Smart Grid Advanced Metering Annual Implementation Progress Report

ATTACHMENT 4

Industry & Customer Research: Non-Utility Owned Storage Units

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Industry & Customer Research: Non-Utility Owned Energy Storage Units

March 17, 2016

accenture

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2. Research Approach
3. Perspective on Energy Storage Market
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Executive summary

Objective

- As part of ComEd's obligation under the Energy Infrastructure Modernization Act, ComEd is required to submit an Annual Implementation Progress Report (AIPR) that provides an overview of the annual energy storage uptake within its utility service territory. This project conducted primary and secondary research on the energy storage industry and specifically activity in Illinois.

Perspective on overall energy storage market

- In 2015, over 2GW of energy storage was commissioned globally. The USA has added 221MW of deployments with 85% in utility (front-of-meter) applications.
- The USA annual deployments are expected to grow to 1.7GW by 2020 with major activities in California, Hawaii, and New York.
- The technology of choice for most new deployments is Lithium Ion (Li-ion), for which the costs are expected decline by 47% by 2020 due to scale and improvements in engineering and manufacturing.

Perspective on Illinois energy storage market

- This 2016 study identified a total of 51.3MW of non-utility owned energy storage deployments in 2015 whereas the previous year's study identified 1.5MW of behind-the-meter installations. No new behind-the-meter installations were found in 2015.
- All new projects are providing frequency regulation services to PJM markets and powered by Li-ion technology.
- The study also identified 39.9MW of storage under construction and more than 3MW of storage under development, including a behind-the-meter project at Chicago's Merchandise Mart.
- At the present time, Illinois is not the primary focus for most vendors due to low demand charges, relatively low electricity prices, and no special incentive programs.

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Methodology, approach, and timeline

The following approach and 3-week timeline was followed for the energy storage market assessment and customer research.

Perform Battery Storage Market Assessment 02/23/16 – 03/08/16	Primary Research of Vendors and Analysis 03/01/16 – 03/11/16	Communicate Findings 03/11/16 – 03/18/16
Perform Market & Industry Assessment	**Primary Research and Analysis**	**Review with Key Internal Stakeholders**
Confirm ComEd Objectives • Identify key aspects of Electrical Storage Systems • Gather details on ComEd service territory **Assess Industry / Market:** • Identify key industry trends • Update energy storage technology options • Provide forward-looking projections • Conduct secondary research	**Prepare Primary Research:** • Identify vendors and contacts • Develop primary research approach/ questions **Conduct Primary Research:** • Interview developers, manufacturers, and installers • Synthesize findings from industry / market scans, secondary customer research, and primary research to identify key elements of storage implementation	**Stakeholder Buy-In:** • Detailed review of identified findings with key stakeholders **Final Messaging:** • Update the findings in line with comments from key stakeholders • Organize and prepare findings for legal / regulatory compliance

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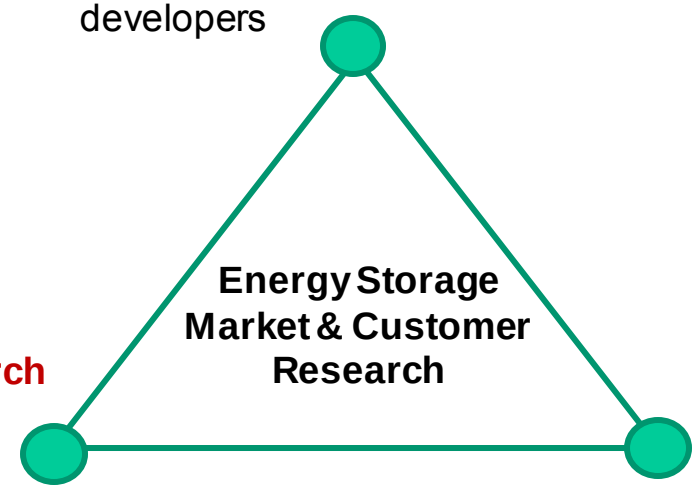
Sources of information

The project utilized primary and secondary research, including vendor interviews and a market / industry scan.

1) Vendor interviews

- Conduct interviews with 17 energy storage vendors across various technologies and suitable uses
- Battery manufacturers, installers, developers



2) Additional primary research

- Interviews with external stakeholders (i.e., trade association, electrical unions, etc.)
- Interviews with internal stakeholders (i.e., net metering, smart grid teams)

3) Market assessment

- Survey of technology types
- Advantages, disadvantages, & applications
- Price points and market sizing
- Value propositions
- Emerging trends

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Energy storage applications span the entire electric grid value chain

Category	Use Case	Description
Grid Integration	Renewables integration	Optimize (smooth, firm, time-shift, adjust ramping) the output and reactive power capabilities from renewables generation and mitigate rapid output changes by optimum dispatch strategies
	Peak shaving	Flatten short-term intra-day peak loads to optimize power consumption and generation from renewable and conventional sources
	Generation Investment Optimization	Reduce / defer the need for generation resources, such as additional peaking plants or demand response resources in the system to meet peak demand
Ancillary Services	Operating reserves	Maintain system balance by providing synchronized and non-synchronized stand-by capacity
	Frequency regulation	Balance continuously shifting supply and demand within a control area with rapid charges and discharges on a sub-hourly, minute-to-minute basis
	Black start	Restart electric supply resources in situations when power systems collapse without pulling electricity from the grid
Generation Operations	Fuel optimization	Hedge and optimize fuel use by utilizing storage during high fuel price hours, in lieu of high priced fuel sources and / or trading excess fuel
	Emissions optimization	Reduce or moderate the operations of fossil-fuel generation to reduce emissions and optimize emissions trading
	Heat rate optimization	Optimize and smooth heat rate ramp up/down of conventional generation to manage load conditions on the system
	Wear and tear	Reduce loading on conventional generation and cycling - particularly Peaker plants during peak hours and mid-range coal plants during off-peak hours
Power Quality & Reliability	Voltage control	Mediate fleeting injections of voltage to maintain uniform and consistent output with renewables
	Volt-Var Optimization	Optimizing voltage and reactive power in the distribution system
	Substation black start	Restart of substations and increased reliability in situations when power systems collapse
T&D Operations	T&D congestion relief	Relief of congestion points due to collocated energy storage injections reducing peak loads
	T&D Investment Optimization	Reduce / defer the need for large transmission, substation, or T&D investments due to collocated energy storage systems supporting end user peak demand
	Wear and tear	Reduce wear and tear on T&D equipment (eg. thermal stressing, frequent tap changer resetting) due to improved voltage and frequency regulation and reduced peak load
	Line loss reduction	Reduce technical line losses through reduction in longer distance transmission and distribution of electricity due to collocated injection of energy storage
End-User	Home Management & Back-up Power	Enable retail load shifting and peak-load shaving to reduce TOU charges, and/or participate in Demand Response program, provide back-up power
	PV & Electric Vehicles	Enable infrastructure, load shifting, improve efficiency & fuel savings, offer protection and control equipment

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Source: Accenture Analysis

Global perspective on overall energy storage technologies (1/3)

	Mechanical			Thermal	Hydrogen
Storage type	**Pumped Hydro**	**Flywheel**	**Compressed Air**	**Molten Salt / Ice / Concrete**	**Hydrogen**
Capacity	176GW	0.96GW	1.6GW	3.6GW	7MW
# of projects	339	44	18	199	8
# of providers	105	39	11	147	8
Useful Life	20+ years	20+ years	15-20 years	20+ years	1500 cycles
Applications	Bulk Power > 10MW	Fast response, 1kW – 100kW, seconds	Bulk Power, > 10MW, hours	1MW – 10MW, hours	Energy & Power Applications
Pros	Matured technology, long lifetime, and nearly unlimited cycle stability	Matured technology, log life, high reliability	Matured technology, high reliability	Long life span, long durations, high efficiency	High efficiency
Cons	Dependence on topographical conditions and large land use, medium efficiency	Low round-trip efficiency (<50% if reheating air), geographic limitation, may require combustion with natural gas, high heat generation	NeeLow round-trip efficiency (<50% if reheating air), geographic limitation, may require combustion with natural gas/diesel to heat the air	Operates at high temperatures	Safety, low cycle efficiencies

Additional Findings:

- Only one new project hydro project (Alstom) of 400MW is announced in 2015.
- A new compressed air technology is in R&D stages. It enables above the ground storage and also fuel savings.
- Several ice based thermal storage units are in deployed in CA. Also, sodium based technologies are not matured in other continents yet.
- Hydrogen technologies are still in R&D stage.

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Source: Accenture Analysis, AECOM Energy Storage Study, US DOE Energy Storage Database, US Energy.Gov

Global perspective on overall energy storage technologies (2/3)

	Chemical		Electrical	
Storage type	**Zinc Air**	**Fuel Cell**	**Ultra capacitors**	**Superconducting Magnetic Coil**
Capacity	Not available	Demo stage	77MW	R&D
# of projects	NA	NA	29	NA
# of providers	NA	NA	29	NA
Useful life	Shorter 2 years	8K – 60K hours	10-15 years	
Power Rating & Duration	Hours - months	Hours –months <50MW	Seconds 1kW – 10kW	Seconds High Power
Applications	Energy applications – peak shaving, load leveling, etc.	Energy applications – peak shaving, load leveling, etc.	Short recharging periods and many cycles per day (ex: ramp rate control)	Short recharging periods and many cycles per day (ex: ramp rate control)
Pros	Very high energy density, light compared to sealed batteries lower cost	Response time almost zero, Advantageous for combined heat and power apps, longer operating time compared to batteries, reliable	Very high power density, reliable, low maintenance, long lifetime, wide temperature range, very fast charge/ discharge	Very quick response time, high round-trip efficiency, very high power output, good for power quality control in manufacturing plants
Cons	Better suited for EVs and electronics, impacted by humidity, lower discharge efficiency	Lower efficiency, limited fueling infrastructure, expensive to produce	Low energy density and 10x larger than comparable battery, expensive, not as well known/ established in US for battery applications	Reliability depends on an energy-intensive refrigeration system

Additional Findings:

- Integrated cooling systems eliminate additional equipment and increase roundtrip efficiency
- UtltraBatteries combine battery and capacitor benefits in one unit
- Existing renewables are being retrofitted with storage technologies
- New Nano-material technologies improving the quality and reliability

Source: Accenture Analysis, AECOM Energy Storage Study, DOE Energy Storage Database

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Global perspective on overall energy storage technologies (3/3)

Storage type	Lithium-ion	Sodium Based	Lead-Acid	Flow Batteries	Ni Based
Capacity	1.4GW	158MW	106MW	119MW	32MW
# of projects	506	65	67	80	7
# of providers	365	62	51	73	6
Power Rating & Duration	Minutes – hours 1kW-10MW	Minutes – hours 100kW – 10MW	Minutes - hours 1kW – 1MW	Hours – months 1kW – 100kW 1MW – 10MW (Zinc)	Minutes – days 0 – 40MW
Useful Life	5-15 years	5-15 years	5-15 years	15-20 years	NA
Applications	Energy management, renewable integration, back-up	High power utility applications	Stationary back-up, energy management	Capacity, energy management, back-up	Power supply, spinning reserves
Pros	Wide temp range, ability to deep cycle and fast charge; small footprint, long life, light weight, very high efficiency	High power and energy densities, high efficiencies, suitable for daily cycling and grid stabilization	Low capital cost, well-established, simple technology, high efficiency (80-90%)	Enhanced reliability, higher capacity with longer term storage	High power and energy densities, efficiency, improved longevity, performs well at low temp
Cons	More expensive (limiting their primary use to power app), safety concerns, requires advanced mfg. capabilities	Safety concerns with high temperature and corrosion issues	Limited service life, capacity decrease when high power is discharged, hazardous material, reliability issues	Early generation batteries have lower energy density, risk of electrolytic degradation over time, high BOS costs	Expensive, cadmium toxicity limits NiCd to stationary application

Additional Findings:

- Electro-chemical technologies are the choices for most of the new projects due to their ability to utilize them for wide variety of power and energy applications.

Source: Accenture Analysis, AECOM Energy Storage Study, DOE Energy Storage Database

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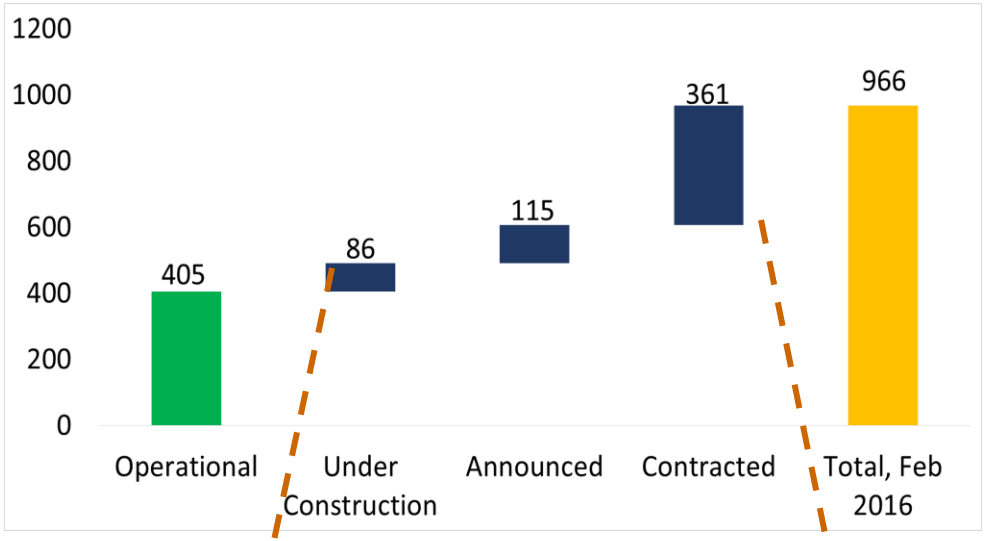
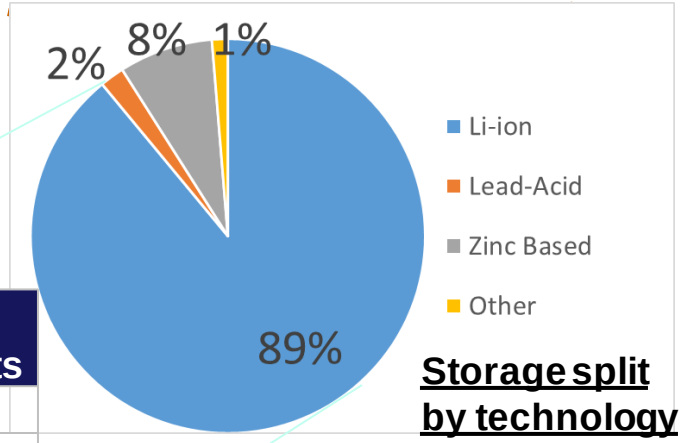
In the US, 2015 saw a 138% growth in electro-chemical storage activity and 184% growth in Li-ion based activity

- In 2015, 562MW of Electro-chemical storage is under construction, announced, or contracted, which is 138% of the existing operational storage.
- 89% of the new projects are Li-ion based whereas the only 67% of the operational storage is Li-ion indicating significant increase in the Li-ion contributions over the other technologies.
- The average size of the Li-ion project is 3.4MW with 69% of the projects are less than 1MW.
- Li-ion also has the significantly higher number of providers (158) over the next runner-up Zinc (39).

The USA Electro-Chemical Storage Capacity (MW)





Storage split by technology

Li-ion Projects

Rated Power	# of Projects
<1MW	85
1-10MW	28
11-20MW	5
21-30MW	3
>30MW	3

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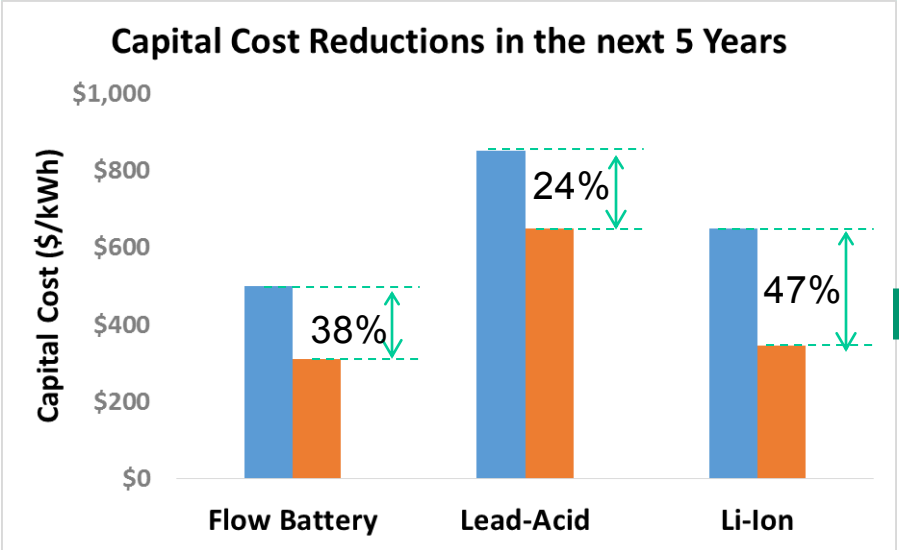
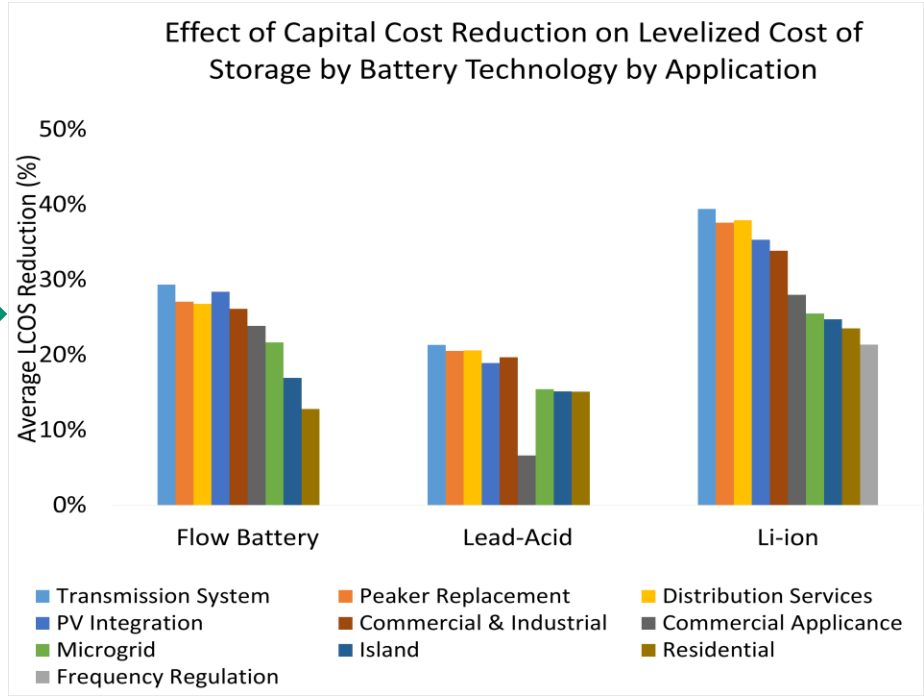
Source: Accenture Analysis, DOE energy storage database

Over the next 5 years, technology capital costs are expected to drop leading to LCOS reductions, especially for Li-ion technology





Drivers for capital cost reductions

- Engineering Improvements in battery chemistry and product design
- Improvements in manufacturing processes through automation
- Giga scale manufacturing plants and large scale deployments
- Advanced materials
- Reduction in Balance of System Costs through hardware improvements and efficient operations

- LCOS reduction impacts are more significant in use case applications with lower discharge hours such as T&D storage, peaker replacement, and renewable integrations.
- LCOS reductions range by technology
  - Li-ion: 21% - 39%
  - Flow: 13% - 29%
  - Lead-Acid: 7% - 21%

(LCOS: Levelized Cost of Storage)

Source: Accenture Analysis, Lazard Estimates and assumptions, Nov 2015 Levelized Cost of Storage Report

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Apart from costs and tariffs, solar installations and electric vehicles will boost energy storage deployments in the coming years

- US energy storage market grew 243% from 65MW in 2014 to 221MW in 2015 with Q4 deployments of 112MW. Annual deployments are expected to reach 1.7GW by 2020, fueled by behind-the-meter applications.
- Costs and regulations continue to be key drivers for the energy storage market.
- Demand charges, electricity prices, load profiles, system costs, and tariffs influence the economics of energy storage projects.
- Frequency regulation, capacity, and deferral will be primary applications in the future installations.
- Energy storage can help address the intermittent nature of PV and other renewable generation. PV installations are expected to reach 64.7GW with YoY growth of 13%.
  - China targets 19.5GW for 2016 and 100 – 200 GW for 2020
  - Influenced by investment tax credit timeline, US is expected to install 13GW in 2016
  - Japan's forecast is 9GW and India plans 3.6GW installations in 2016
- Energy storage can help address the distribution infrastructure issues associated with EV charging stations. Global EV market is expected to grow to 12.7M units by 2020.
  - 16 new models were introduced in 2015
  - US PHEV sales are up 8.9% YoY in the first two months of 2016
  - Plug-in Hybrid Electric Vehicles (PHEV) are expected to exceed pure Electric Vehicles

Source: GTM Research, Melcom Capital Group Global Solar Installations Forecast, IHS Technologies, Inside EVs,

In spite of the optimistic growth projections, the energy storage market still faces challenges

- Unstructured Markets
  - Markets are not completely structured for energy storage. Most of the policies and models are designed to take advantage of renewable generation, which helps energy storage, but markets are not yet optimized for energy storage. For example: energy storage benefits can split amongst different entities — utilities, grid operators, end-use customers – however, no single entity can realize the full value of a storage system.
- High capital investments and inadequate financing options
  - The storage installations require high capital investments. Only a few developers/vendors offer financing vehicles such as project financing to the end users. Some developers are offering savings sharing program. However, in today's market there are not many financing options to minimize capital outlay, especially for C&I and residential customers.
- Excess capacity and grid barriers
  - The grid connection agreements and technical barriers do not allow free flow of the excess capacity. The virtual energy storage network could be constructed to optimize asset utilization and relieve any grid problems. However, the network, systems, and processes are not set up yet.
- Lack of common standards
  - There is lack of common standards, definitions, terminology, and metrics across the industry. It is causing manufacturers to develop their own standards thereby causing compatibility and reliability issues.

Source: Accenture Analysis, AECOM Storage Study 2015, Resilient Power – a project of Clean Energy Group, Aug 2015

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In 2015, Illinois energy storage deployments increased 420% (including under construction projects)

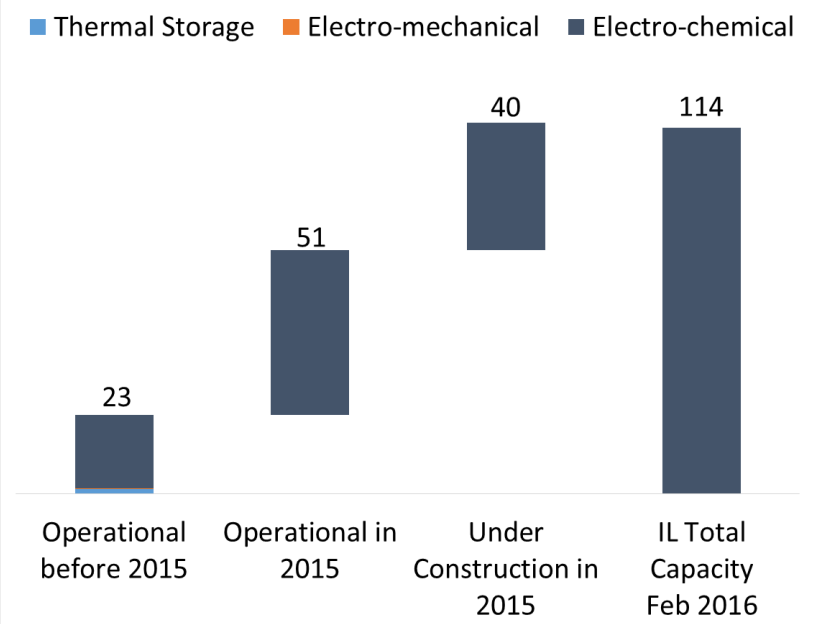
Executive Summary

- The focus on energy storage in Illinois has been on "grid side" deployment, with economics generally not supporting "behind-the-meter" deployment
- The grid side applications have been focused on providing frequency regulation and electric supply capacity to the PJM market
- Lithium-ion batteries have been the technology of choice

New energy storage projects identified in 2015 include:

- 51.3MW of new deployments
  - Grand Ridge energy storage (31.5MW)
  - McHenry energy storage (19.8MW)
- 39.9MW under construction
  - Jake energy storage (19.8MW)
  - Elwood energy storage (19.8MW)
  - IIT pilot (250kW)
- >3MW in pipeline
  - Grand Ridge expansion (3MW)
  - Merchandise Mart DES (details pending)

IL Energy Storage Landscape (MW)



Service	Rated Power (MW)
Frequency Regulation	92.8
Electric Supply Capacity	19.8
Electric Bill Management	1.3
Electric Supply Reserve Capacity (Spinning)	0.3
Black Start	0.3
On-Site Power	0.1

Source: Accenture Analysis, DOE Energy Storage Database

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Case Discussion: West/Southwest Chicago suburb projects (39.6MW) will provide real-time frequency regulation services to the PJM ancillary market

- Renewable Energy Systems Americas Inc. (RES) has announced two of the largest projects – Jake and Elwood – in Joliet and West Chicago in 2015.
- Each of the projects offer 19.8MW of operating capacity and have the ability to store 7.8MWh of energy.
- BYD is the energy storage technology provider and RESolve will perform energy storage control and dispatching.
- The storage batteries will be in 11 modular containers per site. These modular units are expected to simplify the projects construction and improve the reliability of the overall systems.

BYD Li battery modular units
Photo: microgridmedia.com

- The projects will be interconnected to the ComEd grid and provide real-time frequency regulation services to PJM.
- Prudential Capital Group financed the projects for 50% preferred equity, which will be held by Prudential Financial, Inc. and The Lincoln National Life Insurance Company, a subsidiary of Lincoln National Corporation. The financing also included non-recourse senior secured debt representing approximately 50% of the total project costs. The debt included both fixed and floating rate notes, with a maturity of approximately three years.
- RES partnered with local development company GlidePath Power to ensure compliance with City of West Chicago and the City of Joliet rules and regulations and minimize impacts to the local communities.

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Source: PRNewsWire, microgridmedia.com, RES press release

Case Discussion: Behind-the-meter energy storage is under construction at Merchandise Mart, the world's largest commercial building

- Johnson Controls is installing DER at Merchandise Mart, the world's largest commercial building (4.2M sq. ft., hosts 25k people everyday).
- The project will participate in fast response programs and is expected to save 35% on electricity bills.
- The actual storage configuration and size are not available yet.

Source/photo: PRNewswire, Johnson Controls

- Johnson Controls offers two products – L1000 and L2000.
  - L1000 is for in-building storage system, can be used for system back-up, and ranges from 50kW – 250kW.
  - L2000 is a modular storage system, can be used for transmission and distribution deferral, capacity, voltage support, renewable integration, frequency regulation, and other ancillary services ranges from 500kW – 2MW.

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Source/photo: PRNewswire, Johnson Controls

Case Discussion: McHenry energy storage (19.8MW) became EDF's first commercial battery storage project in North America in 2015

- EDF Renewable Energy announced commercial operations of a 19.8MW energy storage project in McHenry County IL, the first battery storage project for EDF in North America.
- It provides fast response frequency regulation services to PJM and is interconnected at the distribution level into ComEd. The project will participate in both the regulation and capacity markets.

Photo: Business Wire

- The battery and power electronics were supplied by BYD America, consisting of 11 containerized units.
- EDF Renewable Energy is one of the largest renewable energy developers in North America with 7.8GW of wind, solar, biomass, and biogas projects developed throughout the U.S., Canada, and Mexico. It has an additional 100MW storage under development.
- EDF Store and Forecast software is used to model and simulate the renewable generation and battery storage dynamics. It also helps manage the dispatch strategy for batteries through effective forecasting of solar and wind generation.
- EDF Renewable Energy acquired a 100% interest in the project late in the first quarter of 2015 from Chicago based GlidePath Power; construction commenced in June 2015.

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Source: EDF Renewable Energy's first commercial storage project in McHenry County Illinois.

Case Discussion: Grand Ridge (31.5MW), the largest energy storage project in IL, became commercially operational in 2015

- Grand Ridge energy storage project is located in La Salle County, IL and because commercially operational in 2015.
- Its power rating is 31.5MW, the world's second largest storage project.
- The project provides fast response services to PJM markets.
- The batteries are containerized and supplied by BYD.
- Grand Ridge is one of the largest co-located renewable generation and storage center with a 210MW wind farm, 20MW solar, and 37MW energy storage.

Photo: PRNewswire

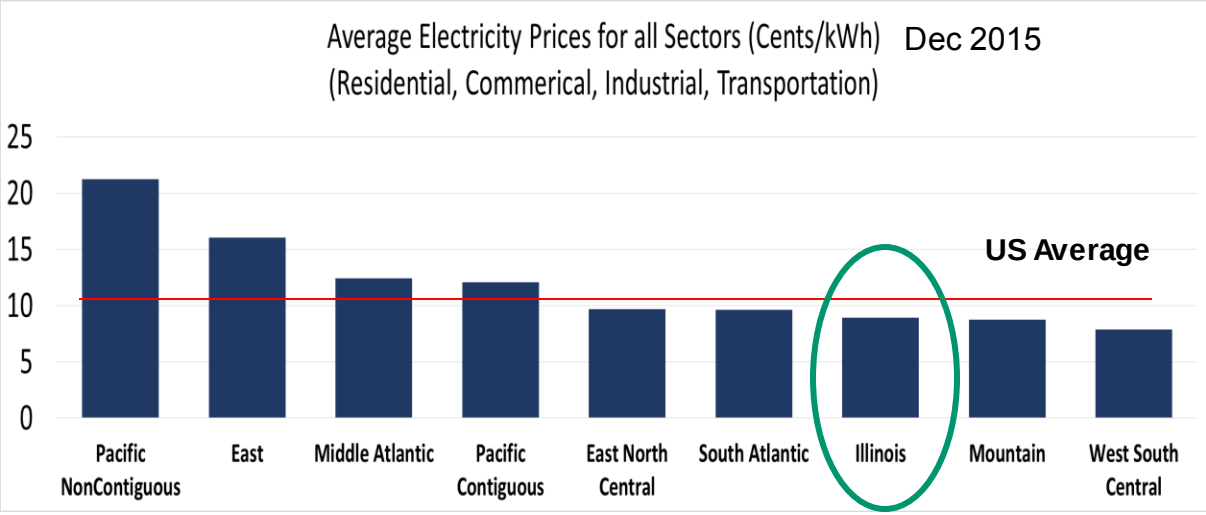
- Another 3MW of energy storage is in the pipeline for development.
- Invenergy's Grand Ridge energy storage is the first storage project to receive Power Engineering and Renewable Energy World Magazines' 2015 Project of the Year Award. Its centralized storage plan received Energy Storage North America's innovation award.
- Invenergy and its affiliated companies develop, own and operate large-scale renewable, natural gas and energy storage facilities in North America and Europe. It has 88MW of storage projects either in operational or in advance development.

Source: PRNewswire, Invenergy, US DOE Energy Storage Database

In spite of large grid scale projects, Illinois is slightly below the US average in behind-the-meter projects

Approximately, 35MW of behind-the-meter storage projects have been deployed in 2015. 94% of the deployments are in CA, Hawaii, and NY. CA leads the non-residential market and Hawaii leads in the residential market. Our investigation didn't find any new behind-the-meter deployments in 2015 for Illinois.

The drivers for low penetration include:



Low energy prices:

IL energy prices are less than the US average and are significantly lower (50% or more) when compared with Pacific and East regions.

Low demand Charges:

IL demand charges fall into one of the lowest groups. HECO and CA have substantially higher demand charges that make energy storage a viable option for electrical bill management and arbitrage.

Little or no policy and incentive programs:

20 states have seen policy activities in 2015. Notably, California's SGIP and DRAM, Hawaii's change in net metering and TOU, and New York's REV plan.

Source: Accenture Analysis, GTM Research, Energy Information Administration, ComEd

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Primary research interviews

2014	2015	2016		
Interviews Conducted	**Interviews Conducted**	**Interviews Conducted**	**Declined/No Reponses**	
• Kinetic Traction Systems • RedFlow • SustainX • Eos • Illinois Capacitor • Ecoult • ZBB Energy Corp • Silent Power • Aquion • A123/ NEC	• AllCell Tech • American Vanadium • Beacon Power • Energy Power Systems • Eos Energy Storage • Green Charge Networks • Greensmith • Ice Energy • Invenergy • Ioxus • NEC Energy Solutions • POWERTHRU • S & C Electric • SiNode Systems • SustainX • UniEnergy Technologies • ViZn Energy • ZBB Energy	• AllCell Tech • CODA • Ecoult • Eguana Technologies • Energy Storage Association • Ensync • Eos Energy Storage • Ice Energy • Intelligent Generation • Ioxus • Light Sail Energy • Primus Power • Reflow Limited • SiNode Systems • Stem • Tabuchi	AES Energy Storage Alstom Grid Aquion Energy Beacon Power CellCube-American Vanadium Electrosynthesis EnerDel Energy Power Systems Enphase Energy Geli Glidepath GNB (Exide) Green Charge Networks Greensmith Gridflex Illinois Capacitor Imergy Invenergy Johnson Controls JLM Energy Kinetic Traction LG Chem Mad Dash Inc. Magnetic Coil Manufacturing	Mitsubishi- Hitachi Power Navitas NEC Energy Solutions OutBack Power Panasonic PCM Powerthru RES Americas S & C Electric Saft Samsung Sanmina SMA Sonnen Batterie SunPower Sunverge SustainX Tabuchi Electric UniEnergy Technologies Viridity ViZn Energy Voith Yunicos Xalt Energy

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Interviewed energy storage vendors span across the USA

Company	Headquarters	Description
AllCell Tech	Chicago, IL	Chicago-based manufacturer of lithium ion battery with thermal control
CODA	Monrovia, CA	CA based solution provider of Li-Iron Phosphate battery and battery management system
Ecoult (East-Penn Mfg..)	Lyon Station, PA	PA based manufacturer of UltraBattery supporting grid, renewable generation, and micro grid applications
Eguana Technologies	Calgary, Canada	Canada based supplier of power control solutions for residential and commercial energy storage systems
Energy Storage Association	Berkeley, CA	A national trade association for energy storage
Ensync	Menomonee Falls, WI	A flow battery manufacturer provides energy management systems for commercial and industrial applications
Eos	New York, NY	Zinc battery aims to provide low-cost energy storage solutions for electric utilities
Ice Energy	Santa Barbara, CA	Provides thermal energy storage system that connects to commercial rooftop A/C units
Intelligent Generation	Chicago, IL	A software platform that employ intelligent battery dispatching strategies
Ioxus	Oneonta, NY	Manufacturer of ultra capacitors, hybrid capacitors, and modules for a variety of high power, energy storage applications
LightSail Energy	Berkeley, CA	A start-up of compressed air technology, which employs the storage tanks above the ground
Primus Power	Hayward, CA	Zinc flow battery manufacturer for large scale grid applications
Redflow Limited	Austin, TX	Zinc-Bromide battery provider supporting off-grid and telecom applications
SiNode Systems	Chicago, IL	Pre-commercial manufacturer of silicon material to replace lithium ion anode
Stem	Millbrae, California	Stem is CA based complete solution provider – Power Scope, Power Store, and Power Monitor – for behind-the-monitor applications for C&I customers
Tabuchi	San Jose, CA	Manufacturer of transformers for electronic equipment, Power Supplies for electronic equipment, and various electronic components

AllCell (1/2)

- AllCell Technologies is a Chicago-based manufacturer of lithium ion battery cells. They produce two sets of products:
  - Low voltage – 24-60 volts, 6 kWh modules that link together to form 50-60 kWh systems
  - High voltage – can scale up to 600- 1100 volts for frequency regulation; 50-290 kWh range of size, all stationary in server / rack arrangement
- Both products use AllCell's proprietary phase change material (PCM), which protects against thermal runaway by absorbing and dissipating heat gradually over time
  - Eliminates expensive air conditioning systems in low voltage systems
  - Aids in thermal management, increasing cycle life 50-100%
- AllCell Technologies and Windfree recenly announced the completion of Chicago's first lithium ion energy storage system connected to a solar powered EV charging station. The project was commissioned in Aug 2013.
  - It includes a 10kW solar canopy, 40kWh battery system, and two Level II charging stations. It helps buffer the electrical grid from the uneven power demands of EV charging while providing enough capacity to charge two vehicles in case of a power outage.
- In 2015, AllCell focused on refining its existing products by using inside designers. No sales are currently reported in Illinois. It shipped its first batch of bricks with 100 cells of 1kWh for EV charging to California for solar/EV charging.

AllCell (2/2)

- AllCell has been supplying storage systems as part of Solar Grid Storage partnership: PJM service areas including Grid Star project at the Philadelphia, Navy Yard, and the Konterra commercial micro grid in Laurel, Maryland.
- AllCell's sales volumes exceed 5MWh of battery systems (evenly divided between transportation and stationary). 90% is funded by product revenues with first two profitable quarters in 2014.
- AllCell showcased their 5 hours long lasting battery in DARPA competition - Humanoid Disaster Response Robot WANDERER. It was able to operate for more than 5 hours and walk on two legs for almost 3 kilometers without recharging.
- AllCell recently formed a partnership with LG Chem to pilot and test new generation product.
- Most of the grid projects get some form of state or federal support. AllCell has benefited from Illinois grants to perform manufacturing upgrades to their facilities.
- Their primary customers include grid storage and C/I customers for frequency regulation in East Coast, demand charge customers and off-grid / EV customers in West Coast, Canada, Iceland, and Caribbean islands.
- California (solar/EV) and island markets are attractive. But, they seek to develop a stronger relationship with the City of Chicago. They are actively following Texas market, which is three times the size of California. It is relying heavily on wind power to combat peak demand problems.

CODA

- CODA manufactures and sells advanced energy storage systems that provide economic and energy resilience for businesses, cities, and society – saving money, generating revenue, increasing resilience, and optimizing energy usage.
- 90% of CODA's sales are in California, and they recently installed a 3.5MW system. Other markets include Maryland, New Jersey, and Georgia. In Illinois, a single system is being piloted, and if successful the company will install it in 17 sites in PJM market for behind-the-market (2MW) applications.
- CODA focuses on resiliency of the network. It recently installed 3 projects in California. In the last year, their product cost went down by 25% and working towards simplifying design and expedite installations (from 4 hr to 1hr).
- CODA is a private investment backed company. It is completely debt financing company, investors are not involved in day-to-day operations. All of their systems are on the balance sheet and they operate their own systems. Investment covers all operations and sales.
- Financing model – The CODA Core™ energy storage system does not require upfront cost for the qualified SGIP customers. Some of the use cases indicate 20-50% savings in electricity bills in California (optimized for facilities with utility bills greater than $2,500 per month and a monthly peak demand of 50kW or higher).

Ecoult

- Ecoult was formed in 2007 by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, and was acquired in 2010 by the United States-based East Penn Manufacturing Company Inc.
- Ecoult utilizes its rights toward the UltraBattery® technology and intelligent energy management systems developed by the CSIRO. They design, engineer, and integrated UBer (UltraBattery® Energy Resource) energy storage solutions that enable the continuous management of energy intermittencies and shifting of energy.
- Ultrabattery provides a hybrid between long-life lead-acid and high power capacitors. The primary applications include renewable smoothing – wind and solar. Because of its hybrid design, it is able to continuously charge and discharge. UPS and control system applications are ideal for this battery. Current installation projects are comprised of 50% behind the meter applications and 50% island/renewable grid applications.
- The technology is efficient and provides a long life time throughput. In 2015, the Ecoult design has realized significant operational improvements – moving from 40% to 70% efficiency.
- In North America, Ecoult is focused on grid connected applications whereas in the other parts of the world, its focus is on providing island off-grids. The installed system were able to provide continuous power to an island of 2000 people for 1 to 2 hours
- Currently, planning to introduce smaller scale systems in Australia followed by other markets. Australia's newly announced Tariffs and high PV installations are key drivers for market growth. Asia is another big market, but they have not penetrated it yet.
- Along with new installations, existing PV Installations are ideal for retrofit applications. For example: 28GW lead-acid are connected today at datacenter – not making any contributions to grid today

Eguana

- Eguana Technologies (TSX: EGT.V) designs and manufactures high performance power electronics for residential and commercial energy storage systems. They are agnostic to battery technology.
- AC coupled topology is taking over a lot of applications -70% systems in Europe are alternating current (AC) coupled. Hawaii is another popular market. The existing solar systems as can be retrofitted using Eguana's systems easily. Installations are straightforward and they can be connected to home panel directly without the need for redesigning.
- With direct current (DC) topology, the systems have to be redesigned for solar panels. Currently, 90% of their customers use AC coupling and 48 V batteries for residential segments. In some instances, 96V, low voltage are found in use. Another advantage of Eguana system is bi-directionality, AC-DC and high efficiencies - 97% one directional and 94% roundtrip.
- Applications include; solar self consumption, backup, grid services, and demand charge management
- Europe is Eguana's main market. In 2015, it sold 5,000 units to Austria and Switzerland ranging 2.5kW – 5kW. It has begun to develop business in North America in residential and small commercial segment. In USA, sold 100 – 250 units to battery manufacturers for residential applications
- There are no specific financing vehicles available. Most customers pay cash or 100% debt financing. The Eguana's systems offer 7 – 11yrs pay back period.
- The bi-directional inverter are good especially with flow batteries. Formed a partnership with LG Chem to develop new technologies . Also, working with Sun Edison and Primus power. Development pipeline includes 150 systems of 5kW in California.

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Ensync

- Ensync offers matrix energy management, which combines two battery technologies - flow and Li-ion. Thus, it opens up multiple value streams – (1) Power applications: PV ramp, frequency regulation, power quality; (2) Energy applications: demand response, rate shifting, critical back-up power.
- Target market includes East Coast for peak savings, West Coast for demand charges. They don't have any current projects in Illinois. But, the Midwest U.S. has opportunity for PJM grid applications such as congestion relief. Hawaii is a good market for solar and storage installations. Caribbean and islands are primary focus outside of US. They serve C&I customers and stationary applications.
- For the C&I market, EnSync has introduced Matrix and Agile Hybrid systems to
  - enable distributed intelligence and active control of inputs and outputs inside buildings
  - allow a building to be connected to others in a micro grid
  - provide seamless connectivity to the utility for smart export on demand
  - deliver cash generation opportunities from a building's distributed energy systems
- Ensync has established partnerships with local project developers, R&D groups, and local sales companies.
- Ensync also offers PPA (Power Purchasing Agreements). No use cases were disclosed during the interview. However, based on the public information on the website, the customers could benefit from the following:
  - No/low upfront capital costs
  - Reduced energy costs
  - Limited risk
  - Can leverage tax credits
  - Increased value of property

Eos Energy Storage

- Eos's zinc hybrid aqueous battery functions like a zinc plating bath – as the battery charges, ions are plated onto the anode; as it discharges, ions dissolve into solution
  - Eos is prototype manufacturing a utility/grid-scale 1MW/ 4MWh system (4 hour duration) using 125 and 250 kW sub-units
  - The "Aurora 1000|4000" will be commercially available in 2016
- Pros: the "zinc-air battery" draws oxygen from outside the casing allowing a higher capacity to volume ratio, lowering costs, extending life to 10,000 cycles (i.e., 30-year lifetime), and avoiding thermal runaway risks inherent to lithium ion technology
  - Eos believes it can produce energy storage systems for as low as $160/kWh (not including controls platform) in order to out-compete gas-fired peaker plants
  - Compared to shorter duration lithium ion, Eos can better serve local capacity / demand management needs
- Cons: not light weight like the lithium ion battery cells found in portable electronics or EVs, operates at 75% efficiency, less well-known technology requires testing
- Eos Energy Storage has raised the first $15 million of a planned $25 million in funding, to scale up manufacturing to meet its planned delivery of 1MW of its zinc air systems
  - The startup is deploying its first AC-integrated battery system for testing with Con Edison in New York (6 kW / 18kWh unit) and GDF SUEZ in Europe (8 kW / 24 kWh unit)
- The target end user is a utility company or manufacturer to serve end of the day peak after solar generation has tailed off

Ice Energy

- Ice Energy manufactures a grid-scale thermal storage system ("Ice Bear") and is testing a commercial/industrial and residential product ("Ice Cub")
  - One Ice Bear connects to a standard rooftop air conditioning unit of any size (4 to 20 tons) and its longevity is the life of the AC unit (20 years or more)
- The thermal storage unit functions by freezing 450 gallons of tap water at night (off-peak hours) and provides cold refrigerant on hot days (peak hours) to operate the AC unit more efficiently
  - Each Ice Bear delivers an average reduction of 12 kW of source equivalent peak demand for a minimum of 6 hours daily, shifting 72 kW-hours of on-peak energy to off-peak hours
- Product is generally cost effective anywhere with summer peak days where the distribution grid has a capacity issue
  - Daytime energy demand from air conditioning is typically 40-50% of a building's electricity use during peak daytime hours
- Ice Energy introduced new product Ice Bear 20, smaller size than Ice Bear 30. This product aims for residential applications.
- IC 20 gives 3-5 years payback period. With incentives, IC 20 is expected to be cheaper than AC units. The drawback of the technology is that it doesn't store electricity thus can not supply it back to grid. It is ideal HVAC applications.
- Nationally there are 1000 ice bear units installed for a total capacity of 10MW
  - That is increasing drastically because Ice Energy has won contracts with Southern California Edison to provide over 2,000 of Ice Bear units (26MW) across West Los Angeles
- Ice Bear units are typically owned by utilities and installed at distributed locations behind the customer meter on commercial and industrial sites
  - Currently there are 3 pilots of 1 unit each in Illinois (Naperville, St Charles, and Evanston)

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Intelligent Generation

- Intelligent Generation is a software platform company that provides optimum battery dispatching services. The software platform is agnostic of energy storage technology type.
- However, the company has specifically demonstrated Li-ion battery technologies using the software platform. Their product optimizes assets utilization thereby reducing operating costs.
- The company also provides PJM market services such as bidding, certification, and acts as a broker to energy storage providers.
- The software platform measures and monitors renewable generation such as solar and wind outputs and dispatches battery as necessary to minimize the fuel costs.
- The primary customers for IntelGen are commercial and industrial partners.
- Intelligent Generation partners with solar developers and employs revenue sharing business mode. Some of the key partnerships include Convergence Energy (St. Charles, IL).
- The typical payback period with such management system is observed 4 to 6 years.
- Focus markets include Texas, New England, Germany, and Japan

Ioxus

- Ioxus is a manufacturer of ultra-capacitors, which are well-suited for ramp management and VAR support
  - Replace with smaller battery and capacitor with a switch so capacitor provides peak demand and battery provides long term power supply → 33% longer mileage, temperature lower, battery lasts 4-8X longer, charge up in 30secs
  - Installing an ultra-capacitor reduces an 800 amp/hr battery down to 50 amp/hr with a 60% cost reduction
- Ioxus has sold a product to utilities in Europe for a feasibility study – 15MW system discharging with high power density for a few seconds
  - China and Japan is a $350-400 million market for large capacitors, growing 26-36% annually
  - They view more traditional battery storage technologies as their primary competitors
  - Sold to couple hundred customers – most of work is project based
- Ioxus manufactures in the US but has limited market penetration to date
  - Transportation subsidies for hybrid buses in US are slanted to only Li-ion batteries whereas Europe is concerned with reducing emissions and exploring multiple technical solutions
  - In the past, capacitors worked well for grid (Tennessee Valley Authority), but most utilities / grid operators are unwilling to pay for the R&D and few engineers know the technology well
- Most products geared towards industrial and transit market – rail, bus, forklift, automated vehicles in factories, system level uninterruptible power
  - Fuel cell vehicles have to use capacitors to modulate the output – they're energy dense not power dense
  - Hybrid vehicles – start/stop use capacitors in Europe – can charge and discharge over a million times – ultra capacitor can be recharged in 5 seconds vs 10-15 min
- Also used for uninterruptible power in oil and gas drilling in US, tied to diesel or CNG generators
  - Working with one of the largest UPS companies with newest product line for industrial and data center applications
  - Greater energy/cost ratio improvement than batteries
- Ioxus is investor-backed – TE Energy Ventures (consortium of Conoco, NRG, GE) and Astor Capital (Alstom Transit, Schneider Electric), and private equity companies

LightSail Energy

- LightSail Energy is a start-up based out of Berkeley, CA. Their technology is based on compressed air. It claims to eliminate two of the traditional challenges that Compressed Air technologies have – fuel efficiency and storing gas underground.
- Traditional compressed air requires natural gas and diesel to keep the system running, which reduces fuel efficiency significantly.
- However, LightSail is developing technology that doesn't require external fuel but the hot air can provide the mechanical movement necessary to keep the piston moving.
- Also, they have designed a UL certified above the ground tanks to store pressurized air. They store pressurized air at 3000psi. This above the ground containerization expands the applications.
- They can now transport the required tanks and can sell in wholesale markets. Also, it is easier to either downsize or upsize required power. Another advantage of this technology is that it can last more than 20 years.
- Finally, there are no safety concerns, usually attached to other electro-chemical technologies.
- The technology is ideal for grid scale energy storage applications, large scale end user applications such as micro grid, island grid, and renewable integration.
- Currently testing the products in-house and expected to get into production by 2018.
- Germany and Japan are some of the markets in their radar. Their business model is to be an OEM. Currently, they are completely venture backed and will be raising another R&D fund followed by growth fund.

Primus

- Primus is a zinc flow battery manufacturer - EnergyCell and Energy Mod. It holds 23 patent and 72 other patents are pending. The Gen 1 flow battery is being manufactured with 20kwh – 72kWh. It is comprised of 14 batteries in total. Gen 2 product is in the process and will replace Gen 1 by April 2016. Gen 2 will have improved package design. The cost of gen 2 will be half of the gen 1 system - $300/kWh.
- Flow batteries are good for long duration and cost effective at large sizes.
- Gen 2 is designed for under 2MW applications. Economics of 10MW would be better. But, smaller sizes have more potential use case applications
- Primus offers mainly stationary utility applications – providing ramping, peak capacity, grid flexibility, renewable integration – reducing the need for peaker plants.
- Primus target market includes New York – where they are targeting a 12 hour system for resiliency purposes. Other markets of interest are California, Hawaii, Texas, Japan, China, Italy, and Germany.
- Primus is a venture backed company, recently raising $25M. Private investment is the main source of funding.
- Primus has two projects in the pilot stage. One is with utilities in Washington for Gen 2 system of < 1MW for renewable integration. Second, a system of 20kW in Kazakhstan, with plans of 1200 units of 125MW- 150MW over the next 3 to 4 years.
- Flow batteries are in odds with Li-ion. Recent large procurement of Li-ion have impacted flow battery opportunities. Though many technologies are still in the development stage, large procurement create off balance focus on some technologies.

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Redflow

- Redflow is featuring a plug-and-play storage system and the ability to self-manage, protect and monitor 24/7 with zinc-bromide technology (ZBM).
- Redflow offers three types of products ZBM, ZBM 2, ZBM 3, they are all 48V DC battery. LSB is their large size storage made up of multiple ZBM batteries. LSB is 660kW in 20 foot container and also could be made smaller size of10ft container.
- Currently, developing a package (ZBM2 + inverter AC) for residential applications in the USA. It is expected to reduce diesel usage by 8% – 30%.
- Their primary target customer is – telecommunications. Installed a several hundred MW if storage projects, with significant installations in 2015. ZBM can discharge 100% without degradation at high ambient temperatures (125 degrees F) and do not require any cooling. Their 48V battery works better at lower voltage, and is perfectly designed for telecom applications. Redflow installed a few systems in Latin America, South east Asia, South Africa, and Europe. In Australia, where LCOE is 29cents per kWh, Redflow is selling LSB for community or neighborhood power generation, also offer storage for grid stability for utilities. Their systems are suitable for high energy displacement but not the frequency regulations.
- In the USA, California, New York, and Hawaii are attractive markets because of regulatory incentives and climate conditions. Illinois is not a near-term market target
- For telecom applications, economics are generally attractive. ZBM costs between $100/kWh - $800/kWh with LCOE of $0.14/kWh. Without financing, it can reach pay back of 2-3 yrs.
- Flow batteries have challenges in finding the off the shelf power electronics. ZBMs have a requirement that they have to go to zero discharging and currently extra adjustments are necessary to facilitate this.
- With LSB, power electronics are integrated and can be directly connected to residential systems without external inverter. However, technology improvements are needed in making seamless integration.

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SiNode Systems

- SiNode Systems is a Chicago-based advanced anode technology startup
  - Lithium ion batteries are traditionally made with ite, but SiNode owns intellectual property for a silicon ene material to replace the ite anode
  - This increases the energy and power density of the battery
  - Leverages a solution-based chemistry process with lower scale costs than ite
  - Best suited for consumer or military grade technologies

- SiNode will sell to battery manufacturers, currently still in R&D and prototyping
  - Working with large battery assemblers in the area (AllCell, Xalt Energy, Navitas) and military
  - Majority of its potential customers are located in Japan, China, and South Korea. So, actively exploring opportunities to partner with a battery manufacturer in Asia .

Stem (1/2)

- Stem was founded in 2009 and expanded into commercial operations in 2013 with residential customers. However, the company pivoted into C&I customer segment, which is their main focus today.
- Stem provides a complete solution – Power Scope, Power Store, and Power Monitor – for behind-the-monitor applications and beginning to expand into grid services. It has recently introduced cloud solutions to its offerings.
  - PowerScope: displays and deploys energy storage intelligently down to the seconds interval.
  - PowerStore: a Li-ion battery storage units procured from tier1 suppliers such as tesla, Panasonic, and LG Chem. However, the software platform is designed to be battery technology agnostic.
  - PowerMonitor: installed at customer site and connected to real-time usage data. Also, enable automatic savings.
- Stem cloud solutions let the customers visualize and analyze the energy usage in real time and enable automated demand charge savings.
- With the C&I customers, it serves a number of industry groups, including hospitality, retail, school districts, food processers, and commercial office buildings.
- There are two sales teams – Enterprise accounts, which focuses on large size accounts such as Home Deport and Extended Stay hotel chain in California and Hawaii and regional teams, who focus on individual customers at different locations.
- Stem formed a partnership with Sun Power, which will enable storage deployments with solar.

Stem (2/2)

- Stem has two prominent value streams. One, it enables C&I customers to save demand charges and also make use of governmental incentives such as California's SGIP. Second, STEM can tap into its existing unused storage across all of its installations and provide capacity services to utilities. In other words, it creates a virtual grid network and dispatches as needed.
- According to Stem use cases, it can generate 10% - 20% savings on demand charges.
- Stem deployed 10MW projects across California and 1MW in Hawaii. California project focus is to reduce demand charges and in Hawaii is to address solar variability.
- Illinois is a future target market. However, demand charges are very low, so it is not economical viable state yet. If large-scale utility applications emerge, they might be more attractive.
- Stem has raised $75M raised from its partners and developing partner networks with suppliers and utilities.
- Stem secured $350M in project financing, which is used to pay for deployment of energy storage systems. For these projects, every dollar that the customer saves, Stem receive 50 cents in lease payments.
- Stem won 85MW grid size storage contracts with Southern California Edison (SCE), with the deployments starting in the second half of 2016 and will ramp up in the next 5 years.
- Stem's pipeline includes three projects of 1MW in Hawaii, two projects total of 250kW in California in addition to its 5 year contract with SCE.

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Tabuchi

- Tabuchi is a manufacturer of inverters and electronic components with headquarters in Japan. Energy storage is a small business unit with <5% of overall business within the company. Tabuchi has overall sales of $600M last year with 90% of its business in Japan. Their secondary markets include China, Australia, and Thailand. Central America, Australia, and Germany are future target markets
- It is expanding its operations in the USA (Northern California, Arizona) and Canada with energy storage. They produce high quality inverter and storage system on a DC bus. All the components including the battery are in a single box, providing a turnkey solution. The typical size of the system is 5.5kW inverter and provides 2kW instantaneous power.
- The system provides automatic transfer switch and is straightforward to install. Tabuchi partners with solar developers to supply their storage systems. Also, partnering with Geli for smart inverters manufacturing.
- Tabuchi uses Panasonic's Li-ion battery. The energy storage system's applications include demand charge management and energy arbitrage. Tabuchi installed some systems in off-grid applications in Asia.
- The company does not offer any specific financing options. The whole unit cost is approximately $11,000. Average pay back is generally 6 – 10 years depending on the location.
- They just began the pilot in Midwest – Indianapolis. No plans for Illinois yet.
- The project pipeline includes two systems of 1 – 2kW battery with 5.5kW solar inverter.
- Some market challenges include finding the good solar panel installers, lack of customer awareness, and unstructured markets.