EPRI ELECTRIC POWER RESEARCH INSTITUTE

Batteries and Energy Storage:
Looking Past the Hype

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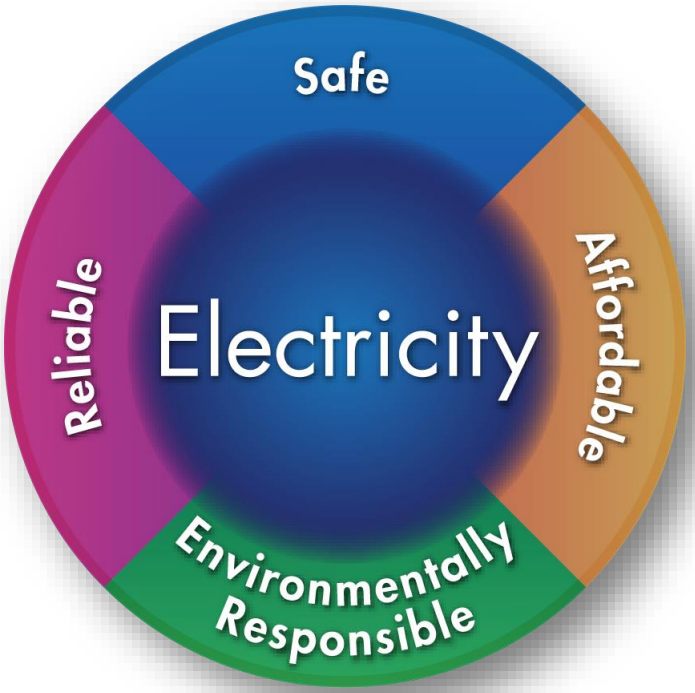
Presentation to Tucson Electric Power
November 2, 2016

Together…Shaping the Future of Electricity

EPRI's Mission

Advancing ***safe***, ***reliable***, ***affordable*** and ***environmentally responsible*** electricity for society through global collaboration, thought leadership and science & technology innovation



The Growing Interest in Energy Storage

Courtesy Tesla Motors, Inc.

Tesla PowerWall 2 Home Battery

"Improvements in batteries and distributed generation could partly or completely eliminate some customers' usage of the power grid…"

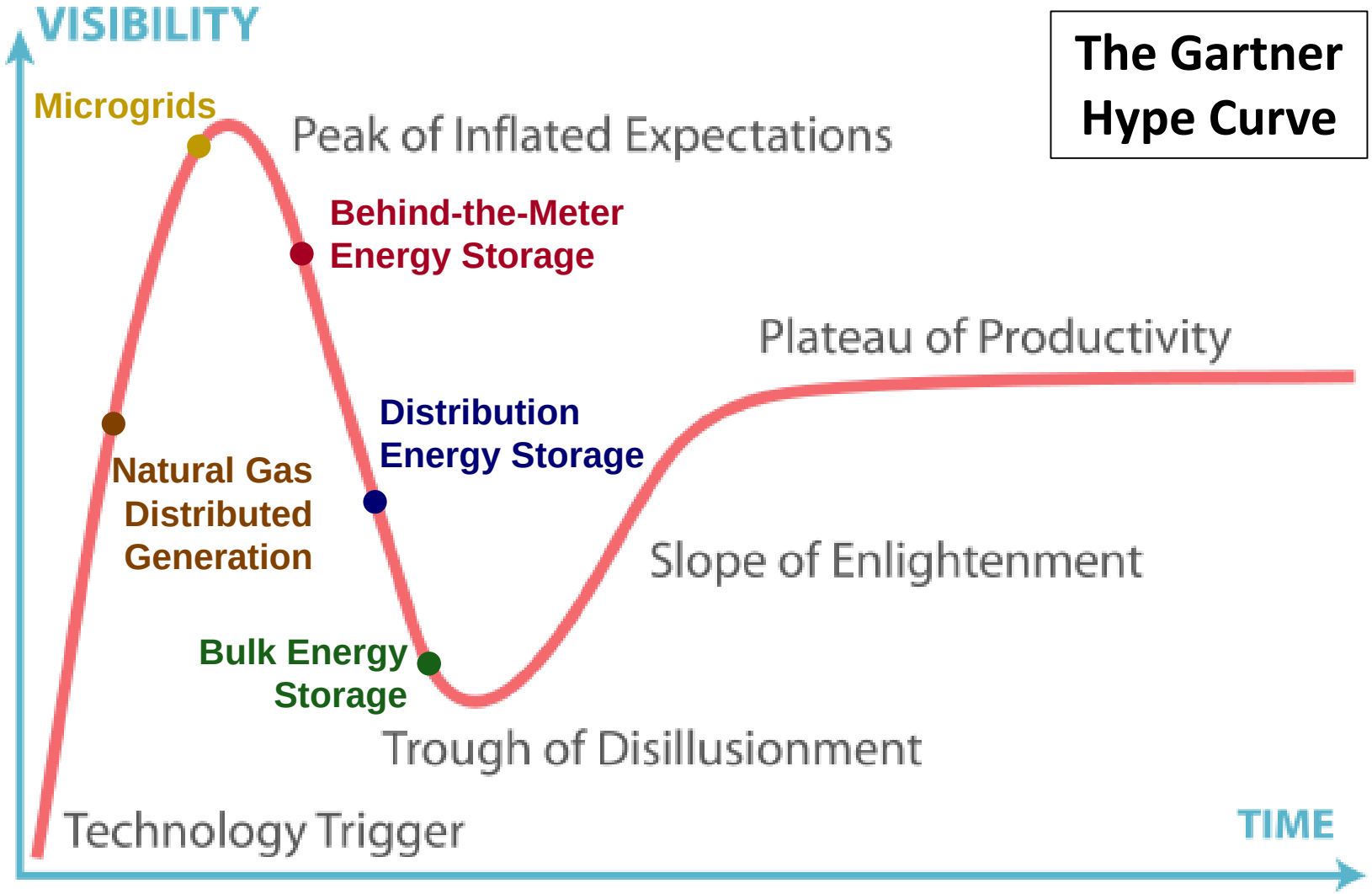
– Morgan Stanley Blue Paper, Solar Power & Energy Storage *July 28, 2014*

"…[the] solar generation/battery storage combination is currently an order of magnitude too expensive to cause much grid defection."

– Moody's Investor Service, "Batteries are Coming but Utilities are not Going Away" *January 6, 2015*

Briefing objective: With no hype on the technology, provide realistic projections on application and market outlook

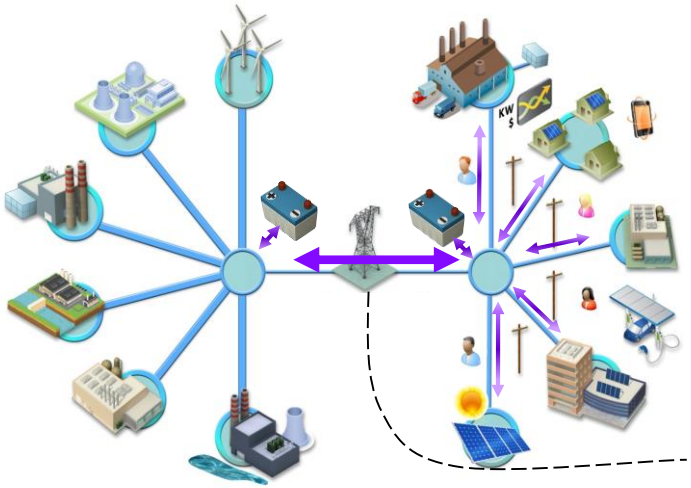
Moving beyond the hype cycle…



Understanding the facts will help us to move beyond the peak of the hype cycle

What can storage do?

- Transmission Level
  - Ancillary Services Frequency Regulation
  - Renewable Shifting/Smoothing
  - Voltage/ Reactive Power Support
  - Capacity/Congestion relief
  - Deferral of transmission upgrades
  - Deferral of peaking plant installation/operation

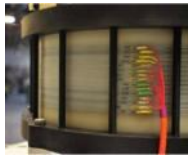


- Distribution Level
  - PV Shifting/Smoothing
  - Increase PV accommodation
  - Power Quality improvement
  - Deferral of distribution upgrades
  - Demand charge avoidance
  - *Assist in many Transmission applications on an aggregated basis*
    - Frequency Regulation
    - Renewables Shifting/Smoothing
    - Power Quality improvement
    - Deferral of transmission upgrades
    - Deferral of peaker installation/operation

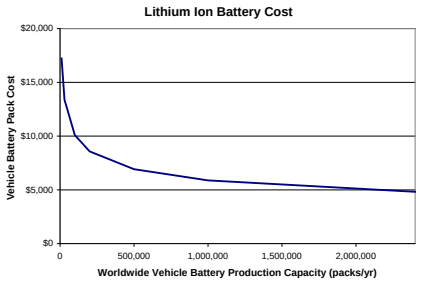
Storage is a key element in enabling 2 way power flow in the grid – some technologies can do it all some are limited

The historical challenges are being overcome

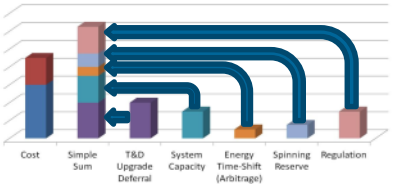
- Technical challenges
  - Performance
  - Life
  - Efficiency
- Economic Challenges
  - High Costs
  - Small Value Streams
- Regulatory Challenges
  - Lack of clear definition
  - Framework designed for existing grid



Advanced Technologies



Lower costs



New Business Models

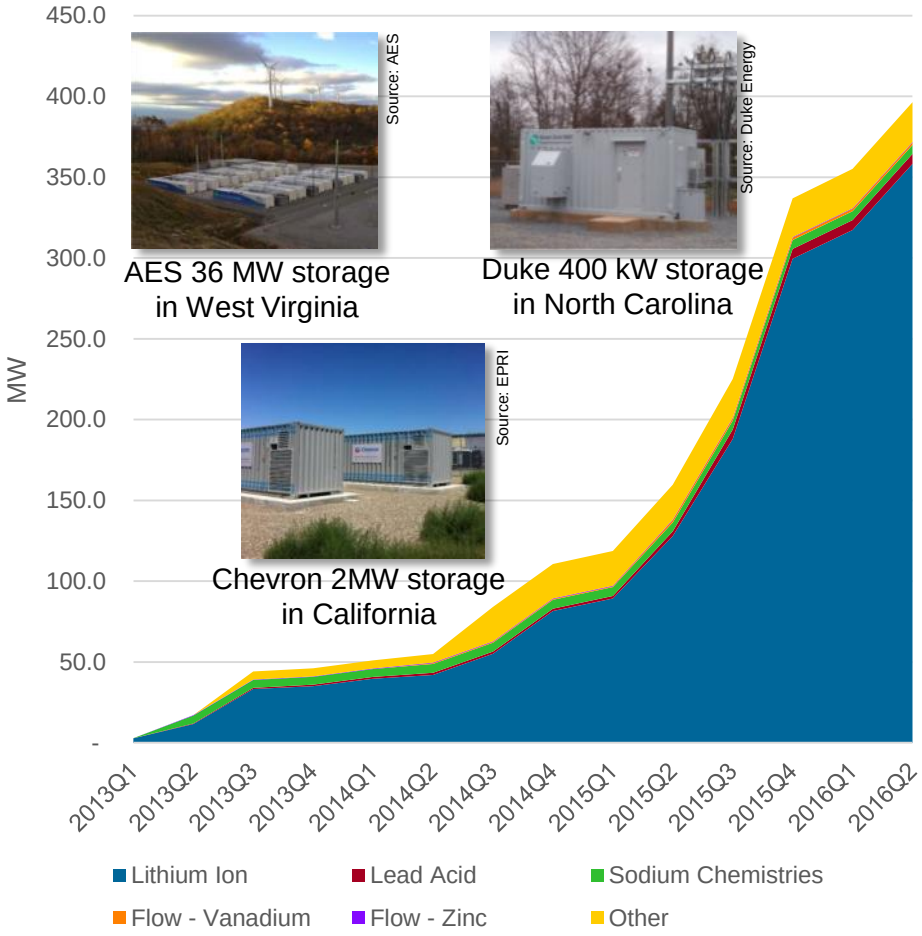
Regulatory Rulings

Legislative Action

Deployment of stationary storage continues

- Investment is still relatively small but rapidly growing
  - Storage to provide ancillary services in energy markets is the largest market
  - Utilities are exploring options at the transmission and distribution level
  - Developers are installing systems on the customer side of the meter
- Many if not most installations are at the demonstration / pilot phase
  - Benefits are understood, but monetization can be difficult
- Note dominance of lithium ion battery in deployments

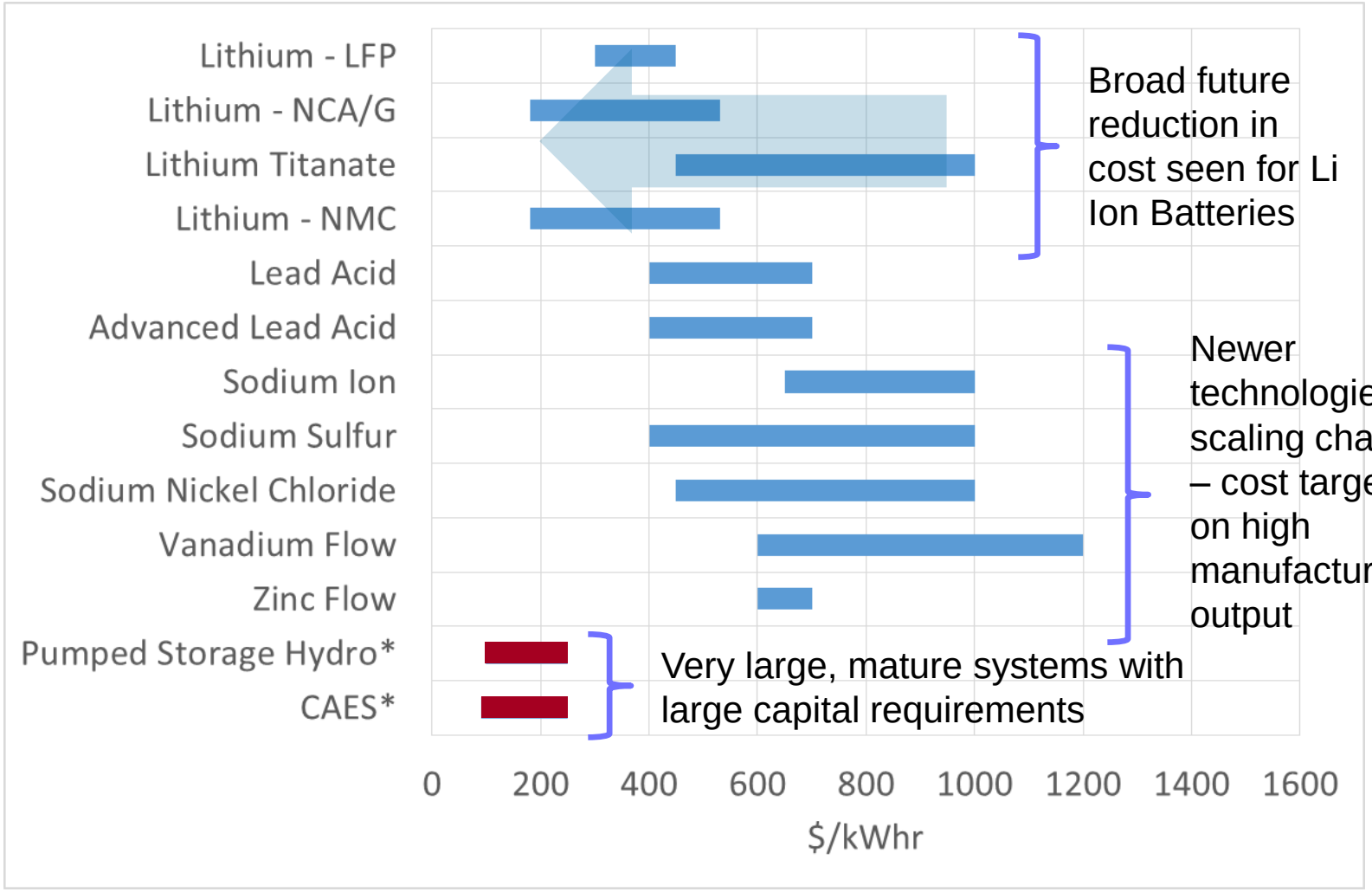
Cumulative Battery Storage Deployments by Technology (MW) Since 2013



Source: GreenTech Research

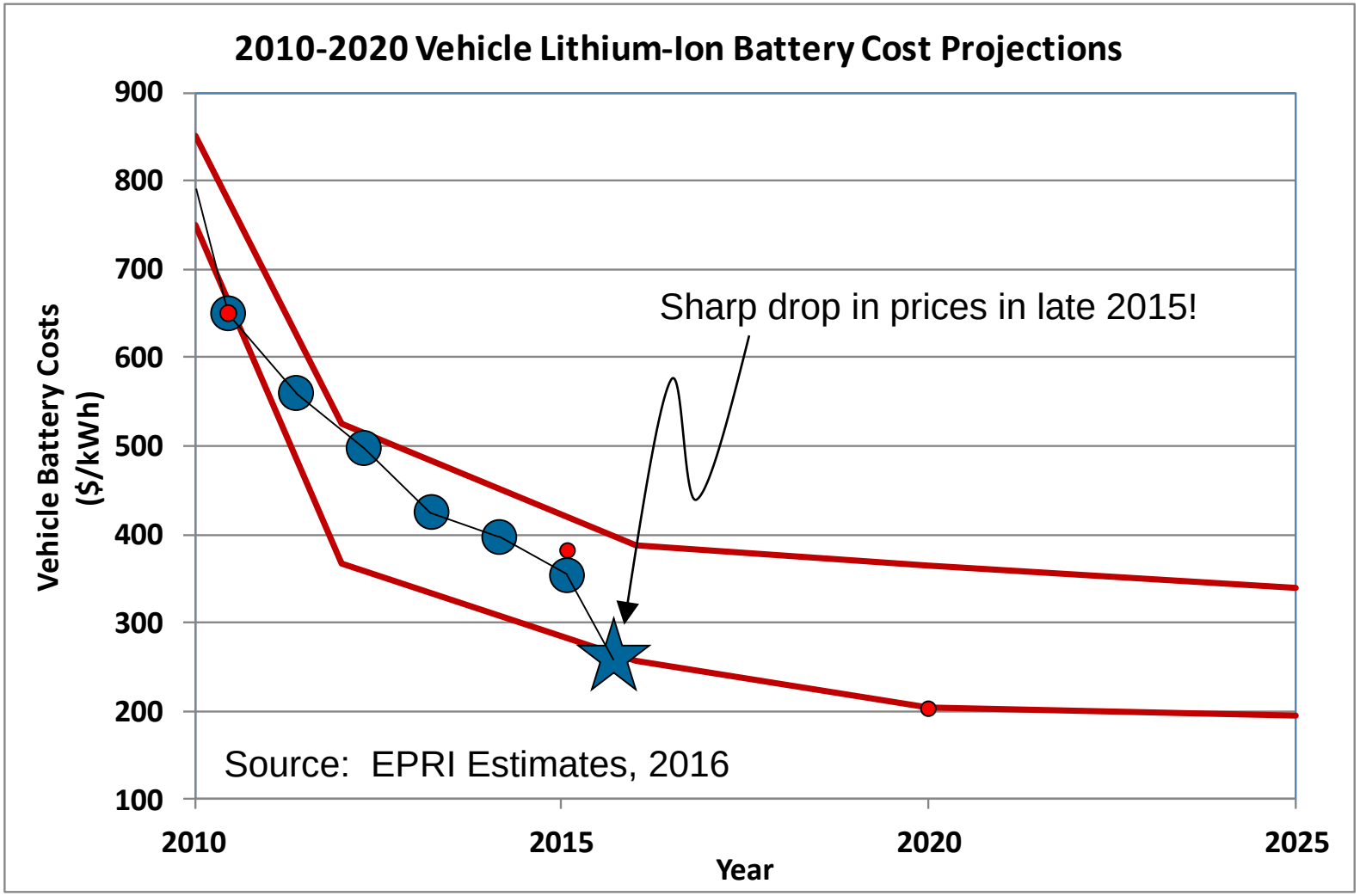
Storage Cost Estimates

EPRI 2015 Energy Storage Cost Estimates – Distributed & Bulk Technologies



* Pumped Hydro and CAES costs are estimated installed costs; all others are battery costs (not including power conversion or balance of plant)

Lithium ion battery prices continue to fall…



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Lithium Ion Technology Outlook

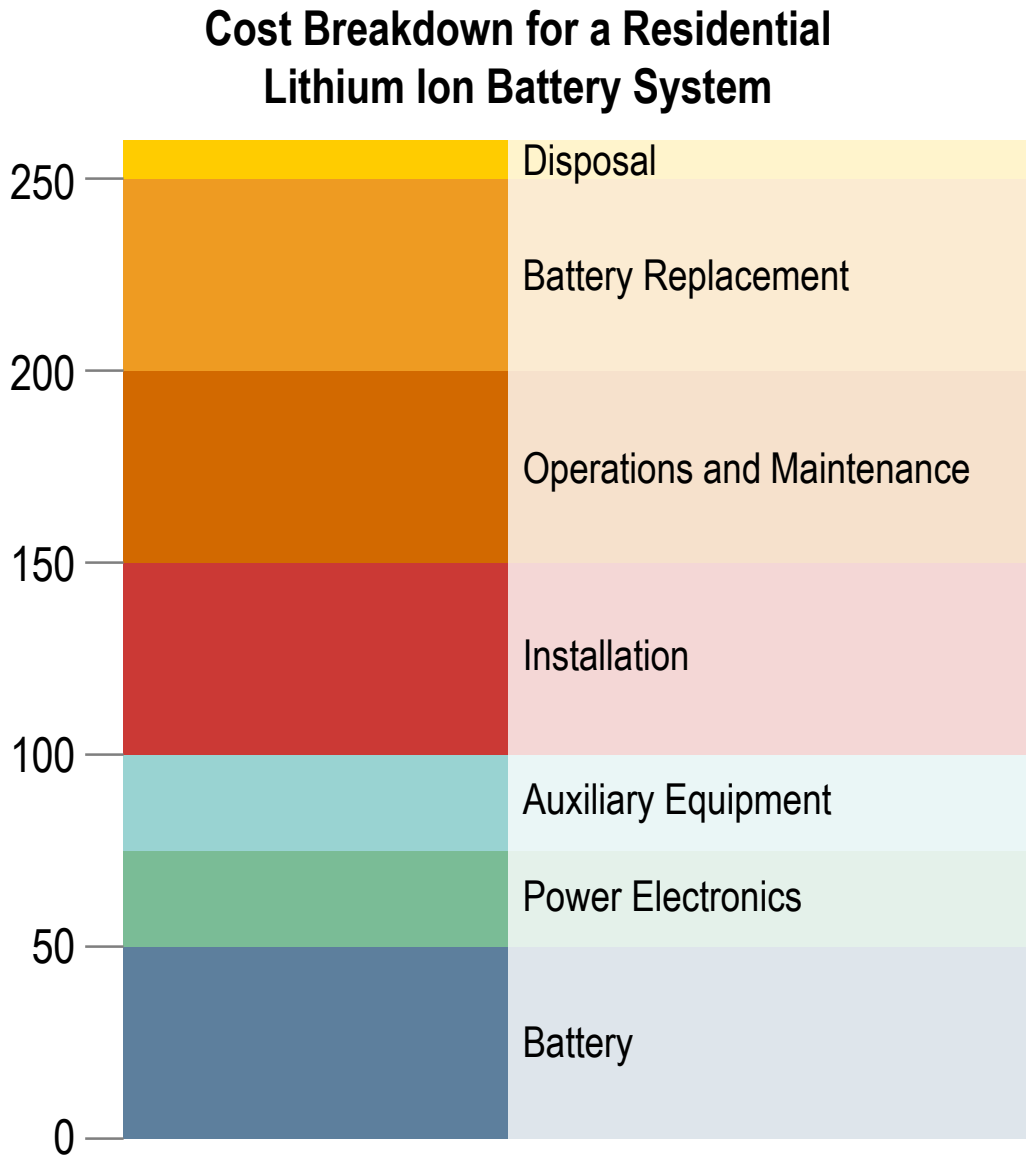
Projected Capital Cost	2015	2020
 Cell	11.5 W for 1 hour $2.00-$2.50 $180-$225/kW	$1.15-$1.40 $100-$120/kW
 Battery Pack	10 kW for 1 hour (dc power) $3,500-$5,000 $350-$500/kW	$2,000-$2,500 $200-$250/kW
 Residential ES System	10 kW for 1 hour (ac power) $10,000-$12,000 $1000-$1200/kW	$5,000-$6,000 $500-$600/kW

Costs can differ significantly at the cell, battery pack, and complete system levels

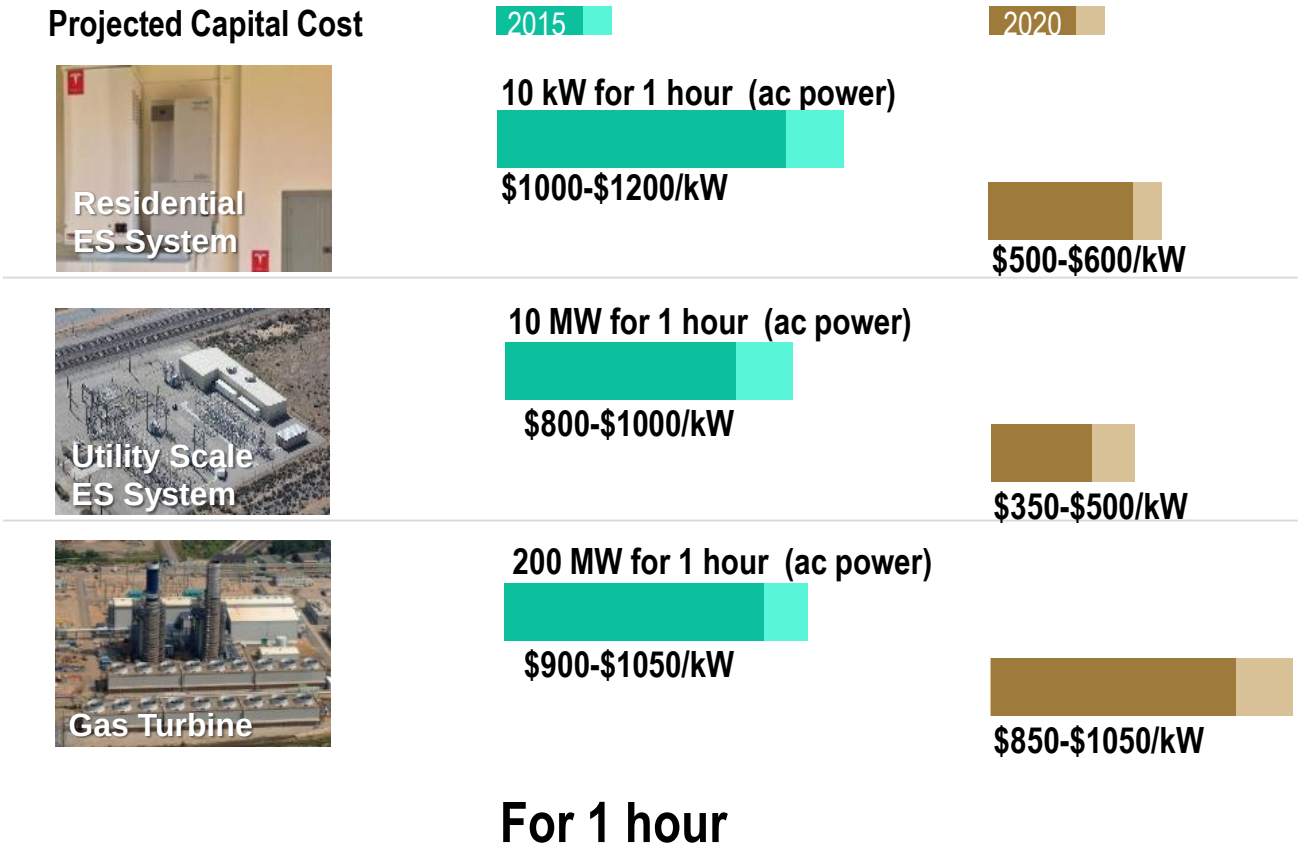
Lithium Ion Residential System Cost Breakdown

Installed system cost can easily be 2 or 3 times the battery cost

Lifecycle cost (including battery replacement, O&M, and disposal costs) could be close to twice the installed system cost

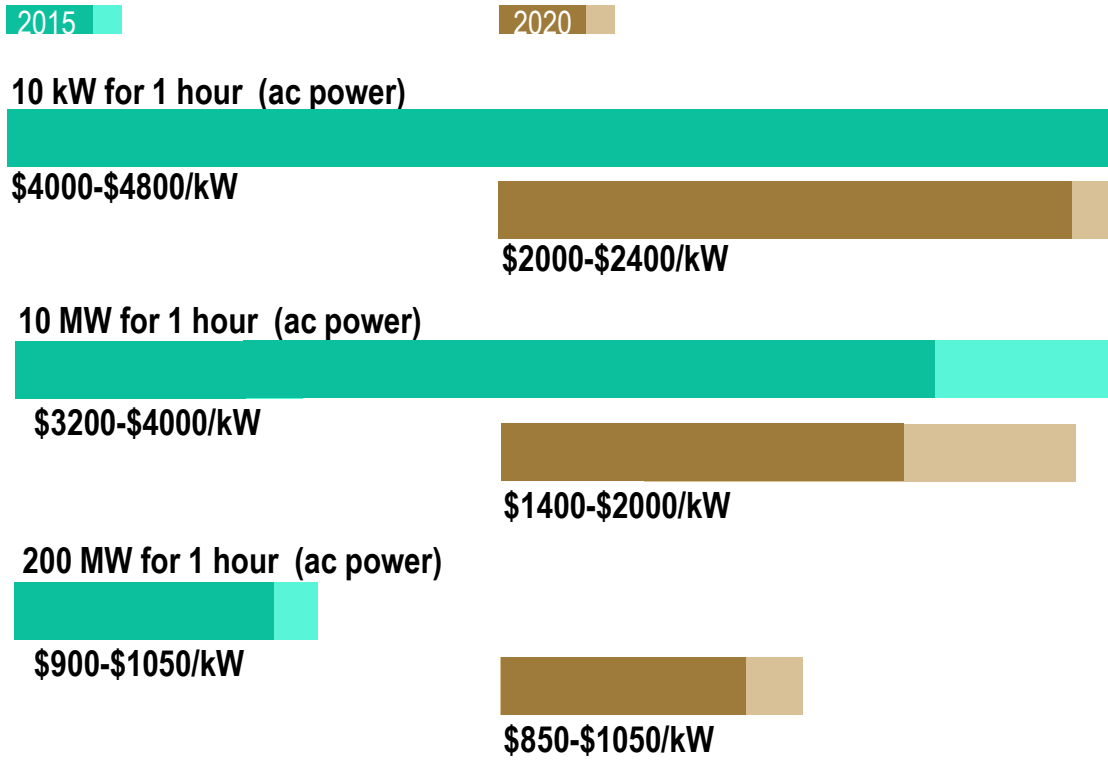


Lithium Ion Technology Outlook



Lithium Ion Technology Outlook

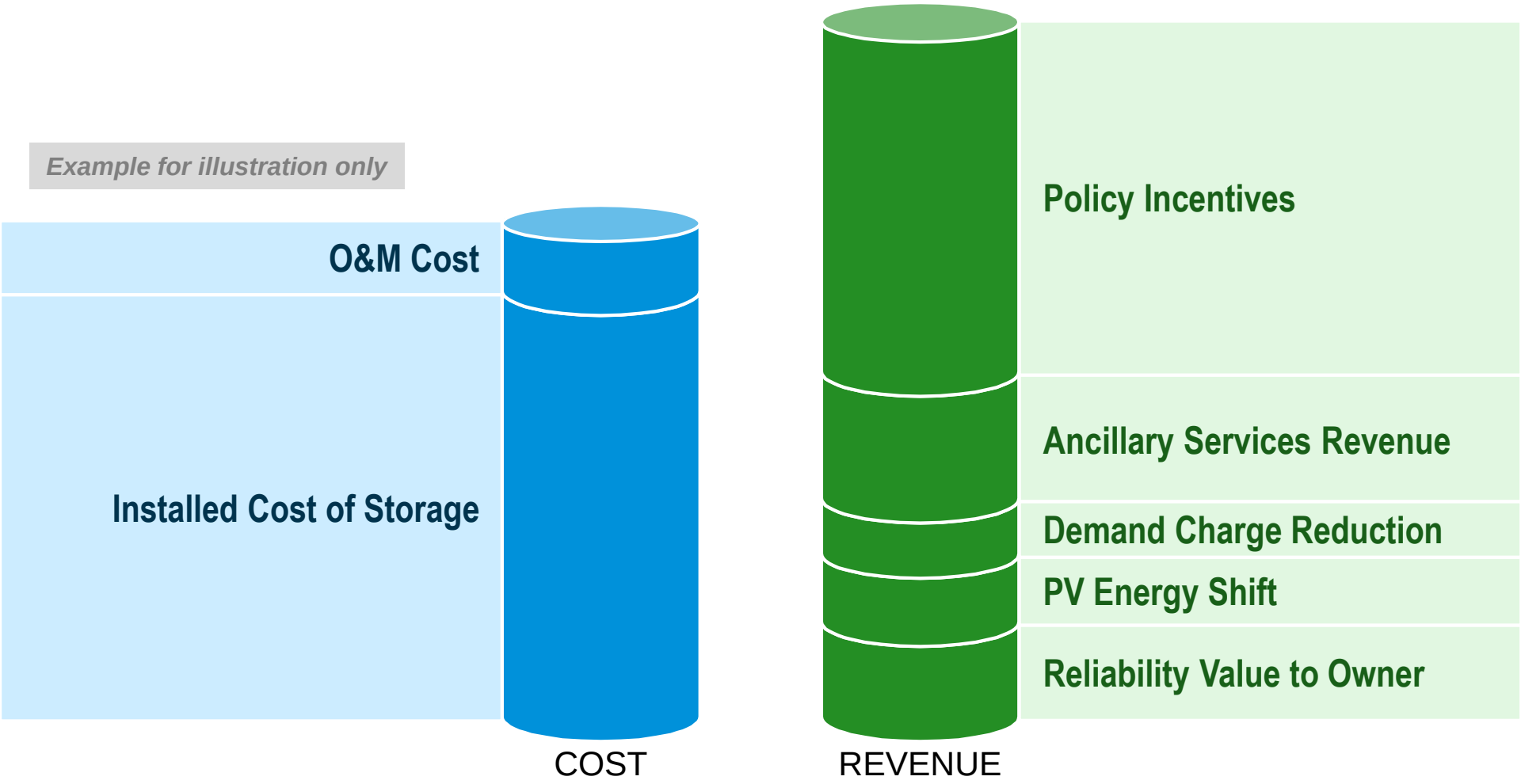
Projected Capital Cost



For 4 hours

The Case for Behind-the-Meter Storage in California

Example for illustration only



The business case presently relies heavily on federal and state incentives

Addressing the Remaining Challenges to Storage

- Costs and performance factors of technology solutions must be better understood
- Tools for understanding the value and grid impacts of storage are being developed
- Ensuring that storage technology solutions are safe, secure, reliable, affordable, and practical
- Create best practices for deployment, integration, operations, maintenance, and disposal
- Integrate storage technology into utility planning and operations processes to improve reliability and reduce costs

Key Takeaways

Energy storage is potentially a game-changer: Low-cost batteries and other energy storage technologies may transform the grid, making it more flexible and more resilient, improving reliability and enabling more renewable penetration

Technology and costs for storage are improving significantly: Widespread adoption of energy storage technologies on the grid is likely to happen in the next 10 years. Much of this deployment may be sited at commercial and industrial customers.

There are still many technical and economic challenges to energy storage: While the technology is now possible, there are still many questions that must be addressed to ensure that storage is a safe, reliable, and cost-effective solution.

Utilities are well-positioned to be integrally involved in storage adoption: While storage is sometimes considered a “disruptive technology” that may lead consumers towards islanded solutions, storage is most valuable as part of an energy network. It is far more likely that storage will be used to augment traditional grid solutions, rather than to replace them.

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