Battery Energy Storage Technologies

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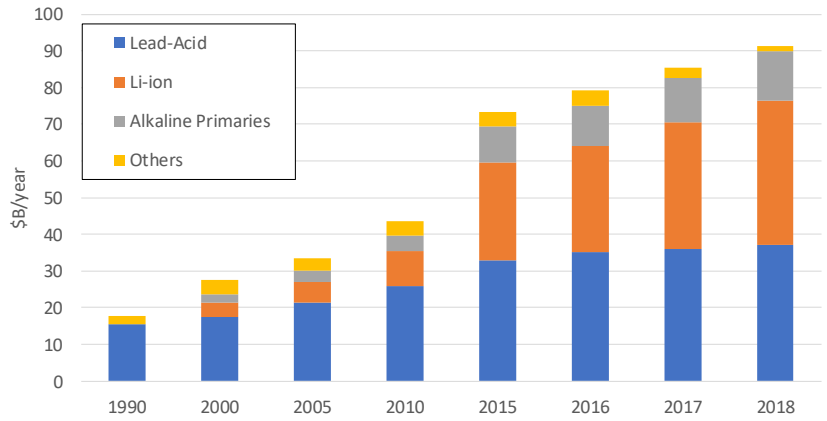
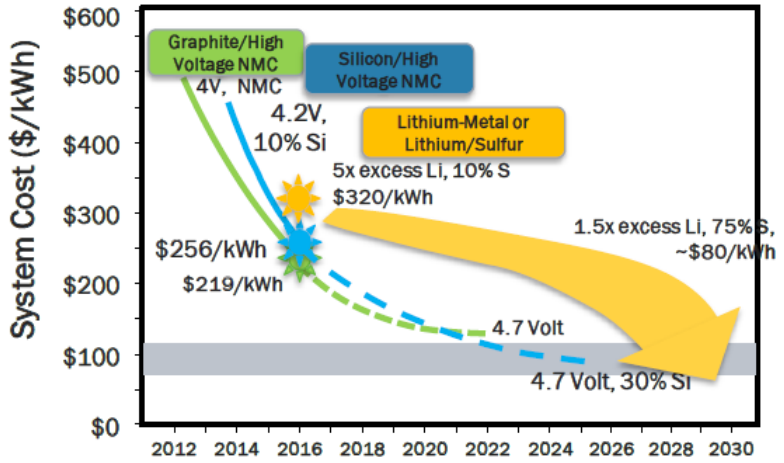
Battery Energy Storage Technologies

Mature Technologies		
	Manufacturing and Cost Metrics	**Key Challenges for Energy Storage, R&D needs**
Lead Acid Batteries	350 GWh/yr $100/kWh (traditional) $300/kWh (advanced)	Deep discharge cycle life Advanced lead acid expensive
Lithium Ion Batteries (LIB) (family of chemistries, LCO, NCA, NMC, LFP..)	400 GWh/yr and growing Pack level price: ~$150/kWh	Increasing energy density Deep discharge cycle life Improving safety
Emerging Technologies		
NaS and $NaNiCl_2$	No economies of scale	High temperature chemistry. Safety, High cost
Flow Batteries (Vanadium, ZnBr, Aqueous organic..)	Not fully mature VFB ~ $300/kWh (System)	Increasing energy density New electrolytes Manufacturing scale
Alkaline chemistries (Zn-MnO2,..)	Lowest cost starting materials, potential for cells <$50/kWh	Full rechargeability, improving Zn utilization Manufacturing scale
Li chemistries (Li-S, Li-air..) **Na-ion batteries** **Solid state batteries (Li, Na)** **Zn-air**		



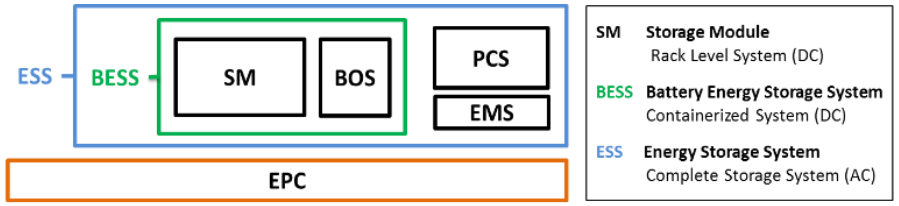
- Lead-Acid: 350 GWh production capacity, $38B/yr
- Li-ion: over 400 GWh and growing capacity, $40B/yr
- Zn-MnO_2 Primary cells: $13B/yr

Source: S. Banerjee, DOE ESGC South/Southwest Workshop, June 2020



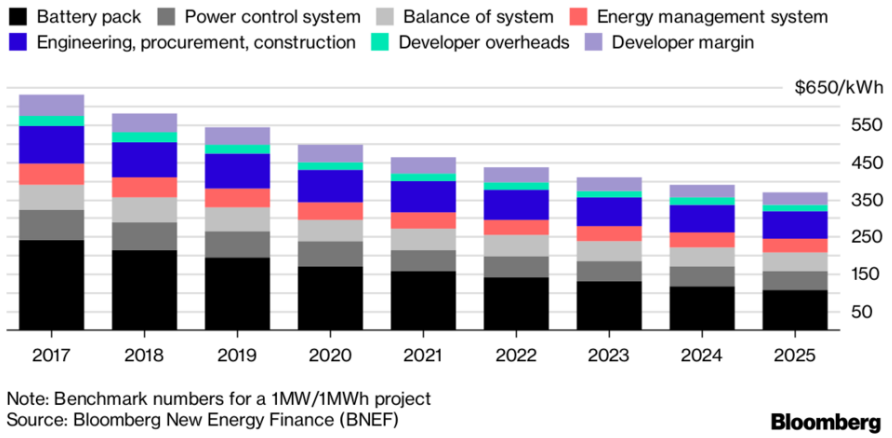
Cost trends for Li-based EV Batteries (pack level)
Source: David Howell, DOE VTO, 2018

Battery Energy Storage is not just about Batteries …



Storage Module (SM)	Balance of System (BOS)	Power Conversion System (PCS)	Energy Management System (EMS)	Engineering Procurement & Construction (EPC)
Racking Frame / Cabinet	Container	Bi-directional Inverter	Application Library	Project Management
Local Protection (Breakers)	Electrical Distribution & Control	Electrical Protection	Economic Optimization	Engineering Studies / Permitting
Rack Management System	Fire Suppression	Connection to Transformer	Distributed Asset Integration	Site Preparation / Construction
Battery Management System	HVAC / Thermal Management		Data Logging	Foundation / Mounting
Battery Module			Communication	Commissioning

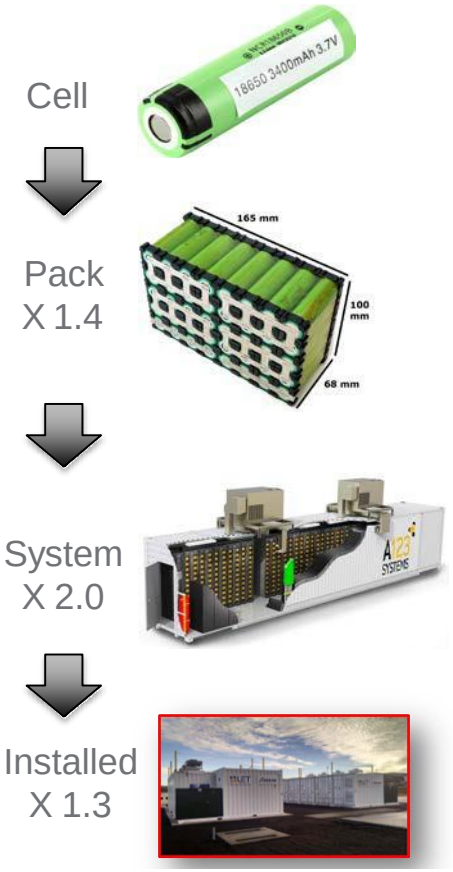
Source: R. Baxter, I. Gyuk, R.H. Byrne, B.R. Chalamala, IEEE Electrification, Aug 2018



Note: Benchmark numbers for a 1MW/1MWh project
Source: Bloomberg New Energy Finance (BNEF)

Bloomberg

Cell to Battery to a Storage System
doubling or tripling in cost from cell to installed system



- Cell Architecture
  - Cell format
    - Cylindrical, Prismatic
    - Bipolar
    - Flow Cell
- Cell Chemistry
  - Aqueous
  - Non-aqueous
- Thermal management
  - Heating
  - Cooling
- Safety
  - Abuse resistance
  - Flammability
  - Toxicity
  - Containment
- Plant Models
  - Modularized
- Power vs. Energy
  - High-power, short-duration discharge
  - High-energy, long-duration discharge
  - Fast Charging
- Modularity and Scalability
  - kW to MW (Power Scaling)
  - kWh to MWh (Energy Scaling)
  - Module stacking and Containerization
- Cycle Life
  - Electrical
  - Thermal
- Operational Aspects
  - Round-trip efficiency
  - Auxiliary power consumption
  - O&M Costs

Integration costs are significant
Big savings in systems and integration..

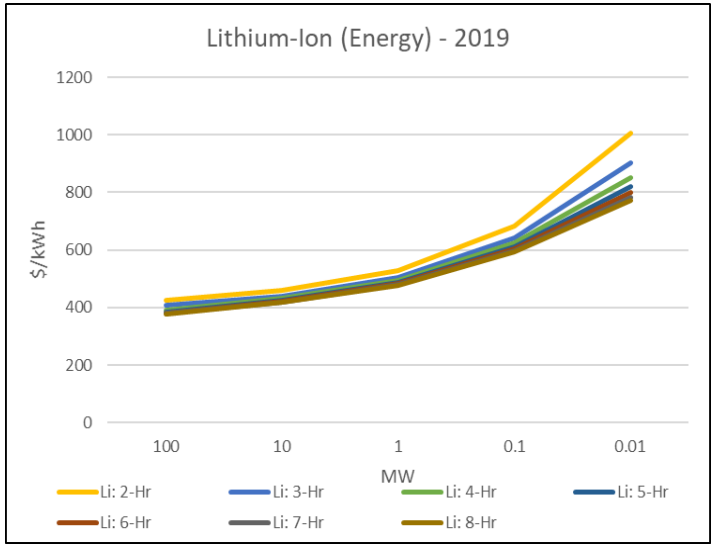
2019 Energy Storage System Pricing Survey

2019 Energy Storage Pricing					
	Size (MW)				
	100	10	1	0.1	0.01
$/kW					
PHS	1676.9				
CAES	1506.2				
FW SD		984.0	1190.0	1500.0	
$/kW (1 Hr)					
Li (Power)	504.2	545.6	629.1		
$/kW (4 Hr)					
LAES	451.0	511.5			
GES	903.0				
FW LD		677.8	766.0	855.3	975.0
Li (Energy)	392.0	430.6	493.4	623.0	850.3
Zn	271.4	289.7	336.8	398.7	
Pb			352.0	425.5	588.4
PbC			557.2	620.0	768.2
$/kW (6 Hr)					
Na	376.3	389.6	428.7		
FB ZnBr	450.9	464.9	478.8	510.6	
$/kW (8 Hr)					
FB V	309.7	372.2	439.0	620.2	
FB Fe	362.7	381.7	404.7	438.4	

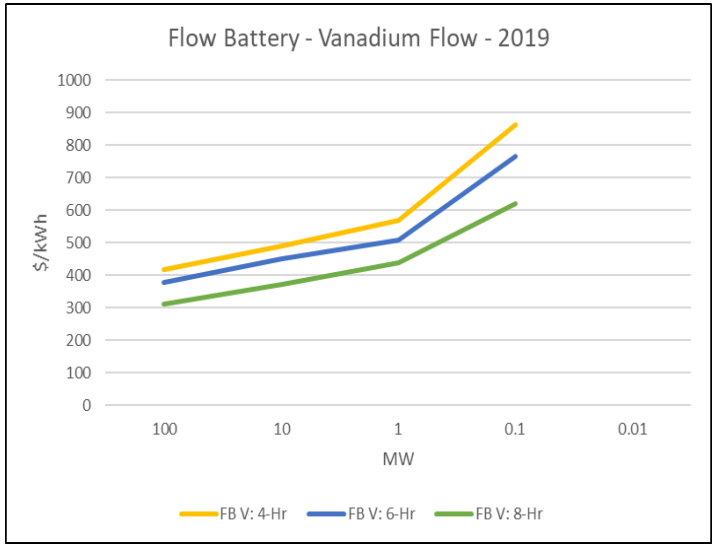
Source: R. Baxter, "Energy Storage Pricing Survey& Energy Storage Financing Study Series," DOE ESS Program 2020 Peer Review, Sept 30, 2020 and 2019 Energy Storage Pricing Survey, Sandia Report: SAND-XXXX, 2020
R. Baxter, Energy Storage Financing: Performance Impacts on Project Financing Sandia Report: SAND2018-10110, Sept 2018

Pricing data based on a survey of 77 data sources from OEMs, System Integrators and utilities.

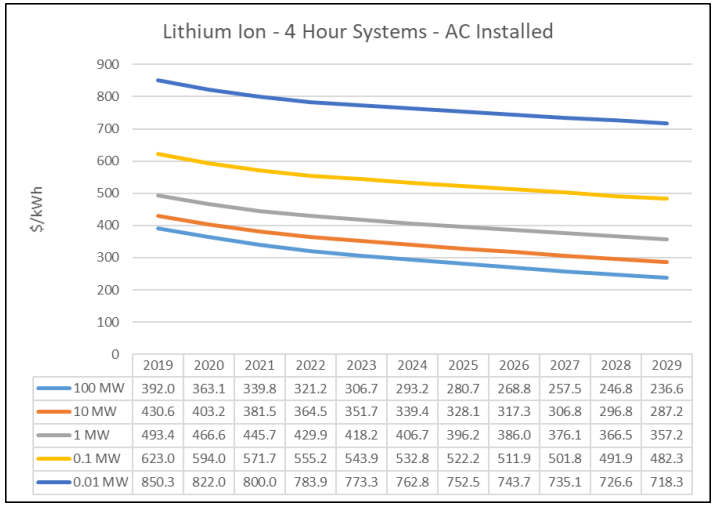
Installed System Costs



Installed System Costs

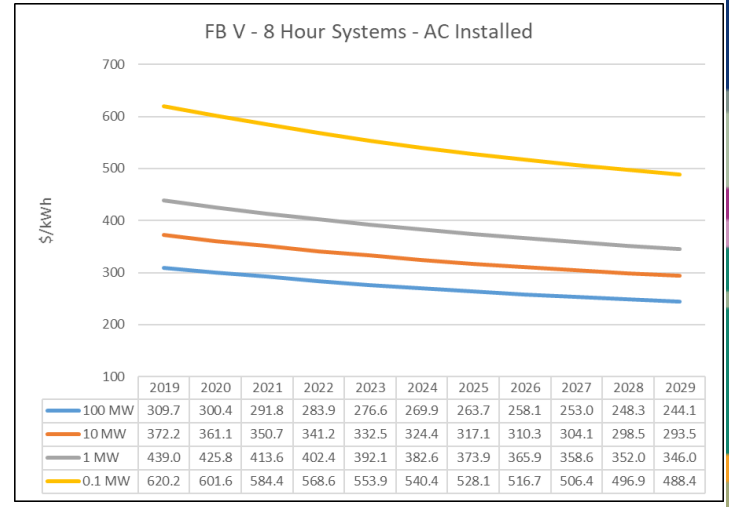


System Price Forecast (Installed)



	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
100 MW	392.0	363.1	339.8	321.2	306.7	293.2	280.7	268.8	257.5	246.8	236.6
10 MW	430.6	403.2	381.5	364.5	351.7	339.4	328.1	317.3	306.8	296.8	287.2
1 MW	493.4	466.6	445.7	429.9	418.2	406.7	396.2	386.0	376.1	366.5	357.2
0.1 MW	623.0	594.0	571.7	555.2	543.9	532.8	522.2	511.9	501.8	491.9	482.3
0.01 MW	850.3	822.0	800.0	783.9	773.3	762.8	752.5	743.7	735.1	726.6	718.3

System Price Forecast (Installed)



	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
100 MW	309.7	300.4	291.8	283.9	276.6	269.9	263.7	258.1	253.0	248.3	244.1
10 MW	372.2	361.1	350.7	341.2	332.5	324.4	317.1	310.3	304.1	298.5	293.5
1 MW	439.0	425.8	413.6	402.4	392.1	382.6	373.9	365.9	358.6	352.0	346.0
0.1 MW	620.2	601.6	584.4	568.6	553.9	540.4	528.1	516.7	506.4	496.9	488.4

Battery Energy Storage Systems - Gaps?

Technology - Need further improvements in cost and performance

- Lower cost, longer duration energy storage is a major gap
- Technologies that can scale from microgrids to large transmission applications
- Further improvements in safety and reliability

Energy storage is new for the electric utility industry

- Markets and Operations – Business Models and Operational Tools
- Analytics – Economics and Planning tools
- Appropriate Regulatory Policy – Business Models, Asset Classification

Industry needs cycles of learning - manufacturing scale through deployments

- Project finance - bankable, warrantees, Performance guarantees, risk management
- Standardization- equipment, permitting, construction processes

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