gas engines, or 20-30 years that is expected in the grid space.