London Economics International LLC

Energy storage – how will it be part of "Grid of Things" in the future?

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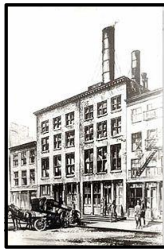
Technology is changing how we consume electricity and affecting our expectations of what the future grid should "do" and "look like"

Sometimes technology leads the development of markets and regulation … but other times, policy serves to catalyze technology

1879

Thomas Edison's first successful light bulb model in 1879

1882



The first central generating plant on Pearl Street in 1882

Also in 1882, the first US commercial operation hydro plant was opened in Wisconsin and within a decade, hundreds of hydropower plants were in operation

1930s

Construction of Hoover Dam, Grand Coulee Dam, Bonneville Dam in 1930s

1935

Liberation of the US began with Public Utility Holding Company Act of 1935, other important acts include: Federal Power Act of 1920, Public Utilities Regulatory Policies Act of 1987, Energy Power Act of 1992 and Energy Policy Act of 1992 and Energy Policy Act of 2005

1958

The first commercial **nuclear** power plant in the US, Shipping Atomic Reactor Power Station

1992-1996

Electricity restructuring (Orders 888, 889) began four years after Order 636 which facilitated open access on natural gas pipelines starting in 1992

2000s

Regional transmission organizations (RTOs) continues to be formed and wholesale markets arise

Today

Shale gas, renewables, electric vehicle and other new technologies continue to shape the future energy world

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LEI worked with WIRES in 2014 to develop a study on Market Resource Alternatives (“MRAs”)


A WIRES Report

on

MARKET

RESOURCE

ALTERNATIVES:

An Examination of New Technologies in the Electric Transmission Planning Process

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WIRES

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LEI’s expertise lies with the electricity sector and other infrastructure industries

LEI combines detailed understanding of specific network and commodity industries, such as electricity generation and distribution, with sophisticated analysis and a suite of proprietary quantitative models to produce reliable and comprehensible results


TRANSMISSION


REGULATORY ECONOMICS, PERFORMANCE-BASED RATEMAKING & MARKET DESIGN


ASSET VALUATION, PRICE FORECASTING & MARKET ANALYSIS


RENEWABLE ENERGY


EXPERT TESTIMONY & LITIGATION CONSULTING


PROCUREMENT

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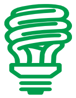
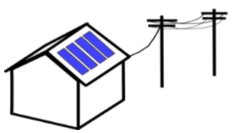
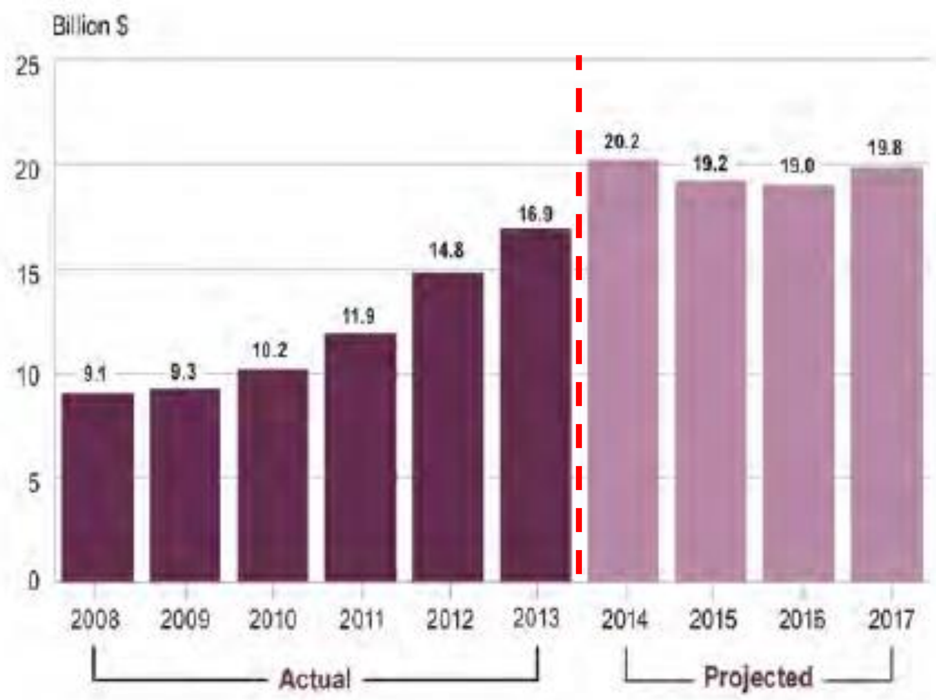
MRAs are 'everything' and 'anything' BUT traditional transmission infrastructure

MRAs include programs and/or technologies that complement the transmission system and provide benefits similar to those provided by the transmission system

	**Energy Efficiency**	improvements that result in the ability to use less energy to provide end-use customers with the same (or a better) level of service in an economically efficient way
	**Demand Response**	changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time or to incentive payments
	**Utility-scale Generation**	relatively large generators that connect to the grid at the transmission (high voltage) level
	**Distributed Generation**	small generation systems located at a customer site
	**Energy Storage**	technologies that allow electricity generated at one time to be used at another time
	**Smart Grid**	technologies that enable a more efficient use of the electric power grid through computer-based remote control and automation

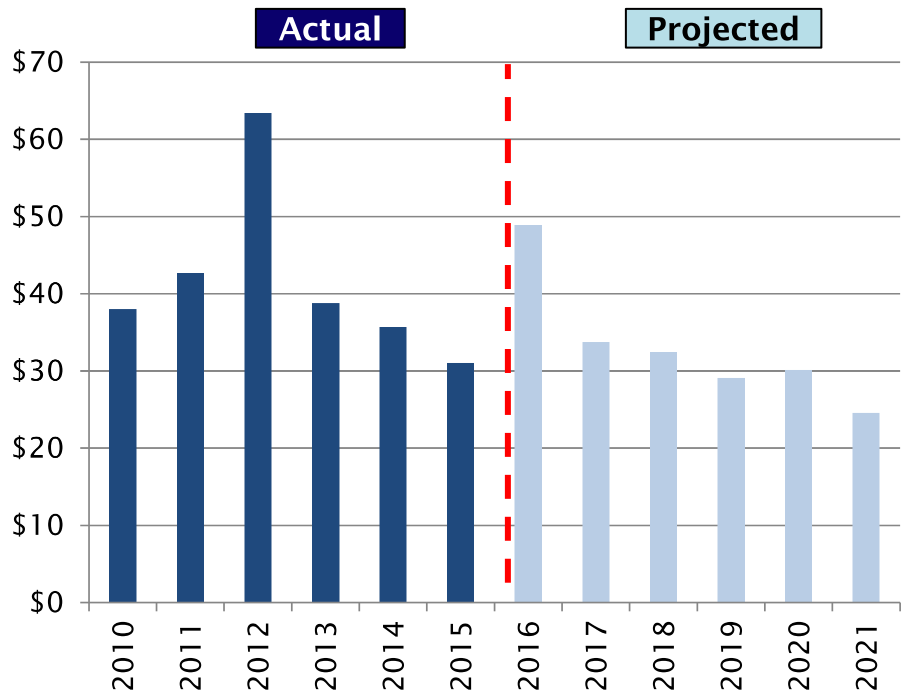
Investment is needed in the "system" – not just in generation or just in conventional transmission hardware

The historical and projected transmission investment in the US*



Source: Transmission Projects: At A Glance, Edison Electric Institute, March 2015
**Note: the figure above represents the transmission investment by Edison Electric Institute members which include IOUs and independents transcos.*

The historical and projected generation investment in the US



Source: LEI estimations
Note: For the historical investments, LEI reviewed the historical year-on-year capacity additions by type and by region and multiplied it by their capital costs. Same approach was used in projecting generation investments in the next six years. The capacity additions are based on the modeling result of LEI's Semi-annual Regional Market Update on nine US markets

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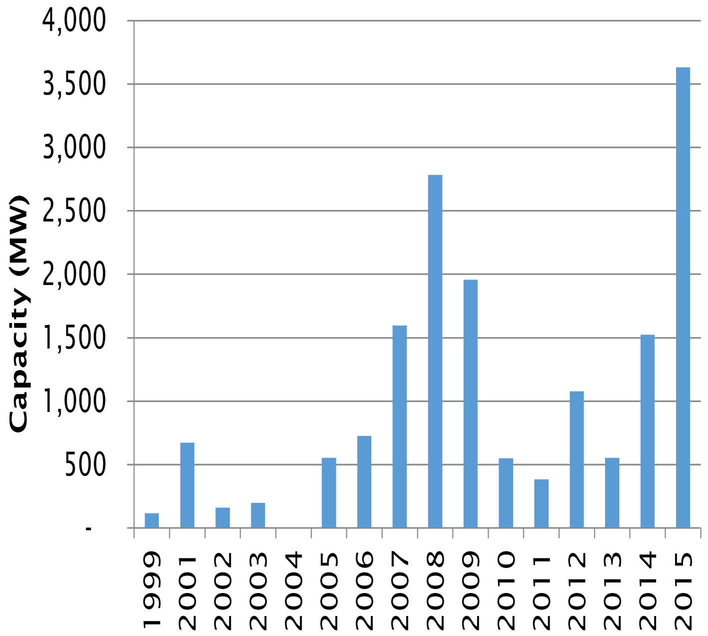
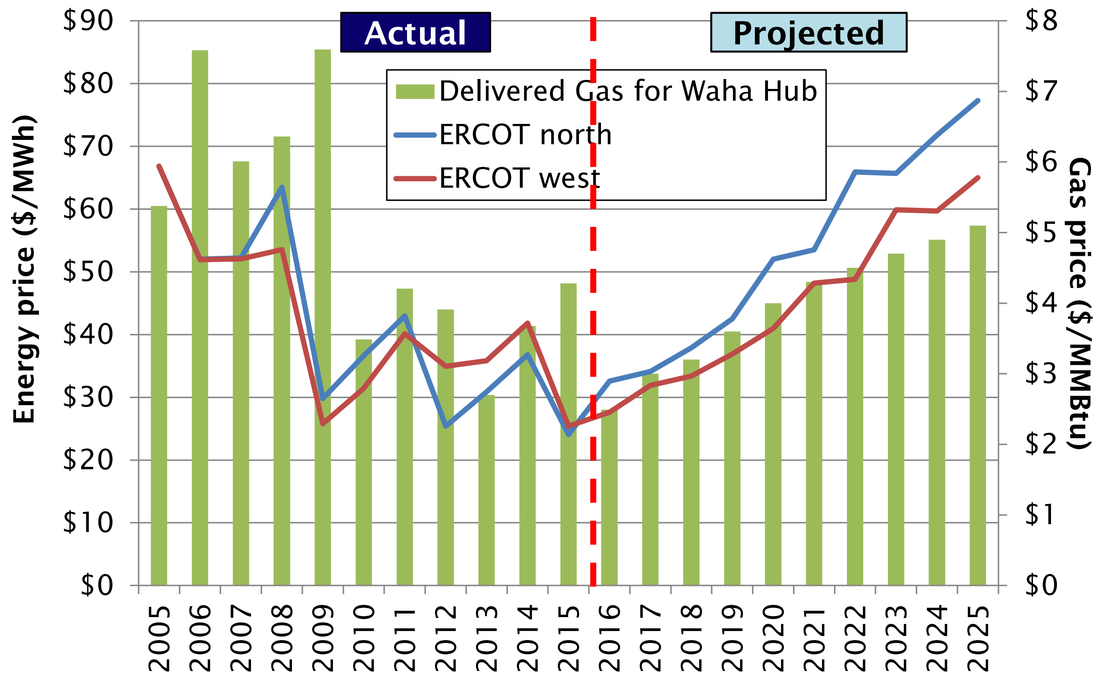
$7 billion Competitive Renewable Energy Zone (CREZ) project has provided pathway for roughly $26 billion of new generation… and we aren't done with this catalytic process

2005	Mid-2008	End of 2010	Early 2014
CREZ was approved in 2005	CREZ projects and plans were finalized in mid-2008	The construction began end of 2010	The construction was complete in early 2014

Wind capacity additions in ERCOT



ERCOT north and ERCOT west energy price and delivered gas price



Source: Historical prices are from ERCOT; forecast prices based on LEI's Continuous Modeling Initiative (Base Case, 2015)

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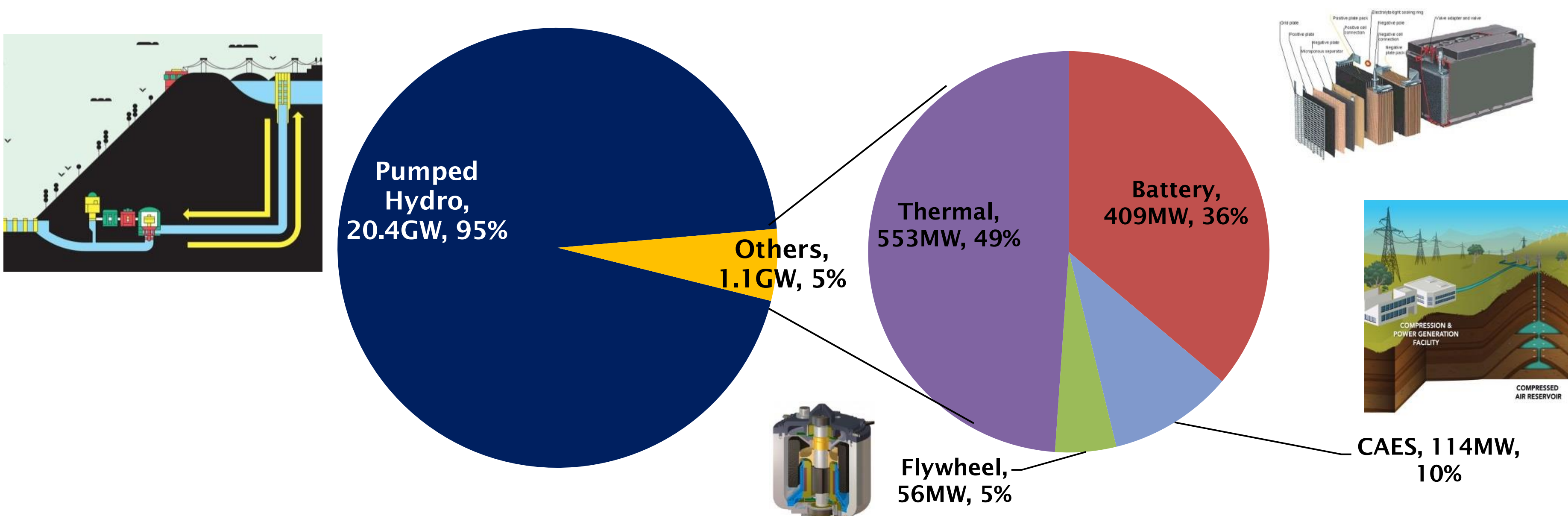
Pumped storage technology has been around for many decades but adoption of other energy storage technologies is just beginning

- Pumped storage has been used in Italy and Switzerland since 1890's, while first US pumped storage was built back in 1930 in CT
- Compressed Air Energy Storage ("CAES") was used in Germany back in 1978
- Batteries have been used to provide ancillary services in US since 1994
- Flywheels have been used to store energy since invention of steam engine, but deployment for grid energy storage and ancillary services is very recent

Operational Energy Storage Projects in the US



Source: US Department of Energy Global Energy Storage Database

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Energy storage technologies can be used in a wide range of applications and at different scales and geographical spans

Back-up power	providing backup power at multiple scales, ranging from second-to-second power quality maintenance for industrial operations to daily backup for residential customers
Peak shaving	by minimizing electricity purchases during peak electricity and shifting these purchase to periods of lower rates, behind-the-meter customers can use energy storage systems to reduce their bills
Load following/ peak price suppression	load following, which manages the difference between day-ahead scheduled generator output, actual generator output, and actual demand
Ancillary services	providing reserve, regulation and voltage support services
Black start	restoring operation to larger power stations in order to bring the regional grid back online in the event of a grid outage
Renewable integration	enhancing development and integration of renewable generation and spurring the additional renewable development
Transmission and distribution deferral	delaying, reducing the size of, or entirely avoiding utility investments in transmission or distribution system
Transmission congestion relief/ price suppression	deploying downstream of congested transmission corridors to discharge during congested periods and minimize congestion in the transmission system
Resource Adequacy	defer or reduce the need for new generation capacity and minimize the risk of overinvestment

***Customer services**, service generally provided at local area and consumer-scale; paid by the consumers*

***ISO/ RTO services**, service generally provided at both system wide and local area; markets exist at ISOs or bilateral contracts for non-ISOs*

***Utility services**, service generally provided at system wide and utility scale; no formal market exists and are viewed as "social' products*

Source: LEI analysis; US Department of Energy. "Grid Energy Storage", December 2013; Rocky Mountain Institute, "Economics of energy battery storage, October 2015

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Can energy storage devices be a component of a transmission solution?

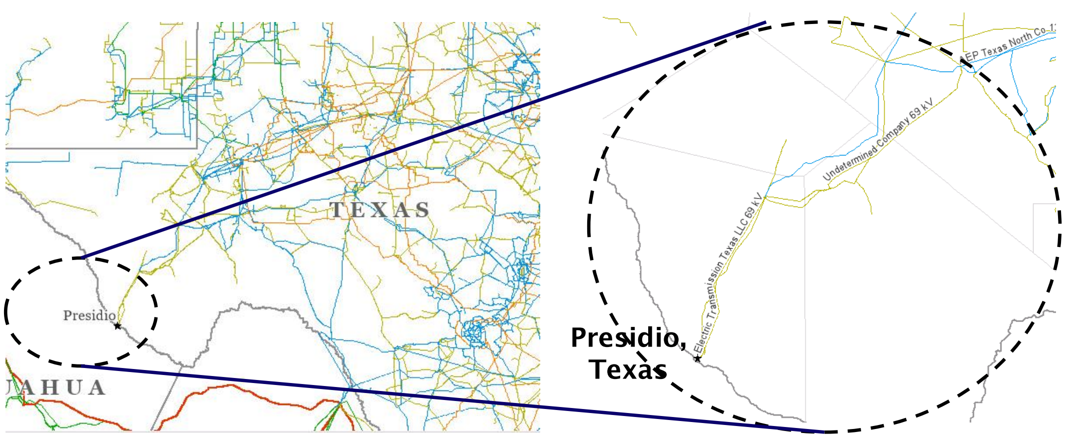
► Presidio, Texas: battery treated as another transmission component and it also complemented new transmission investment

Issue

- The city of Presidio, Texas, is located in the deserts of West Texas on the banks of the Rio Grande River
- Prior to 2010, the city suffered from a large number of power outages because the only transmission line bringing power from neighboring Marfa to the city was a 60-mile, 69-kV line constructed in 1948
- This aging transmission line crosses harsh terrain and its deteriorating condition and frequent lighting strikes have resulted in unreliable power for the residents of Presidio

Solution

- Electric Transmission Texas (ETT) proposed the construction of a sodium-sulphur (NaS) battery system, a second 138/69-kV autotransformer at Marfa's Alamito Creek Substation and a new 69-kV transmission line connecting the Alamito Creek Substation to Presidio
- The primary purpose of the NaS battery is to provide backup power for an aging transmission line and to reduce voltage fluctuations and momentary outages for the city and residents of Presidio
- The battery system can respond quickly to rapid disturbances as well as supply uninterrupted power for up to 8 hours in the case of a transmission outage



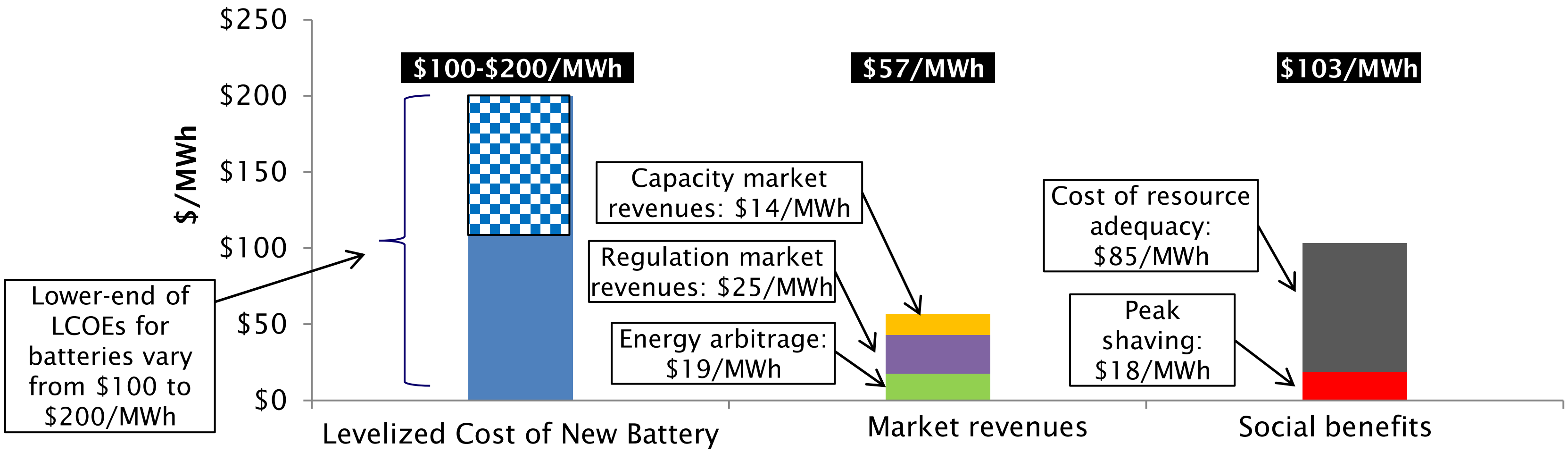
Result

- The NaS battery was energized in late March 2010 and dedicated on April 8, 2010
- After completion of the new transmission line, the battery system remains operating - source of voltage support and backup power

When energy storage is providing services akin to transmission, benefits to the system likely to exceed the value that can be monetized under existing market rules and products

- **AC transmission has some properties of a public good, more specifically, we can refer it to "common-pool resource"**
  - AC transmission service is **non- excludable** in that consumers cannot be effectively excluded from use, but also **rivalrous** as congestion arises and therefore presents a limit
  - Upshot? Free rider problems and "market" will not be able to produce enough
- **Energy storage can impact wide range of consumers and thereby create system-wide benefits much larger than the private value from market sales**
  - For example, load following capability lowers the energy prices, similar to congestion relief of new transmission, benefiting many consumers

Illustrative example: Benefits of energy storage from private and social (system) perspectives



Sources for costs: Lazard, Lazard's levelised cost of storage analysis, November 2015; Sandia National Laboratories, DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA, July 2013; sources for benefits: LEI calculations based on historical market data

Identification, evaluation, and even regulatory or market re-design may be necessary to advance adoption of new technologies into the Grid of All Things

- **Energy storage technologies need to be identified as part of the transmission hardware arsenal and not just as a "NTA"**
  - Recognition that there is overlap and conventional classifications are being blurred
- **Benefits and costs need to evaluated comprehensively and on equal footing between various solutions**
  - We have a long history of system planning which recognizes and emphasizes the value of reliability. .. measuring economic benefits of new transmission investment is relatively new, though extensive assessments have already been performed in this field
  - Complementarity and the "multiplier" effect needs be evaluated
- **Policymakers and regulators need to gain comfort in accepting energy storage – when it has common-pool resources attributes like transmission - as an element of transmission that can be recovered in transmission rates from all consumers**
  - Alternatively to regulated transmission treatment, wholesale markets (and especially ancillary services) may need to be redesigned to properly pay for the value that energy storage can provide