Li-Ion vs. Lead Acid

Summary of Li-Ion advantages compared to Lead Acid

- **Li-Ion Advantages**
  - Higher voltage in Lithium Ion over Lead Acid 3.7v vs 2.0v (almost 2x)
  - Greater Energy Density per unit Weight (3x), Volume (6x)
  - Lighter / smaller providing more portability, less storage space, could even eliminate storage boxes
  - Tolerates Higher Temp (140F vs 80F), No Air Conditioning required (vs spending 10% of capacity)
  - Faster recharge time, and More time between recharges (26 wks vs continuous or max 2 wks)
  - Higher turnaround charge efficiency (97% vs 75%)
  - More Discharge Cycles (2x)
  - Deeper Discharge Tolerance (95% vs 50%) – Can offset cost due to shallow Lead Acid discharge
  - State of Health and State of Charge can be readily and remotely monitored
  - Longer time between service (24-36+ mos vs 6 mos)
  - Replacement timeframe Li-Ion 5-7 years Lead Acid 1.5 - 2 years

- **Li-Ion Disadvantages**
  - Li-Ion Protection Circuitry is custom & expensive
  - Lead Acid Overall Circuitry is Commercial off the Shelf (COTS) & inexpensive
  - Li-Ion volatility must be closely managed and addresses with safety considerations in design
  - Individual Cell cost ROM Li-Ion $300-$400 / kWhr vs Lead Acid $80-$100 / kWhr
  - Sys Cost (with circuitry) ROM $500 / kWhr $125 / kWhr

Details of Comparison: Lead Acid - Li-Ion

	Lead Acid	Li-Ion (Cobalt)
• **Energy Density**		
• Nominal Cell voltage	2.0v	3.7v
• Voltage operating range	1.8-2.1v	3.2-4.1v
• Wh/kg	35-40	140-150
• Wh/liter	70	400
• Size of a 1 kWh battery	14 Liters 873 cubic inches	2.5 Liters 153 cubic inches
• Weight of a 1 kWh battery	25kg, 55lbs	6.7kg, 14.8 lbs
• Size of a 1 MWh battery	14,285 Liters, 504 cubic feet (1/2 of a 20' shipping container)	2,500 Liters, 88 cubic feet
• Weight of a 1 MWh battery	25,000kg, 55,115 lbs	6,700kg, 14,770 lbs

- Reference sizes and weights
  - 20 Ft Shipping container 1160 cu ft, 4928 lbs
  - 40 Ft Shipping container 2360 cu ft, 7392 lbs

Details of Comparison: Lead Acid - Li-Ion

	Lead Acid	Li-Ion (Cobalt)
• **Temperature**	**Requires Air temp Control >75F** **Loses** 50% every 10F >77F	
– High temp Survival / Life Reduction	OK to 25C (77F)	OK to 60C (140F)
Life % remaining at Disch Temp	100% at 77F	100%
	50% at 87F	100%
	25% at 97F	100%
	12% at 107F	100%
	6% at 117F	100%
	3% at 127F	100%
	0% at 137F (60C)	100%
– Low Temp (Partial Functionality)	To -40C	To -25C
• **Charging**		
– Over-chargeability	Tolerant (forms H_2 gas)	Intolerant - Vents
– Protection Circuitry (Overvoltage and Discharge)	COTS, inexpensive	Custom, expensive
– Constant Charging rate in terms of C	0.07C rate	C rate (10x faster)
– Recharging time duration	10 x the capacity	1x the capacity
– Recharge interval	needs recharge weekly	needs recharge every 6 mos
– Turnaround Charge Efficiency	75%	97%
– Temp range of Charge	-40C (-40F) – +27C (80F)	-20C (-4F) – + 55C(131F)
– Cost to recharge (as % of capacity)		
Self Discharge %/month or year	8%/month, 63%/year	1.5%/month, 17%/year

Details of Comparison: Lead Acid - Li-Ion

	Lead Acid	Li-Ion (Cobalt)
• **Operation**		
• Voltage profile (during discharge)	Sloping	Flat
• Failure mode	will not accept charge	predictive based on cycles
• (assumes traditional control circuits)		and efficiency
• Cycles		
– At 10% discharge	1750	4000+
– At 50% discharge	500	1000
– At 95% discharge	250	500
• State of charge measured by	Voltage level	Coulombs transferred
	Rough	Exact
• **Costs**		
• Cell cost	$80-$100 / kWhr	$300-$400 / kWhr
• Assembled Sys Cost (with circuitry)	$125 / kWhr	$500 / kWhr
• Maintenance costs and frequency	SLA = 2%	None
•	VRLA=10%	
• Operating costs		
– Air conditioning	8% of capacity	None required
– Service Interval	6 mos	12 mos
• Replacement timeframe	2 years	5-7 years
– Assumes life is not limited by number of discharge cycles, instead by time		