

Battery Storage: In front of the meter

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Scope:

- Battery Service Benefits
- Battery Basics
- Types of Batteries: Top Contenders
- Revenue & Regulation
- Concerns
- Examples

Battery Services:

- Transmission & Distribution System
- Peak Shaving & Generation Capacity
- Frequency Regulation
- Renewable Integration

Battery Basics:

Basics

- Power (kW)
- Capacity (kWh)
- Cycles
- Degree of Discharge
- Efficiency

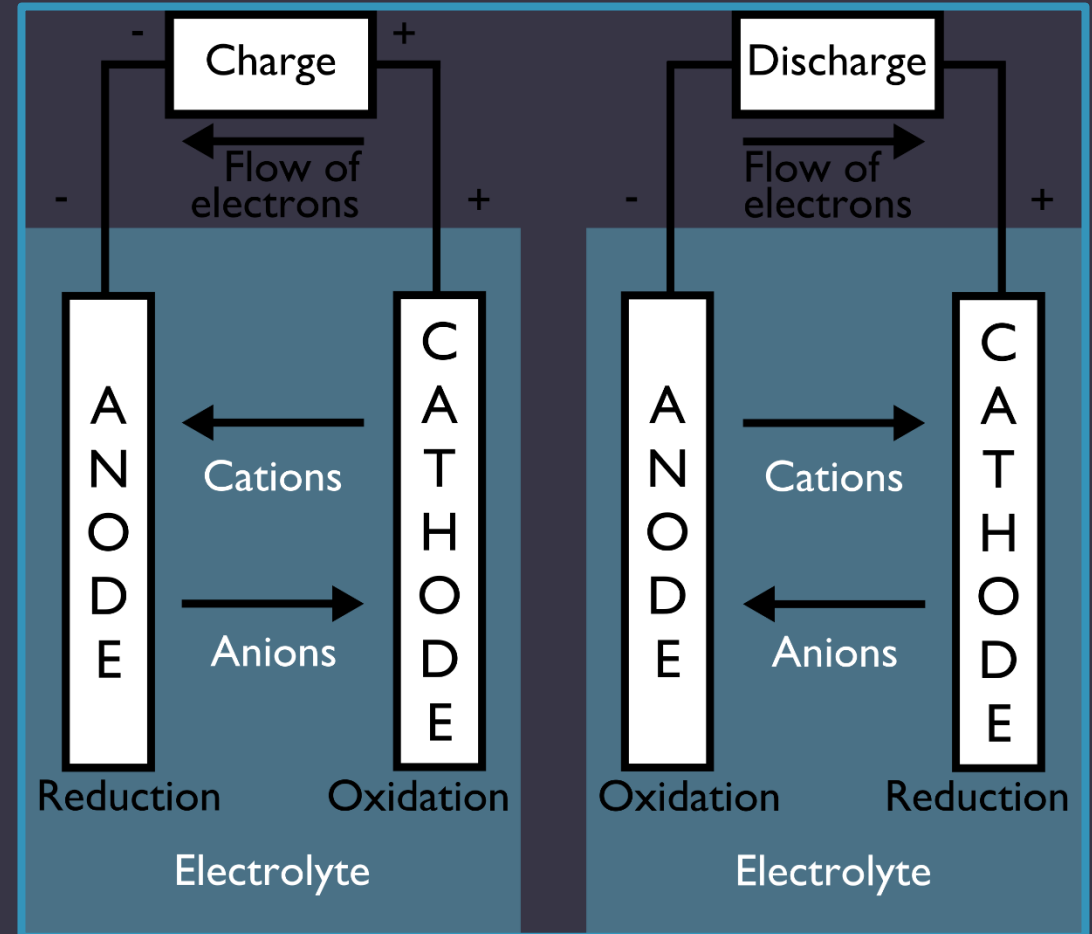
Value Metrics

- \$/kWh
- \$/kW
- Levelized Cost (\$/kWh)

$$LC = \frac{(cost)}{(capacity)(efficiency)(DoD)(cycles)}$$

Battery Technologies

- Advanced Lead-Acid
- Lithium-Ion
- Flow Battery (Redox)
- Sodium-Sulfur (NaS)



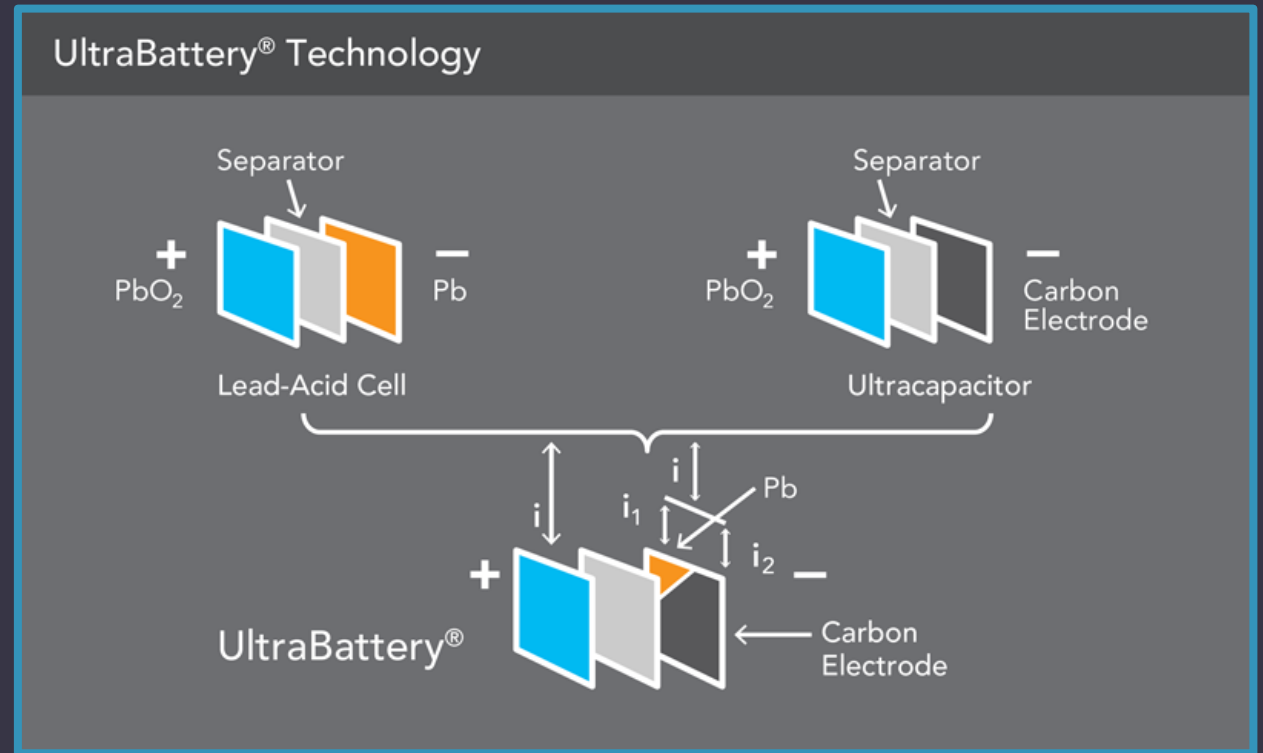
Advanced Lead-Acid (e.g. car battery) :

Pros:

- Old technology with improvements
- Relatively high efficiency
- Low self discharge rates

Cons:

- Short lifespan
- Need temperature control



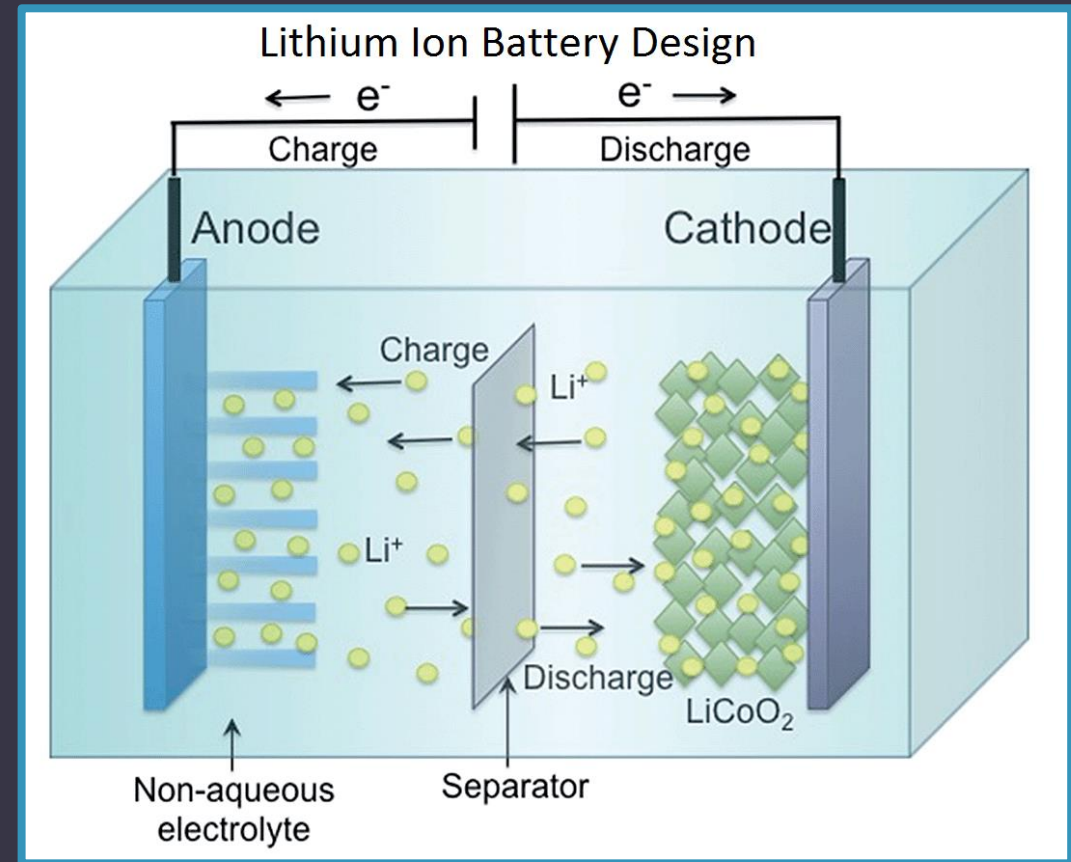
Lithium-ion (e.g. cell phone battery :

Pros:

- Compact
- Fast response time
- High cycle efficiency

Cons:

- Degree of discharge tradeoffs with lifespan
- Expensive hardware
- Thermal runaway



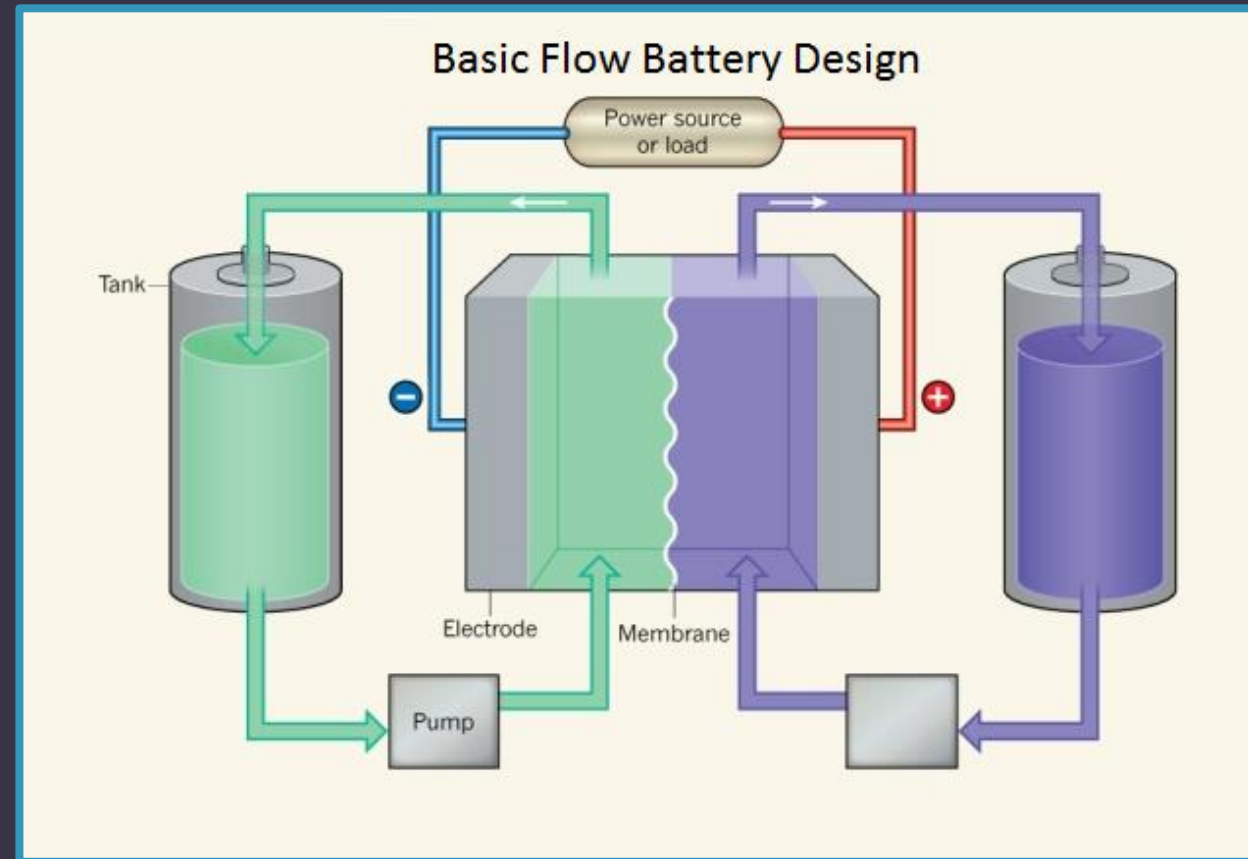
Flow Batteries:

Pros:

- Power and capacity are independent
- High power and energy capabilities
- Low self discharge rate

Cons:

- High initial and maintenance costs
- Low efficiency



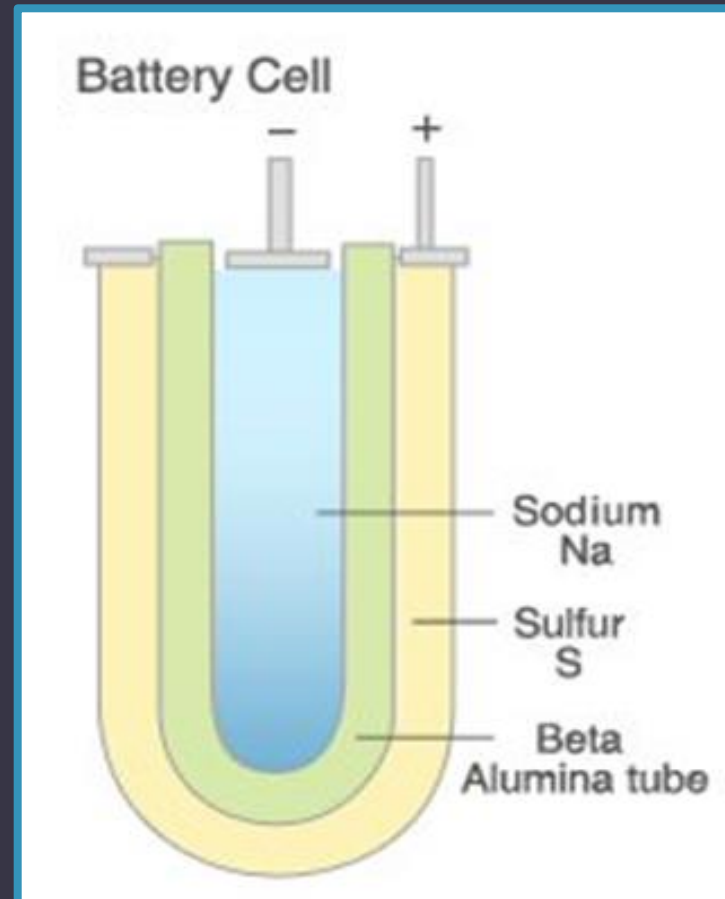
Sodium-Sulfur:

Pros:

- High energy density
- High efficiency
- Recyclable

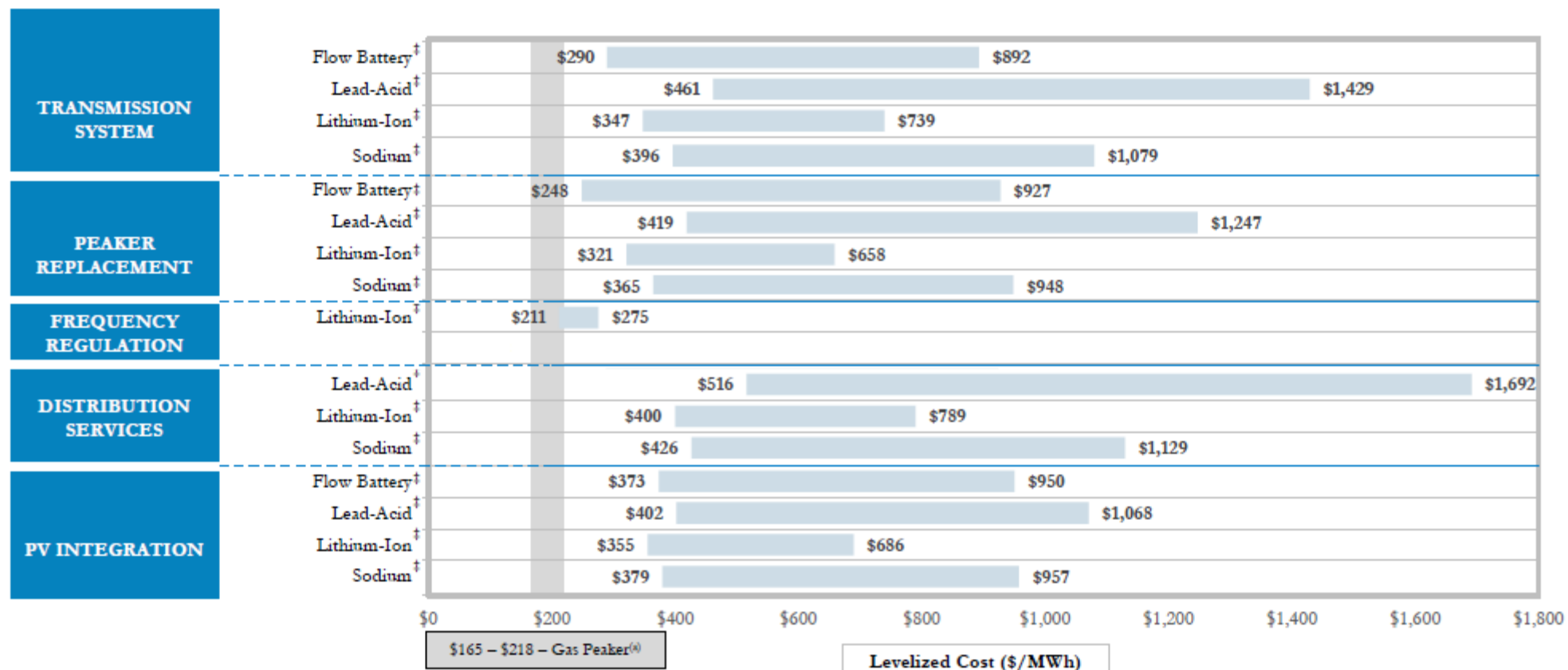
Cons:

- High operating costs
- Safety concerns



Unsubsidized Levelized Cost of Storage Comparison

Certain “in front of the meter” technology and use case combinations are cost-competitive with their dominant or “base case” conventional alternatives under some scenarios, even without the benefit of subsidies or additional, non-optimized streams of revenue; such observation does not take into account potential social or environmental externalities associated with energy storage (e.g., environmental benefits associated with avoided gas peaker investment, etc.)



Source: Lazard estimates.

Note: Here and throughout this presentation, unless otherwise indicated, analysis assumes 20% debt at 8% interest rate and 80% equity at 12% cost for all technologies and use cases. Assumes seven year MACRS depreciation unless otherwise noted. Analysis does not reflect impact of evolving regulations/rules promulgated pursuant to the EPA's Clean Power Plan.

† Indicates battery technology.

(a) Indicates illustrative conventional alternative to energy storage. Not intended to reflect the sole conventional alternative (or source of value from replacing such alternatives). The lowest cost conventional alternative for a particular use case may not be the lowest cost conventional alternative for another use case.

Revenue & Regulation

- Concerns:
 - Complexity
 - Regulations
- Solutions
 - Feedback to FERC
 - Performance revenue
 - Mandates

Concerns

- Recycling & Disposal
- Safety Standards
 - Manufacturing
 - On-site

Examples:

Battery Technology	Location	Name/Utility	Size	Description
Flow (Redox)	Modesto, CA	Primus Power	25MW/75MWh	Will help compensate for the variability of wind and solar energy
Advanced Lead-Acid	Ector & Winkler County, TX	Notrees Windpower	36MW/9MWh	One of the largest battery projects in the world
Lithium Ion	Indianapolis, IN	Indianapolis Power and Light Co.	20MW	Finished in June 2016; first utility scale Li-ion battery project in MISO
Sodium-Sulfur	Charleston, WV	American Electric Power (AEP)	1.5MW/7.2MWh	First Sodium-Sulfur project in the U.S.

Questions?
