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Electricity Storage in Utility Applications

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United States Energy Association

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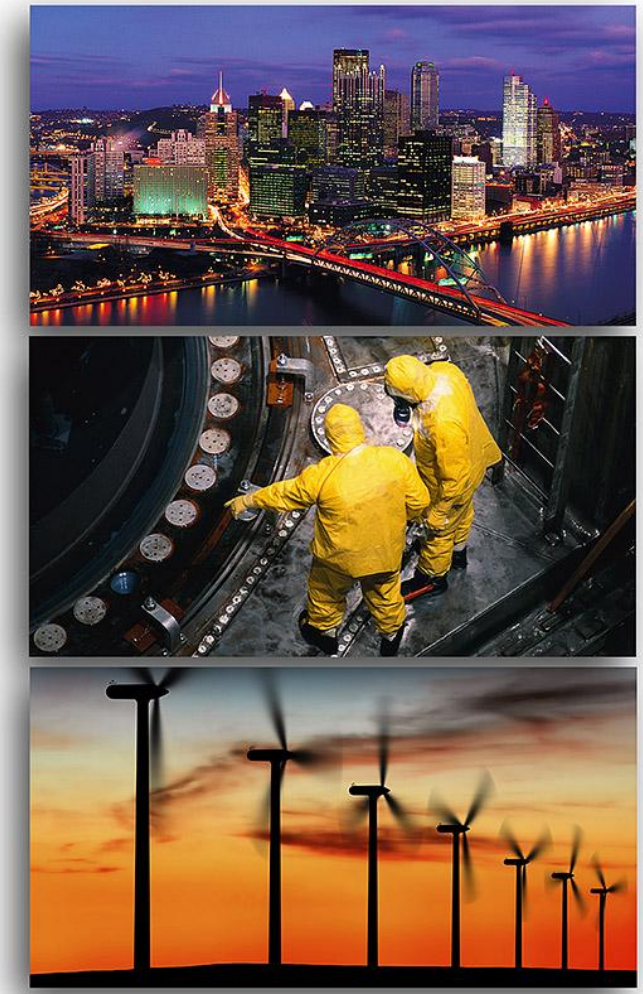
The Electric Power Research Institute (EPRI)

- Independent, non-profit, **collaborative** research institute, with full spectrum industry coverage
  - *Nuclear*
  - *Generation*
  - *Power Delivery & Utilization*
  - *Environment & Renewables*
- Major offices in Palo Alto, CA; Charlotte, NC; and Knoxville, TN

Our Members…

- 450+ participants in more than 40 countries
- EPRI members generate more than 90% of the electricity in the United States
- International funding of more than 18% of EPRI's research, development and demonstrations
- Programs funded by more than 1,000 energy organizations



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Our Role…

Help Move Technologies to the Commercialization Stage…

Technology Accelerator!

EPRI Energy Storage Program Mission

Facilitate the availability and use of grid-ready storage options

- Understanding storage technologies and capabilities
- Identifying and calculating the costs and values of storage
- Specification and testing of storage products
- Implementation and deployment of storage systems





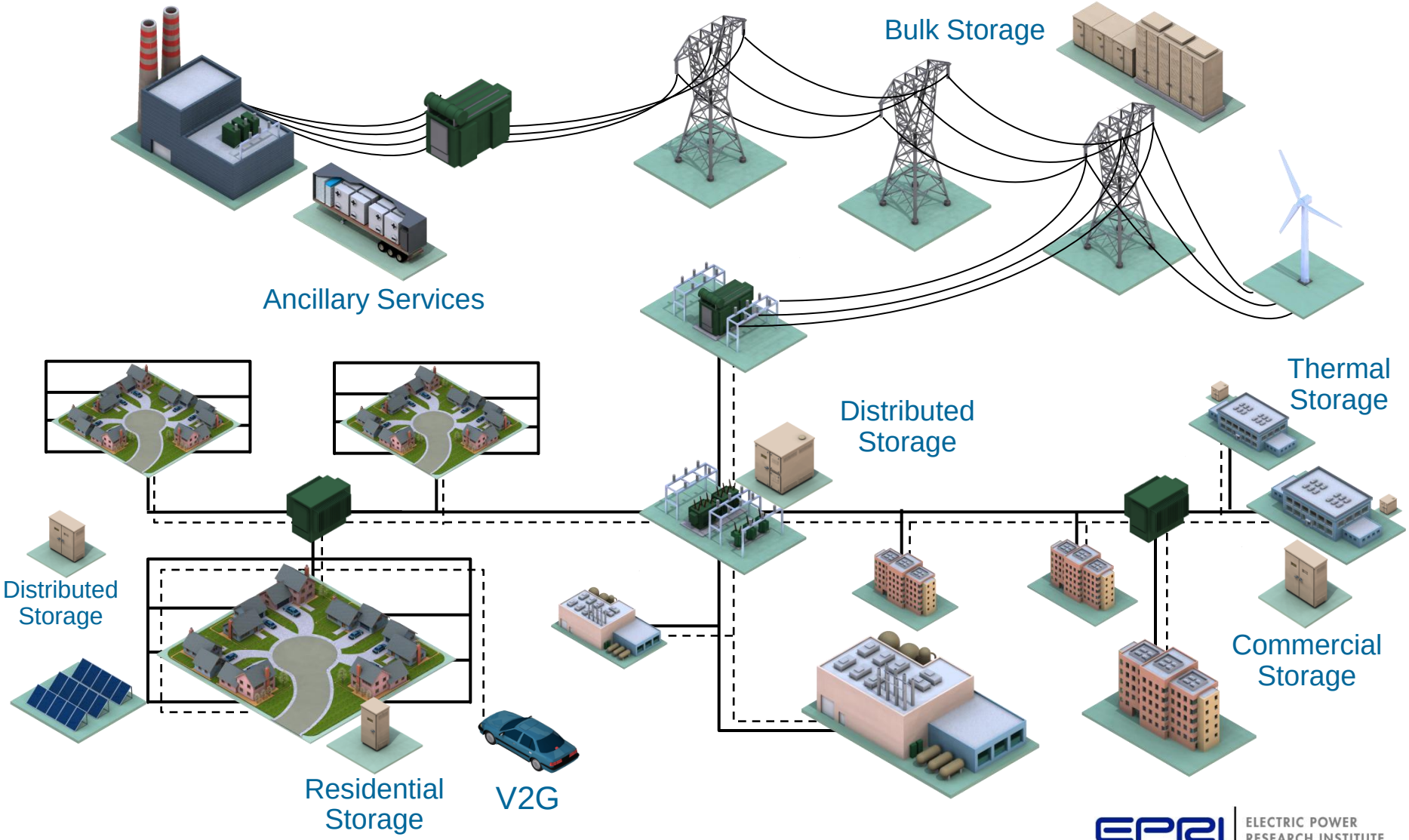
Storage: A Flexible Asset for a Changing Grid

- A resource for shifting energy or load from one time to another
- A local source of capacity to supply peak demand and enhance reliability and resiliency
- A method to enable load shifting to improve asset utilization and defer capital investment
- An option to provide flexibility to mitigate variability from renewable generation






The Roles of Storage on the Grid



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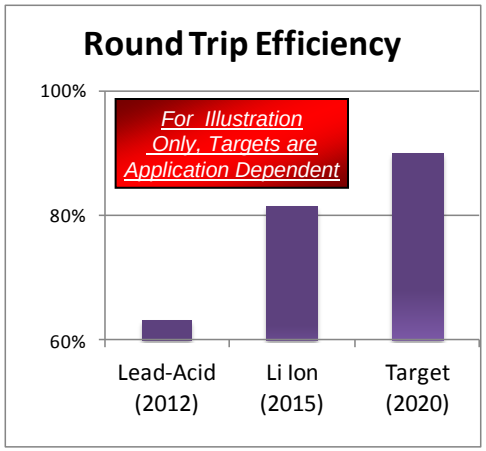
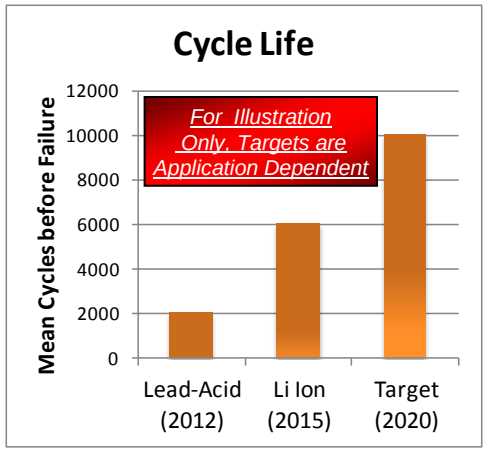
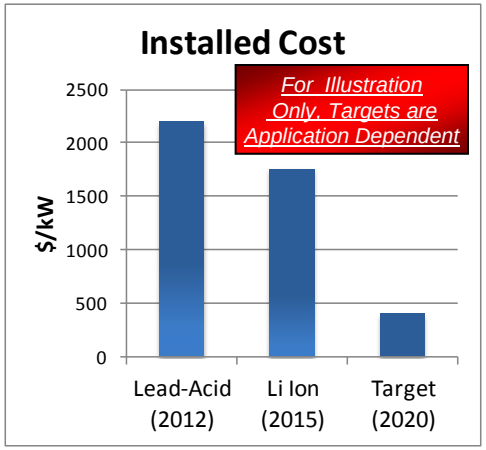
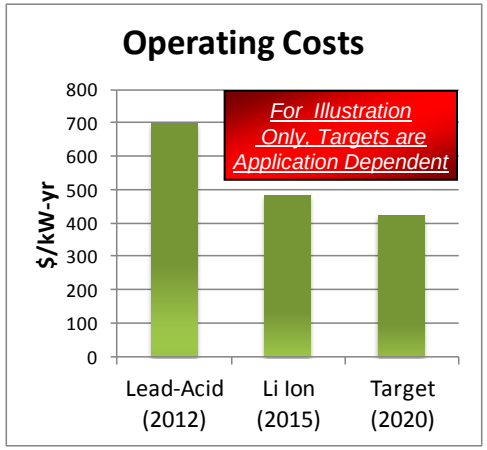
Challenges to the Use of Energy Storage

- Efficiency was not high enough
- Life was not long enough
- Costs were not low enough









Technical challenges are one reason storage has not been widely implemented

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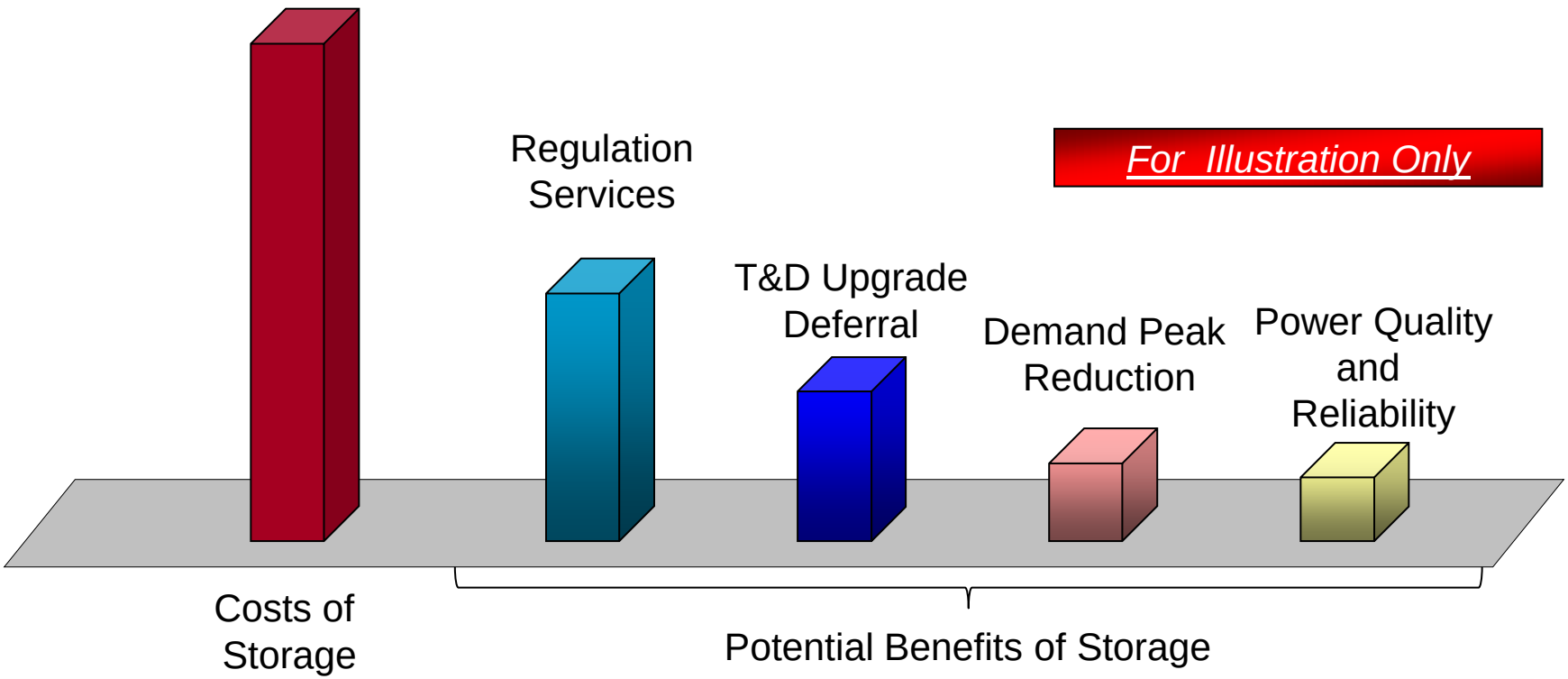
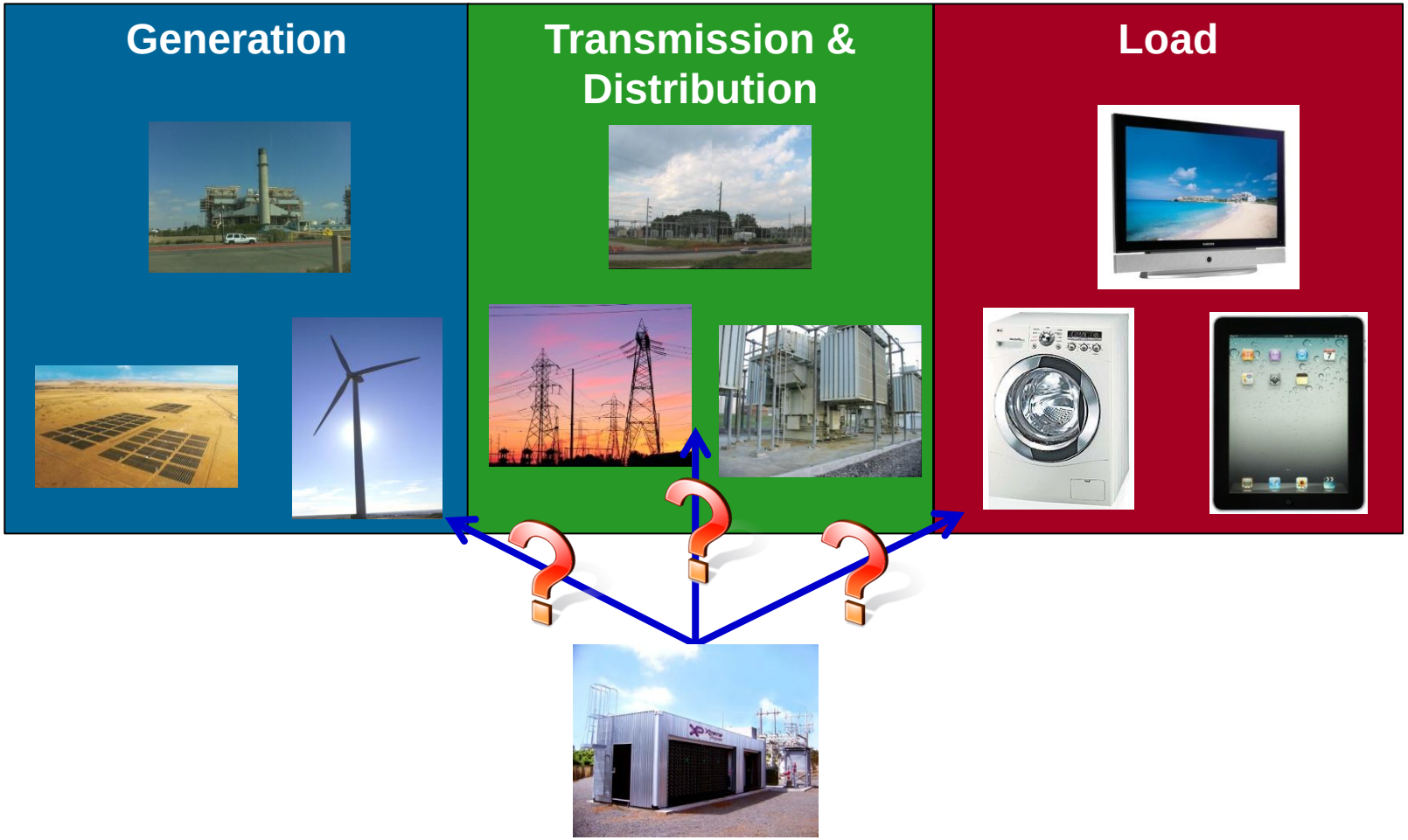
Challenges to the Use of Energy Storage



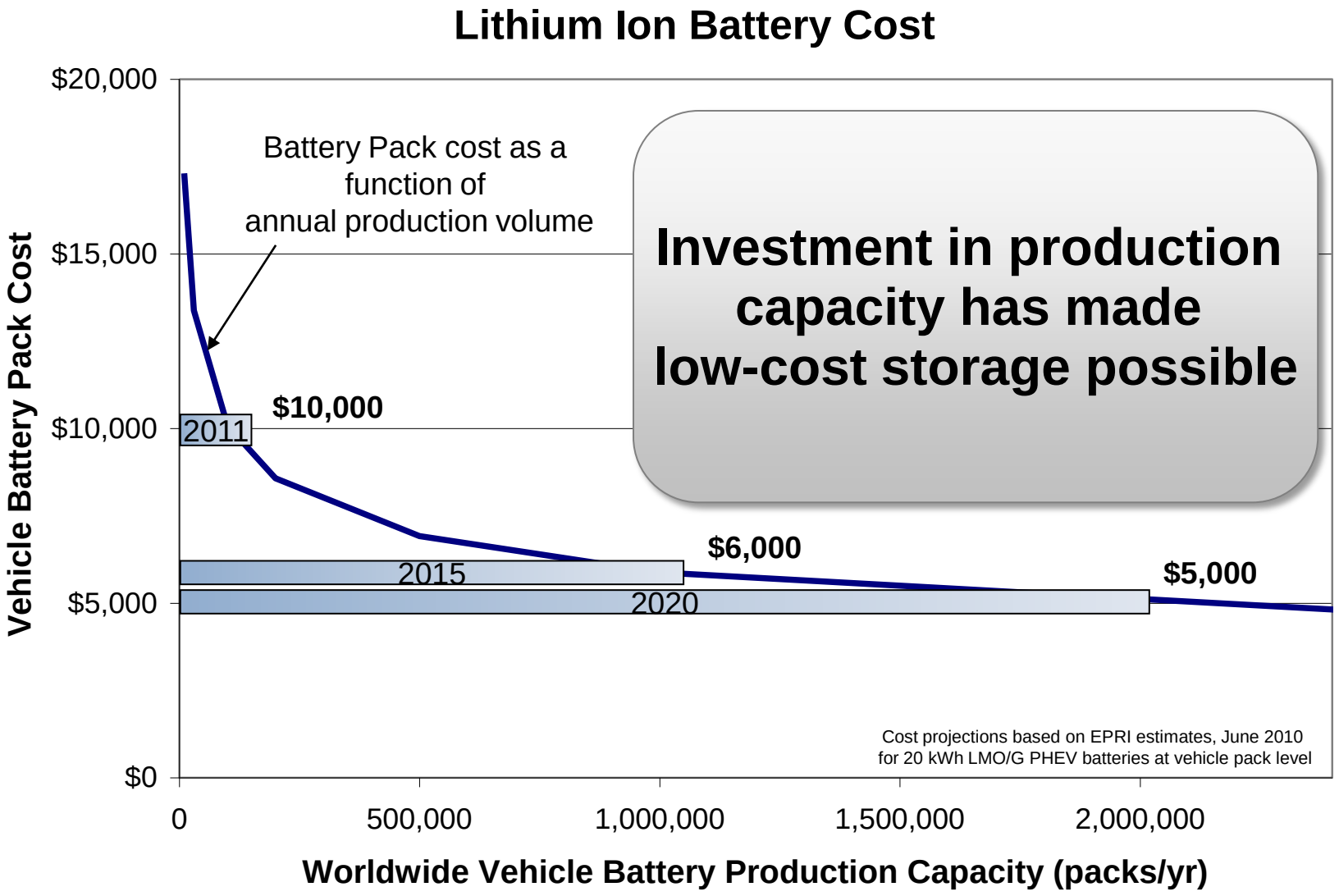
The economic case for energy storage has not been straightforward

Challenges to the Use of Energy Storage



Storage does not fit neatly into the regulatory framework

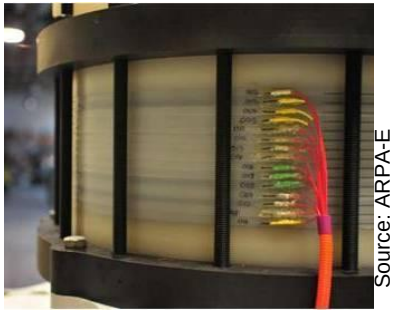
Now, storage costs are falling



Government-funded research has played a role…

- DOE ARRA Projects help stakeholders better understand construction and integration
  - Four projects are complete and installed
  - 11 more to go
- ARPA-E: Nearly 1/3 of program awards related to storage
  - Developing early-stage technologies with potential for the future
- These programs also develop a strong technical resource for storage in the technical community

Source: PNM



Source: ARPA-E / Primus Power

Source: DOE

…but business investment is also important

Source: GE

Source: LG Chem

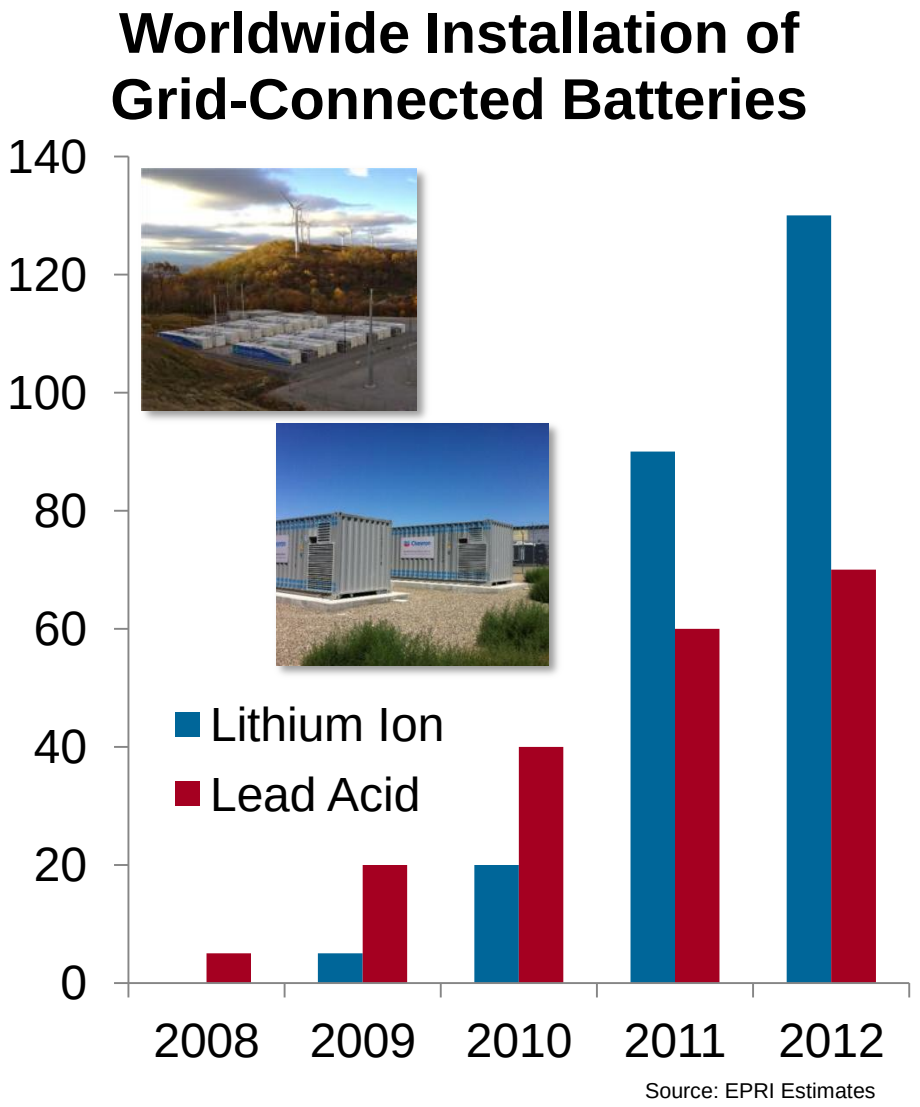
Source: **KEPCO**

- Larger companies are entering the market
  - Multinationals investing billions in research
  - Large-scale manufacturing plants built over last 2-3 years
- Investment leverages consumer electronics and electric vehicle uses

Deployment began with demonstrations…

…but has led to commercial deployment

- Most investment in deployment has come from IPPs and ESPs for ancillary services
- Some deployment on customer side of the meter, but often owned by developers taking advantage of favorable legislation (SGIP program, demand response)



Governments are taking a hand…

- New storage legislation coming about in Japan, Germany, South Korea, California, New Jersey…
  - Most storage legislation incentivizes customer-side storage
  - California has mandated 1.325 GW of utility energy storage by 2020
- FERC Ruling 784 simplifies accounting rules for storage in the U.S.

California Storage Mandate

California AB 2514 (Sept 2010)

- Started out as a bill establishing specific storage procurement targets
- Final bill stated that CPUC must “open a proceeding to determine appropriate targets”
- CPUC conducted an “Order Instituting Rulemaking” Proceeding, to determine framework for analyzing storage needs

California Storage Mandate

- Initial Straw Proposal issued June 10th 2013
- Final Proposal issued Sept 3rd 2013
- 1.325 GW of storage in California by 2020
  - Pumped hydro > 50 MW not eligible
- Bi-annual targets (starting in 2014) with location / utility breakdown
  - ~30% CAGR of storage capacity until 2020
- Request for Offer process (changed from Reverse Auction)
- Some reduction and deferment possible if storage not cost-effective

CPUC Proposed Storage Procurement Targets

Table 1 – Initial Proposed Energy Storage Procurement Targets (in MW)

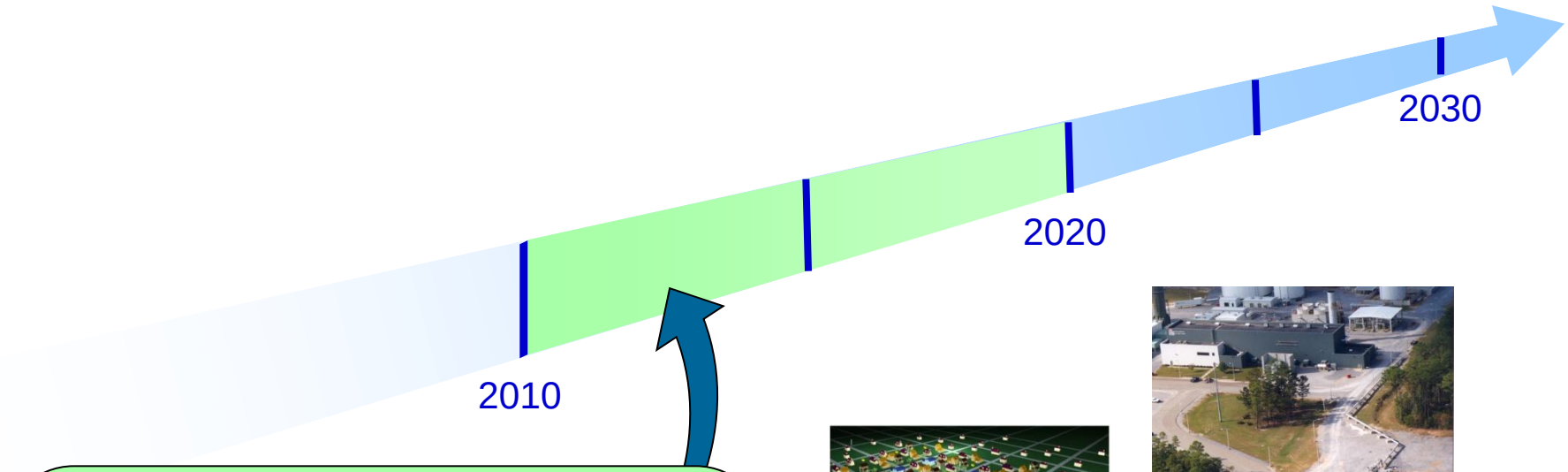
Use case category, by utility	2014	2016	2018	2020	Total
Southern California Edison					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal SCE	**90**	**120**	**160**	**210**	**580**
Pacific Gas and Electric					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal PG&E	**90**	**120**	**160**	**210**	**580**
San Diego Gas & Electric					
Transmission	10	15	22	33	80
Distribution	7	10	15	23	55
Customer	3	5	8	14	30
Subtotal SDG&E	**20**	**30**	**45**	**70**	**165**
Total - all 3 utilities	**200**	**270**	**365**	**490**	**1,325**

Still, many challenges remain

- Tools for understanding the value and grid impacts of storage are still in development
- Grid-ready energy storage products are the exception, not the rule
- Grid deployment, integration, and operation of storage are still major unknowns

Storage options will not become viable without a concerted, targeted, industry-wide effort

The Future of Energy Storage



Near Term:
Establish Expectations and Develop Products for Focused Markets

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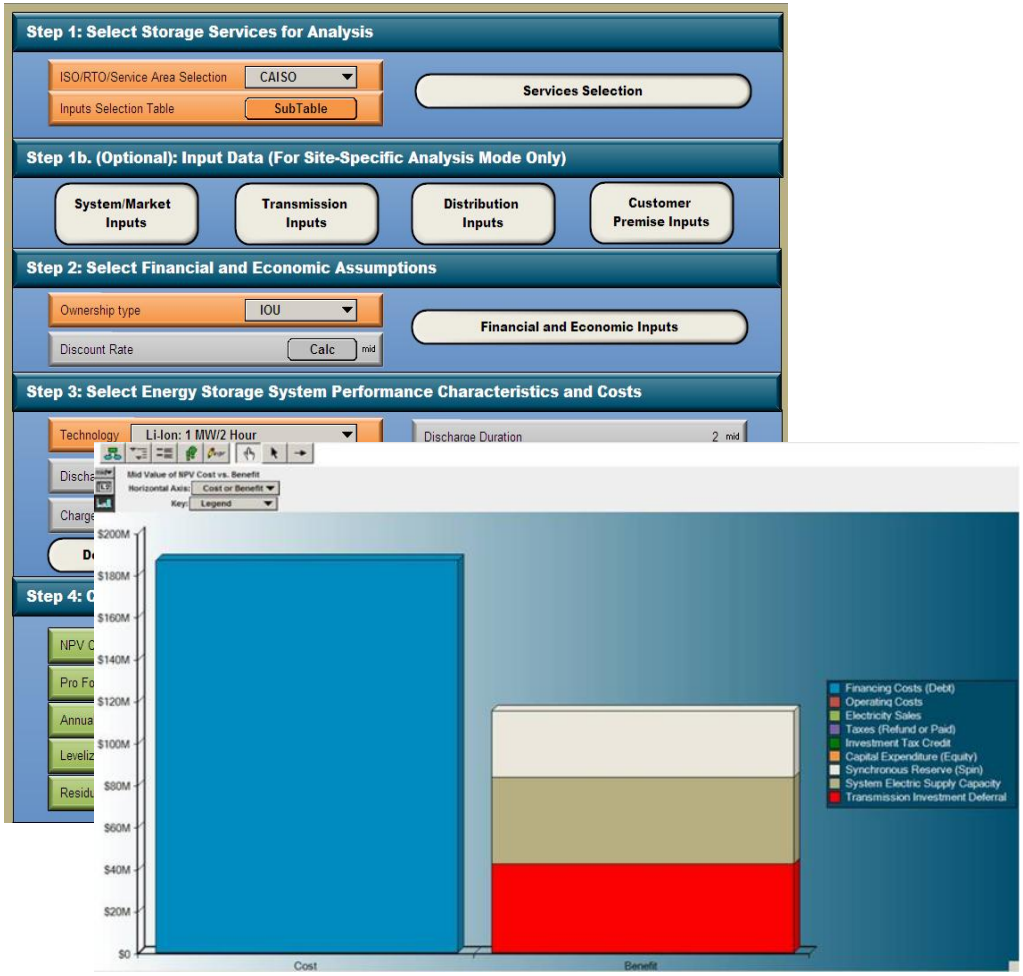
Developing analysis tools for storage

- Leading analysts are developing standard analysis methodologies for value and grid impacts of storage
- Utilities and regulators are now examining and verifying these methodologies



EPRI Energy Storage Valuation Tool 3.0

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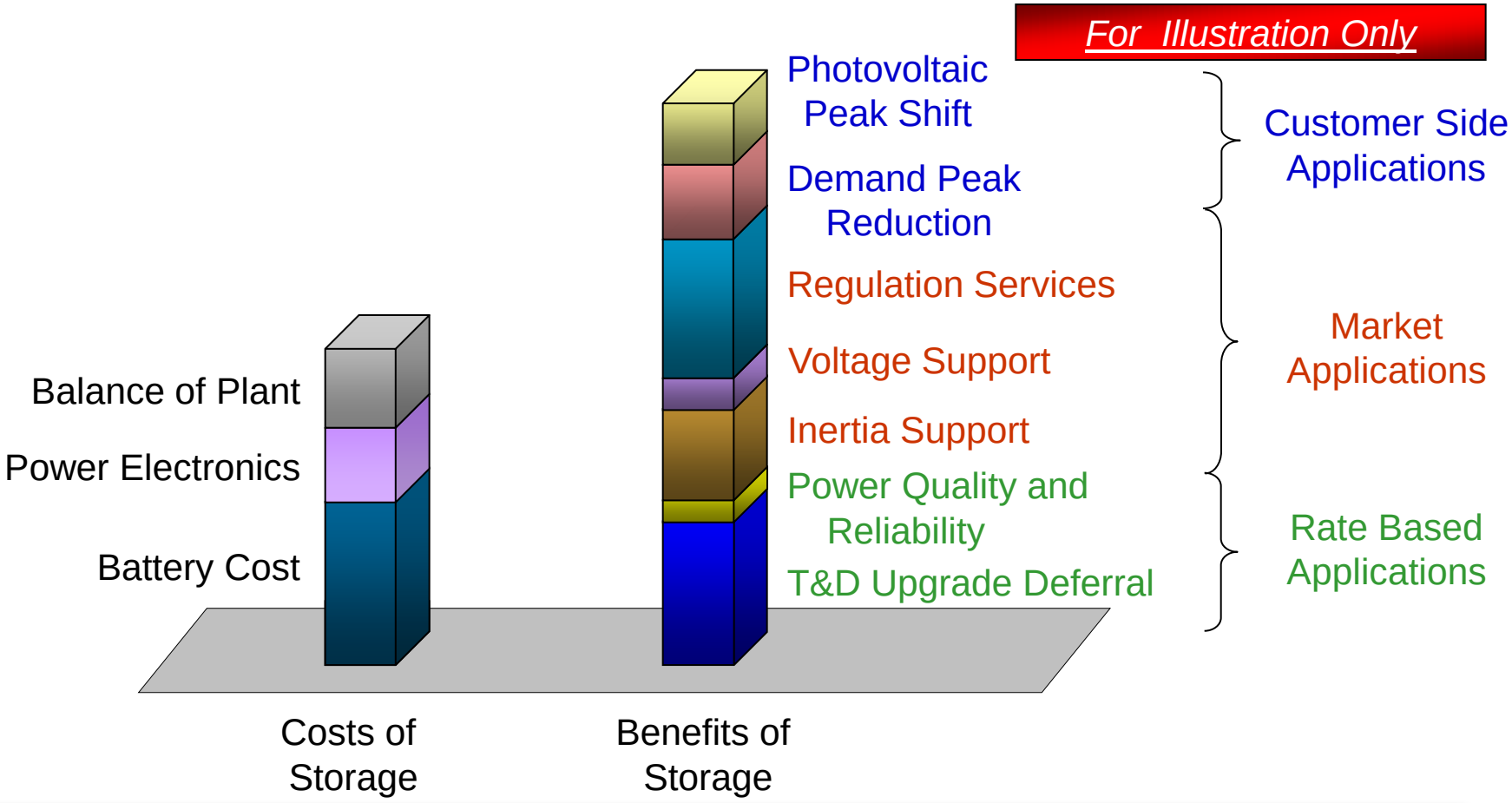
Analyzing the Value of Storage



Using storage for multiple applications can be effective, but is highly site-dependent

Creating a Complete Storage Product

Storage Technologies

- Define duty cycle and expectations for life and efficiency
- Characterize performance in different regimes

Power Conditioning System

- Define critical functions and performance levels
- Test capabilities to understand optimal performance

Product Integration

- Guidelines for integration of components to ensure proper performance
- Test and evaluate product as a whole

Acquiring complete, working systems has been the most challenging part of energy storage efforts to date

Enabling Storage Solutions

- Industry need: Reliable, cost-effective storage-based solutions in four areas:
  - Large-scale bulk storage as a balancing resource for renewables (> 50 MW for several hours)
  - Substation storage for transmission and distribution asset upgrade deferral (1 – 10 MW for 2 – 6 hours)
  - Edge of grid systems (25 – 100 kW for 2 – 4 hours)
  - Residential and commercial systems on the customer side of the meter (5 – 50 kW for 2 – 4 hours)

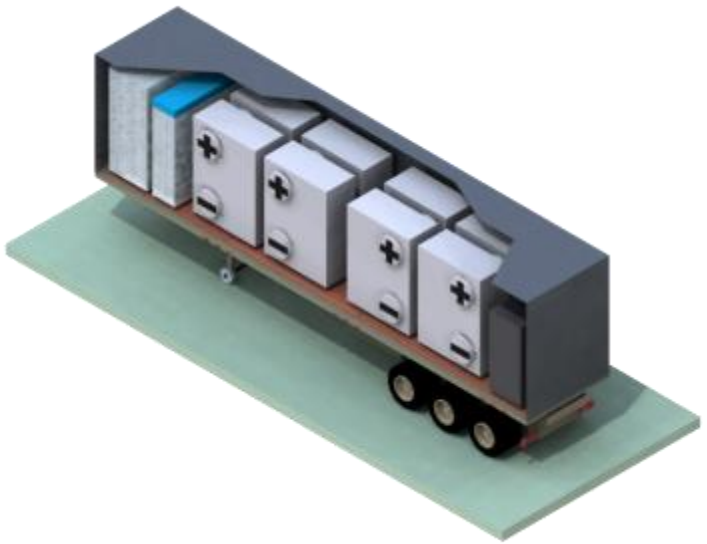
Developing and Qualifying a Standardized Product

Objectives

- Demonstrate technology and practices throughout the lifecycle of a standard storage product
  - Procurement
  - Operations
  - Value assessment

Approach

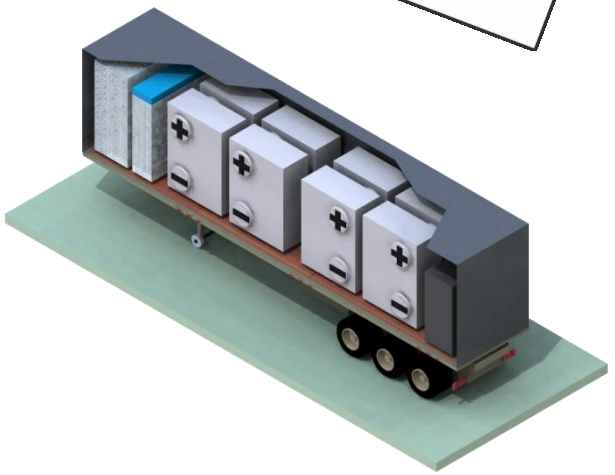
- Facilitate transition from customized project to a standardized storage product
- Deploy a qualification product at a utility site
- Validate expected interconnection and grid impacts with empirical data
- Compare estimated stacked value from models to achieved value in operations



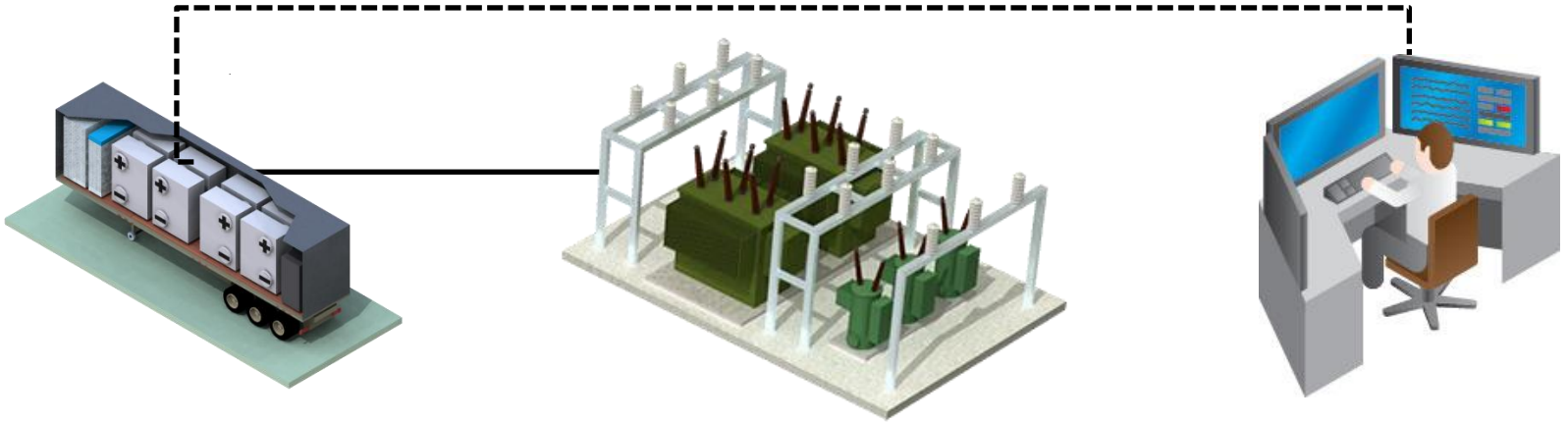
Facilitating Customizable Standard Products

- Utility members and vendors collaborating to produce common approaches, functional requirements, specifications, and test plans for utility applications

- This work is in progress through technical forums such as the EPRI Energy Storage Integration Council



Grid Deployment and Integration



Field Deployment

- Installation, operations, and disposal best practices
- Siting and permitting issues
- Safety and emergency protocols

Grid Integration

- Physical interconnection and protection protocols
- Methods for understanding the effects on the distribution system

Control and Dispatch

- Communication and control protocol
- SGIP and cybersecurity
- Developing optimal dispatch algorithms

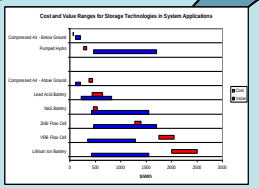
Interconnection of storage to the grid is still relatively poorly understood

Research programs are key…

Technology Watch and Strategic Intelligence

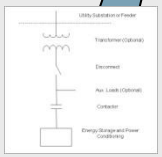
Strategic Intelligence

Cost and Technology Capabilities



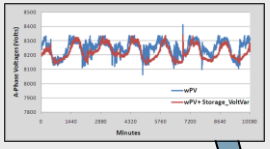
Energy Storage Valuation Tool

Storage for Grid Support
Application Needs; Validated Capabilities



Functional Requirements and Technical Specifications

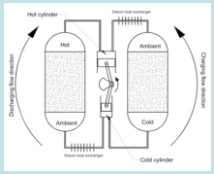
Storage Testing and Validation



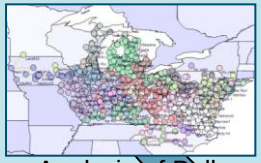
Distribution Impacts and Applications of Storage

Bulk Storage for Renewable Generation

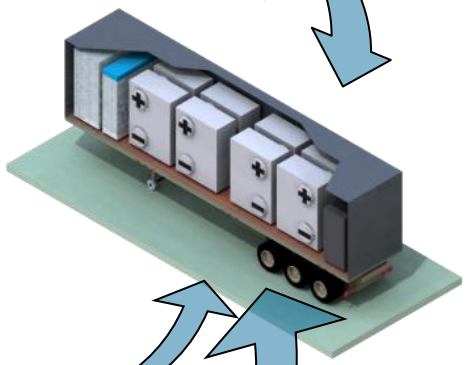
CAES



Bulk Storage Technologies



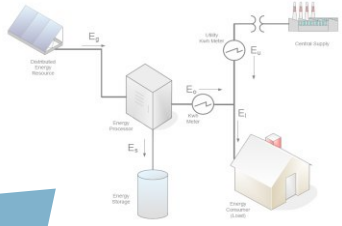
Analysis of Bulk Storage Technologies



Collaborative research programs are directly influencing demonstrations and pilot programs

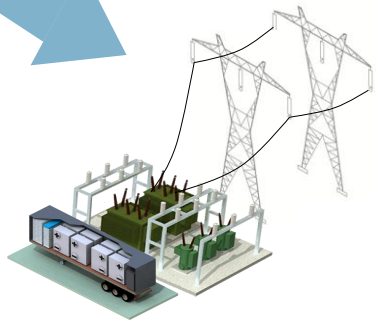
…to the goal of a standard approach to storage

A body of data that informs future standards for the application of storage

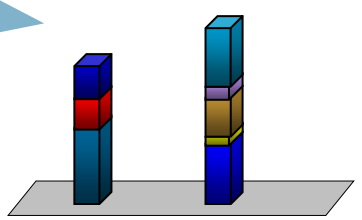


Reference Specifications

Common Operations and Dispatch Algorithms

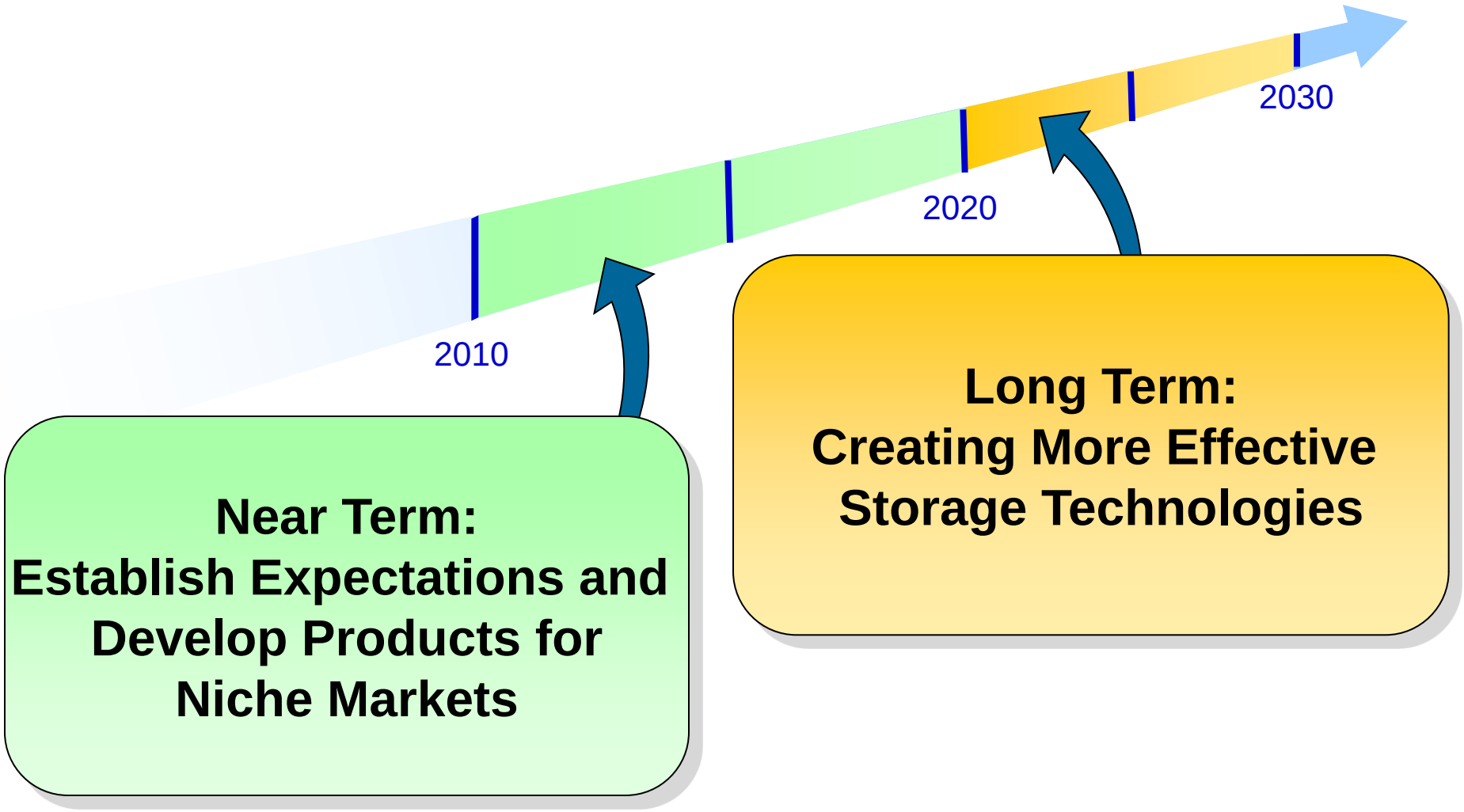


Interconnection Standards



Validated Analysis Tools

The Future of Energy Storage



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Key Performance Metrics for Storage Technologies

Cost

- Low materials and manufacturing costs
- Low integration costs
- Low recycling and disposal costs

Reliability

- Durable, long-life components
- Operable under wide range of conditions
- Well-defined failure characteristics and expected life

Efficiency

- High coulombic efficiency with low polarization
- Low self-discharge losses
- Minimal parasitic loads from cooling and other functions

Control

- Well-defined use cases
- Effective and well-established control algorithms

Future Directions?

Today's research is promising, but will take time to commercialize!

Energy Density (Wh/kg)

400

100

50

0

1860 1950 1985 1994 2015 2030

Time of First Introduction

Lead-Acid
25 – 45

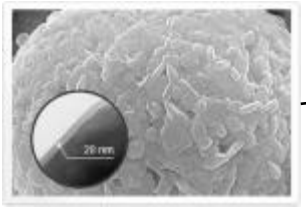
Nickel-Cadmium
35 – 60

Nickel-Metal Hydride
50 – 75

Lithium Ion
110 – 140

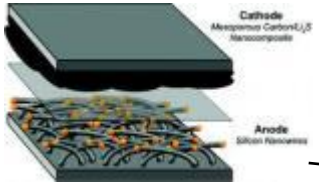
Advanced Lithium Ion
150 – 200

Source: Envia



Layered Cathodes

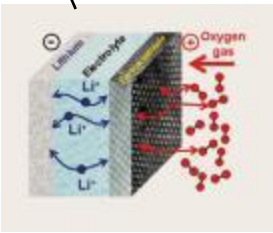
Courtesy Y. Cui group, Stanford University



Lithium Sulfur

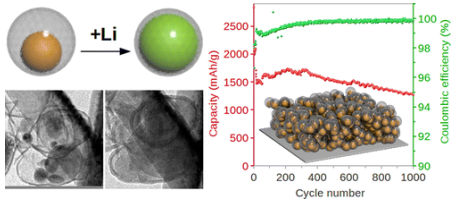
?
~400 Wh/kg?

Source: Excellatron



Lithium Air

Courtesy Y. Cui group, Stanford University



Silicon Anodes

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Energy Storage Key Resources

- Key Reports:
  - *Electric Energy Storage Technology Options: A White Paper Primer on Applications, Costs and Benefits* (EPRI 1020676)
  - Executive summary (EPRI 1022261)
  - *Functional Requirements for Electric Energy Storage Applications on the Power System Grid* (EPRI 1022544)

Together…Shaping the Future of Electricity