Storage: A Power System Game Changer?

Storage Trends and Challenges – Realizing the Benefits of a New Resource

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NARUC Annual Meeting
November 15, 2016

Introducing EPRI

Independent
Objective, scientifically based results address reliability, efficiency, affordability, health, safety and the environment

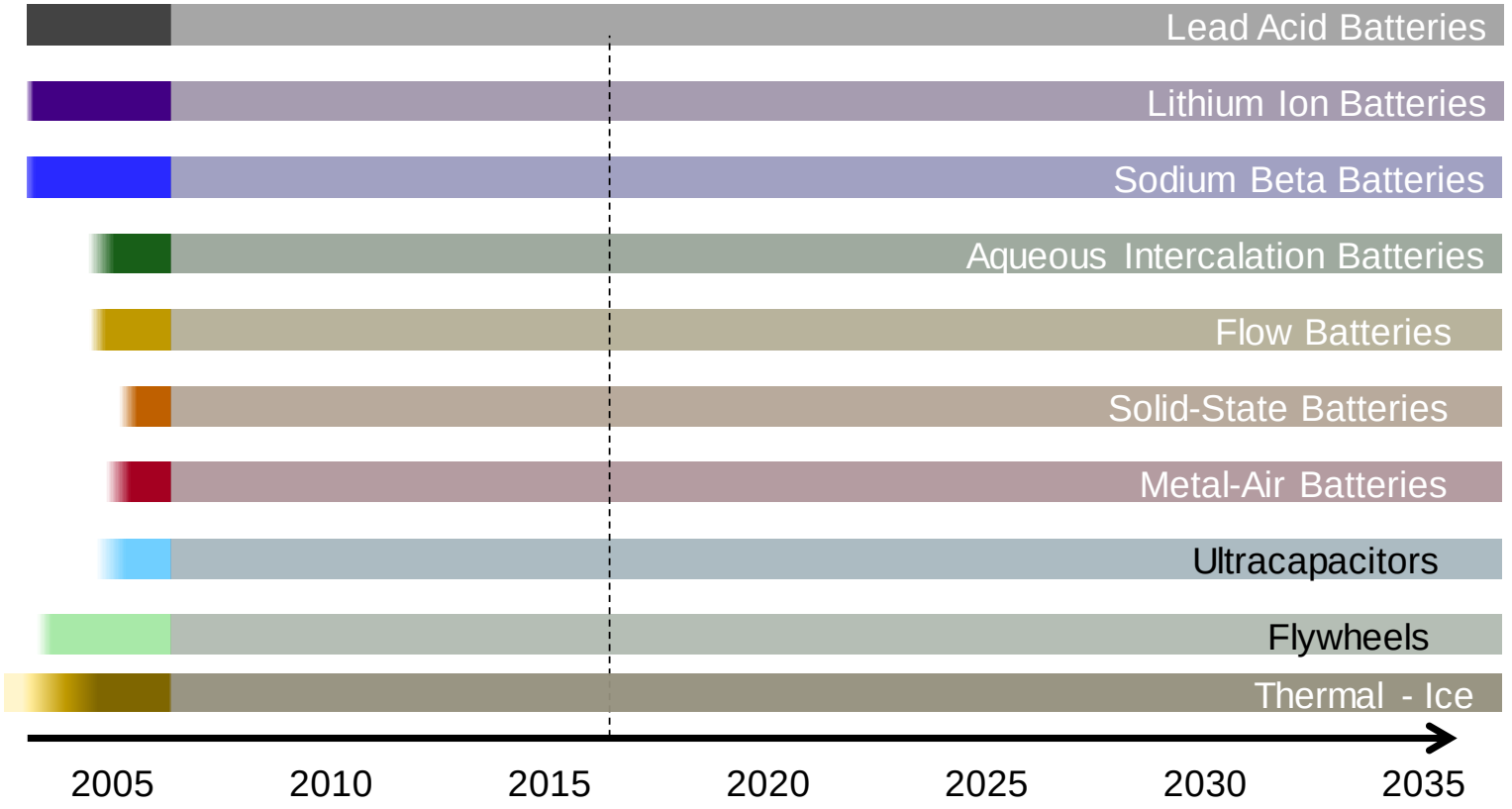
Nonprofit
Chartered to serve the public benefit

Collaborative
Bring together scientists, engineers, academic researchers, industry experts

Agenda

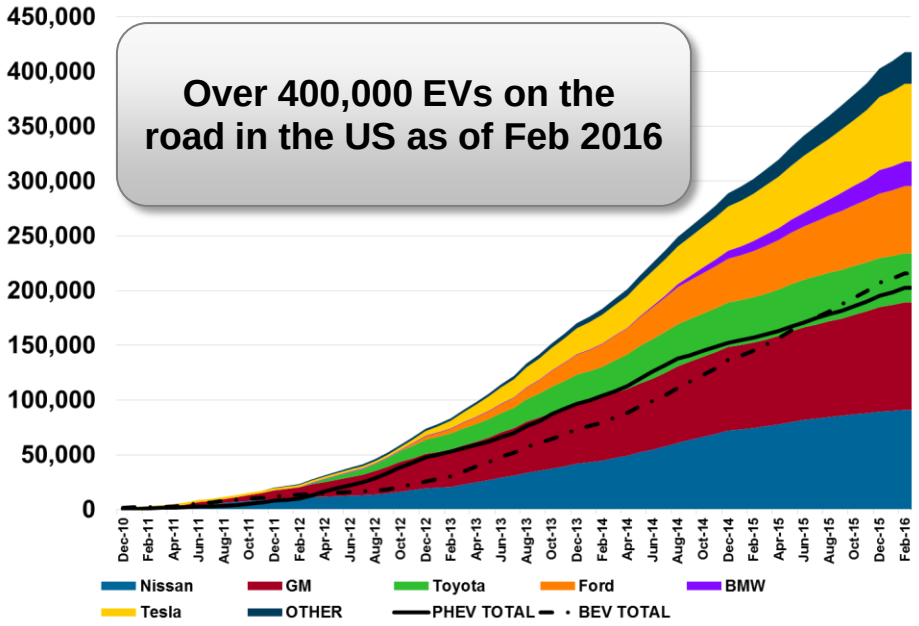
- Storage Trends – Cost and Installation
- What can storage do?
  - Transmission Level
  - Distribution Level
  - Aggregated Distribution
- Challenges – How to Assess and Realize the Benefits of Storage
  - Modeling and Planning
  - Controlling the Systems – Future Vision
- What is EPRI doing?

Spectrum of Storage Technologies - A Possible Timeline for Widespread Deployment

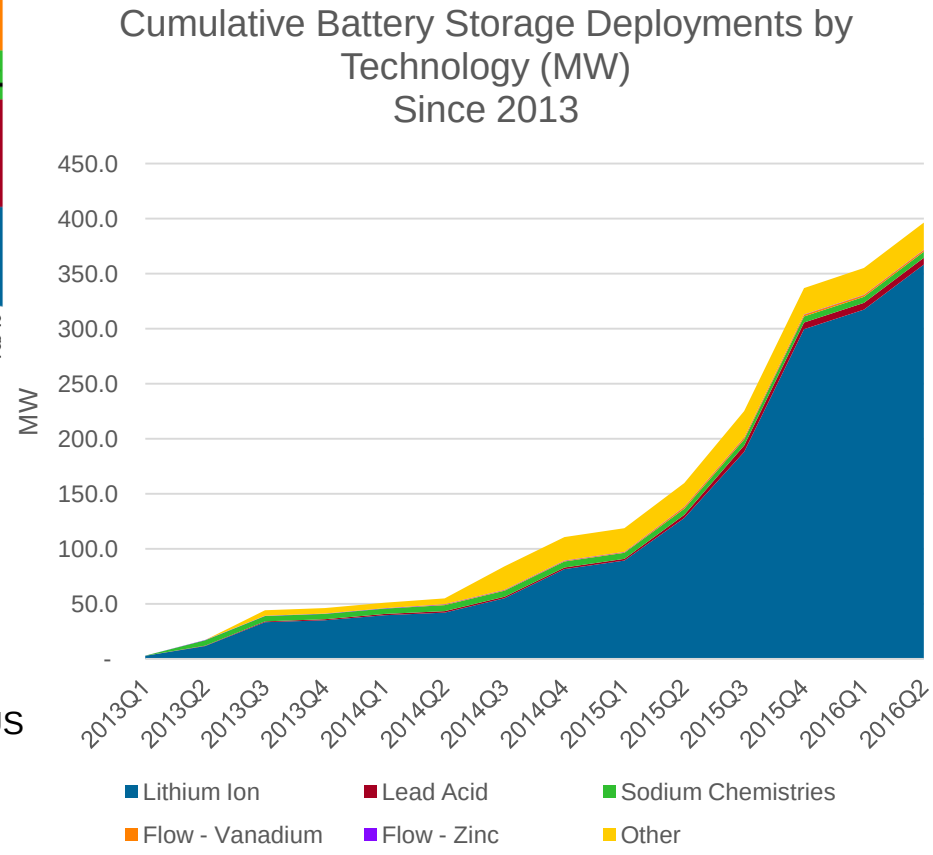


- **A wide variety of technology approaches are at play with large R&D budgets (stemming from auto industry in part)**
- **Highly dependent on economics and regulatory policy**
- **Lithium Ion battery technology will be the dominant technology for stationary applications in the foreseeable future**

Why Li-Ion? …driven in part by electric vehicle sales growth

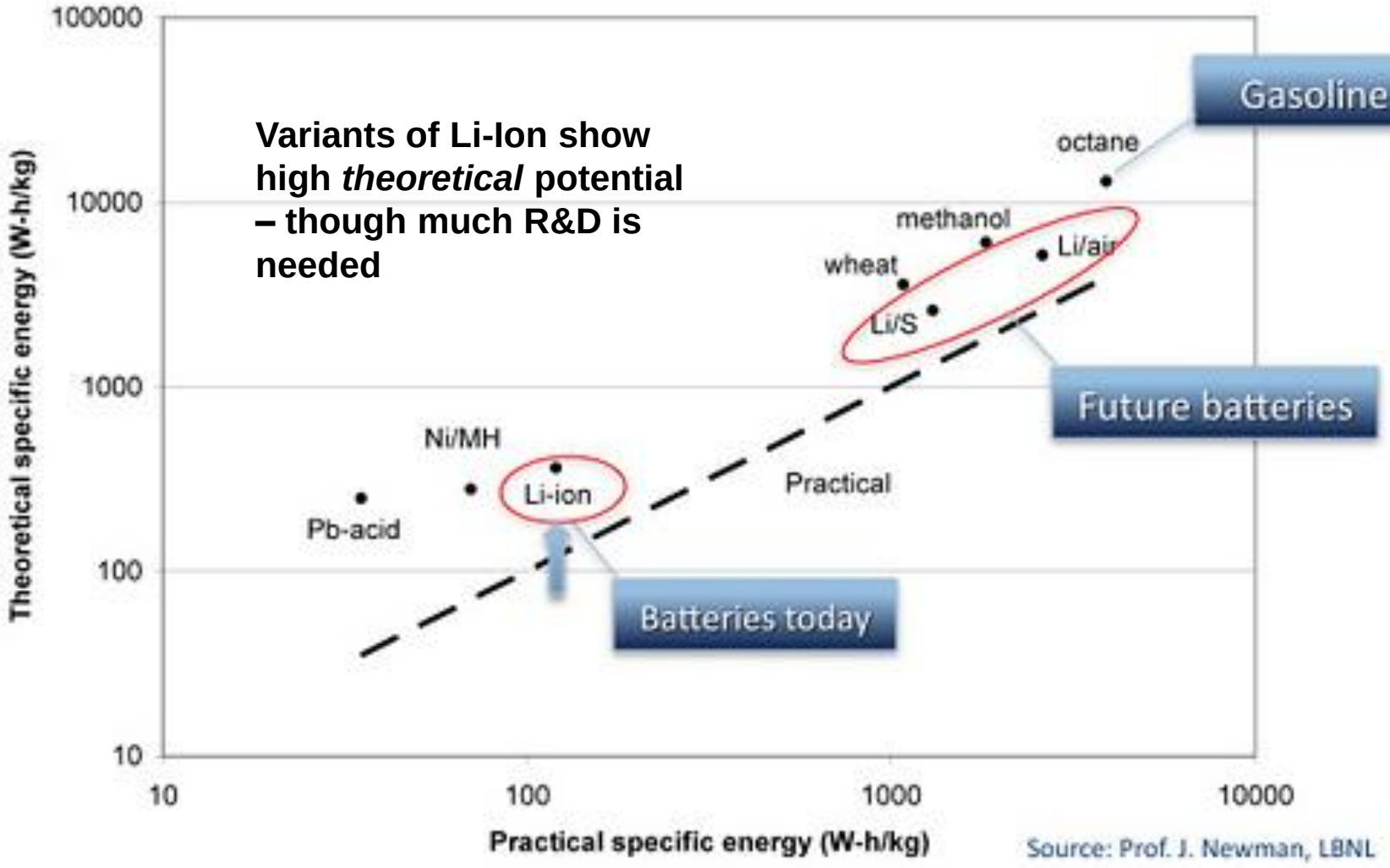


Li-Ion is dominating deployments with other technologies showing relatively little recent growth



Data Source: GTM US Energy Monitor Q3 2016

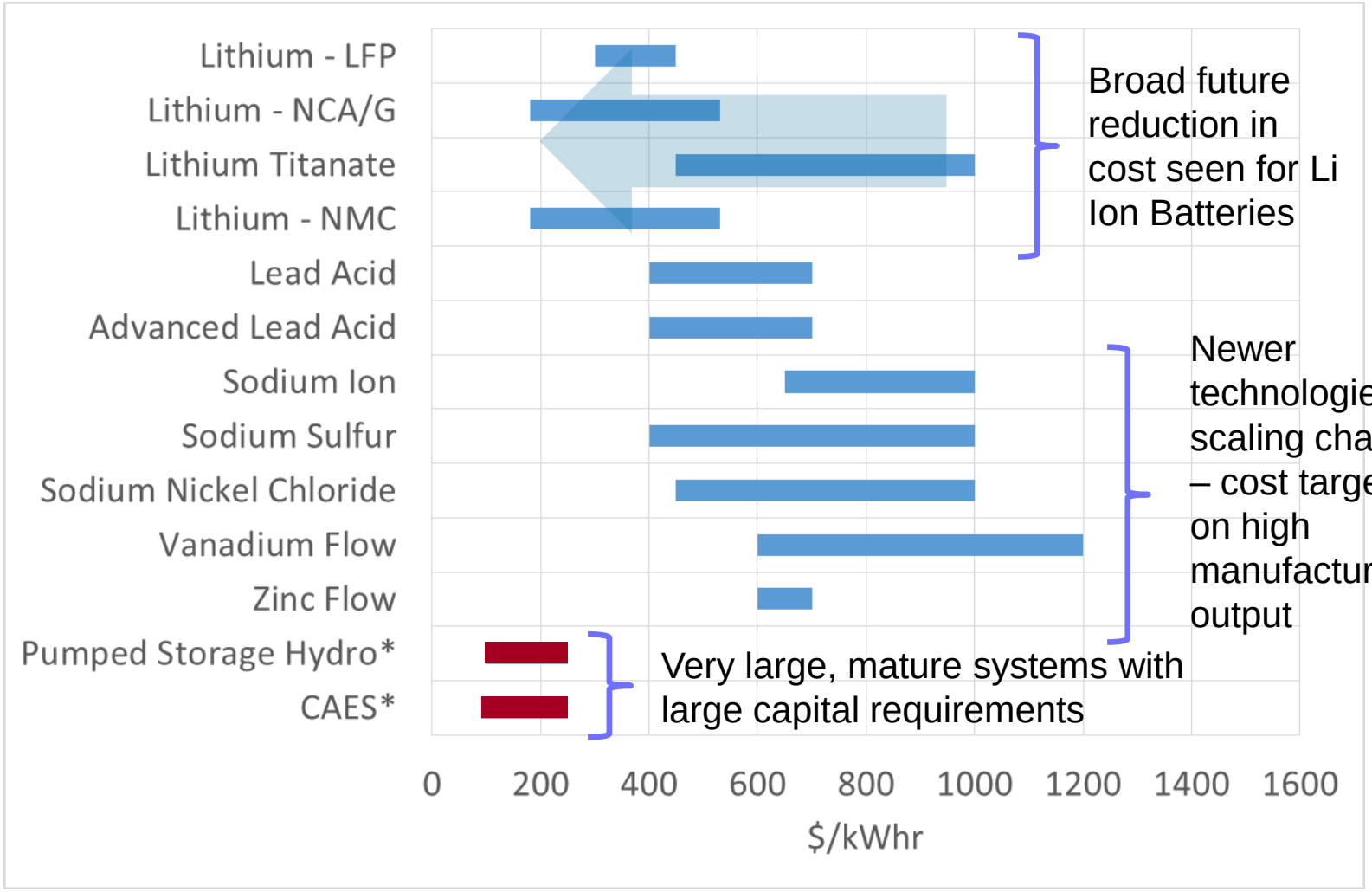
Why Li-Ion? - Huge increases in projected energy density



Secondary Source:
DOE/JCESR

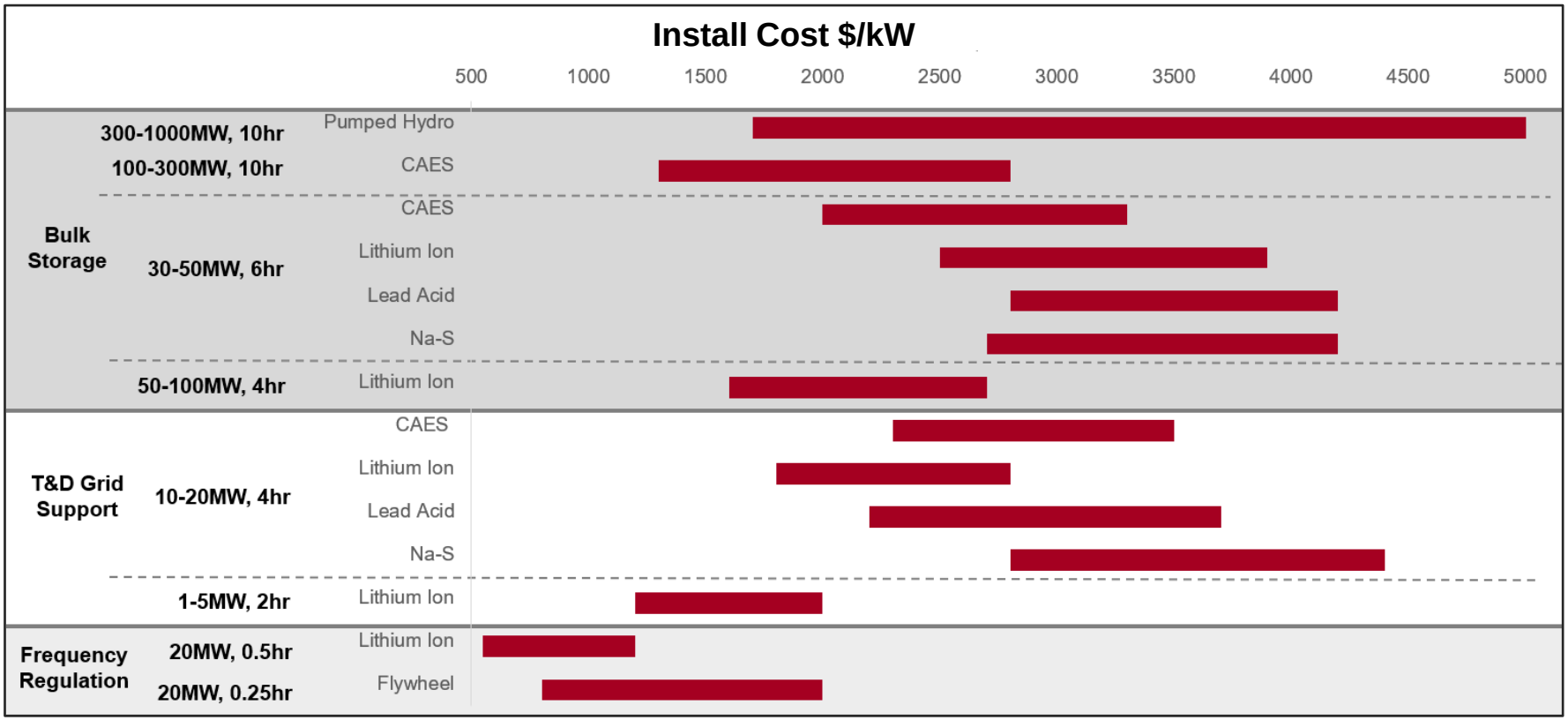
Storage Cost Estimates

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)

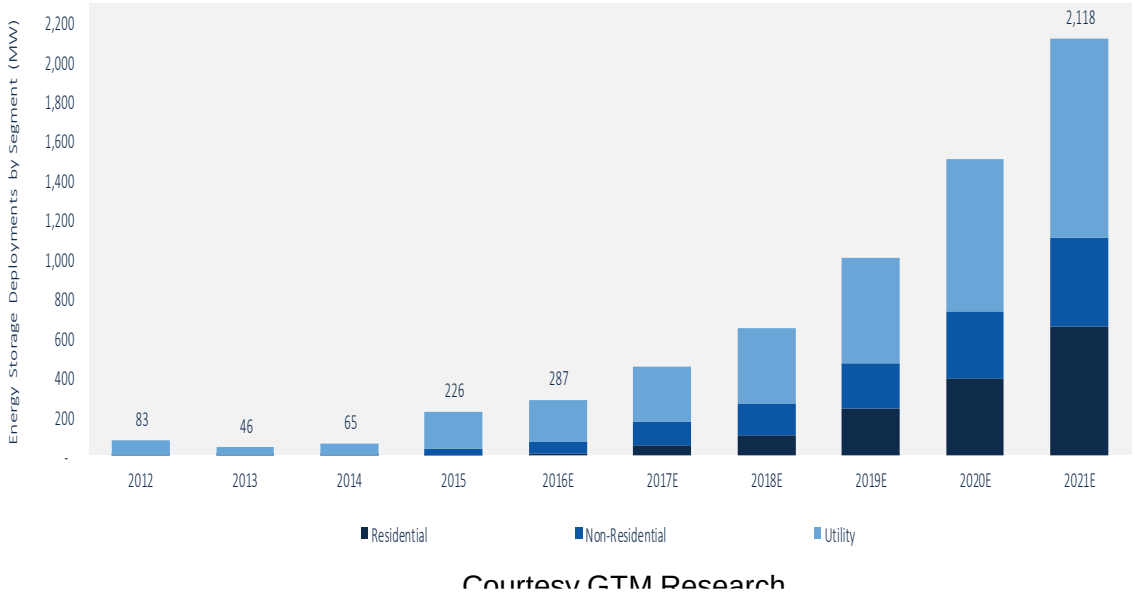
Energy Storage Installed Cost Summary: 2017



- Costs are for 2017 installation reference year only and assumes overnight installed costs.
- Suppliers and publicly available studies indicate continuing trend of cost decline for battery-based storage technologies, particularly lithium-ion.
- Installed costs exclude land costs, owners costs, contingency. Detailed list of inclusions and exclusions is provided in previous section.
- Average is not necessarily mid-point of the range

How big is the market projected to be? Adoption hinges on policies, costs and proven capabilities

U.S. Annual Energy Storage Deployment Forecast, 2012-2021E (MW)



Courtesy GTM Research

•Many projections depict huge growth in energy storage

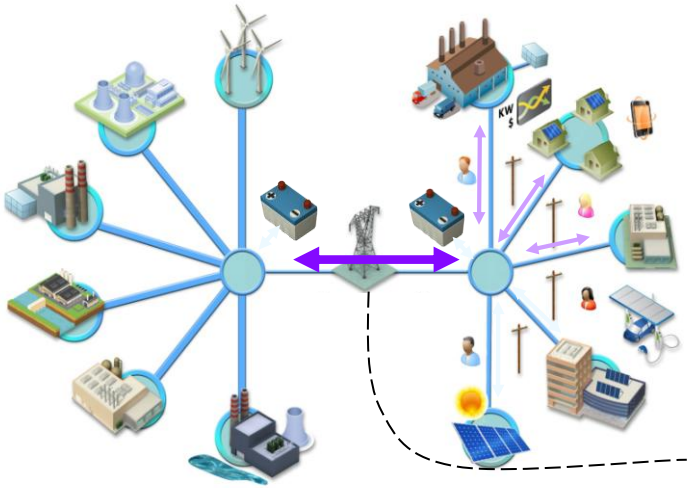
- Annual growth rates of ~10%
- Compare to smart phone growth of 7-13%
- But….exponential growth figures are being applied to a small market - what does this mean?

What are the dependencies underneath these predictions?

- Known Costs
- Known Benefits (chicken before the egg– models needed up front)
- Known Reliability
- Uniform Policies/Incentives
- Robust Controls

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

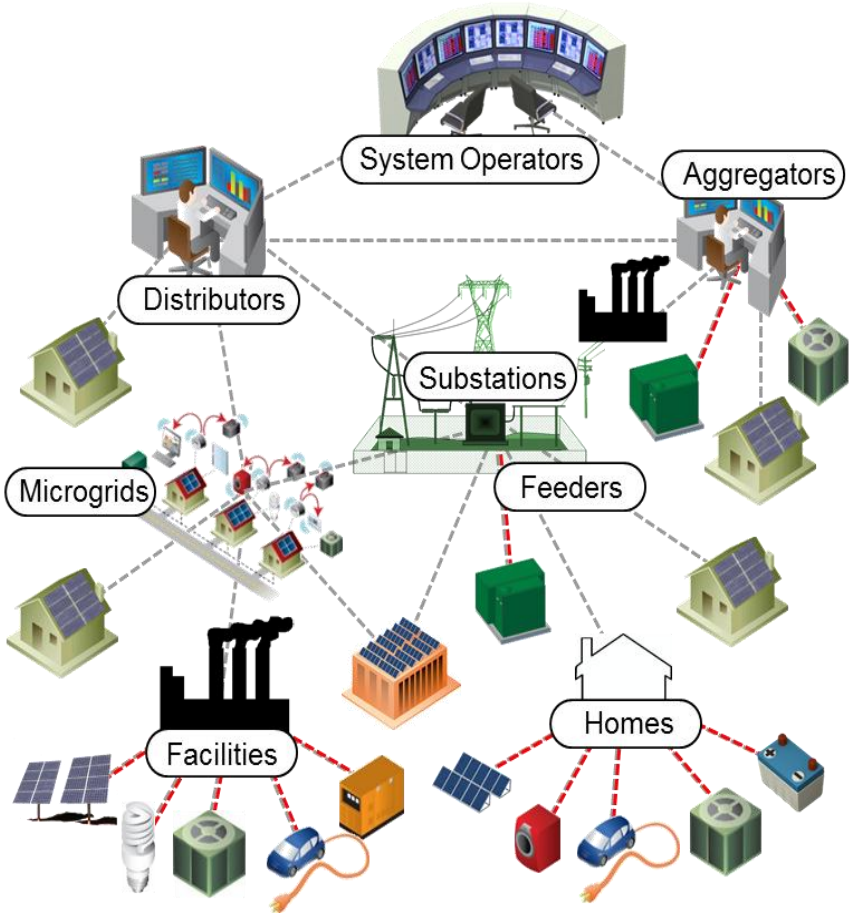


- Distribution Level
  - PV Shifting/Smoothing
  - Increase PV accommodation
  - Power Quality improvement
  - Deferral of distribution upgrades
  - Demand charge avoidance
  - *Assist in many Transmission applications on an aggregated basis*
    - Frequency Regulation
    - Renewables Shifting/Smoothing
    - 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 Challenges are numerous and are being addressed

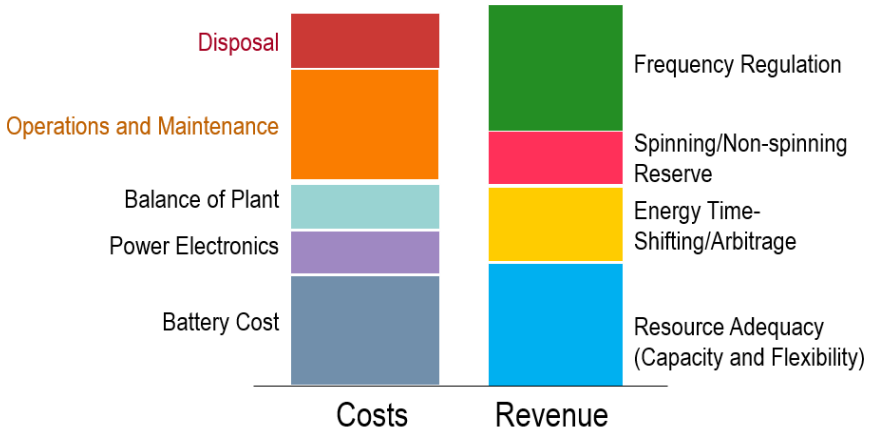
- Assessing Benefits in the face of an evolving planning process with many stakeholders
  - Modeling Benefits in the context of the whole system
  - Numerous tools are needed
- Controlling Storage so all available benefits are tapped
  - Vision: Sophisticated grid optimizing and coordinating reliable and safe dispatch of numerous distributed and centralized resources
    - Many players (traditional and new)
    - Massive amounts of new data
    - Accurate forecasts
    - All devices need to speak the same language (interoperability) in a cyber secure setting
- Reliability of storage technologies is still not understood – needed for:
  - Warranties/wraps
  - Understanding technology life and operating costs



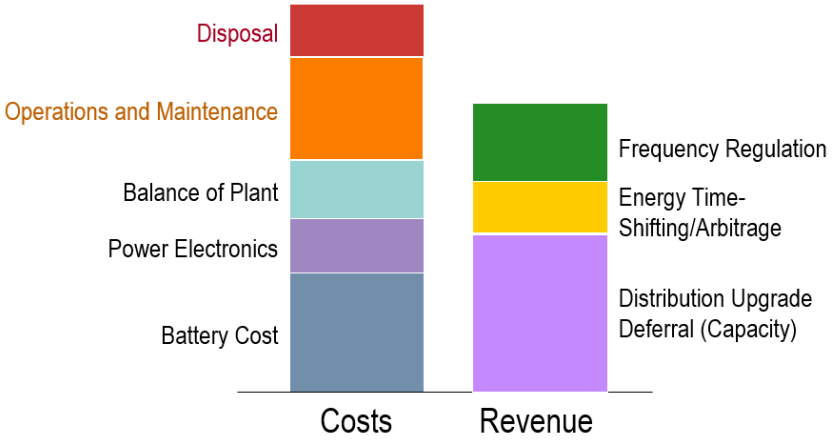
What About Benefits – Do they exceed the Costs?

For Illustration Only

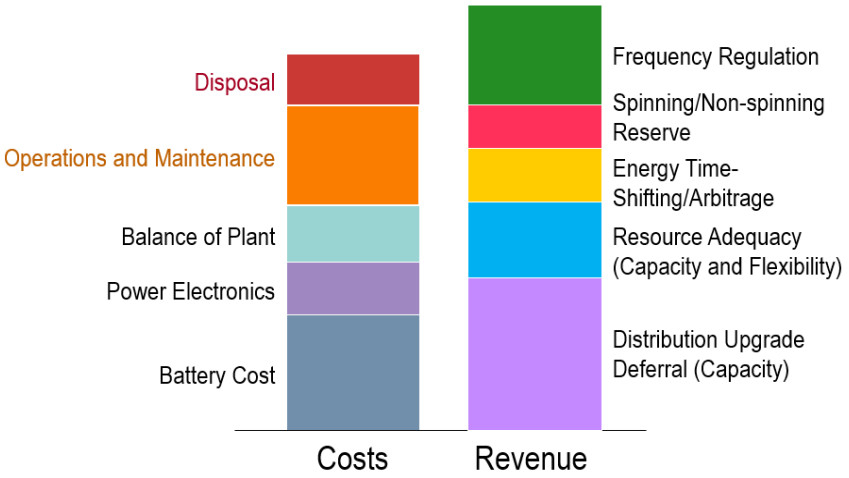
- Transmission level assessment



- Distribution level assessment



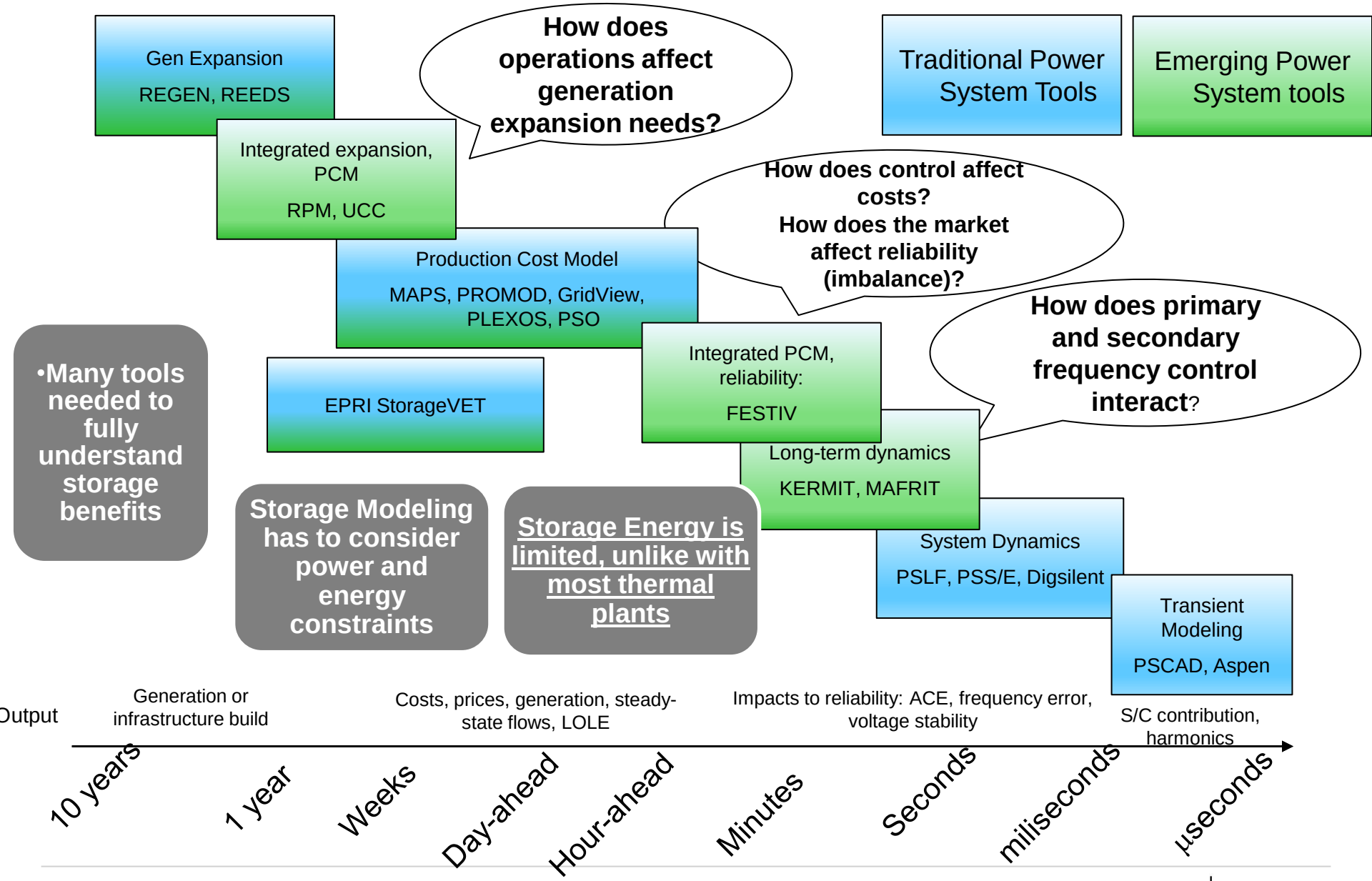
- Aggregated Distribution level assessment



•When enough benefits are stacked the economics justify storage

- All costs need to be understood on a Present Worth/lifetime basis
- Storage is capable of many applications
- Sophisticated controls are necessary to tap the benefits
- Further research is needed on edge of grid vs centralized resource benefits

The Challenges with Modeling Storage



The Integrated Grid– Managing the System with New Resources

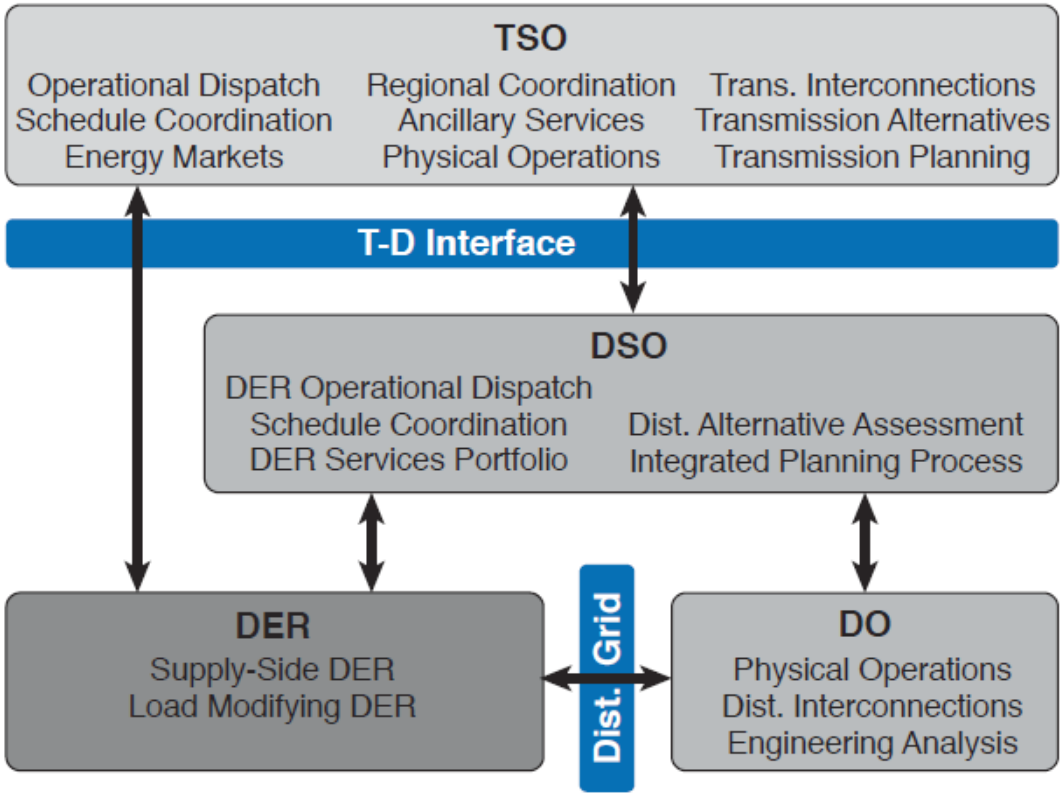


Figure 1. LBNL Integrated Systems Operational Framework [11]

EPRI Report: Program on Technology Innovation - Common Needed Attributes Of Architecture For An Integrated Grid – Sept 2016 TR 3002009240

- Critical to coordinate all these Entities in order to manage reliability through a set of traditional and distributed resources.
- Requires interplay of utility legacy systems (metering, systems management) and new systems on the edge of the grid
- Introduces new data, information, and computational capabilities

What is EPRI doing?

EPRI's Architecture for an Integrated Grid project consists of five interrelated pillars at various stages of development:

- **Pillar One: The Enterprise Interoperability Platform.** EPRI developed Common Information Model - facilitates utility information and communications infrastructures to integrate legacy, new, and future systems
- **Pillar Two: Open Application Platform.** EPRI is helping vendors develop a computer-based platform that will enable electric meters and other utility devices to "learn new tricks" after being installed - turn their products into platforms for innovation.
- **Pillar Three: Open Telecommunications.** EPRI is working to enable data transfer among grid devices and enterprise systems
- **Pillar Four: Cyber Security.** EPRI will develop approaches that provide cyber security for the enterprise interoperability and open application platforms.
- **Pillar Five: Distributed Energy Resources.** EPRI is developing software and other tools to integrate distributed and network based energy resources.

Together…Shaping the Future of Electricity

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Energy Storage as a Flexible Capacity Resource

Advancion®
Energy Storage

Kiran Kumaraswamy
Market Development Director
AES Energy Storage

15th November 2016

AES
we are the energy

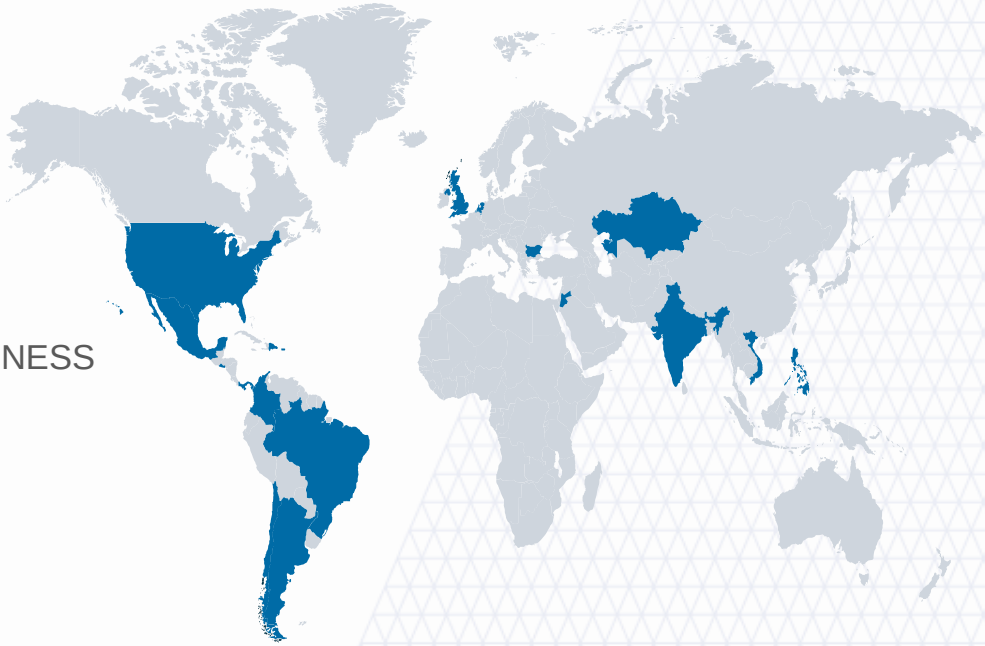
About the AES Corporation

Mission: Improving lives by providing safe, reliable and sustainable energy solutions in every market we serve.

6 MARKET-FACING STRATEGIC BUSINESS UNITS

4 CONTINENTS

17 COUNTRIES



AES Serves **10M** CUSTOMERS

8 **UTILITY** COMPANIES

21,000 GLOBAL WORKFORCE

$37B TOTAL ASSETS OWNED & MANAGED

$15B TOTAL 2015 REVENUES

36,000 MW GENERATION CAPACITY

Nearly a decade of storage project experience is built into AES Advancion energy storage technology solution

432 MW

In operation, construction or late stage development

Los Andes

Angamos

Kilroot

Netherlands

Masinloc Philippines

2007 2008 2009 2011 2013 2015 2016

Carina

Barbados

Laurel Mountain

Tait

Warrior Run

Harding Street

Alamitos 2020

Contains Forward Looking Statements

Advancion® is a complete solution for clean flexible power combined with full turn-key delivery

Available around the globe for third party users of Energy Storage assets

Advancion Nodes in an Array | **AES NETHERLANDS** | Zeeland, The Netherlands

Advancion Node Controller

Batteries in a Advancion Node

HMI Control Screen

AES Advancion® Solves the "Energy Trilemma," creating a clean, unbreakable grid

A smarter investment for the energy infrastructure

Energy Storage is uniquely placed to support all three goals

Energy storage is a cost-effective alternative to peaking power plants

Storage competitively contracted for local capacity in California

- Capacity, local reliability
- Peak power/off peak mitigation
- Ancillary services

Impact

✓ Competitive bid vs thermal peaker, cost effective

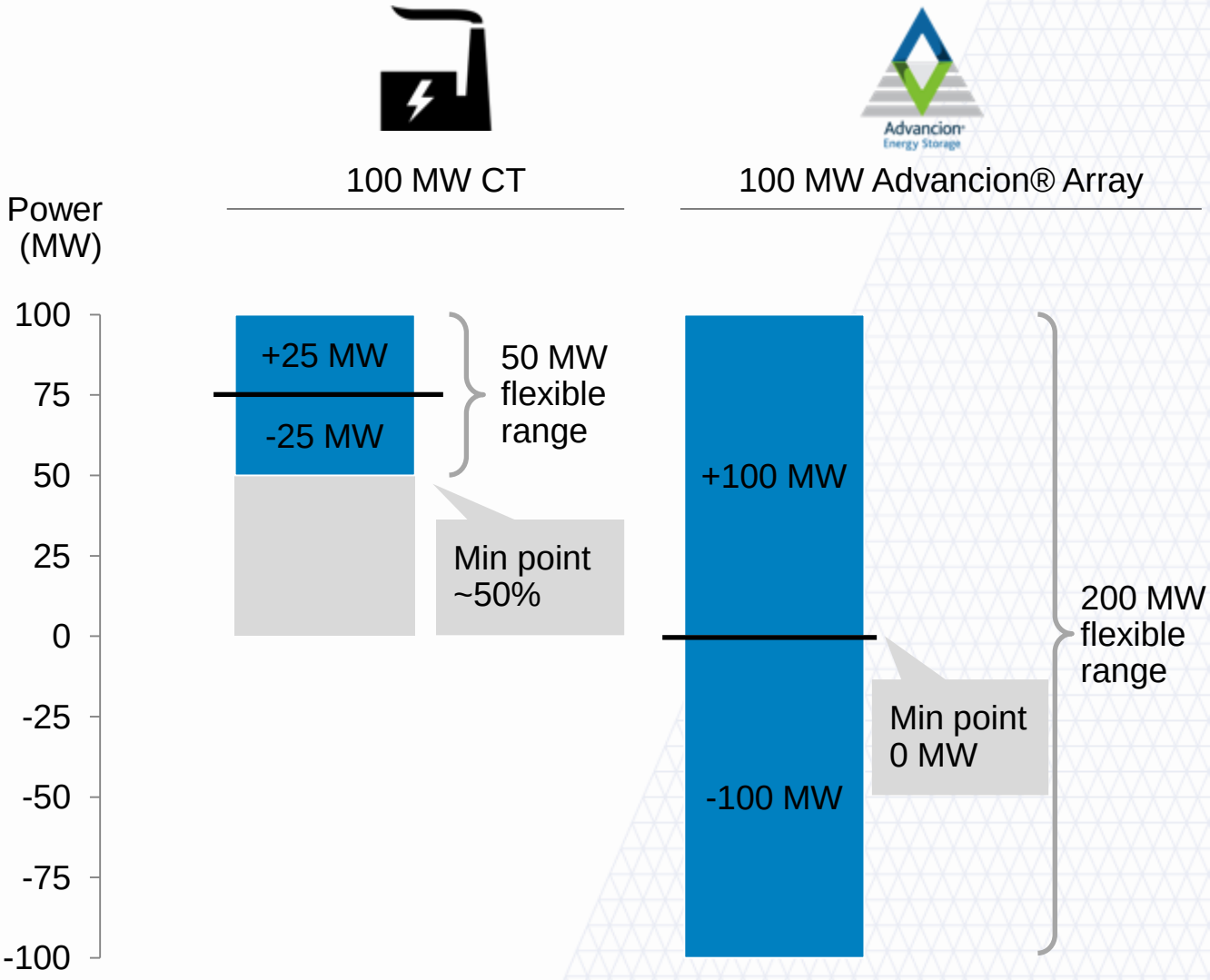
✓ Replaces environmental retired units

✓ Meets flexibility (duck curve)

100 MW Alamitos Energy Center

Long Beach, California

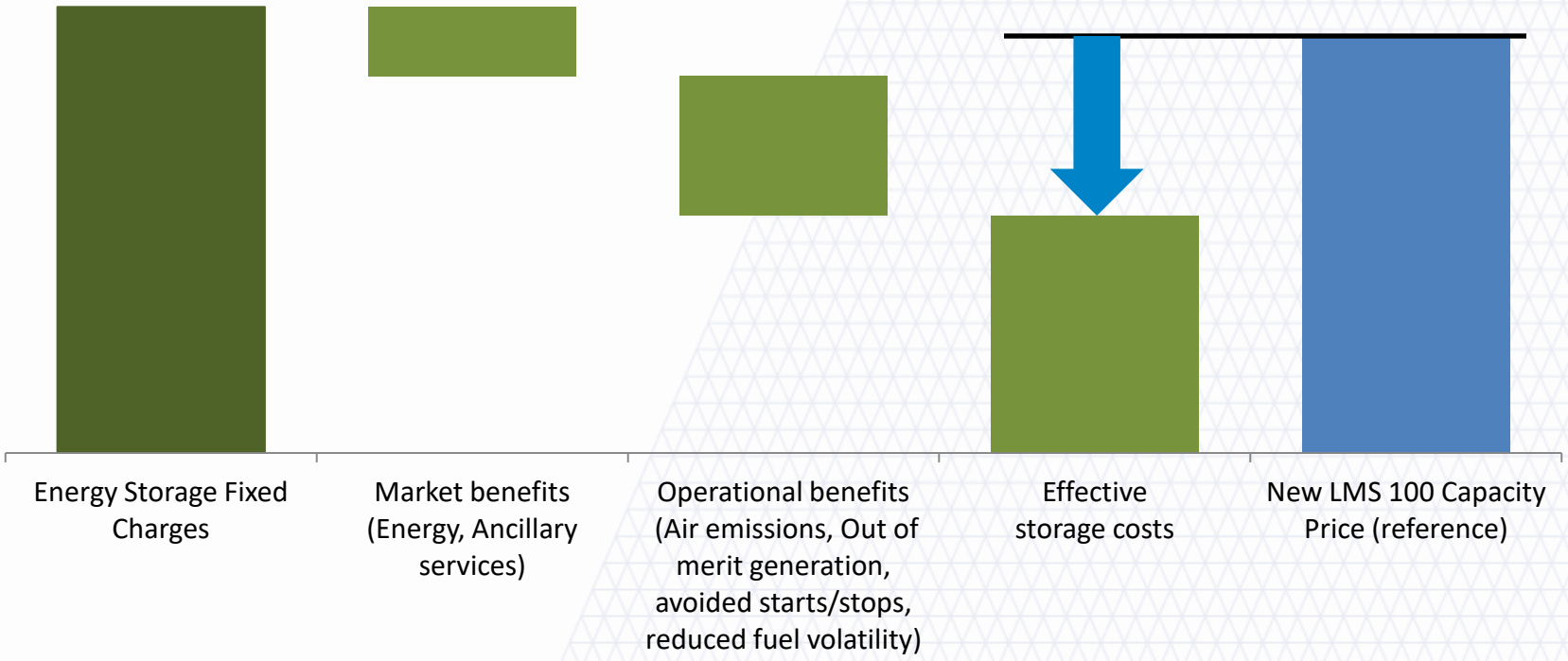
Storage provides up to 4 x the effective resources and unique flexibility compared to traditional peakers



Unique capabilities of battery storage

- Fast ramp (<250 msec)
- Always synchronized
- Unlimited starts / stops (no cost)
- Broader operating range

Storage is cost effective today; Operational benefits are significant.



Thanks!

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