

# Are Markets Ready for New Energy Storage Technologies?

*Presentation for 34<sup>th</sup> IAEE*

*Prepared by:*

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# Building a renewable supply will require innovation in technology and market design

- **The US Federal Energy Regulatory Commission (FERC) has issued a number of proposed rulemakings to clear way for energy storage to participate in regulation service markets in order to provide the economic motivation for innovation**
  - **regulation markets in the US are typically based on bids from supply and a market-clearing price for service, co-optimized in many cases with the price of energy and other ancillary services**
  - **out of the five centralized wholesale markets studied, four markets have opened doors for energy storage**
- **An analysis of levelized cost of flywheels and li-ion batteries, compared to the current regulation service compensation, shows that these technologies, without subsidies, are currently not fully economic in the US at current market prices**
  - **as gas prices - and, as a result, electricity prices - increase in the future, these technologies may become viable, given that they have an effective zero variable cost**
  - **the growing penetration of intermittent resources could enhance the economics of future energy storage projects by increasing the demand for more regulation (pushing up price) or through the creation of new classes of product for regulation service**



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# Plan of presentation

**1. Overview of regulation service**

2. Overview of regulation service markets in the US

3. New players in the regulation service markets in the US

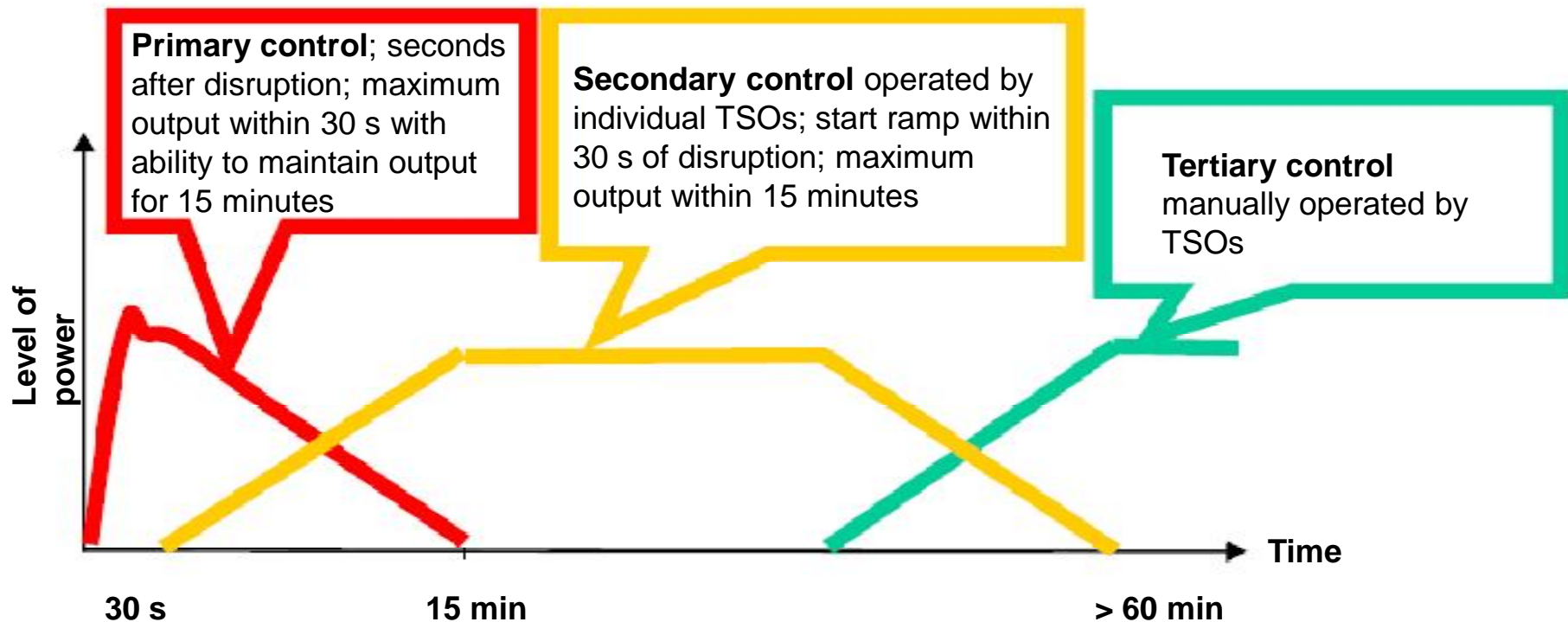
4. Analysis of viability of certain energy storage technologies

5. Conclusions

# Regulation service, as it is known in the US, is called frequency control in Europe

**What is Regulation Service?** Regulation service is used by control area operators to correctly match the moment-by-moment generation with load. All electric power systems require regulation service as it ensures the continuous balancing of resources with load and helps maintain scheduled interconnection frequency at either 50 or 60 Hz, depending on the market. Regulation service is typically known as primary control in the ENTSO-E countries, and known as regulating power in the Nordic power market.

Classification of frequency control in ENTSO-E



# Regulation service has risen in prominence as a result of increasing intermittent renewables

- Wind capacity increased worldwide by almost a third (32%) in 2009; despite the economic crisis, some countries were able to add substantial wind capacity: US (10 GW), Spain (2.5 GW), Germany (1.9 GW), Italy (1.1 GW), and the United Kingdom (1.1 GW)
- Several studies showed that increasing wind capacity in future will require significant increase in regulation service requirements
  - However, for conventional generation providers, regulation service is a substitute for energy production. Typically, conventional generators prefer energy sales
  - Emerging energy storage technologies such as batteries and flywheels offer a viable solution to the increasing needs for regulation services

## Regulation service and wind generation in Europe

- wind penetration is expected to increase in the coming years as the European Union's climate and energy package aim to source a certain percentage of the energy mix from renewables (consequently regulation service is needed)
- wind plants are required to provide frequency control in some countries, while exempt in other countries, depending on whether such service is mandatory or procured on a commercial basis

Source: International Energy Agency (IEA) 2009 Wind Annual Report, released on July 2010

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# The provision of regulation service varies depending on the regulatory framework and market design

- In jurisdictions served by a **vertically integrated** utility, the utility generally **self-provides** regulation service on a **cost-of-service basis** from its generation assets as part of an obligation to serve its load
- In regions that have **wholesale power markets**, regulation service is typically **procured by a central system operator** on a **market basis**; suppliers are compensated through **market mechanisms**
- FERC has only recently opened up participation in this market for non-conventional resources (demand response, emerging energy storage technologies)
- Our study focuses on **five US power markets** where regulation service is procured on a market basis: California ISO (CAISO), Electric Reliability Council of Texas (ERCOT), New England (ISO-NE), New York ISO (NYISO) and PJM Interconnection (PJM)

## European Example

- grid operators are typically responsible for procuring such services (e.g. National Grid in the UK)
- regulation services are procured on a mandatory basis (for example, in Spain and the Netherlands) or on a commercial basis (such as in Denmark and Germany)
- unlike the US markets where centralized auctions are performed to procure regulation services, bilateral contracts are typically used in Europe through either negotiated contracts or tendered bidding

Source: NREL and EPRI

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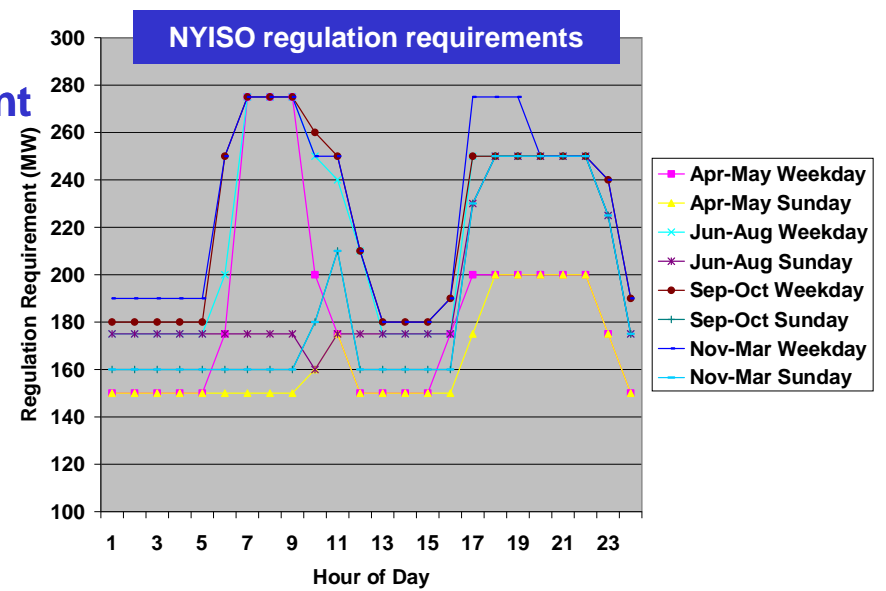
# Regulation service markets in the US are a small but vital component of the overall wholesale market

2010	Footprint (sq. miles)	Installed capacity (MW)	Electrical peak load (MW)	Annual consumption of electricity (GWh)	Annual regulation procurement (GWh)	Regulation service as a % of annual consumption
<b>CAISO</b>	1 state (123,000)	57,000	47,000	230,000	3,200	1.4%
<b>ERCOT</b>	1 state (200,000)	83,000	67,000	320,000	6,500	2.0%
<b>ISO-NE</b>	6 states (less than 68,000)	34,000	27,000	129,000	600	0.5%
<b>NYISO</b>	1 state (47,000)	41,000	33,000	162,000	1,700	1.0%
<b>PJM</b>	13 states & D.C. (169,000)	165,000	136,000	713,000	8,300	1.2%

Source: 2010 ISO/RTO Metrics Report; various ISOs/RTOs

# The five US regulation service markets have similar requirements for qualified resources and procurement targets

- Qualified resources have to be capable of receiving and responding to signals in very short period, pass a prequalification test and provide satisfactory performance
- In practice, only operating, synchronized resources (with available, uncommitted capacity not already dispatched for energy) can participate in the market
- System operators calculate procurement targets on an inter-hour basis, according to changes in conditions in order to comply with North America Electric Reliability Corporation (NERC) standards
  - typically, highest regulation requirement occurs during ramping period
  - despite growing demand over the last ten years, most ISOs have been able to stabilize or even reduce the amount of regulation procurement; however, intermittent resources will pose an increase in the amount of regulation procurement



Source: NYISO



## In spite of a similar “market institution” concept, some differences exist in terms of application/implementation

	Products	Participants	Markets	Compensation mechanisms
<b>CAISO</b>	Regulation Up Regulation Down	Conventional resources and new technology	Day-ahead and real-time	Opportunity cost considered in calculating clearing price
<b>ERCOT</b>	Regulation Up Regulation Down	Conventional resources only	Day-ahead	Opportunity cost considered in calculating clearing price
<b>ISO-NE</b>	Single product	Conventional resources and new technology	Real-time	Opportunity cost paid separately from clearing price
<b>NYISO</b>	Single product	Conventional resources and new technology	Day-ahead and real-time	Opportunity cost considered in calculating clearing price
<b>PJM</b>	Single product	Conventional resources and new technology	Real-time	Opportunity cost paid separately from clearing price



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# Flywheels are recognized as technically capable suppliers of regulation services

Flywheels	
Notable Characteristics	<p>Very fast response time (4 milliseconds or less)</p> <p>May be used for short durations of up to 1 hour</p> <p>Low maintenance</p> <p>Not affected by temperature fluctuations</p> <p>Take up relatively little space</p> <p>Quick recharge</p>
Size	Usually between 100 kW – 1,650 kW
Lifespan	Up to 20 years
Efficiency and duration	85-87% ; 0.25-1 hour
Capital costs	US\$1,950-2,150/kW (for ISO frequency regulation and renewable integration application)
Applicability	Can serve as backup power systems for low-power applications or as short-term power quality support for high-power applications
Challenge	High capital cost due to special packaging and internal overcharge protection circuits

Source: NREL, Energy Storage Association, Electric Power Research Institute (EPRI)

- a flywheel is a cylinder that spins at high speeds, storing kinetic energy
- flywheels can be combined with a device that operates either as an electric motor that accelerates the flywheel to store energy or as a generator that produces electricity from the energy stored in the flywheel
- the amount of stored energy is dependent on the speed, mass, and configuration of the flywheel



Photo source: Beacon Power



# Lithium ion (li-ion) batteries are another commercially available technology for 1-4 hour power cycling requirements

## Li-ion batteries

<b>Notable Characteristics</b>	Long cycle life Compact Quick recharge – charging of fully depleted batteries can be done in just 2-3 hours High energy density Specific characteristics of the lithium ion cells require well-adapted battery management and control systems
<b>Size</b>	25-35 MW
<b>Lifespan</b>	Can exceed 3,000 cycles or over 8 years if cycled daily
<b>Efficiency and duration</b>	80-93% ; 0.25 to 1 hour
<b>Capital costs</b>	US\$ 1,085-1550/kW (for ISO frequency regulation and renewable integration application)
<b>Applicability</b>	Utility grid-support applications, frequency regulation, wind and photovoltaic smoothing, transportable systems for grid-support
<b>Challenge</b>	Presently too expensive for large-scale utility applications

- li-ion batteries convert chemical energy into electrical energy (electricity) by oxidation and recycling of their materials
- when charged, the lithium atoms in the cathode become ions and move through the electrolyte to the carbon anode where they are combined with external electrons and deposited between carbon layers as lithium atoms; during discharge, the reverse of this process occurs

AES' Energy Storage li-ion battery in New York



Photo source: AES Energy Storage

Source: NREL and EPRI

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# US policymakers have paved the way for non-generation resources to provide ancillary services, including regulation services

- The US Federal Energy Regulatory Commission (FERC) has issued a number of Orders and Notice of Proposed Rule Making (NOPR) to encourage the adoption of new technologies
  - Order No. 890 and 719 provide the basis for non-generator resources to participate in ancillary service markets “on a comparable basis to services provided by generation resources”
  - NOPR on Integration of Variable Energy opens up new markets for non-generators as wind developers are allowed to purchase new class of regulation service from third-party non-generation resources
  - NOPR on Frequency Regulation Compensation proposed a two-part payment, including a performance payment, which favors and remunerates fast-response technologies

2007

Order No. 890

2008

Order No. 719

2009

2010

NOPR on  
Integration of  
Variable  
Energy

2011

NOPR on  
Frequency  
Regulation  
Compensation





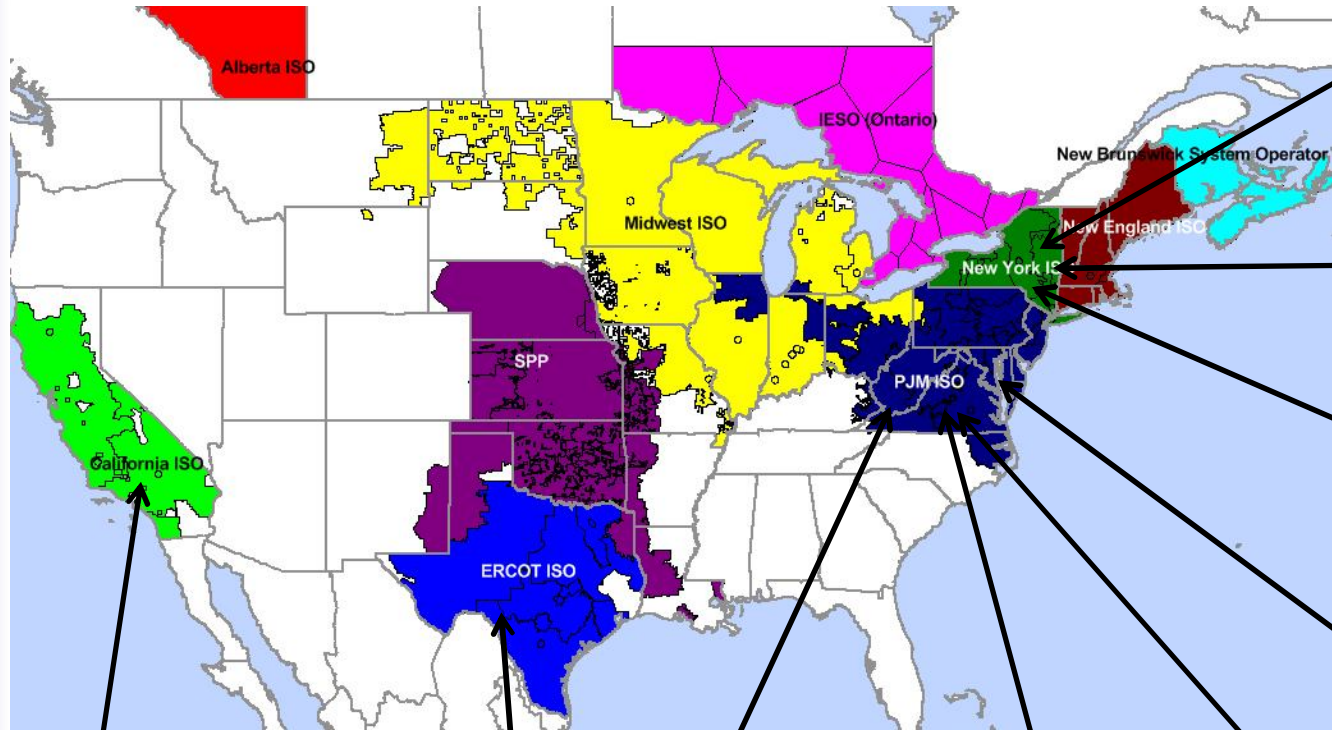
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## Following FERC's policies, the ISOs/RTOs have taken actions

- NYISO has created a new resource category for Limited Energy Storage Resources (LESRs), where they are allowed to provide regulation services only and dispatch is based on speed of response
- PJM developed a new “frequency based” signal for LESRs, which allows resources to self manage energy and capacity
- ISO-NE currently operates a pilot program for alternative technologies to provide regulation services and to be compensated based on performance (i.e. mileage payment)
- CAISO recently opened the door to LESRs and once FERC approves the required tariff changes, LESRs are allowed to bid into the market
- ERCOT has identified benefits of LESRs and is still studying on how to integrate them



# Several flywheels and li-ion battery facilities are targeting regulation markets that are already operating or under construction



**Company:** AES  
**Technology:** Li-Ion battery  
**Size:** 2 MW  
**Location:** Huntington Beach, California  
**Online date:** 2008

**Company:** AES  
**Technology:** Li-Ion battery  
**Size:** 2 MW  
**Location:** Indianapolis, Indiana  
**Online date:** 2007

**Company:** AES  
**Technology:** Li-Ion battery  
**Size:** 1 MW  
**Location:** Pasadena, Texas  
**Online date:** 2007

**Company:** Beacon Power  
**Technology:** Flywheel  
**Size:** 20 MW  
**Location:** Chicago, IL  
**Online date:** None yet

**Company:** AES  
**Technology:** Li-Ion battery  
**Size:** 1 MW  
**Location:** Norristown, Pennsylvania  
**Online date:** Nov. 2008

**Company:** AES  
**Technology:** Li-Ion battery  
**Size:** 8 MW (Phase 1)  
**Location:** Johnson City, NY  
**Online date:** 2009

**Company:** AES  
**Technology:** Li-Ion battery  
**Size:** 12 MW (Phase 2)  
**Location:** Johnson City, NY  
**Online date:** 2011 (Under construction)

**Company:** Beacon Power  
**Technology:** Flywheel  
**Size:** 20 MW  
**Location:** Stephentown, NY  
**Online date:** June 2011

**Company:** AES  
**Technology:** Li-Ion battery  
**Size:** 32 MW  
**Location:** Bellington, West Virginia  
**Online date:** 2011 (Under construction)

**Sources:** Beacon Power, AES Energy Storage



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# Regulation prices differ between markets due to resource mix variations and other power market fundamentals

- **PJM is the largest market in terms of total costs due to its relatively large geographical footprint**
- **The northeast markets (ISO-NE, NYISO and PJM) generally have paid higher average prices for regulation services**
- **Non-conventional storage technologies, like flywheels and small scale lithium batteries, cannot provide energy and therefore do not have any opportunity costs when providing regulation services**
- **In markets where opportunity cost is paid separately (e.g. ISO-NE and PJM), these technologies do not receive such payments**

	<b>2010 costs (\$ millions)</b>	<b>2010 all-in price (\$/MWh)</b>	<b>2010 price for regulation*** cost(\$/MWh)</b>
CAISO	\$39.13	\$12.30	\$12.30
ERCOT	\$117.55	\$18.08	\$18.08
ISO-NE	\$14.33	\$24.12	\$14.47
NYISO	\$48.29	\$28.81	\$28.81
PJM	\$264.72	\$32.07	\$18.08

Note: All-in prices are calculated based on total market costs divided by the total MWh of regulation service procured. They can be viewed as an indicator of the average compensation for regulation service providers  
\*\*\* This excludes the standalone opportunity cost payments that non-conventional storage technologies are not eligible for

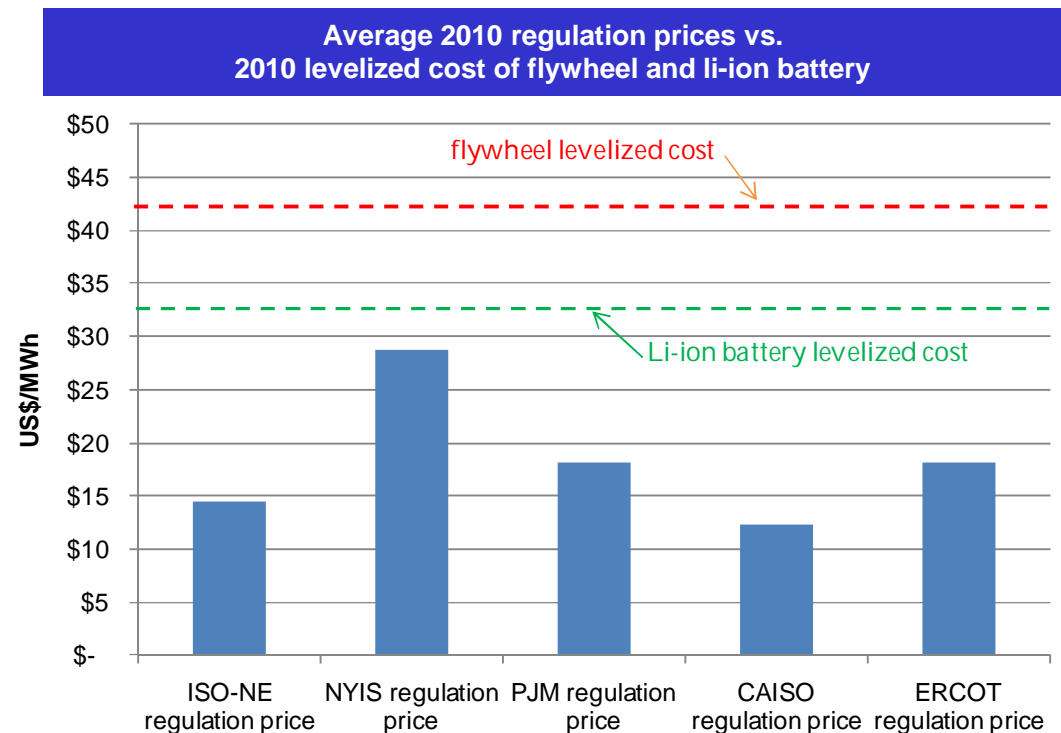
# An analysis was performed to evaluate whether annualized capital investments and operating costs can be recouped from 2010 market prices

- The levelized cost analysis model takes into consideration capital and operating costs
- Capital costs for both technologies are determined based on the actual projects currently in operation
  - **Capital cost for flywheel technology** - based on Beacon Power's estimated total cost for building its second flywheel technology in Pennsylvania
  - **Capital cost for the li-ion battery** - based on the AES Energy Storage's estimated total costs for building its 20 MW battery in Johnson City, NY

2010 dollars	Flywheel	Li-ion battery
Capital cost (\$/kW)	\$ 2,500	\$ 1,200
Leverage	60%	60%
Debt interest rate	8%	8%
After-tax required equity return	15%	15%
Debt financing term (year)	12	8
Equity capital recovery term (year)	20	8
Nominal variable O&M, \$/MWh	\$1.50	\$5.00
Nominal fixed O&M, \$/kW/year	\$13.90	\$6.00
Levelized costs at 97% (flywheel) and 95% (li-ion battery) load factor, \$/MWh	\$43.60	\$ 32.90

# Investment in flywheels and li-ion batteries does not appear to be economic on a standalone regulation market revenue basis

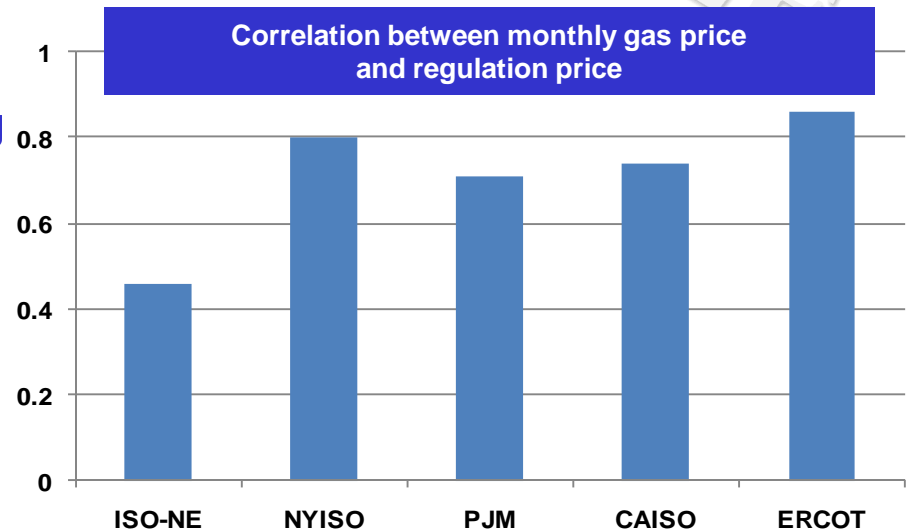
- This analysis is based on the assumption that all revenue streams are coming solely from regulation service payments
- Regulation payments need to rise to the range of \$33/MWh for flywheels and \$44/MWh for li-ion batteries, respectively, to break-even on operating costs and capital cost, as well as provide a commercial reasonable return. The 2009 regulation payments range between 28% and 66% of the levelized costs for flywheels and between 37% and 88% of the li-ion batteries
- However, the “break-even” window is not far off: for a high-priced market like NYISO, regulation prices would need to rise by only 10% for the li-ion battery to break even



Source: Regulation prices based on actual 2010 regulation prices from the respective ISOs

# Regulation market prices are closely linked to energy market dynamics

- The provision of regulation service is based on the marginal costs of generating energy and the opportunity costs of foregoing energy sales
- Higher energy market prices will improve economic opportunity in regulation markets
  - Across the US markets, energy prices are commonly set by gas-fired generation
  - A correlation analysis shows that there is a strong relationship between spot natural gas price and regulation price over the long run
- Based on the historical correlation analysis, li-ion batteries will break-even in NYISO if gas prices increase by approximately 18%
- In other US markets, gas prices would need to double or triple to make regulation price high enough to sustain the battery technology
- Flywheels, whose levelized cost is higher, require an even greater increase in gas prices to buoy regulation market prices such that break-even revenues are achieved



Source: Ventyx, the Velocity Suite; Bloomberg  
Note: data of 2008-2010 is used for this analysis



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# In addition to changes in market fundamentals, policy changes can enhance the economics of energy storage projects

- Additional certainty in the market rules and tariff under which storage will operate would help reduce existing barriers for investment
- Performance-based compensation will put energy storage technologies in a more advantageous position compared to conventional resources (such a measure has already been proposed by FERC)
- Growing penetration of intermittent resources could increase the demand for regulation service – accommodating introduction of new regulation providers without jeopardizing a situation of price reductions (due to oversupply)
- Creation of other product markets, such as the new load-following service proposed by FERC in its recent NOPR for Integration of Variable Energy Resource, could provide incremental market opportunities
- Government support to research - and ultimately develop - energy storage could encourage technological gains and capital cost reductions

In the meantime, the US government is partially subsidizing such investment. The American Recovery and Reinvestment Act (ARRA) of 2009 provided financial support to energy storage technologies:

- ARRA provided loan guarantees for storage technologies at competitive rates
- ARRA's \$185 million federal funds generated 537 MW of new storage facilities to be added to the grid (with estimated project value of \$772 million)

## LONDON ECONOMICS INTERNATIONAL LLC

### INTRODUCTION TO LONDON ECONOMICS

*London Economics International LLC (LEI) is a global economic, financial, and strategic advisory professional services firm specializing in energy, water, and infrastructure. The firm 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.*

*The firm also has in-depth expertise in many economic and financial issues related to the electricity sector, such as asset valuation, procurement, regulatory economics, and market design and analysis. LEI has done extensive work with electricity markets in North America, Europe, Asia, and the Middle East, and has a comprehensive understanding of the issues faced by the utilities and regulators alike.*

*LEI has extensive experience in several areas, including:*

**ELECTRICITY:** *London Economics International LLC has participated in the birth and development of competitive electricity markets worldwide. Our strategy practice has helped traditional IOUs in the creation of competitive gencos, assessment of the establishment of independent transcos, and valuation of synergies with associated businesses. Market design achievements include use of game theoretic techniques to assess bidding strategy and creation of sophisticated contracting structures to mitigate market power.*

**NATURAL GAS:** *LEI's natural gas related activities include assessment of the synergies between the natural gas and electric power industries, examination of performance-based ratemaking and total factor productivity for natural gas distribution companies, and developing screening methodologies for potential investments in the natural gas industry.*

**TRANSPORTATION:** *London Economics is at the forefront of analyzing key issues related to pricing and privatization of key transportation infrastructure. This includes analysis of the implications of road pricing, regulation and development of privatized ports, and lessons from the UK rail privatization process.*

**RENEWABLES:** *LEI provides a range of services associated with the renewable energy industry. This includes working with developers to value potential revenue streams from renewable energy credits (RECs) and/or emissions offsets, advising private equity funds to craft investment plans targeted at "green" technologies, and counseling governments and regulators on creating policies which efficiently incentivize investment in renewable energy.*

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