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

February 17, 2015

accenture

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Executive Summary

Project objective: To understand the market for third party non-utility storage companies within ComEd's territory

Background

- As part of ComEd's obligation under the Energy Infrastructure Modernization Act (EIMA), ComEd is required to submit an Annual Implementation Progress Report (AIPR).
- With the AIPR, ComEd is required to provide a refreshed view of annual non-utility energy storage uptake within its utility service territory.

Project Tasks

- Perform market and industry assessment of third party non-utility storage companies as a whole and specifically within ComEd territory.
- Conduct detailed primary research on third party non-utility storage companies.
- Develop stakeholder communications to present key findings from research.

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Key Takeaways

- Across the United States and globally, the energy storage market is on the cusp of rapid growth
  - Developers have targeted C&I customers, interconnecting systems on both sides of the meter, primarily in geographies with regulatory mandates/incentives or specialized use cases.
  - The residential market is witnessing an increase in solar-plus-storage deployments.
- In ComEd's service territory, approximately 1.54 MW of distributed non-utility energy storage has been deployed behind-the-meter – with more than 7.5 MW expected in the near future.
  - However, large grid-scale projects bidding into PJM's ancillary services market have dominated the storage marketplace "taking all the oxygen" away from distributed, customer-sited storage.

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Key Findings

- Last year, we reported **one non-utility vendor** sold energy storage in ComEd's territory (250 kW) compared to **three vendors** as of this year (~**1.54 MW**).
  - Addition of AllCell 40 kW li-ion storage at Chicago EV charging station and CALMAC 1.25 MW IceBank thermal storage system at Underwriters Laboratories
- Distributed, customer-sited energy storage technologies **do not have a large presence in ComEd's service territory** primarily due to economics
  - Despite declining battery prices, storage system costs per kWh – combined with challenges monetizing multiple value streams – still outweigh the benefits for most customers
  - No Illinois state/local mandates, tax credits, or rebates to stimulate energy storage adoption
- Additional impediments to growth include:
  - A fragmented and immature marketplace has resulted in the value proposition not being well-understood by customers
  - There are challenges monetizing applications up and down the value stream
- Energy storage companies are mostly **targeting large commercial and industrial (C&I) customers**
  - The economics of stand-alone storage for residential or small business (SMB) customers is less attractive than for larger C&I customers with systems scaled for price reduction
  - Solar penetration and dual-use of the investment tax credit (ITC) favor solar-plus-storage among residential market
  - Grid-scale storage offers additional value propositions for the wholesale market (e.g., transmission-sited and behind-the-meter systems participate in the ancillary services market)

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Methodology, Approach, & Timeline

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

Perform Battery Storage Market Assessment 01/28/15 – 02/06/15	Primary Research of Vendors and Analysis 02/02/15 – 02/12/15	Communicate Findings 02/12/15 – 02/13/15
Perform Market & Industry Assessment	**Primary Research and Analysis**	**Develop Stakeholder Communication Package**
Confirm ComEd Objectives & Conduct Internal Interviews: • Identify key aspects of Electrical Storage Systems • Gather details on ComEd service territory (e.g., customer requests for storage) **Assess Industry / Market:** • Identify key industry trends • Map energy storage technology options • Understand industry regulations and incentives • Approximate market size and growth potential	**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 • Key discussion points include analysis methodology, market size, and other key findings **Final Messaging:** • Update the findings in line with discussions with key stakeholders • Organize and prepare findings for legal / regulatory compliance

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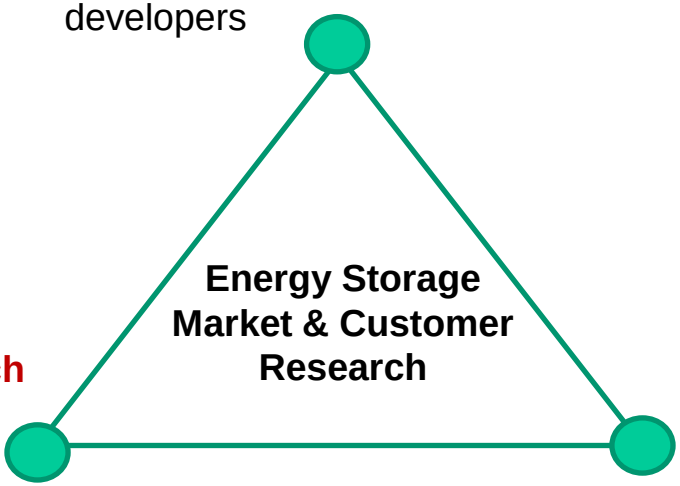
Sources of Information

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

1) Vendor interviews

- Conduct interviews with 15+ 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, but this report focuses on non-utility third party vendors

Generation & System-Level Applications	**Wholesale Energy Services**	Utility-scale storage systems for bidding into energy capacity and ancillary services markets
	Renewable Integration	Utility-scale storage providing renewables time shifting, load and ancillary services for grid integration
T&D System Applications	**Stationary Storage for T&D Support**	Systems for T&D system support, improving T&D system utilization factor, and T&D capital deferral
	Transportable Storage for T&D Support	Transportable storage systems for T&D system support and T&D deferral at multiple sites as needed
	Distributed Energy Storage Systems	Centrally managed modular systems providing increased customer reliability, grid T&D support and potentially ancillary services
End-Use Applications	**ESCO Aggregated Systems**	Residential-customer-sited storage aggregated and centrally managed to provide distribution system benefits
	C&I Power Quality and Reliability	Systems to reduce TOU energy charges, participate in Demand Response programs and/or demand charges for C&I customers
	Home Energy Management	Systems to shift retail load to reduce TOU energy and demand charges and/or participate in Demand Response program
	Home Backup	Systems for backup power for home offices with high reliability value

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Despite lithium ion emerging as a leading technology, numerous storage systems and battery chemistries fulfill energy / power needs

Utility-Scale ALT 4-10

Commercial-Scale

- Flywheel
- Thermal
- Compressed Air
- Advanced Lead Acid
- Redox/ Hybrid Flow
- Zinc-Air
- Sodium Sulfur
- Super-capacitor
- lithium ion

- Lithium ion is emerging as a market leading technology.
- However, numerous other technologies are suitable for various applications.
- Companies looking for new revenue streams for batteries developed for transportation (i.e., stationary storage, second life applications).
- Market consolidation occurring as new promising technologies are introduced.
- Challenge to monetize value for all potential applications throughout the value chain.

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Electrochemical batteries vary in their applications, technology development stages, advantages, and disadvantages

Electrochemical Battery Storage Technologies

	Lithium Ion	Lead Acid	Sodium (NaS, NaNiCL)	Redox Flow (Vanadium, Hybrids)	Nickel (NiCd, NiMH)
Stage	Commercial	Commercial (advanced)	Commercial	Commercial/ Demo	Demo
Advantages	Wide temp range, ability to deep cycle and fast charge; small footprint, long life, light weight, very high efficiency	Low capital cost, well-established, simple technology, high efficiency (80-90%)	High power and energy densities, high efficiencies, suitable for daily cycling and grid stabilization	Enhanced reliability, higher capacity with longer term storage	High power and energy densities, efficiency, improved longevity, performs well at low temp
Disadvantages	More expensive (limiting their primary use to Power applications), safety concerns	Limited service life, capacity decrease when high power is discharged, hazardous material, reliability issues	Safety concerns with high temperature and corrosion issues	Early generation batteries have lower energy density, risk of electrolytic degradation over time	Expensive, cadmium toxicity limits NiCd to stationary application
Applications	Power & Energy	Power	Power & Energy	Power & Energy	Power

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Energy Applications: storage system discharge over periods of hours with correspondingly long charging periods (ex: peak shaving, load leveling)

Power Applications: short periods of discharge (seconds to minutes), short recharging periods and many cycles per day (ex: ramp rate control)

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Chemical and mechanical storage technologies vary in their applications, technology development stages, advantages, and disadvantages

	Chemical		Mechanical		
	Zinc Air	**Fuel Cell**	**Flywheel**	**Compressed Air**	**Pumped Hydro**
Stage	Demo	Commercial/ Demo	Commercial (advanced)	Commercial (advanced)	Commercial (advanced)
Advantages	Very high energy density, light compared to sealed batteries lower cost, long cycle life at low-rate discharge	Advantageous for combined heat and power, longer operating time compared to batteries, reliable	Besides pumped hydro, most common commercial storage, above or below ground, high reliability	Besides pumped hydro, most common commercial storage, above or below ground, high reliability	Well-established technology with > 120 GW installed worldwide, very long lifetime, and nearly unlimited cycle stability
Disadvantages	Better suited for EVs and electronics, impacted by humidity, lower discharge efficiency	Lower efficiency, limited fueling infrastructure, expensive to produce	Low round-trip efficiency (<50% if reheating air), geographic limitation, may require combustion with natural gas	Low round-trip efficiency (<50% if reheating air), geographic limitation, may require combustion with natural gas	Dependence on topographical conditions and large land use, medium efficiency
Applications	Energy	Energy	Energy	Energy	Energy

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Energy Applications: storage system discharge over periods of hours with correspondingly long charging periods (ex: peak shaving, load leveling)

Power Applications: short periods of discharge (seconds to minutes), short recharging periods and many cycles per day (ex: ramp rate control)

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Electrical and thermal technologies vary in their applications, technology development stages, advantages, and disadvantages

	Electrical		Thermal
	Supercapacitors	**Superconducting Magnetic Coil**	**Thermal / Ice Storage**
Stage	Demo	Demo	Commercial (advanced)
Advantages	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	Very thermally efficient for load shifting on peak cooling days, scalable for commercial or utility-scale storage
Disadvantages	Low energy density and 10x larger than comparable battery, expensive, not as well known/ established in US for battery applications	few, small SMES products commercially available, reliability depends on an energy-intensive refrigeration system	Limited to air conditioning applications, large space requirements, limited market outside CA
Applications	Power	Power	Energy

Energy Applications: storage system discharge over periods of hours with correspondingly long charging periods (ex: peak shaving, load leveling)

Power Applications: short periods of discharge (seconds to minutes), short recharging periods and many cycles per day (ex: ramp rate control)

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Each energy storage technology has unique strengths and weaknesses in cost, response time, flexibility, safety and longevity

● = Good

◑ = Medium

○ = Poor

Different technologies are suited for different end use applications, making the market fragmented.

	Pumped Hydro	CAES-Below Ground	CAES-Above Ground	Sodium Sulfur	Lead Acid	Advanced Lead Acid	Lithium Ion	Zinc Bromine	Vanadium Redox
Low capital cost/ kWh	●	●	○	○	○	◑	○	◑	○
Large volume of energy storage capacity	●	●	●	●	○	○	○	●	●
Long life (high # of life cycles)	●	●	●	◑	○	◑	◑	◑	◑
Quick response time (milliseconds)	○	○	○	●	●	●	●	◑	◑
Safe (non-toxic, non-combustible)	●	●	◑	○	○	○	○	○	○
Flexible to locate (in cities)	○	○	○	○	◑	◑	◑	◑	◑
Low O&M costs	●	●	◑	◑	◑	◑	◑	◑	◑
In commercial production	●	●	◑	●	●	◑	◑	○	○

Source: eoS website

As a result, each energy storage technology has a different set of end-use applications

Application	Description	CAES	Pumped Hydro	Flywheels	Lead-Acid	NaS	Li-ion	Flow Batteries
Off-to-on peak intermittent shifting and firming	Charge at the site of off peak renewable and/ or intermittent energy sources; discharge energy into the grid during on peak periods	◑	◑	○	●	●	●	●
On-peak intermittent energy smoothing and shaping	Charge/discharge seconds to minutes to smooth intermittent generation and/or charge/discharge minutes to hours to shape energy profile	○	◑	◑	●	●	●	●
Ancillary service provision	Provide ancillary service capacity in day ahead markets and respond to ISO signaling in real time	◑	◑	◑	◑	◑	◑	◑
Black start provision	Unit sits fully charged, discharging when black start capability is required	◑	◑	○	●	●	●	●
Transmission infrastructure	Use an energy storage device to defer upgrades in transmission	○	○	○	●	●	●	●
Distribution infrastructure	Use an energy storage device to defer upgrades in distribution	○	○	○	●	●	●	●
Transportable distribution-level outage mitigation	Use a transportable storage unit to provide supplemental power to end users during outages due to short term distribution overload situations	○	○	○	◑	●	●	●
Peak load shifting downstream of distribution system	Charge device during off peak downstream of the distribution system (below secondary transformer); discharge during 2-4 hour daily peek	○	○	○	●	●	●	●
Intermittent distributed generation integration	Charge/Discharge device to balance local energy use with generation. Sited between the distributed and generation and distribution grid to defer otherwise necessary distribution infrastructure upgrades	○	○	○	●	◑	◑	◑
End-user time-of-use rate optimization	Charge device when retail TOU prices are low and discharge when prices are high	◑	◑	○	◑	◑	◑	◑
Uninterruptible power supply	End user deploys energy storage to improve power quality and /or provide back up power during outages	○	○	◑	●	●	●	●
Micro grid formation	Energy storage is deployed in conjunction with local generation to separate from the grid, creating an islanded micro-grid	○	○	○	●	●	●	●

Definite suitability for application ● ; Possible use for application ◑ ; Unsuitable for application ○

Source: GTM Research

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Utilities, consumers, and generators of renewable energy share value provided by storage systems, particularly the load shifting/price arbitrage applications

Distributed Energy Storage Value Propositions

Grid / Utility

Time/load shifting
- Storage allows generation output to flatten between daytime and nighttime load differential
- Improves operating efficiency, reduces fuel costs, and defers investment in generation and T&D upgrades

Power quality
- Provides frequency control
- Improves voltage drops by discharging electricity and reduces voltage rises by charging electricity

Efficient use of the network
- Large-scale batteries at substations help to mitigate congestion

Isolated grids
- Stabilizes power supply to islands where small-capacity generators must meet demand
- Supports microgrid applications

Emergency power supply
- Protection and control equipment

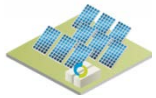
End Consumer

Time/load shifting
- TOU rates incentivize customers to flatten their electricity load and avoid demand charges (C&I customers only)
- Storage helps reduce peak power demand during the day and to buy/charge electricity at off-peak times

Emergency power supply
- Storage can substitute for emergency generators during an outage
- Provides continuous supply for critical appliances (i.e., fire sprinklers and security equipment)
- Quality of semiconductor and liquid crystal manufacturers' products are impacted by even momentary outages

Electric vehicles and mobile appliances
- EV batteries can be used to power in-house appliances ("vehicle-to-home") in combination with solar power and fuel cells ("vehicle-to-grid")

RE Generator



Time/load shifting
- Renewable energy can be effectively used by storing surplus electricity and using it when necessary
- Enables renewably-generated electricity to be sold when price is high, maximizing profit for RE generators

Effective grid integration
- Solar and wind output is intermittent due to clouds or wind which makes connecting to the grid difficult
- Energy storage can absorb this fluctuation more cost effectively than a phase shifter providing ramp rate control

Source: IEC Electrical Energy Storage and GTM Research

However, these value propositions are contingent on technology costs and the ability of users to monetize numerous applications

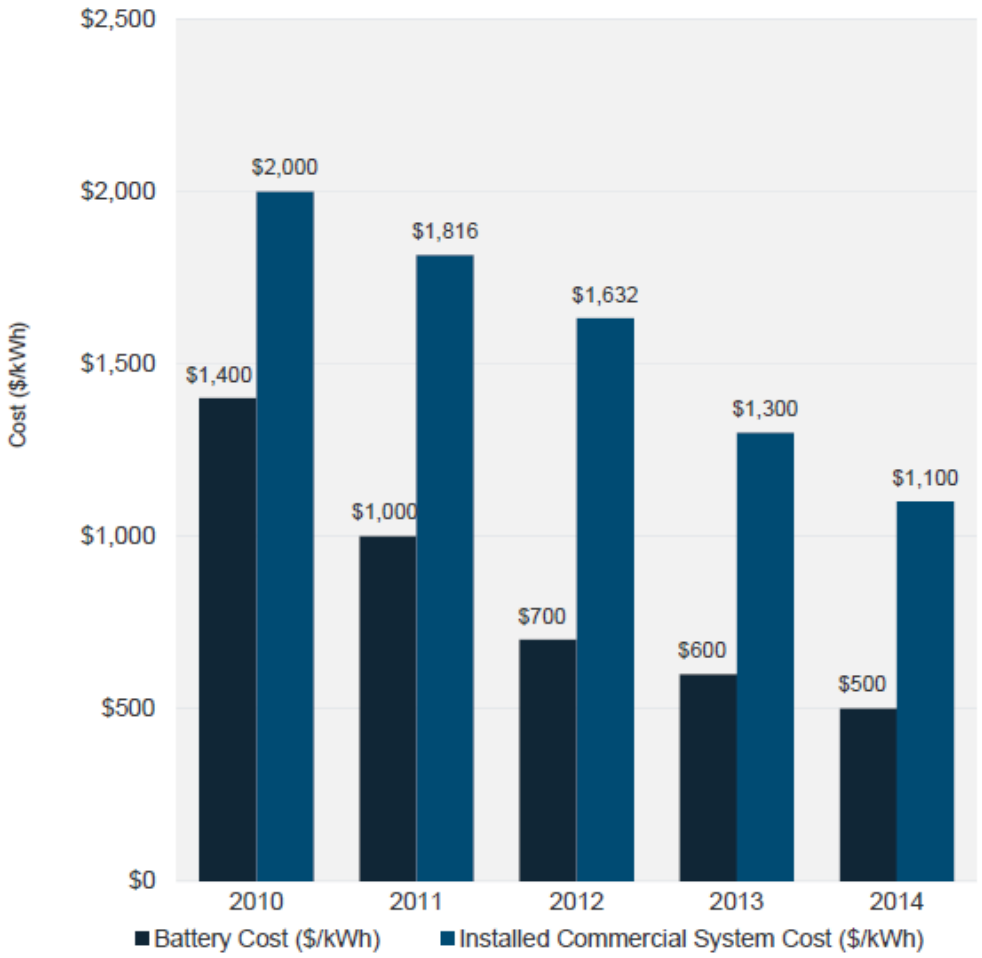
It is very difficult to value an energy storage system today due to the range of technologies and costs, the ambiguity of possible revenue streams, and the changing regulatory environment. There are, however, a few key indicators to watch, including:

Energy Prices	Increased volatility and high wholesale energy costs will improve the economics for storage systems
Renewable Integration	As penetration increases so do the challenges of managing the grid with significant intermittent power. Energy storage will be necessary.
Regulations and Market Structure	Regulatory mandates and market conditions will help to enable the monetization of all energy storage applications across the value chain
DER Penetration	Storage systems will help overcome the challenges of integrating distributed energy resources into the distribution grid
Technology Costs	Cost reductions for batteries will occur as new technologies are developed and as energy storage solutions scale, both in the transportation and electricity sectors

Driven by a growing EV market and economies of scale in manufacturing, lithium ion battery cell and system costs will continue to steadily decline

Once long-lasting batteries reach an installed cost of less than $300/kWh, energy storage begins to displace peak power plants and distribution investment

Battery and Storage System Costs 2010-2014



- Lithium ion battery costs have decreased on average by 23% each year since 2010
- Total commercial system costs have dropped 17% from $3400 kWh in 2010 to $1600/kWh in 2014 for a 2-4 hour storage system
- Cost reductions are a result of manufacturing capacity expansion in anticipating a rapid boom in EV market
- 2020 projection: battery costs to reach $250/kWh-$300 and commercial system costs to be under $600/kWh

Source: GTM Research and Forbes "The Battery Revolution"

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In addition to price declines, a number of emerging trends are expediting growth in the non-utility, third party energy storage market

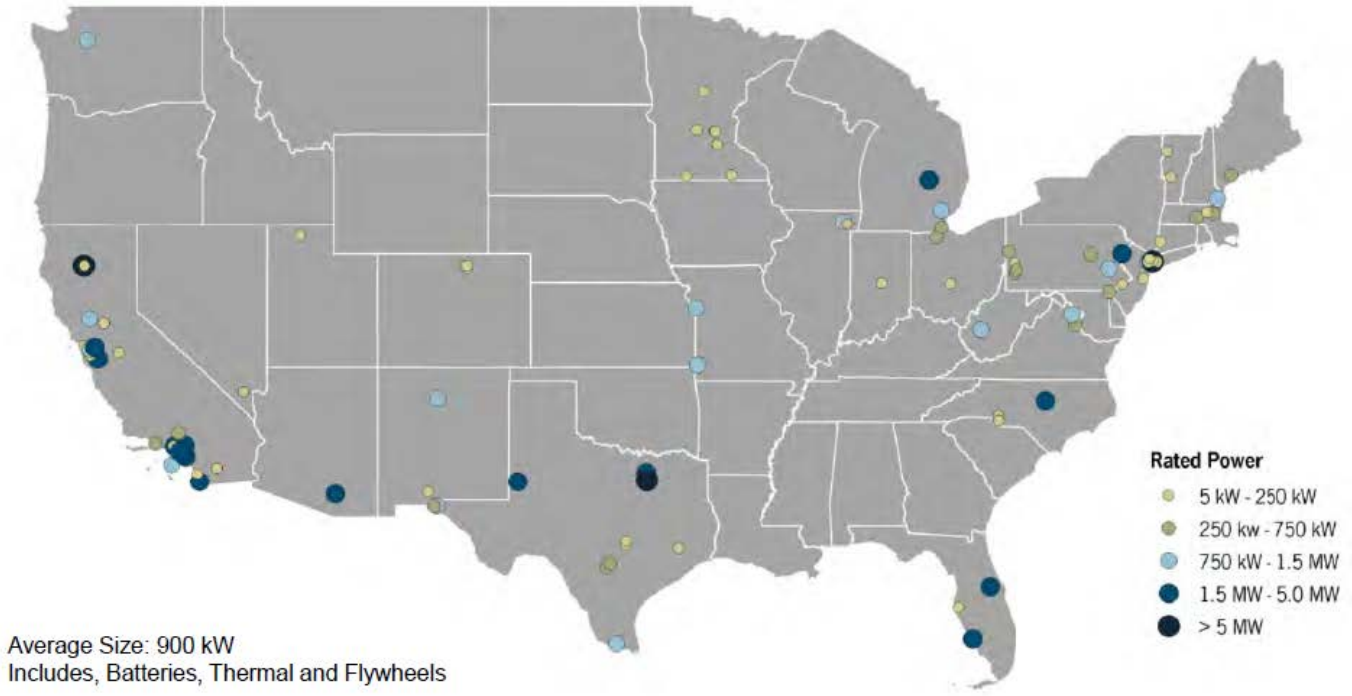
- **2014 experienced an increase in behind-the-meter partnerships**
  - SunPower teamed up with KB Homes, Enphase is working with Lennar Homes and Vivint Solar on a pilot in Hawaii, SolarCity is working on solar-plus-storage for Wal Mart, and Extended Stay America has chosen Stem to install storage at many of its hotels in California
  - 2015 will experience creative partnerships beyond solar and storage – home builders, HVAC dealers and retail energy companies could add storage to their offerings
- **SolarCity launches energy storage for business using Tesla battery packs**
  - SolarCity has already made a foray into residential solar combined with energy storage -- now it expects to build and finance 30 to 50 commercial solar-battery systems next year behind the meter
  - Tesla's "giga-factory" helps lithium-ion battery technology reach scale and drive price reductions
  - The EV manufacturer just announced in February it is unveiling a home battery, beginning production in 6 months
- **Distributed storage has faster growth prospects than grid-scale technology in most places**
  - Nationwide, selling residential and commercial solar-plus-storage packages has been easier than getting utilities to invest in major grid-scale storage projects due in part to an unclear market structure and regulatory environment (i.e., is storage a generation, transmission, or distribution asset?)
  - In Illinois, however, favorable frequency regulation rules (i.e., FERC 755) have driven growth in grid-scale storage
- **California PUC makes ambitious regulatory commitments with local capacity requirement**
  - California's AB 2514 legislation calls for 1.3 GW of energy storage
  - In addition to grid-scale storage, customer-located storage can be used to meet the mandate, opening a large opportunity for third-party ownership models behind-the-meter
- **Texas to overhaul grid-balancing services with energy storage**
  - Oncor released a proposal to spend more than $5 billion to add 5 GW of energy storage on the Texas grid
  - A key question is how Oncor/ ERCOT can monetize multiple energy storage value streams simultaneously

Source: Energy Storage Report and Greentech Media

Price declines and regulatory mandates have helped fuel storage deployments along the East and West Coasts of the U.S. and in Texas

- As of year end 2014, there were approximately 120 distributed energy storage projects deployed for the purposes of electricity bill management (i.e., demand charge reduction), frequency regulation, and renewable energy integration
  - The DOE, however, does not differentiate between distributed *customer-sited* storage and distributed *grid-scale* storage (i.e., interconnected to transmission or distribution voltage), so actual number of non-utility, third party systems may be smaller
  - The majority of these projects are under 750 kW and many are power-focused (e.g., high capacity, short duration) applications

Map of Distributed Storage: Operational, Announced, and Under Construction



Source: U.S. DOE, GTM Research

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Whereas storage may connect at transmission or distribution voltages, behind-the-meter / customer-sited storage offers the most system-wide benefits

Ownership Models for Energy Storage

Ownership Model	Examples of Project Owners/Operator	Characteristics	Example
Merchant / Unregulated	Xtreme Power, AES Energy Storage, Beacon POWER	Typically interconnected at transmission voltages and compensate through market mechanisms.	Duke / Xtreme Power Notrees Wind Farm (ERCOT), Beacon 20 MW Flyhweel (PJM), AES Laurel Mountain (PJM)
Utility	AEP American Electric Power, SMUD, DTE Energy	Typically interconnected at distribution voltage. Cost recovery via rate-base.	AEP Ohio, SMUD
Behind-the-Meter	stem, SolarCity, Tesla, Demand Energy	Typically interconnected at secondary distribution voltages. Most financing to date has been equity/cash.	Demand Energy – Barclay Tower, STEM – Interncontiental Hotel

- Behind-the-meter, customer sited storage has typically been financed on the balance sheet, although new financial models (e.g., Green Charge Network's "Power Efficiency Agreement" and Stem's lease program) will help to overcome high capital costs.
- Storage systems behind-the-meter may also qualify for the solar investment tax credit (ITC) under a dual-use clause.

Locational Benefits of Energy Storage

	Transmission/ISO	Distribution	Customer Sited
T&D Deferral	•	•	•
Frequency Regulation	•	•	•
Peak Shaving		•	•
Renewable Integration	•		•
Emergency Backup			•

- Energy storage sited upstream from loads provides only marginal benefit to downstream applications.
  - In the wholesale market, an IPP's profit from energy storage is limited to frequency regulation.
  - Distribution utilities cannot participate in the wholesale market due to regulatory constraints.
- In contrast, PJM allows aggregated behind-the-meter storage systems to participate in the wholesale ancillary services market, expanding their range of applications / use cases.

Source: GTM Research

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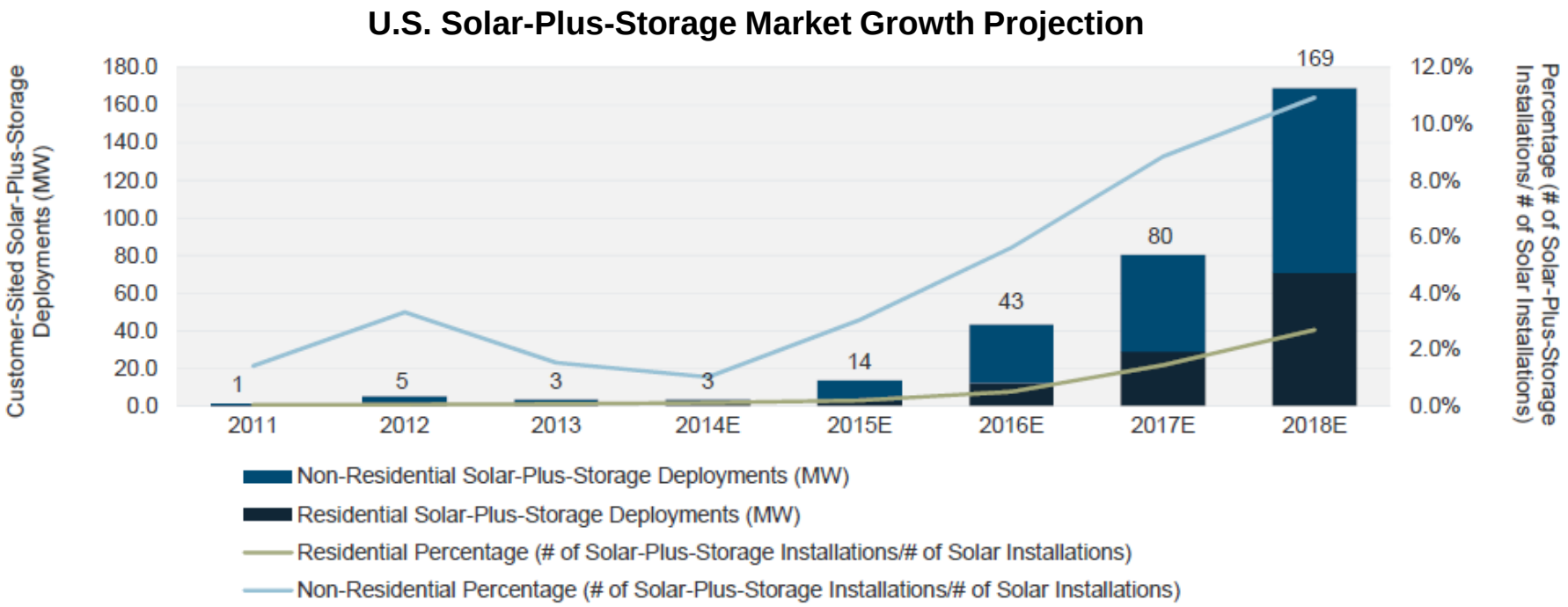
Among the behind-the-meter projects, customer-sited solar-plus-storage is on track to grow to 170 MW by 2018 in the U.S.



- Behind-the-meter solar-plus-storage market is projected to grow from a modest 3.4 MW in 2014 to 13.5 MW in 2015, reaching 43 MW before the ITC benefits are slated to wind down by year-end 2016
- Despite the growth rate slowing in 2017, annual solar-plus-storage deployments may reach 80 MW, and as state incentives are likely to proliferate around the country, the annual solar-plus-storage market could reach 170 MW by 2018
- In terms of size, the commercial market will dominate residential storage, driven by better economics of demand-charge management and lower per kWh battery prices
- In Illinois, Intelligent Generation reported 10MW of commercial and residential solar + storage projects in the pipeline

Source: GTM Research

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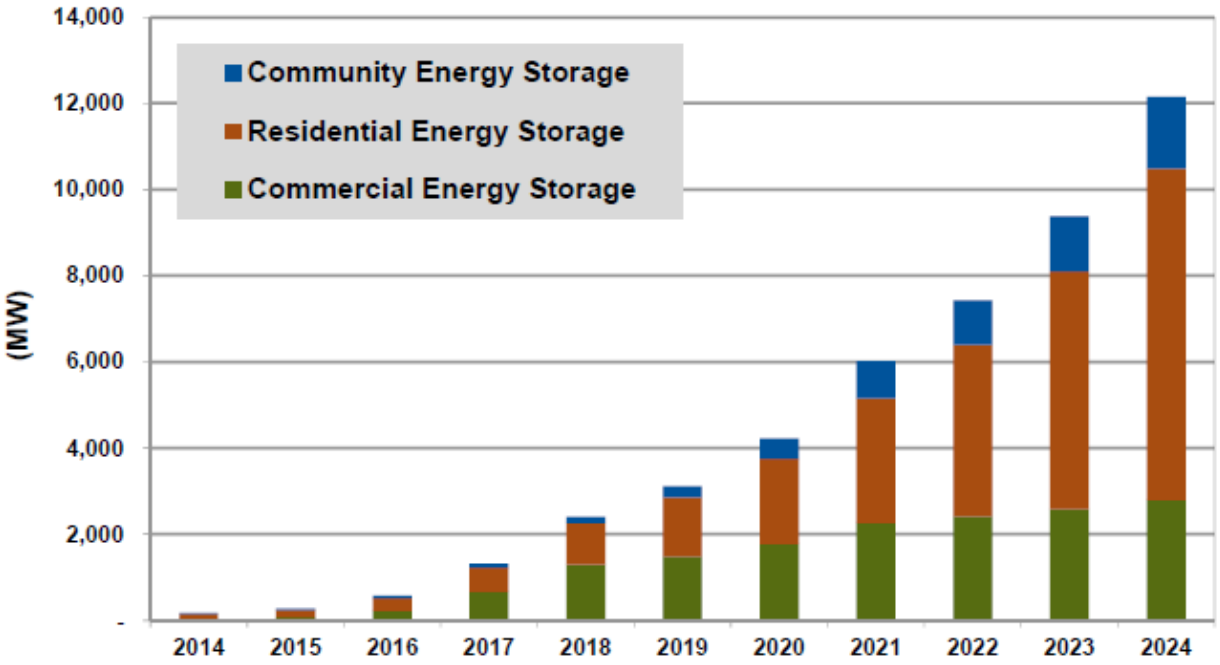
Worldwide, distributed energy storage is forecast to grow from 172 MW in 2014 to more than 12 GW in 2024

Advances in battery chemistries and declining price points have helped meet the demand for distributed energy storage created by solar PV, EV charging, and home energy networks, according to Navigant.

Forecast Distributed Energy Storage System Power Capacity by Application, World Markets 2014 - 2024



- Community storage is expected to remain a niche application given highly customized systems and a difficult business case to establish (e.g., T&D deferral)
- Commercial storage relies on demand charges or active DR to secure sufficient ROI – peak/off-peak price arbitrage may not be a sufficient business case
- Residential storage will lead the market driven by DER (solar) adoption, backup to the grid, load shifting/ price arbitrage, and perception of improved property value

Source: Navigant Research 4Q 2014

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Despite limited storage projects in the Midwest, Chicago is a favorable location for battery technology innovation

- ***"When it comes to battery technology innovation, Chicago is leading the charge" – The Clean Energy Trust***
- **U.S. Department of Energy awarded a multi-partner team led by Argonne National Laboratory $120 million over 5 years for research into advanced battery systems**
  - The Joint Center for Energy Storage Research (JCESR or "The Hub") is a public/private partnership of national labs, universities, and industry solely focused on next generation battery technologies
- **New paradigm for battery R&D**
  - JCESR has partnered with domestic manufacturing companies to hand-off successful prototypes for scale-up
  - Integration of basic science, battery design, prototyping, and manufacturing collaboration is akin to the Bell Labs research model, a "first" for energy storage innovation
- **Breakthrough achievements**
  - The battery technology in the Chevy Volt is based in part on breakthroughs pioneered by Argonne
  - Battery Performance and Cost model (BatPac) is a techno-economic analysis tool to predict system-level cost and performances of next-generation battery technologies
- **Early stage "seed funding"**
  - Annual investment in Illinois clean tech startups has averaged only $1.8 million since 2001
  - However, the Energy Foundry, Clean Energy Trust, and Illinois Department of Commerce and Economic Opportunity awarded $1 million in early-stage funding, half of which went to two Chicago-based battery startups – Glidepath and SiNode Systems
- **Emergence of grid-scale storage in Chicago**
  - RES Americas is scheduled to complete construction on 40 MW of grid-scale storage in August 2015, which would make it the largest, commercial energy storage project in North America

Source: Clean Energy Trust and IST Coalition

Consequently, the following non-utility distributed energy storage projects in Illinois are connected behind-the-meter

Project Name	Technology Type	Rated Power in kW	Duration HH:MM	Status	Service/ Use Case
Illinois Institute of Technology RDSI Perfect Power Demonstration	Zinc Bromine Flow Battery	250	2:00	Under Construction	Black Start
Underwriters Laboratories – SBB and Calmac	Ice Thermal Storage	1250	14:00	Operational	Electric Bill Management
AllCell Chicago EV Charging Station	Lithium ion Battery	40	1:00	Operational	On-Site Power
Ice Energy project at 1028 Central St., Evanston, IL	Ice Thermal Storage	10	6:00	Operational	Electric Supply Capacity
Ice Energy project at 1200 W Ogden Ave, Naperville, IL	Ice Thermal Storage	10	6:00	Operational	Electric Supply Capacity
Ice Energy project at 200 Devereaux Way, St Charles, IL	Ice Thermal Storage	10	6:00	Operational	Electric Supply Capacity
EnerDel Mobile Hybrid Power System	Lithium ion Battery	15	5:20.00	Operational	On-Site Power

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Denotes storage project in ComEd service territory

Source: U.S. DOE Energy Storage Database

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A range of energy storage vendors were interviewed to assess the existing market and current demand

- Conducted interviews with 18 vendors:[1]
  - AllCell– Chicago-based manufacturer of lithium ion battery with thermal control
  - American Vanadium – sales agent for Gleidmeister's leading commercially available vanadium flow battery
  - Beacon Power – modular carbon fiber flywheel systems that store kinetic energy in a rotating mass
  - Energy Power Systems – manufacturer of advanced lead acid battery for both grid-scale and behind-the-meter
  - Eos – zinc battery aims to provide low-cost energy storage solutions for electric utilities
  - Green Charge Networks – developer of commercial li-ion energy storage units, software system, and PEA
  - Greensmith – energy storage software, services & systems for multiple applications on both sides of the meter
  - Ice Energy – thermal energy storage system that connects to commercial rooftop A/C units
  - Invenergy – Chicago-based developer of utility-scale storage systems and renewable generation
  - Ioxus – international manufacturer of ultra-capacitors for UPS, ramp management and Volt/Var support
  - NEC Energy Solutions – subsidiary of A123, manufacturing lithium iron phosphate batteries
  - POWERTHRU – flywheel systems that provide ride-through power and voltage stabilization for power quality
  - S & C Electric – developer of grid-scale sodium sulfur energy storage systems
  - SiNode Systems – pre-commercial manufacturer of silicon graphene material to replace lithium ion anode
  - SustainX – isothermal compressed air energy storage company
  - UniEnergy Technologies – vanadium flow battery for energy and power applications
  - ViZn Energy – zinc iron redox flow battery for use with capacity needs
  - ZBB Energy Corporation – manufacturer of modular Zinc-Bromide batteries used for energy storage

- Primary interview objectives:
  - Understand vendor's **technology**, **target geography** and **customer**
  - Determine **number of installations** in ComEd footprint (if any)
  - Estimate **sales volume** in other US markets
  - Gather additional market information from vendors

[1] Larger description of interviewees in appendix

The Illinois market for energy storage has yet to be tapped

- Energy storage within ComEd service territory
  - Of the 18 vendors interviewed, **3 have sold non-utility, third party energy storage** units in ComEd's service territory
    - ZBB Energy Storage – 250 kW (2 hour duration: 500 kWh) project with the Illinois Institute of Technology as a beneficiary of a DOE grant
    - AllCell – 40 kW (1 hour duration: 40 kWh) lithium ion storage system connected to a solar powered EV charging station
    - Calmac & SBB – 1.25 MW (14 hour duration: 17.5 MWh) IceBank thermal storage system at Underwriters Labs
  - Two additional vendors in Illinois are worth watching:
    - Ice Energy – 30 kW (2 hour duration: 60 kWh) deployed across Illinois, but these 3 pilots were sold to municipal utilities
    - Green Charge Networks – 7.5 MW across 100 sites (60-90 kW per unit) expected in 2015-2016
  - Multiple vendors mentioned **barriers to entry in ComEd territory** including:
    - Wholesale power market "taking up the oxygen" with ancillary services
    - Unclear regulatory structure and an inability to monetize multiple value streams
    - Lack of consumer demand due to insufficient economics of projects (e.g., high battery / inverter costs)
    - Lack of financial incentives at state and/or local level
    - Long lead time to receive interconnection / net metering permits
- Customer insights:
  - Customers with energy storage systems in Illinois are **primarily large commercial or industrial companies** with a few residential customers
    - ComEd received 160 net metering applications in 2014 and 25 applications as of February 2015; however, data on the number of battery storage systems deployed is not tracked
    - 3 known residential customers own storage systems and participated in the "Smart Home Showcase"
  - Current trend to buy storage for industrial and commercial purposes may be changing with increased penetration of residential solar + storage

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Over time, we expect to see an increase in demand for energy storage (both non-utility distributed storage and grid-scale)

Drivers that could influence adoption within ComEd service territory include:

- Demand for stabilization of the grid
  - Energy storage serves as a "shock absorber" for the grid and can keep faults from transferring around the grid
- New ownership/business models to reduce capital costs for end customers
  - "Power Efficiency Agreement" borrows from the solar PPA and offers a storage-as-a-service model
- Change in **regulatory framework** – additional opportunities in the frequency regulation market as well as opportunities for **utilities to rate base storage** as generation / load assets
- Incentives
  - Federal/state **government grants** for energy storage demonstrations
  - A **state storage mandate** that allows behind-the-meter storage to count towards utility storage requirements (i.e., similar to SoCal Edison)
  - **Distributed generation incentives** like California's Self Generation Incentive Program (SGIP), can provide paybacks for energy storage systems in under five years
  - If SGIP is combined with the **federal solar Investment Tax Credit (ITC),** the payback period can fall to less than two years for solar-plus-storage systems
  - Future **incentives for the EV market and storage** whereby grid-connected electric vehicles could charge at night and discharge during peak time when not in use
  - Other **state incentives** in Illinois to stimulate customer demand in ComEd territory
- Older, better understood technologies are more readily accepted as an alternative power source
  - Maturity of industry and technology of capacitors is cited as a large factor for their continued growth and sales
- Decrease in levelized cost of storage relative to fossil fuel generation and movement towards **maximizing efficiency** and cleanliness of fossil fuel generation
- Emergence of a stationary storage market for secondary life EV batteries

However, there are still several factors inhibiting an immediate increase in demand in the market

Growth tends to be inhibited by:

- Lack of regulation / incentive for storage at grid-scale or down the value chain
- Unclear regulatory and market structure for monetizing multiple value streams simultaneously (e.g., participating in wholesale market, time/load shifting, and T&D deferral for example)
- Energy efficiency / other demand side management
- Persistently low power prices in the Midwest
- Most battery cell technologies and storage system technologies (i.e., inverters) remain too expensive to be cost effective or profitable
- Difficult environment for raising capital necessary for expansion
  - Many energy storage companies are start ups facing resource challenges
  - Some are still in their pre-commercial phase and have not yet brought a product to market
  - Wall Street favors companies with big balance sheets who are backed by LG, Samsung, etc.
- Market is relatively new and technologies do not have past history
  - Benefits may be understood but technology has not been implemented before, leading to a chicken and egg scenario in terms of sales and growth
  - Utility companies tend to be more cost sensitive as they do not always have the ability to build energy storage into rates
  - Pay-for-performance packages boost energy storage
    - Under pay-for-performance plans, grid operators implement pricing structures that pay faster-ramping resources a higher price for their service
    - Speed and accuracy is considered when utilities purchase regulation service for transmission
- Fragmented market without one clear market leading technology creates marketing hurdles

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Appendix I: Vendor Interviews

Vendor Interviews

- 2015 Interviews Conducted:
  - AllCell
  - 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
- Declined / No Response:
  - A123 Energy
  - AES Energy Storage
  - Alstom Grid
  - Aquion
  - CellCube- American Vanadium
  - Coda
  - Ecoult
  - Electrosynthesis
  - EnerDel
  - EnerVault
  - GE Energy Storage
  - Glidepath
  - Gridflex
  - Hydrogenics
  - Illinois Capacitor
  - Imergy
  - Intelligent Generation
  - Johnson Controls
  - Kinetic Traction Systems
  - LG Chem
  - LightSail Energy
  - Mad Dash Inc.
  - Magnetic Coil Manufacturing
  - Navitas
  - Panasonic
  - PCM
  - Primus Power
  - Redflow Ltd
  - RES Americas
  - Samsung
  - Saft
  - Silent Power
  - Solar Grid Storage
  - Stem
  - Viridity
  - Vycon
- Internal Interviews/Other:
  - Lynn Briney
  - Toni Garza
  - Thomas Kay
  - Nishit Mehta
  - John Parise
  - Vincent Gutierrez
  - Brandon Wilson
  - Clean Energy Trust

Third Party Non-Utility Vendors Interviewed (1/3)

Company	Technology	Headquarters	Illinois Sales
AllCell	Lithium Ion	Chicago, IL	Yes
American Vanadium	Vanadium flow	Vancouver, BC	No
Beacon Power	Carbon fiber flywheel	Tyngsboro, MA	Yes
Energy Power Systems	Advanced lead acid	Troy, MI	No
Eos Energy Storage	Zinc air	New York, NY	No
Green Charge Networks	Lithium ion “Green Station”	Santa Clara, CA	No
Greensmith	Lithium Ion / technology agnostic	Rockville, MD	No*

* Denotes sale / development of grid-scale storage, not distributed customer-sited storage

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Third Party Non-Utility Vendors Interviewed (2/3)

Company	Technology	Headquarters	Illinois Sales
Ice Energy	Thermal "Ice Bear" storage	Santa Barbara, CA	Yes
Invenergy	Lithium Ion / technology agnostic	Chicago, IL	No*
Ioxus	Ultracapacitor	Oneonta, NY	No
NEC Energy Solutions	Lithium Ion nanophosphate	Westborough, MA	No
POWERTHRU	Advanced flywheel system	Livonia, MI	No
S & C Electric	Zinc Iron Air	New York, NY	No
SiNode Systems	Silicon graphene (lithium ion anode)	Chicago, IL	No

* Denotes sale / development of grid-scale storage, not distributed customer-sited storage

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Third Party Non-Utility Vendors Interviewed (3/3)

Company	Technology	Headquarters	Illinois Sales
SustainX	Isothermal compressed air	Seabrook, NH	No
UniEnergy Technologies	Advanced vanadium flow battery	Mukilteo, WA	No
ViZn Energy	Zinc Air	New York, NY	No
ZBB Energy Corporation	Zinc Bromine	Menomonee Falls, WI	Yes

* Denotes sale / development of grid-scale storage, not distributed customer-sited storage

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AllCell

- Chicago-based manufacturer of lithium ion battery cells
  - 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%
- Primary grid storage C/I customers for frequency regulation are on East Coast US, whereas demand charge customers and off-grid / EV customers are West Coast
  - Sales volumes exceed 5 MWh of battery systems (evenly divided between transportation and stationary)
  - 90% funded by product revenues with first two profitable quarters in 2014
- AllCell Technologies and Windfree announced the completion of Chicago's first lithium ion energy storage system connected to a solar powered EV charging station
  - Includes a 10 kilowatt solar canopy, 40 kilowatt-hour battery system, and two Level II charging stations
  - 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
  - Commissioned in August 2013
- Bidding on 2 additional projects in Chicago with a developer

American Vanadium (1/2)

AMERICAN VANADIUM
AN ENERGY STORAGE COMPANY

- American Vanadium is the North American affiliate of Gildemeister, a global machinery and energy solutions company that manufactures a commercial vanadium flow battery
  - Production of the “Cell Cube” launched in 2007 and has developed into a turnkey product, including the battery, installation, connection to the grid, and customizable controls unit
  - The company recently opened a vanadium mine in Nevada
- The battery technology has approximately 65-70% roundtrip efficiency, excels in long duration energy applications (2, 4, or 8 hour systems), and is very modular / scalable
  - Large Cell Cubes produce 200 kWh each, whereas the small Cell Cubes include 10, 20, and 30 kWh systems
  - Compared to lithium ion batteries, the Cell Cube excels beyond 2 hour duration and maintains a lower cost per kWh as more electrolyte is added for scale efficiencies
- American Vanadium has a broad customer base primarily interested in its large-scale Cell Cube
  - Multi-dwelling residential (Europe) up to utility scale installations
  - Microgrids and isolated/off-grids
  - Power generation groups (IPPs)
- This technology suits a broad range of use cases as well:
  - Demand shaving, charge at night / discharge during the day (NY and CA)
  - PV smoothing and demand reduction
  - Reliability and substitute for diesel generators on isolated grids
  - T&D deferral (i.e., replace substation upgrade with energy storage)

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American Vanadium (2/2)

AMERICAN VANADIUM
AN ENERGY STORAGE COMPANY

- While there are more than 100 Cell Cube installations by Gildemeister around the world, American Vanadium's North American sales have been limited thus far
  - 1 system in CO, 3 systems in NY, and installing 2 systems in Canada (3 MW with average 3 hour duration for 15 MWh)
  - There is a dual-use case for solving intermittency and peak smoothing with solar-plus-storage among commercial customers in US and residential in Europe
- The vanadium flow battery is not in Illinois right now – the target market includes places with high renewable penetration or areas with high demand charges (i.e., CA, NY, HI, and TX to a lesser extent)
  - A business case could develop in Illinois for T&D capital deferral or for off-grid communities, but power is currently too cheap in the Midwest

Beacon Power

- Beacon develops fast response flywheel-based energy storage systems for utility-scale high power, short duration uses, including:
  - Power grid efficiency, frequency regulation, grid reliability, renewable integration and ancillary services
  - $725-750 per kW AC output including all power electronics
  - Average discharge is 45-60 seconds
- Beacon's flywheel is targeted towards customers looking for applications that require 4-5 min energy storage at most as opposed to hours which we associate with RE ramp up
  - Balancing short term differences in supply and demand that system operators cannot plan on
- There are 406 Beacon flywheels spinning today with a cumulative 8 million operating hours
- Three plants in commercial operation providing frequency regulation to ISO grids (all merchant plants without long-term contracts)
  - 0.5 MW in MA (2008)
  - 20 MW in NY (2011)
  - 20 MW in PA for PJM (2013)
- Beacon foresees additional opportunities in high penetration renewable markets – Hawaii (solar) and Alaska (wind), Caribbean (solar and lack of stable grid) – providing resilience for microgrids, and combining with a hybrid storage system for both power and energy applications
- Advantages: Flywheel has 100,000 cycle life; maintains 10x cycling capability of batteries
  - No degradation in power output over time and full state of charge is available at all times, compared to batteries which are often limited to 80-20 state of charge
  - 0% - 100% state of charge is a more predictable and useful tool to the utility operator

Energy Power Systems

- Venture-backed startup that manufactures advanced lead acid batteries with substantially longer life and higher power / charge acceptance than typical lead acids
- High cycle life allows an EPS battery to provide uninterrupted power supply and participate in revenue generating services (i.e., ancillary services market, load shifting) at the same time
- Pre-commercial stage of product development; sampling product with utility, commercial/industrial, and residential customers
- Observed traction in the residential energy storage market, which is typically slow to adopt due to high cost of energy storage per kWh
  - Lower price point (~$150/kWh) than lithium ion, especially when combined with rooftop solar
  - Particularly helpful in emerging markets where grid is problematic
- Other advantages include:
  - Safer technology (lower risk of thermal runaway / overheating) and may be more accepted than lithium ion
  - Permitting becomes easier for large commercial buildings
- Company plans to offer full battery systems, including racks and containers and work with solar customers that already have an inverter available

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 1 MW/ 4 MWh 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 in 2015 – planned delivery of 1 MW 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

Green Charge Networks (1/2)

- Green Charge Networks developed a utility software to manage distributed generation on a single system through a DOE grant and a contract with ConEd of NY
- Root technology is a smart controller with sophisticated software that monitors facility loads on a second-by-second basis
  - Now in its 3rd revision the "Green Station" system includes a lithium-ion battery and software platform that reduces the power (kW) demand component of the customer's monthly electric bill
  - Targeted towards commercial clients with demand charge reduction needs
- Green Charge Networks builds its own hardware for 30 kW (1-2 hour duration: 30-60 kWh) and 250 kW (2 hour duration: 500 kWh) storage systems, all modular and scalable depending on customer load profile
  - Systems are 5 MW or below
  - Samsung provides lithium ion cells, 94% round trip efficiency, 10 year performance warranty
- Green Charge Networks has sold to 56 customers, consisting of 5 utilities and more commercial and municipal customers than any other battery storage company (i.e., Walgreens, Safeway, Kohls, and 7/11 among others)
  - Walgreens alone has installed Green Stations on more than 100 distinct premises
  - Geographically focused primarily in CA and NY, TX and HI, as the East Coast for microgrids and resiliency
- Green Charge is in the contracting process in the Chicago area
  - 100 commercial sites averaging between 60 and 90 kWh of battery systems (total of 7.5 MW capacity)

Green Charge Networks (2/2)

- The company offers a no upfront cost “Power Efficiency Agreement “(PEA)
  - Leveraging capital from outside investors, Green Charge installs, owns, and operates the equipment on a 10 year warranty and shares in the savings as a form of payment (similar to solar PPA)
  - Depending on the customer, demand is reduced 30-50%
- View li-ion as long-term play – 250 kW / 500 kWh system has a battery cost of $750 per kW
  - Price point for a 30 kW / 30 kWh system cost started around $1850 per kW
  - Goal is to drop below $500 per kW of all system costs (excluding installation)
- Main cost reduction hurdle is inverter cost
  - More competition in that market is needed
  - Expect a 30% decrease in inverter cost, and a 15-20% drop in li-ion cost per year but only if buying at scale
- Green Charge is the only battery company that integrates weather data into its software platform, handling terabits of data
- Also investigating opportunities for secondary life applications of electric vehicle batteries
  - EV cells can be further cycled in a second life 1,000 to 2,000 cycles until the capacity drops from 80% to 60% of its initial capacity
  - Agreement with a large EV company to repurpose their batteries into stationary energy storage
  - Purchasing second life batteries at 25% cost of new, which may allow Green Charge to offer storage systems in cheaper electricity rate states
  - Systems would be 2x the size given lower capacity requirement

Greensmith

- Greensmith provides energy storage software and system integration for storage developers, featuring a technology agnostic platform for multiple applications on both sides of the meter
  - Key selling point: battery management systems provide a necessary protective layer for safety
  - To date, Greensmith has integrated 12 different battery manufacturers and 6 inverter types allowing customers to “mix and match” the technology that suits their needs
  - Consequently, Greensmith is reflective of the market having integrated 4 different battery chemistries with lithium ion being the primary battery type
- Deployed a 20 MW system in the Lee/Dekalb counties – a merchant based system that plugs into PJM’s transmission grid
  - ComEd involved with connection, but storage system provides frequency regulation at the transmission grid level (not considered a distributed customer-sited project within scope)
- 2014 was a “landmark year” for grid-scale storage with renewable developers entering the energy storage market
  - Greensmith commissioned more than 23 MW of grid-scale projects utilizing the company’s GEMS energy storage software platform with an additional 25+ MW in the pipeline for 2015
  - In contrast, behind-the-meter projects with a demand charge based model are difficult to monetize – storage system relies on absolute perfection for meeting peak reduction
- Privately-held, VC-backed company was launched in 2008 and has deployed more than 43 systems for 17 customers (including 9 utilities) to date

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 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
- Nationally there are 1000 ice bear units installed for a total capacity of 10 MW
  - That is increasing drastically because Ice Energy has won contracts with Southern California Edison to provide over 2,000 of Ice Bear units (26 MW) 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)

Invenergy

Invenergy

- Invenergy is an independent power producer headquartered in Illinois with 65 MW of grid-scale energy storage in operation or under construction across 4 sites
  - Two in Illinois (Invenergy Grand Ridge Wind Project BESS 1.5 MW and Invenergy / Xtreme Power Grand Ridge Storage Project 32 MW)
  - One in Texas , one in West Virginia, all participating in the wholesale / ancillary services marketplace
- Using lithium ion batteries positioned as high power, short duration rather than high energy uses, such as:
  - Frequency regulation
  - Automatic generation control (every 4 to 6 seconds)
- The target customer is the electric utility using applications that require 4-5 min energy storage at most
- Invenergy seeks to develop projects, enter into long-term agreements with utilities and successfully project finance them
  - However, lack of understanding in utilizing storage technology is a roadblock to future growth
  - Confusion about storage as a distribution vs. generation asset makes accounting and rate basing storage very difficult

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Ioxus (1/2)

- Ioxus is a manufacturer of ultra-capacitors, which are well-suited for ramp management and VAR support
  - Installation – replace with smaller battery and capacitor with a switch so capacitor provides peak demand and battery provides long term power supply → 33% longer mileage, battery temperature lower, battery lasts 4-8X longer, charge up in 30 seconds
  - Company calculates that installing an ultra-capacitor reduces an 800 amp/hr battery down to 50 amp/hr with a 60% cost reduction
- Geographically, Ioxus has sold a product to utilities in Europe for a feasibility study – 15 MW 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
  - US uses lithium ion batteries for start stop and rest of world are not – ARPA E and lobbying for batteries is huge roadblock to capacitors
  - Sold to couple hundred customers – most of work is project based
- Ioxus manufactures in the US but has few sales
  - 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), but most utilities / grid operators are unwilling to pay for the R&D and few engineers know the technology well

Ioxus (2/2)

- Most products geared towards industrial and transit market – rail, bus, forklift, automated vehicles in factories, system level UPS
  - 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 UPS 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 PE companies

NEC Energy Solutions

- NEC acquired the grid and commercial battery systems unit from a A123 solutions, a lithium iron phosphate (“nanophosphate”) manufacturer
  - Use A123 power and energy cells but have systems in design with other chemistries
  - Commercial business is lead acid replacement modules – car battery or small UPS system under desk for example; life of li-ion is 3-4x longer despite higher cost
  - Grid storage solution sells power systems – frequency regulation, smoothing and ramping of wind/solar, short 15 min duration from charge to discharge, usually only swing of charge 5-10% with high power
- PJM – 20 MW in Ohio doing frequency regulation, 2 MW in PA (demo system), Laurel Mtn, WV 32 MW; systems owned by AES which is an independent power producer
  - Lots of interest in Illinois – NEC worked closely with Glidepath/RES Americas on 2 projects of 20 MW connected to transmission voltage
  - Starting to see peak demand savings/ load shifting in CA but need modification in system design
  - Thinking that battery prices will come down but inverter prices won’t come down – racks and cooling and containers aren’t going to drive price decrease
- NEC’s battery system includes an over-riding management platform, 7 different levels of safety and security – battery cells don’t experience thermal runaway and don’t rapidly disassemble
  - Systems are very modular – modules, trays, racks, etc with safety measures in each scale to take system offline when it malfunctions
  - Come equipped with alarming system, fire protection system
- Obstacles to growth include: economics of the projects and lead time to get interconnection permits
  - No installations yet for data centers in the MidWest
  - Considering a new project: batteries built into data center equipment
  - Smaller scale –storage systems in substations to support peaks, outages, and other applications

POWERTHRU

- POWERTHRU designs, manufactures and markets advanced flywheel energy storage systems that provide ride-through power and voltage stabilization for power quality and power recycling applications
  - Designed to provide high-power output and energy storage in a compact, self-contained package, POWERTHRU flywheel products are a long-lasting, low-maintenance
  - The company shipped its first commercial production flywheel in 2004
- Lightweight, and environmentally-sound alternative to flooded and valve regulated lead-acid (VRLA) batteries in uninterruptible power supply (UPS) systems
  - Provide critical ride-through time between the power outage and the generator coming online.
  - Continuous power during brief utility disturbances without impacting the capacity and expected lifetime of the flywheel
- Around 1500-2000 units installed worldwide
  - Midwest ISO has some of our flywheels installed in their data center, but they are not considered large enough to support the grid
  - Units installed in Indiana, Michigan and Wisconsin, but don't know of any in Illinois
  - Met with Detroit utility that doesn't think POWERTHRU flywheel is large enough for them
- The POWERTHRU PT190 can provide 190 kw for 10 seconds, so it's great for an industry that experiences dips and sags in the power
  - Batteries degrade with every discharge, but flywheels do not, so that makes them perfect solutions to power quality issues

S & C Electric (1/2)

S&C ELECTRIC COMPANY
Excellence Through Innovation

- S&C electric was founded in 1909 by two former ComEd who invented a new type of fuse
  - Private company, now employee-owned, continues to serve utilities as the largest customer segment, also C/I
  - Business is half in US, half rest of the world - 2 dozen projects connecting over 150 MW of capacity
- S&C manufactures its own inverters and does the integration of battery systems to inverter and EPC installation
  - Buy battery cells from 3rd party vendor
  - Sodium sulfur batteries use S&C inverter, sodium nickel chloride, lithium ion, and lead acid
- There are a wide variety of use cases
  - Demonstrate automatic islanding and peak shaving, which requires a robust control platform to manage all applications
  - Also: voltage control, power factor correction, solar smoothing/ramping
- Sales team grew up in the utility world, so that's the majority of S&C's energy storage systems to date; produced MW-scale systems for over 10 years
  - Also 25 kW community energy storage system between step down transformer and the load
  - S&C has not yet deployed systems to ComEd or ComEd customers yet
- Launching 250 kW system now – same functionalities but compact footprint of 3 x 3 x 6 feet; provides voltage support and power factor correction
  - Accustomed to "mission critical" applications with < 1/60 of a second to prevent millions of dollars in losses

S & C Electric (2/2)

S&C ELECTRIC COMPANY
Excellence Through Innovation

- Core technology that our inverters use are used by our UPS systems which go exclusively to commercial and military/government customers
  - Battery cell drives the economics and long-term performance, but the interaction with the system is inverter and software controls
  - As a customer the way you gain visibility and mgmt of the system is through control software package which comes standard on our inverters
  - Ability to design not just storage system but also interconnect to the grid and provide switch gear to do that is a nice advantage and full turnkey solution
- Frequency regulation for large C/I (in PJM and maybe MISO, ERCOT) is the value proposition that makes the most sense today, also customers with high demand charges
  - As business models change towards DER, demand charges may become a bigger portion of bills, which requires more energy storage
  - Solar ramp control is big opportunity but no market structure in place to account for it yet – proper market structure is a greater driver of growth than incentives
- Future of industry: battery companies that can take single cell and make it work in transit and stationary application (e.g., Tesla, Samsung and LG)
  - More creative financing solutions in the future
  - Hawaii is a test bed for showing how a large penetration of solar strains the grid and will benefit from storage applications

SiNode Systems

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

- High electricity prices incentivize storage because customers start thinking about shifting their peak demand
  - Market-wise, Illinois and the Midwest have the lowest electricity rates in country (also why solar penetration is low); this is a benefit of so many nuclear plants
  - As a result, target market for end system is outside Illinois

SustainX (1/2)

- SustainX is an 8-year old, venture-backed manufacturer of isothermal compressed air energy storage (ICAE) technology, which enables a “site-anywhere, zero-emissions storage solution”
  - Compressed air at ambient temperature can be stored until needed with minimal energy losses
  - When power is needed, isothermal expansion can deliver electrical energy with no requirement for natural gas combustion (i.e., operates more like a battery)
- Primary product offering is a 2 MW module so a 10-20 MW project uses this as a building block with two air storage options
  - Small scale – steel pipe
  - Large scale – natural gas storage (lined rock cavern) used for 4-10 hr mid-duration range or if want longer duration go back to traditional storage (salt)
- SustainX operates a 1.5 MW full-scale prototype at its headquarters in MA; General compression has a 2 MW system in TX
  - Primary market is 10- 50 MW scale; T&D utility, IPP / renewable developer, or large industrial company is the target customer
  - Opportunity in North America (Texas and Ontario); larger opportunity in Asia where there is not cheap natural gas to compete with
  - Capable of expansion into Illinois but not currently active (smaller component suppliers may have had sales however but data not available)

SustainX (2/2)

- SustainX is in the middle of a merger with General Compression (another company in isothermal CAES), which brings together 2 big groups, they use salt storage options
- Funding: backed by VC, PE, and equity funding from strategic investors (GE is one)
- Key features of technology – delivers high energy but allows flexibility in terms of duration that you wouldn't get with batteries
  - Large, scalable, more distributed storage solution than conventional hydro or traditional compressed air
  - Not as fast in our power control but can still deliver in 1-2 second timeframe (better than typical compressed air); much faster cold start times (< 60 seconds)
  - CAES also requires the appropriate geology, which makes project siting a challenge
- SustainX's product pairs wind or other renewables with a 4-6 hr up to 100 hr storage solution to deliver schedulable and dispatchable storage
  - Focused more on capacity issues, T&D or grid asset upgrade substitution
  - Scale of project determines price point – $1200-1500 dollars per kW on average

UniEnergy Technologies (1/2)

- UniEnergy Technologies (UET) has developed a vanadium flow battery storage system
  - Delivers up to 600kW peak power and 2.2MWh energy in a footprint of only five 20' containers
  - Affiliate produces electrolyte using UET's patented new generation vanadium electrolyte
  - Siemens provides the control platform but also have some in-house software
- PE funded by a group investing in vanadium flow companies for over 10 years
- Use case: t**ime shifting (peak shaving) simultaneously with short duration** (i.e., frequency regulation that PJM is paying for) and renewable integration
  - Battery has response time < 100 ms and a long cycle life without drop in capacity factor
  - Market now is recognizing a different set of use cases for long duration storage
  - Outcompetes lithium ion for durations longer than 2 hours on the basis of levelized cost of storage (LCOS) – Lithium also has a lower state of charge
- UET target geography is HI, AK, TX, CA, Ontario, Germany, China, UAE, Jordan, Turkey, and South Korea
  - Some interest in the Chicago area, but lots of "oxygen" has been taken by frequency regulation of PJM
  - Awareness of other territories and having systems installed (e.g., "iron in the ground") is expected to speed up development in North America

UniEnergy Technologies (2/2)

- 2015 pipeline includes $10 million with 3.5 MW; scaling up manufacturing to produce up to 100 MW per year
- Target customer is a utility, C/I, microgrid with existing installations:
  - Already has a 1 MW installation on Schweitzer lab microgrid
  - Installed by Avista IOU which is advanced with its smart grid
  - Installing a 500 kW system in next 2 months in CA with SGIP and demand charge reduction + integration with cogeneration facility (customer side of the meter)
  - Industrial park site with interconnection of a 20 MW battery (PG&E)
- For utilities, a 50 MW gas peaker plant only delivers 25 MW peak capacity, whereas a 60 MW gives you 100 MW of capacity – IRP should look at flex of battery to serve as both load and generation
- Challenge is demonstrating and validating the technology
  - First generation vanadium flow batteries weren't energy dense enough and sensitive to temperature (vanadium salt solution would precipitate)
  - Now in its 3rd generation battery system

ViZn Energy

- ViZn develops a commercial zinc iron redox flow battery that provides 2-4 hours of capacity (long duration)
  - Technology was originally developed by Lockhead under DOE research
  - Targeting two products – 50-100 kW and 250 kW scale
- Target geographies include island / microgrid communities (if > 50% power is from diesel, then strong case) or mining / industrial situations (punishing environments for a li-ion battery with high cooling requirement)
  - PJM is purely ancillary services market, whereas flow battery works better where there is a capacity need
  - Microgrid project in IL could generate a need for the battery
- Currently ViZn is launching demonstration projects
  - 300 kW deployed with the intent to put in 4 MW and 2 hours (approximately 10 MWh, 75% of which is overseas, 25% in US)
  - Seeing batteries for T&D support and power quality issues
  - Also critical power needs or trying to “green up” manufacturing for C&I customers
- Additional selling point is 10 to 20 year life – this is a focal point for utilities
  - Storage has more value the closer we get to the load
  - Very compelling option for vertically integrated utilities, but compensation schemes and regulatory environment have not yet been vetted out
- Funded completely through private high net worth individuals, $25M raised to date
  - Goal is to be the battery supplier; working with inverter companies, system integrators, etc – may move to an end-to-end business model in the future with additional funding

ZBB Energy (1/2)

- ZBB (zinc bromide battery) is an Australian company that went public in 2008 and acquired its recent flow battery technology from Johnson Controls in 2010
  - Technology is an aqueous electrolyte composed of zinc bromide salt dissolved in water
  - ZBB's controls system is unique in providing distributed generation with the ability to switch AC/DC simultaneously behind-the-meter
  - Software and controls provides a turnkey solution to SMB, C&I, and utility customers
  - Moving to sales of entire systems with power electronics and storage
- Systems are scalable from 50 kW up to multi-megawatt batteries and focused on 2 markets: C&I behind the meter and utility customer
  - Deployments for microgrids/ resorts, some are grid interactive, smart buildings and system can interface with JC or Honeywell
  - Utility tend to be very large batteries (CA bids now), 5 MW- 50 MW installations, tend to focus on long discharge requirements
- Installed systems at ~ 30 locations worldwide with about 6 MW of installed capacity
  - Joint venture in China (grid scale), partner in South Korea, rest of focus in North America (Hawaii, CA, East Coast and islanded areas)
  - Most US utilities want to buy storage and put it on their substations to avoid negative pricing, all would buy storage if they had a way to rate base it
  - Involved in TX with Oncor – want a 3 hr discharge time which is ideal for large flow batteries

ZBB Energy (1/2)

- 1 installation in Illinois: 250 kW / 500 kWH energy (2 hour power duration) storage system for use in a micro-grid application for the Galvin Institute's "Perfect Power" system at the Illinois Institute of Technology campus
  - Demo facility used to charge at night and discharge battery onto microgrid during the day
  - Additional sales anticipated in Chicago and Gary, Indiana
  - Well-suited for large industrial buildings, but not a lot of solar energy penetration in IL or WI

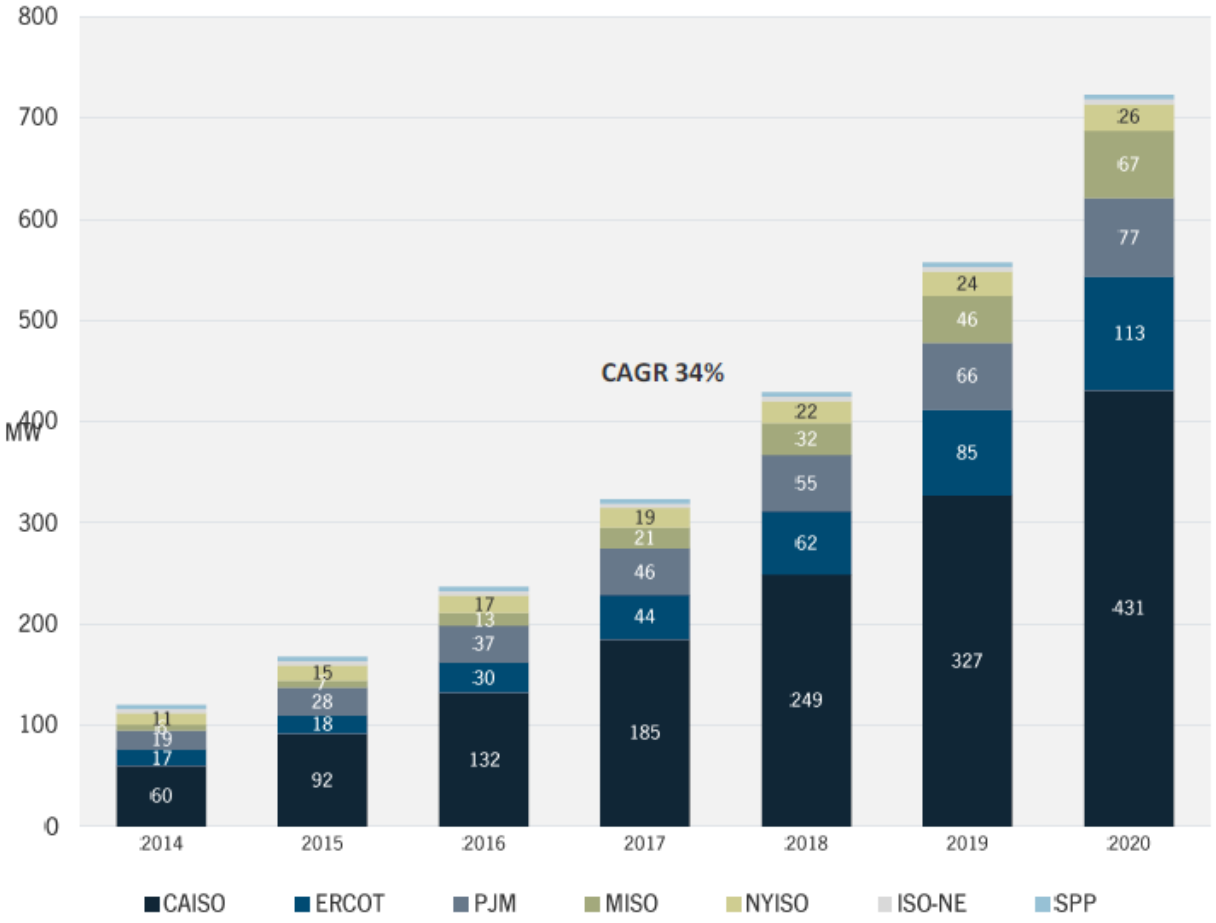
- ZBB has flexibility to enter the market in multiple ways
  - Recently signed a PPA in Hawaii, installing solar, batteries and selling power to customer below the utility's rate
  - Also sell products to project developers – Invenergy or Duke or Black and Veatch , Chevron or other EPC which are getting serious about storage will buy equipment from ZBB
  - Sometimes ZBB quotes projects directly, other times we work through bigger developers

Appendix II: Grid-Scale Energy Storage

Similar to distributed storage, the commercial, grid-scale energy storage market is poised for rapid growth across the U.S.

The market for commercial energy storage in the U.S. is expected to surpass 720 MW by 2020 up from 100 MW at the end of 2014, representing a 34% CAGR.

Cumulative Installed Capacity by RTO/Region



- PJM will continue to be the fastest-growing market for frequency regulation due to favorable FERC rulings 755 and 748.
- In addition, PJM has been the only ISO where aggregated behind-the-meter resources have been able to participate in frequency regulation market.

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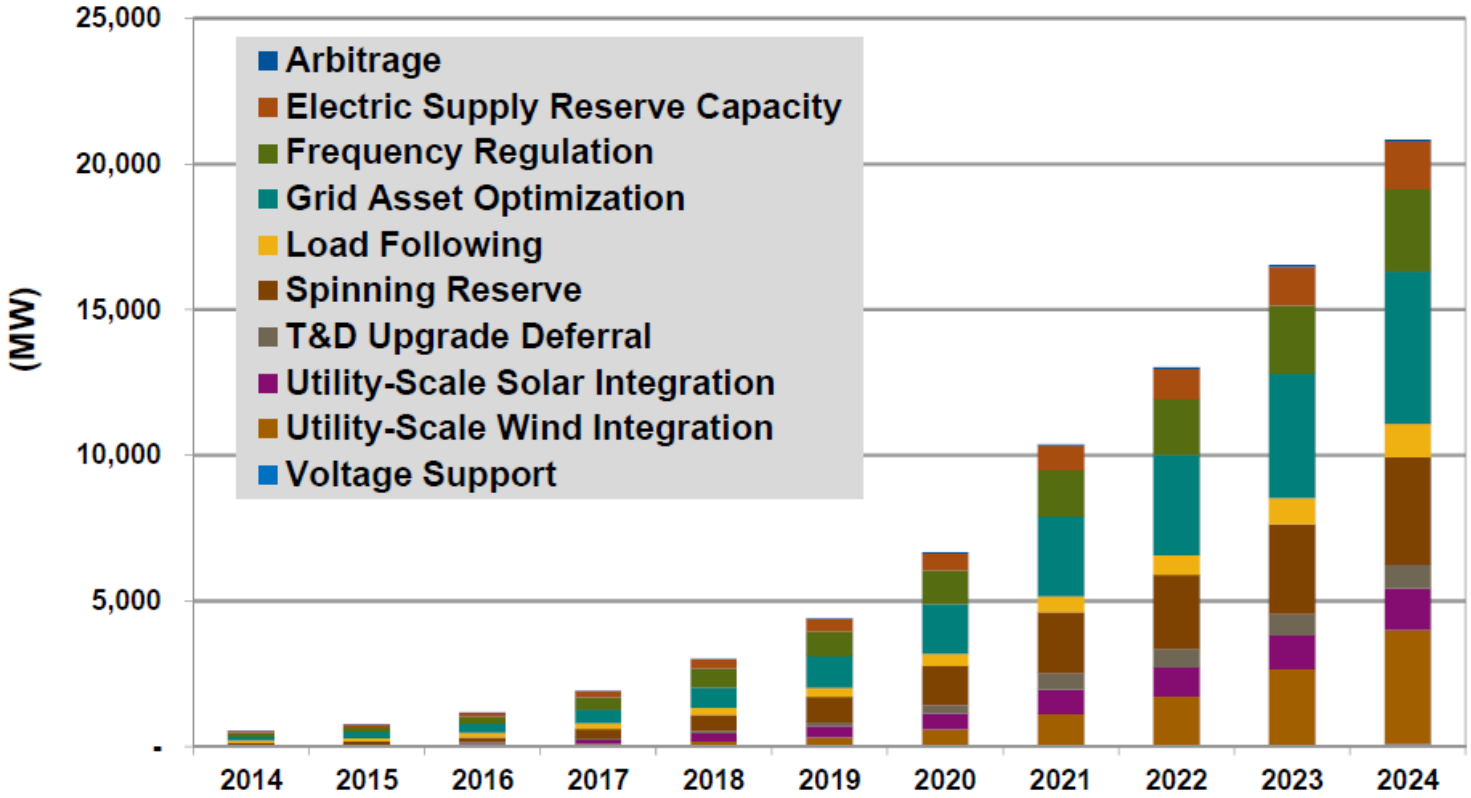
Worldwide, installed energy storage for the grid and ancillary services (ESGAS) is expected to grow substantially over the next decade

Installed ESGAS Power Capacity by Application, World Markets: 2014-2024



Source: Navigant 3Q14

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The following grid-scale energy storage projects connect to PJM through ComEd's distribution grid and provide ancillary services (e.g., frequency regulation) to the ISO

Project Name	Technology Type	Rated Power in kW	Duration HH:MM	Status	Service/ Use Case
Invenergy Grand Ridge Wind Project BESS	Lithium Ion Titanate Battery	1500	0:15.00	Operational	Frequency Regulation
Jake Energy Storage Center: RES Americas	Lithium Iron Phosphate Battery	19800	0:24.00	Contracted	Frequency Regulation
Elwood Energy Storage Center: RES Americas	Lithium Iron Phosphate Battery	19800	0:24.00	Contracted	Frequency Regulation
S&C CES: Chicago/PJM Frequency Regulation	Lithium Ion Battery	150	0:0.00	Operational	Frequency Regulation
Moheny Energy Storage Center: Glidepath	Lithium Iron Phosphate Battery	19800	0:24.00	Proposed	
Invenergy / Xtreme Power Grand Ridge Storage Project	Lithium Ion Battery	32000	N/A	Proposed	
NextEra Lee/Dekalb Project	Lithium Ion Battery	20000	N/A	Proposed	

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Denotes storage project is proposed or in plenary stages

Source: U.S. DOE Energy Storage Database

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