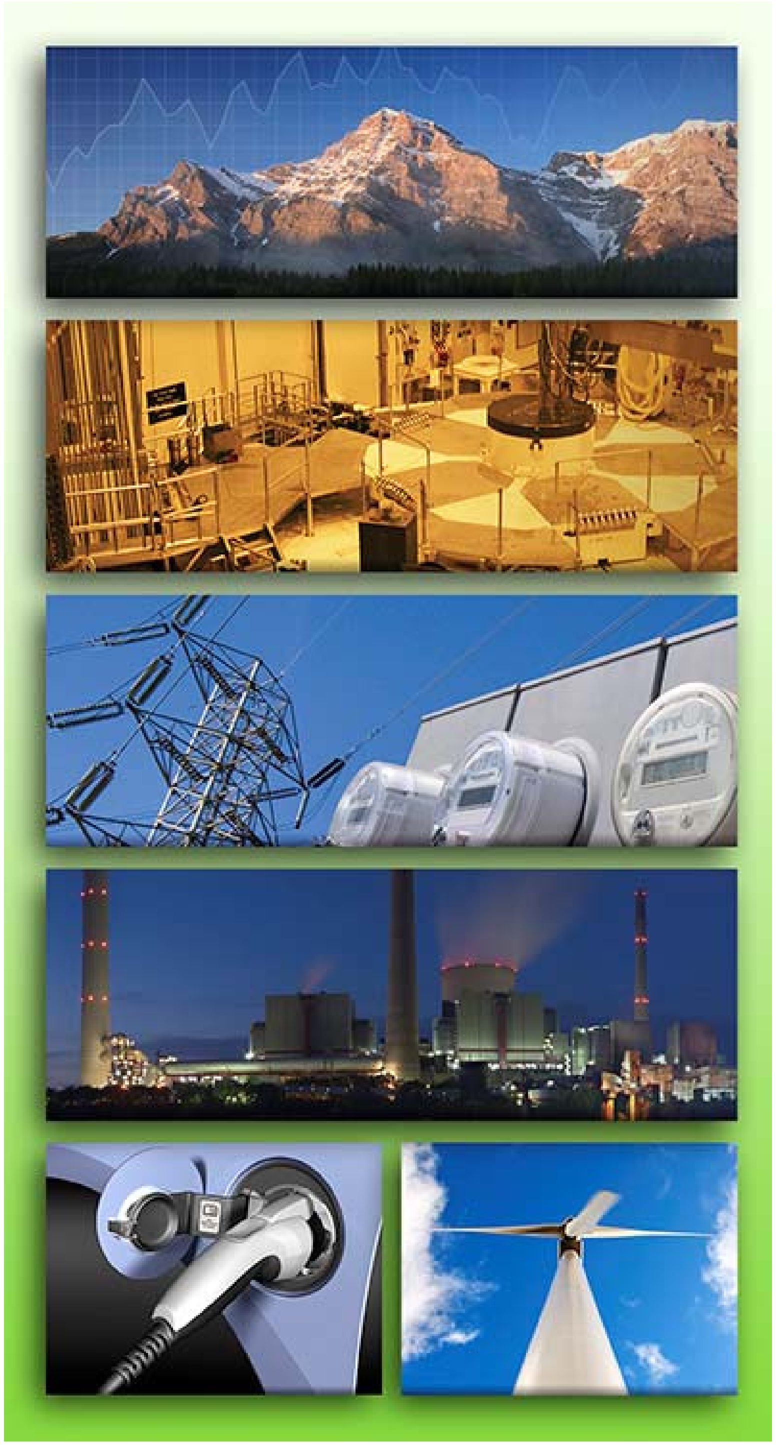

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Impacts of Energy Storage Systems in Addressing Regional Wind Penetration:

Case Studies in The New York Independent System Operator and Electric Reliability Council of Texas

Interim EPRI Report: 1020082

December 2010

EPRI Project Manager

Dan Rastler

Energy Storage Program

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Product Description

Optimal use of electric energy storage systems is expected to play a key role in supporting wind integration, relieving transmission and distribution (T&D) congestion, and improving the balance of supply and demand. However, there have been very limited assessments of what types and sizes of storage systems are optimal and what locations are the most promising. In 2009, an EPRI initial assessment of energy storage in ERCOT (EPRI report 1017824) recommended more regional market simulation studies to further the understanding of the role and benefits of energy storage to support renewable integration. This project evaluated the Independent System Operator (ISO) system benefits of bulk and distributed energy storage system deployment under regional specific wind penetration scenarios in the PJM, NYISO, and ERCOT markets to assess the role and value of energy storage options and address key research questions on the role and value of wind to support wind integration.

Product Description

Results and Findings

These case studies show that transmission congestion can play a key role in siting compressed air energy storage systems (CAES). The economic performance of CAES depends on capital costs, the price of natural gas, and the ability of CAES to participate in day-ahead ancillary energy service markets. Larger CAES systems (800-2000 MW) that use multiple trains and larger compressors should be analyzed, as they would enable more opportunities to participate in day-ahead markets.

Bulk and distributed storage systems can be potentially sited at or near transmission congestion nodes to improve wind integration and ISO System Benefits. Although analysis of distributed storage deployment illustrates their potential value to ISO systems, owner benefits are low assuming a 10% discount rate and a high-cost structure for battery systems. Given the benefits to ISOs that would result from targeted siting of distributed or bulk storage systems, a mechanism should be considered where ISO benefits could be monetized by owners of distributed storage systems.

Product Description

Challenges and Objectives

The objectives of these case studies included:

- Estimating the value and role of different energy storage options in addressing regional wind penetration estimates with a focus on compressed air, bulk battery, and distributed battery systems
- Estimating how much additional renewable integration is possible using energy storage
- Assessing the relative economics of energy storage systems vs. other fossil generation options
- Assessing the critical variables that influence the role of storage—market rules, generation mix, T&D robustness, types and sizes of loads, location of wind relative to load
- Estimating the impacts of different energy storage portfolios on production costs/benefits and greenhouse gas (GHG) emissions
- Assessing the role of energy storage in minimizing the thermal cycling of base load generation and estimating the CO2 emission impacts of energy storage
- Using the research findings to more clearly define the technical, performance, operational and functional characteristics of storage systems to support renewable integration

Product Description

Applications, Values, and Use

Electric utility strategic planners, resource planers, renewable managers, R&D managers and Independent System Operators can use the results of this work to plan and implement strategies in bulk and distributed energy storage solutions for renewable integration. The research findings will also help set the further direction for more detailed studies and market simulations

EPRI Perspective

Further investigations of bulk and distributed storage systems in congested transmission nodes, i.e. with high locational marginal prices, should be undertaken in concert with Load Serving Entities (LSE). Future studies should undertake integrated analysis of distributed storage systems and their benefits to LSEs and ISOs. Additional regional integrated storage, transmission, and bulk generation market simulations should be conducted under higher wind penetration scenarios like those envisioned in under EPRI's Prism 2.0 modeling activities.

Product Description

Approach

The project team selected the PJM, NYISO and ERCOT systems for energy storage system assessment, including compressed air energy storage, bulk batteries, and distributed battery systems. Each of the ISO studies involved only a single study year. The team conducted market simulations using the UPLAN market simulation model and its underlying suite of databases as the analytical platform with EPRI providing estimates of the cost and performance of energy storage options. Inputs from PJM, NYISO and ERCOT provided inputs in terms of wind penetration and location and the transmission grid configuration for the study year. Multi-year analysis, high wind penetration scenarios, and CAES site optimization were beyond the scope of this research study.

Keywords

Wind integration
Bulk energy storage
Distributed energy storage
ISO market simulations

Analysis of Energy Storage Systems to Address Regional Wind Penetration in NYISO and ERCOT

Executive Summary

Introduction

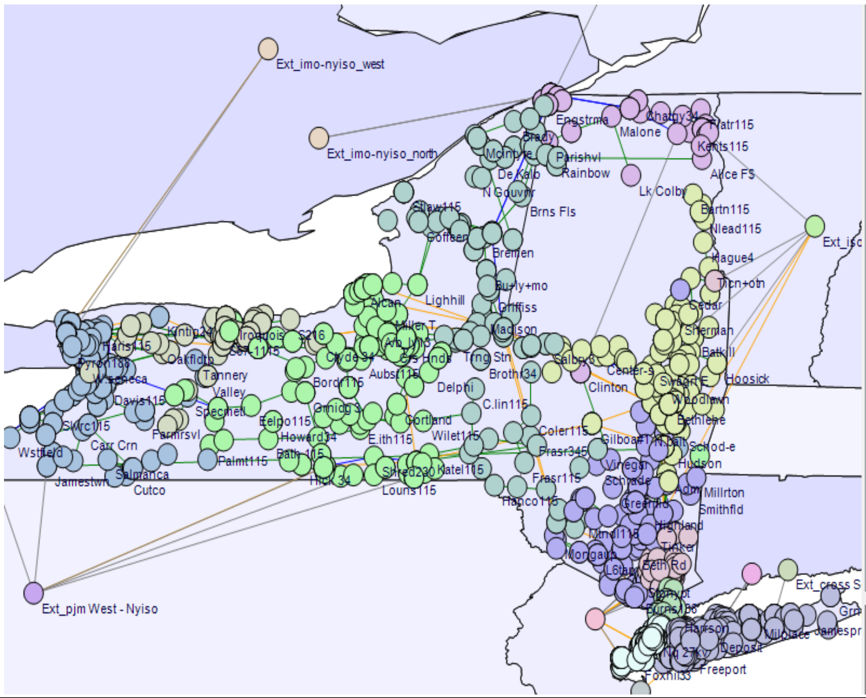
Electricity storage systems may play a pivotal role in overcoming the grid operational challenges of variable renewable generation. Optimal use and placement of electric energy storage systems could play a key role in supporting wind integration, relieving transmission and distribution (T&D) congestion and improving the balance of supply and demand. However, key research questions remain un-resolved regarding the impacts of storage to support wind integration, specific storage systems characteristics and requirements, and the location and dispatch requirements of energy storage systems to support renewable integration while providing storage system owners with a reasonable return on investment.

There have been very limited in depth regional analysis with integrated portfolio and T&D grid simulations to estimate the impacts of storage, what types of storage systems are optimal and what locations are the most promising. In 2009, EPRI conducted an initial assessment of energy storage in ERCOT (EPRI:1017824). A key recommendation from that research report was to conduct more in-depth market simulation studies to further the understanding of the role and benefits of energy storage to support renewable integration.

In setting up research project, EPRI collaborated with NYISO staff who provided input regarding the study year, the amount of wind penetration, and details regarding the the Transmission Network configuration for the study year.

Executive Summary
Analysis of Storage Systems in NYISO

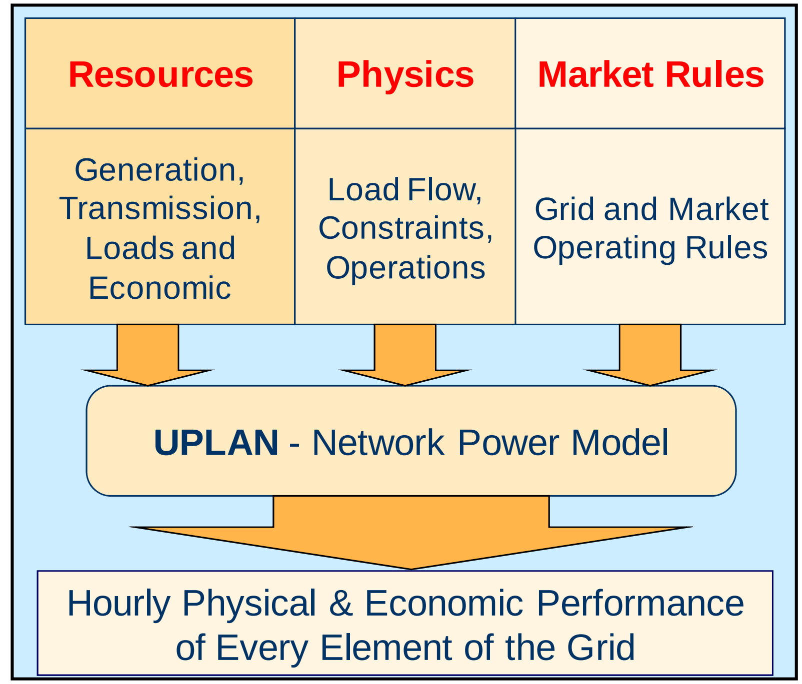
NYISO Simulation



Study Year: 2013	
Demand / Generation Mix	
Transmission Topology	
Commodity Prices	
Wind Additions: 4.2 GW	

Executive Summary – Market Simulation Approach
UPLAN Simulation Model[1]

- UPLAN uses marginal cost based generator offers and opportunity cost based offers for A/S, storages and other secondary resources to determine nodal Locational Marginal Prices.
- One year of hourly nodal prices at the bus where storage is located are generated; Hourly storage operation is optimized using linear programming;
- Monthly net income is maximized which equals revenue minus charging cost, fuel cost, and emission cost;
- The scheduled hourly charging MW is treated as load and added to the storage bus
- The scheduled hourly discharging MW is treated as the storage maximum available capacity in the unit commitment and dispatch.
- Impacts of Storage Portfolio is the difference from a Base Case (no storage) and the UPLAN Storage Portfolio Case.

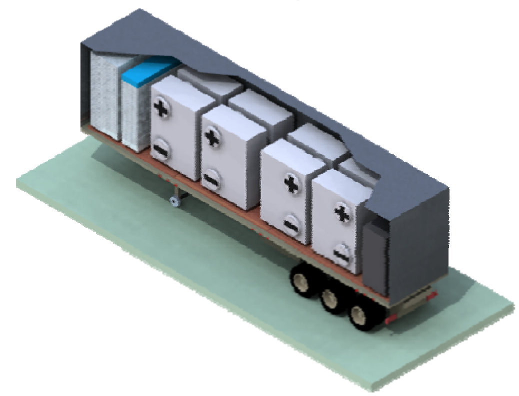


UPLAN enables a detailed, granular simulation of market dynamics based on characterization of generators and the transmission network along with realistic representation of market protocols.

UPLAN Network Power Model

http://www.energyonline.com/products/uplane.asp

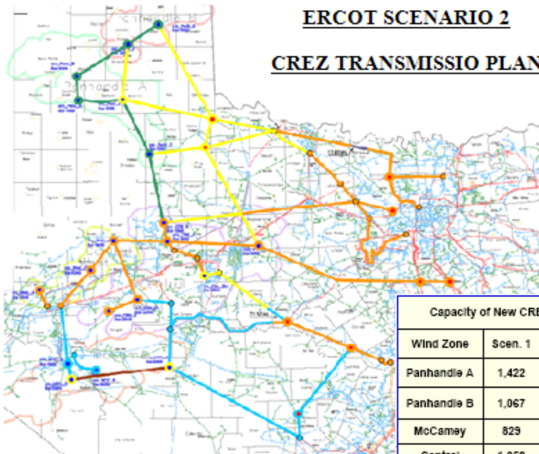
Executive Summary – NYISO
Energy Storage Portfolios were Analyzed



Compressed Air Energy Storage	Bulk Battery System	Distributed Battery
	150 MW x 1	1 MW x 400
150 MW		
20-30 hrs	6 hrs	2 hrs
3950 Btu kWh*	80% ac-ac eff.	85% ac-ac eff.
0.75 Energy Ratio		
$ 700 - $ 1000 / kW	$ 1200-$1500/kW	$ 1200-$1500/ kW

* A non-fuel CAES cycle was also analyzed

Executive Summary- ERCOT



Capacity of New CREZ Wind by Scenario (MW)

Wind Zone	Scen. 1	Scen. 2	Scen. 3	Scen. 4
Panhandle A	1,422	3,191	4,960	6,660
Panhandle B	1,067	2,393	3,720	0
McCamey	829	1,859	2,890	3,190
Central	1,358	3,047	4,735	5,615
Central West	474	1,063	1,651	2,051
Total*	12,053	18,456	24,859	24,419

* Assumes 6,903 MW of existing wind capacity

ERCOT CREZ Scenario 2	Advanced Bulk Battery
Study Year: 2015	24 MW
Assess dispatch in ERCOT	2 hr
Assess cycles and life	90 % ac-ac eff
Assess owner & ISO values	$ 800-$1200/ kW
Battery sited near wind farm	

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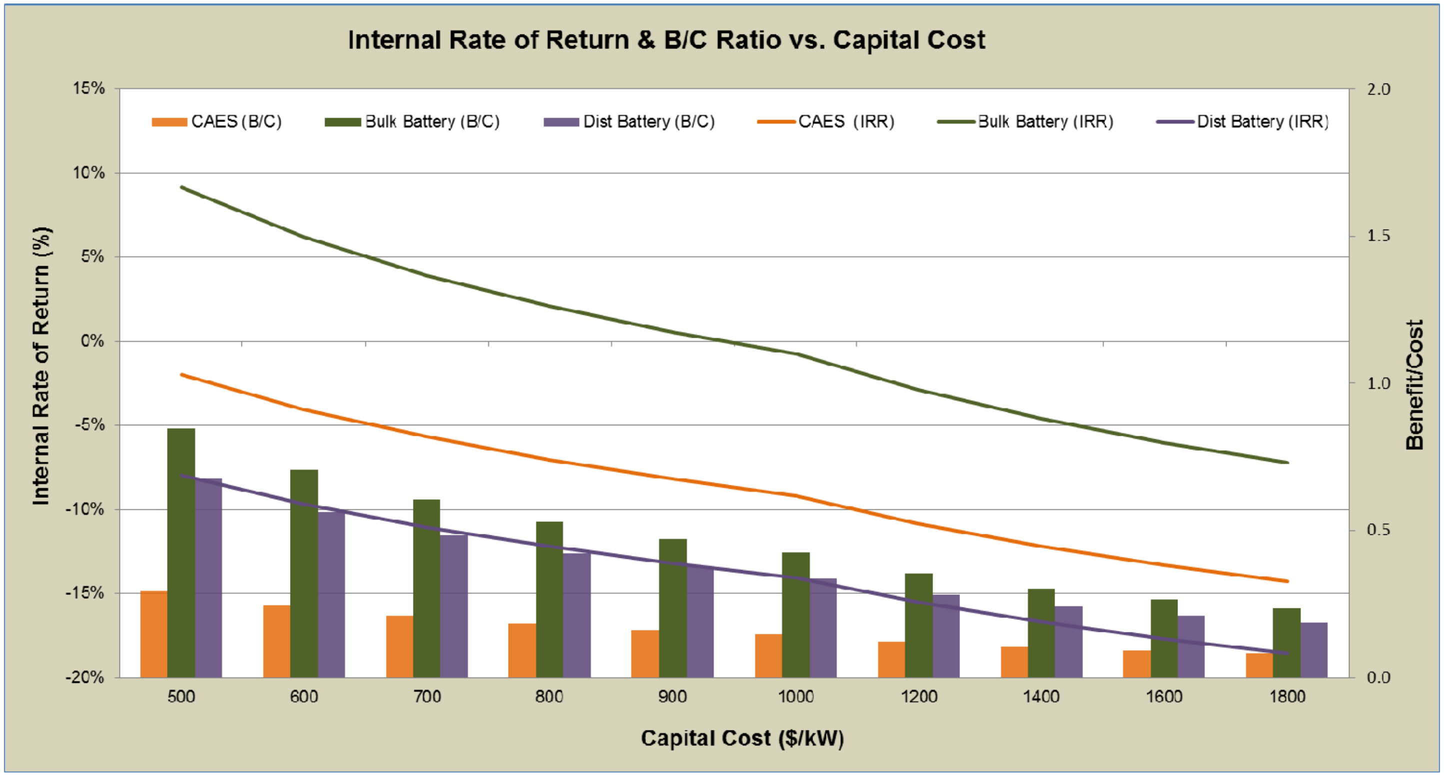
Executive Summary

The assessment of the energy storage systems included in this interim report for NYISO and ERCOT was carried out for the following cases:

- Base Case: Base case simulation (without any storage systems)
- CAES: Compressed Air Energy Storage Analysis for NYISO
  - NYISO – A 150 MW CAES unit was located in Greenidge, New York
  - Summary 2009 EPRI CAES study in ERCOT EPRI:1017824
- Bulk and Distributed Batteries: Battery Storage Analysis
  - Bulk Battery (NYISO) – This scenario replaces the NYISO CAES scenario with one 150 MW bulk battery.
  - Distributed Battery Storage (NYISO) – This scenario employs 400 x 1 MW in NYISO placed at different demand buses across all the zones
  - Summary 2009 EPRI Battery study in ERCOT EPRI:1017824.
- Battery Life Cycle Analysis in ERCOT:
  - Bulk battery in ERCOT – 2 x 24 MW batteries located at ERCOT wind buses combined life cycle optimization with energy and A/S revenues.

NYISO Storage Case Results
Executive Summary – Study Year 2013

Analysis of Owner Benefits for all the storage Technologies



- Operating life of 15 yrs
- Discount factor = 10%
- Overall Benefit / Cost = PV Net Income / Capital Cost
- The Bulk Battery is placed at the Greenidge and Meyer Bus

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NYISO Storage Case Results
Executive Summary – Study Year 2013

	Optimize Day Ahead Schedule (DAS)			
	Compressed Air Energy Storage @Greenidge (CAES)	**Bulk Battery @Greenidge**	**Distributed Battery**	**Bulk Battery @ Meyer**
Energy Rev	**16.01**	**13.49**	**9.93**	**13.50**
Regulation Up	1.99	5.94	1.12	6.12
Regulation Down	1.75	1.95	0.76	2.03
Spin	0.05	0.13	1.69	0.15
Non-Spin	2.15	1.97	-	1.95
A/S Rev	**5.94**	**9.99**	**3.57**	**10.24**
Capacity Rev	**0.52**	**0.47**		**0.46**
Total Rev	**22.47**	**23.95**	**13.50**	**24.19**
Fuel Cost	15.81	14.55	7.05	14.54
VOM	1.09	-	-	-
FOM	1.04	-	-	-
Emission CO2	0.27	-	-	-
Emission NOX	0.00	-	-	-
Emission SOX	-	-	-	-
Total Cost	**18.22**	**14.55**	**7.05**	**14.54**
Net Income	**4.25**	**9.40**	**6.45**	**9.66**
Capacity Factor	**20.79%**	**19.57%**	**3.30%**	**19.57%**

*All values are in $ millions

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NYISO Storage Case Results Summary - 2013

	CAES - Greenidge ($ million)	Bulk Battery - Greenidge ($ million)	Distributed Battery ($ million)
Producers' Benefits	-46.8	-23.5	-12.3
Consumers' Benefits	46.5	31.4	20.7
Total NYISO System Benefits	-0.3	7.9	8.4

The percent change in System Benefits is very small compared to total system cost of $7 billion. Low societal benefits are also due to increases transmission losses.

*** Production cost savings/Net Societal Benefit = Change in NYISO system-wide generator production costs + purchase costs - sales revenues**

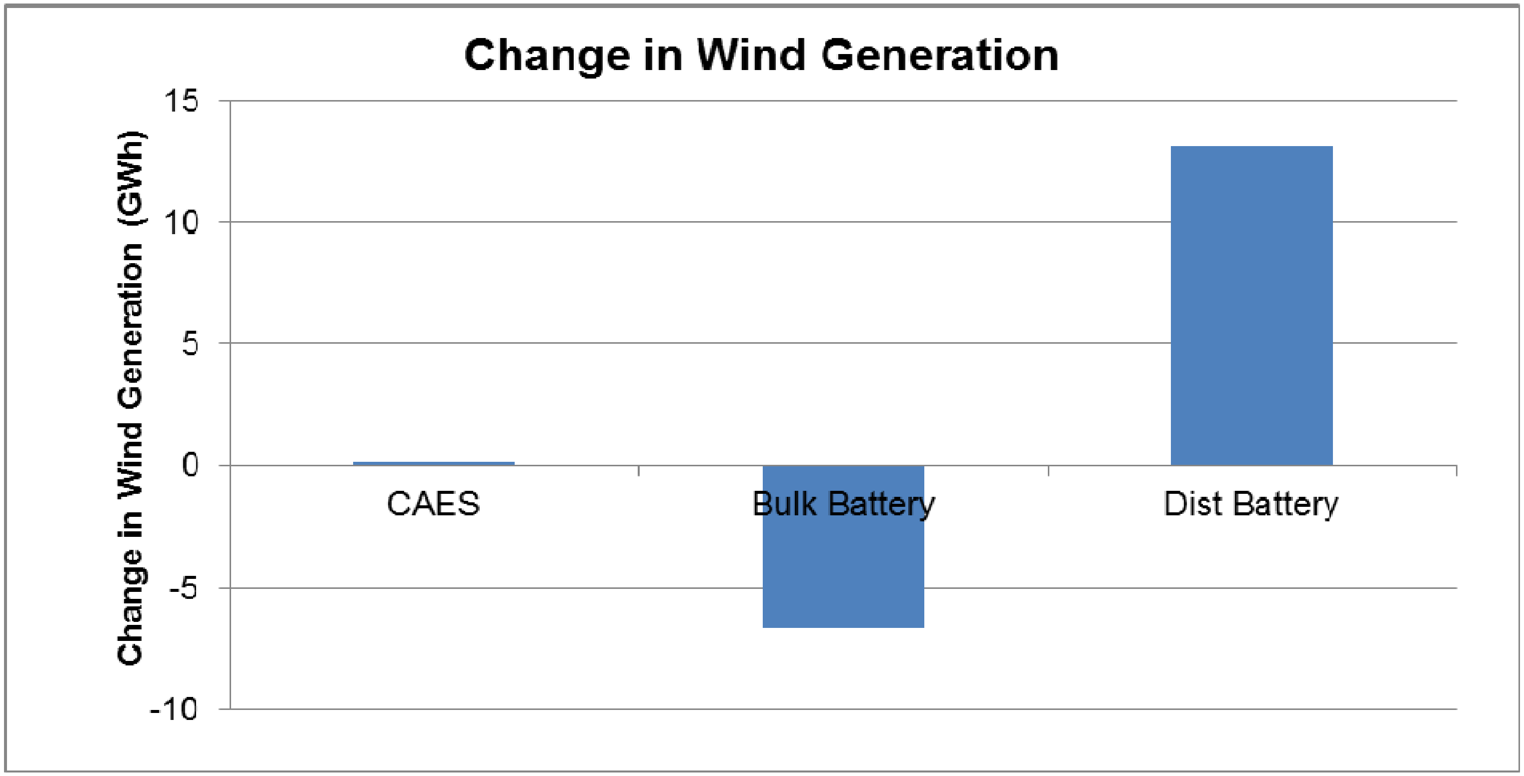
Producer Surplus = Generator Revenues – Generator Costs

Consumer Surplus = Change in Consumer Payments

NYISO Storage Case Results
Impact on Wind Generation in 2013

Distributed batteries increase wind generation.

CAES and Bulk Battery have limited impact on wind generation



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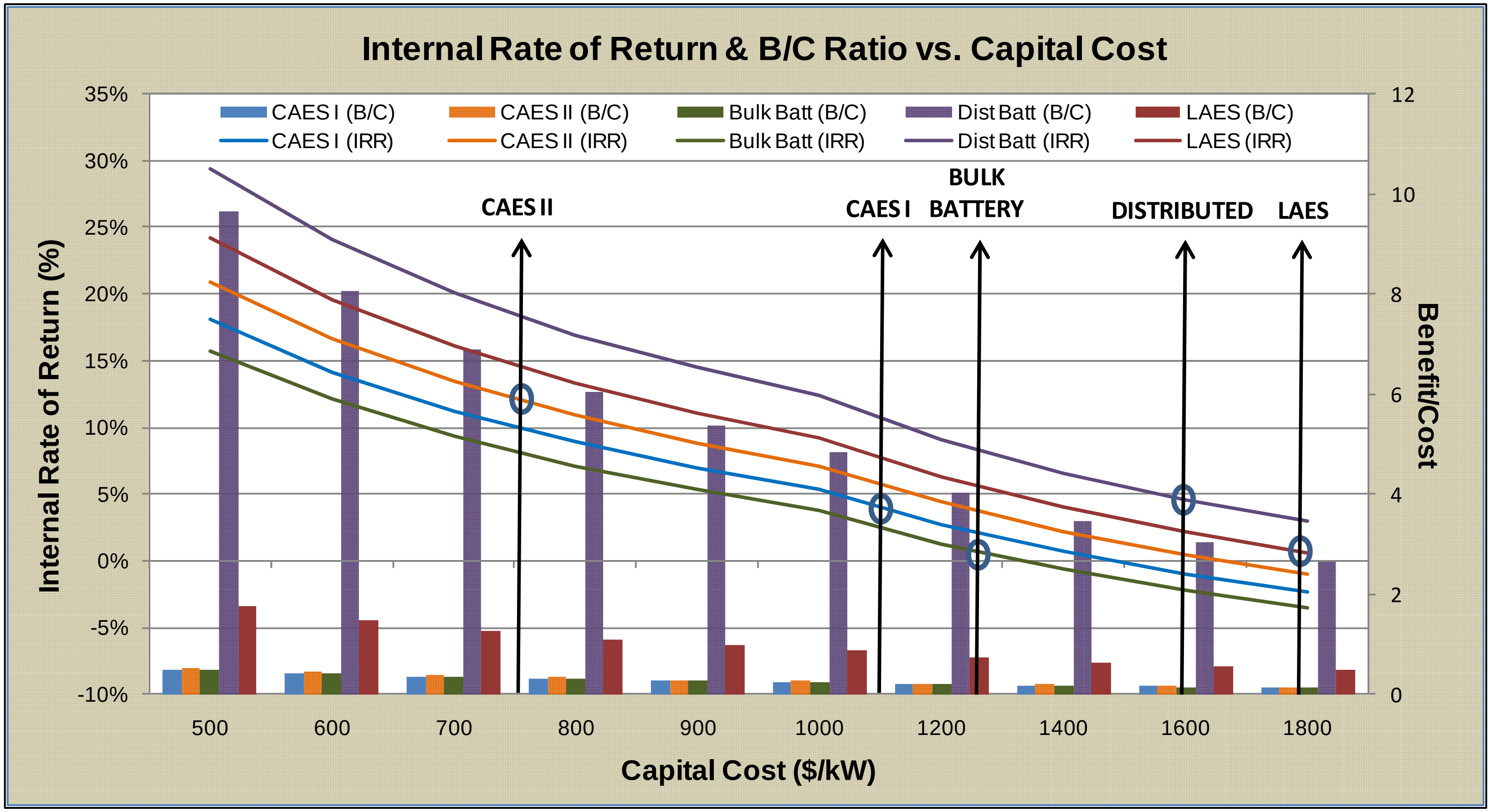
ERCOT Battery Storage Case Results – Study Year 2015

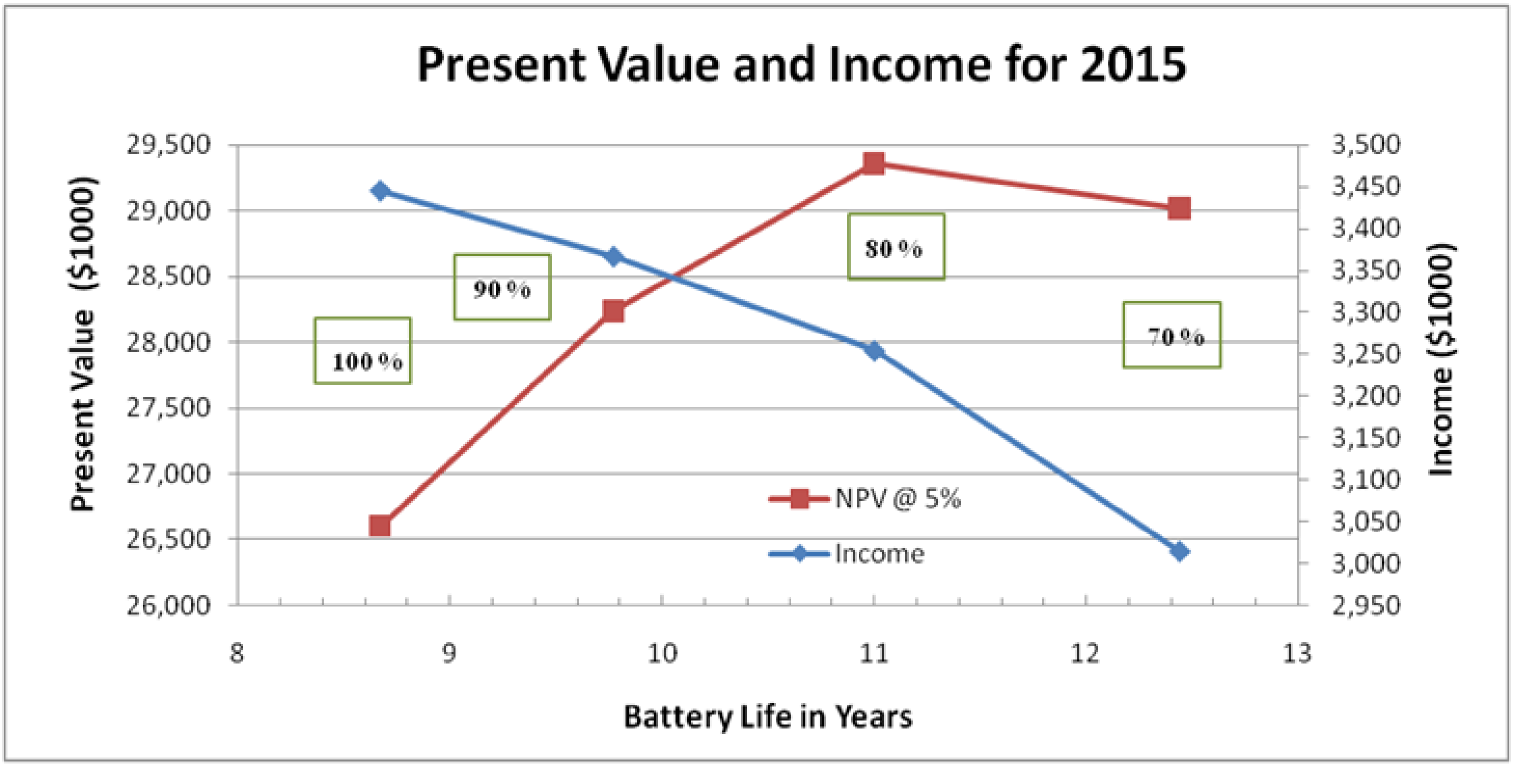
Executive Summary – ERCOT Storage Study (From EPRI:1017824).



The 2009 study examined the role and value of CAES, Bulk Battery, Distributed Battery (Dist Battery) and Liquid Air energy Storage Systems (LAES)

ERCOT Battery Storage Life optimization Case Results Executive Summary

Key Result: Present value and Net Income at various battery life. The battery life depends on the operating state of charge (SOC). For example, at 80% SOC, the battery life is 11 years and Net Income is about $3.26 million with a NPV of $29.4 million over 11 years.



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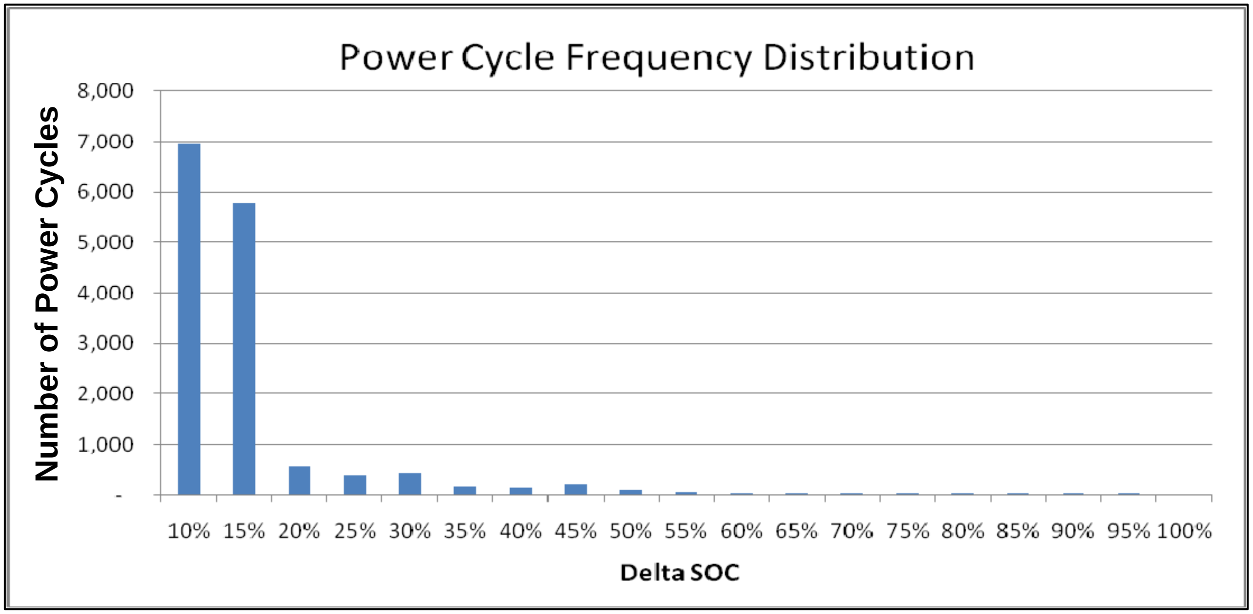
ERCOT Battery Storage Case Results

Number of Power Cycles vs. change in state of battery charge

Power Cycle Frequency is the number of times the SOC of the battery changed. For example, in the graph below, the battery changes its SOC 7000 times at 0 – 10% magnitude. At 10% the life of battery is approximately 250,000 cycles. Therefore, at 7000 power cycles, the unit life is estimated to be 11 years.

For advanced battery to compete, A/S revenue are essential but the high cycles and depth of discharge needs to be carefully modeled to ascertain longer battery life.



Study Preliminary Conclusions – Impacts of CAES

Transmission congestion plays a key role in siting CAES energy storage systems

- The economic performance of CAES depends on: the capital costs; the cost of natural gas; and the ability of CAES to participate in day ahead ancillary energy service markets. Revenues come from a mixture of energy and ancillary services.
- For large scale storage sites further analysis should investigate use of over sized compressors so that the compressors can be used for storing sufficient energy to run the CAES at a very high capacity factors to take advantage of pumping periods with low cost off-peak power. The revenues from additional ancillary services such as non-spin may make CAES systems more economical.
- Larger CAES systems (800-2000 MW) which use multiple trains should also be analyzed as they would enable more opportunities to participate in day-ahead markets.
- The revenues from no-fuel CAES cycles show some promise, which warrants further research for higher wind penetration scenarios than studied. High energy charging ratios for no-fuel CAES cycles may limit the economics of such advanced CAES cycles.
- The year 2013 is used as the base case for the NYISO simulation. The base case includes 4.3 GW of new wind.
- Transmission congestion costs were estimated at $ 0.9 billion with major transmission congestion occurring in Central to East and North to South zones.
- In NYISO, the CAES study site location did not exhibit favorable results, mainly due to the lack of arbitrage opportunities and the limited wind penetration in the study year. Other sites and study years should be investigated with alternative wind penetration scenarios.
- Prior studies of CAES units in ERCOT found these units can become economical viable when there is sufficient wind and CAES contributes to effective utilization of wind in West Texas.

Study Preliminary Conclusions – Impacts of Bulk and Distributed Storage Portfolios

Bulk and Distributed Storage Systems can be sited at or near Transmission congestion nodes thus improving wind integration and ISO System Benefits

- Locating bulk or distributed energy storage near high LMP areas can improve wind generation on the system.
- The distributed battery gives high system wide benefits, reduces fossil fuel generation and CO_2 emissions. Distributed batteries placed near load centers have the highest performance.
- Bulk and Distributed Storage systems can be sited and interconnected on the high side of the Transmission Node or within the distribution planning area of these Load Serving Entities. However, once located in the distribution side their efficacy in congestion management may be compromised;
- In the NYISO simulations locating distributed storage near NY Central, NY City, Long Island and Mohawk control provides ISO system benefits of $6.5 million for the study year.
- Bulk options sited at Greenridge and Meyer provide ISO system benefits of $ 14.6 and $ 14.5 million respectively.
- The capital costs for Bulk and Distributed storage systems assumed in this analysis are aggressively low and represent system target costs for several emerging technologies that are still under development or in early demonstration. Current costs of Bulk and distributed storage systems are 2 to 3 times higher than the costs assumed in this study.
- Analysis of distributed storage deployment illustrates potential ISO system values, however owner IRRs are low with the assumed discount rate and high battery cost structure. Given the impacts and value to the ISO due to targeted siting of distributed or bulk storage systems under wind penetration scenarios, a mechanism should be considered and developed were ISO benefits can be monetized by owners of distributed storage systems.
- In the ERCOT simulations it was observed that current protocol does not support the battery integration into the ERCOT electricity grid: Batteries pay zonal price during charging and get paid nodal price for discharged power. This introduces an unfair arbitrage opportunity. Batteries are a potentially valuable A/S resource and should be given a preferred treatment in A/S markets.
- Battery operation should be optimized considering the energy component, A/S component, and life cycle
- Simulation results indicate that there is hardly any arbitrage opportunity in the energy market after A/S market participation

Study Observations

- This study NYISO indicates that CAES system economics and impacts critically depends on plant siting, and the assumed generation on the margin in the simulation scenario. A 2009 ERCOT-EPRI study showed an IRR of 12.1% **(capital set at $750/kW and life at 15 years),** primarily attributed to increased wind penetration, **lower capital expenditure** and competition against natural gas combined cycle plants.
- As this study was limited to conditions in 2013 and 2015, future analysis should be undertaken to asses the long term impacts of storage in these regions under much higher wind penetration scenarios, future generation mix, and transmission grid configurations.
- Future viability of CAES will improve as further RD&D increases system efficiency, reduces capital cost and co-optimizes CAES dispatch in the day-ahead-markets (energy, regulation up/down, spinning and non-spinning reserve). The total ISO system benefits are expected to improve with increased wind penetration.
- Transmission expansion plan in MISO may allow import to the Eastern region from wind rich Dakotas. The wind may reduce electricity prices during off-peak periods which will increase the efficacy of bulk storage systems like CAES.
- The distributed batteries showed positive social benefit in NYISO and ERCOT. The IRR of the distributed batteries should also improve as costs are expected to decrease with advances in R&D and in volume manufacturing especially for battery systems which can leveraged from platforms used for PHEV and EVs. However there may also be siting limitations in deployment of large distributed systems
- Distributed Batteries have added advantages due to their use for mitigating transmission/distribution flow congestion and their use in providing transmission / distribution grid services (e.g., VAR control, and power quality). The ISO system benefits showed there are opportunities Load Serving Entities and ISOs to work together on targeted storage deployments and use.

Study Observations
EPRI Perspective

The study limitations included the following: only a single year was used in the analysis; there was limited wind penetration in the NYISO study year, the scope did not include site / plant design optimization; and battery system costs assumed were relatively low compared to current costs These are important factors influencing the research findings. These key factors need to be investigated in the future R&D efforts to better assess the impact of energy storage plants on wind integration. Several other key factors impact the study findings:

– Electricity demand and prices in NYISO may look quite different when the US the economy recovers beyond 2015.
– Significant number of coal and fossil steam retirements are expected over the next five years due to economics and pending and / or proposed environmental regulations. This could have a significant impact on the study results especially if new additions also include natural gas combined cycle units.

As more fossil plant base load generation is removed and replaced by renewable generation plants (driven by Public Policy RPS mandates), stable transmission system operation by the RTOs will become more difficult due to the inherent power fluctuation characteristics of renewable generators (i.e., wind and solar). Thus, the quick response rates of energy storage plants may be more valuable than estimated in this study , but these operational values are not easily quantified.

A lower cost of capital for “rate based storage assets” than the 10% return used in the study could improve owner economics.

Analysis of Energy Storage Systems to Address Regional Wind Penetration in NYISO and ERCOT

Introduction

This research project is one element of a coordinated effort within EPRI to address the challenges of renewable integration in the electric enterprise

EPRI has identified the following key research questions

- How much additional renewable integration is economically feasible on the US electric system using energy storage?
- What is the scale and type of energy storage that is economic for balancing; reliability, improved T&D utilization and optimizing T&D investments?
- What are the relative economics of energy storage vs. other fossil generation (e.g. combined cycle generators)?
- Can storage improve the economics of wind without a contractual relationship, based on existing price signals in markets? If not, what market rules may be beneficial?
- How does this vary by ISO region and function of wind penetration? What are the critical variables that influence the role of storage? Market rules, Generation mix, T&D robustness, types and sizes of loads, location of wind relative to load.
- What are the optimal storage portfolio storage mix and what are the cost / benefits including GHG implications. What storage mix provides the least cost and greatest system benefits such as production cost savings?
- What is the role of storage in T&D investment planning; operation, use, asset management and congestion management given future wind penetration assumptions.
- What role can storage play in minimizing the thermal cycling of fossil generation assets and improving the value of other base load generation assets like nuclear.
- Using real world market simulations of energy storage portfolios, what are the technical, performance and functional characteristics of storage systems to improve renewable integration and to system benefits to the electric enterprise ?

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Analysis of Energy Storage Systems to Address Regional Wind Penetration in NYISO and ERCOT

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Market Simulation Approach

To begin to address the research questions and objectives of this project two in-depth regional studies in NYISO and ERCOT were conducted utilizing detailed market data, wind penetration forecasts and a accurate physical simulation of the grid.

The scope and objectives were developed with input from representatives at NYISO.

For the ERCOT case, EPRI wished to investigate the impact of an advanced battery system and possible challenges within the ERCOT market.

Characteristics of energy storage systems and their operating features were developed with input from EPRI staff.

Ranges of capital costs estimates were made for compressed air energy storage systems including the estimated performance of a non-fuel CAES cycle still under R&D

Aggressive performance and costs estimates were made for Bulk and Distributed Batter Systems to test the impacts on the system

Market Simulation Approach (cont'd)

EPRI contracted with LCG Consulting to perform separate regional market simulations. LCG Consulting used their UPLAN model for this analysis with input from NYISO and ERCOT.

UPLAN enables a detailed, granular simulation of NYISO, and ERCOT market dynamics based on detailed characterization of generators and the transmission network along with realistic representation of market protocols. The assessment of the energy storage systems was carried out utilizing different energy storage portfolios:

- Compressed Air Energy Storage
- Bulk Energy Storage
- Distributed Energy Storage

Impacts of Storage Portfolio was estimated by calculating the difference from the UPLAN Base Case (no storage) and the UPLAN Storage Portfolio Case.

UPLAN Network Power Model

UPLAN Model's Day Ahead Scheduler (DAS) determines hourly schedules for all resources. UPLAN develops locational marginal price (LMP) and carries out the following tasks:

⇨Select and schedule day-ahead resources in appropriate amounts and locations to meet forecast energy (load) and ancillary service (reserve) requirements using Security Constrained Unit Commitment (SCUC).

⇨Dispatch generators to meet load in the most economical manner based on generator bids (costs) subject to transmission and other constraints.

⇨Resolve all congestion in the DAS that satisfies all constraints. Optimize transmission utilization using Load flow (OPF).

⇨Co-optimization of Energy and Ancillary Service Markets. Produces A/S prices and the capacity of each generator offered for Ancillary Services on an hourly basis.

⇨Optimizes DAS for Hydro, Pumped Hydro and Storages

⇨In the subsequent **Security Constrained Economic Dispatch (SCED)** step the committed energy and A/S resources are dispatched hourly and the locational marginal prices are determined at every bus in the region.

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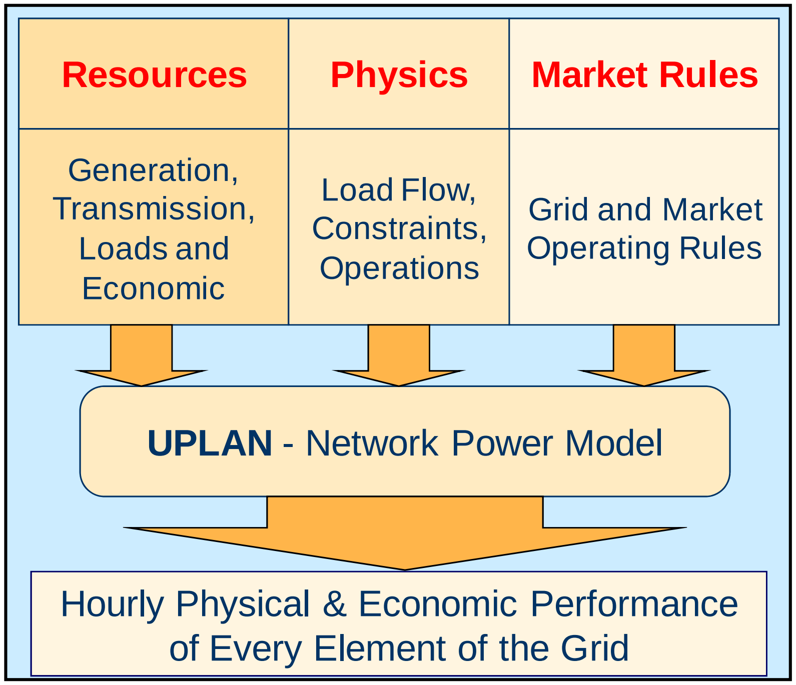
Approach – UPLAN Simulation Model[1]

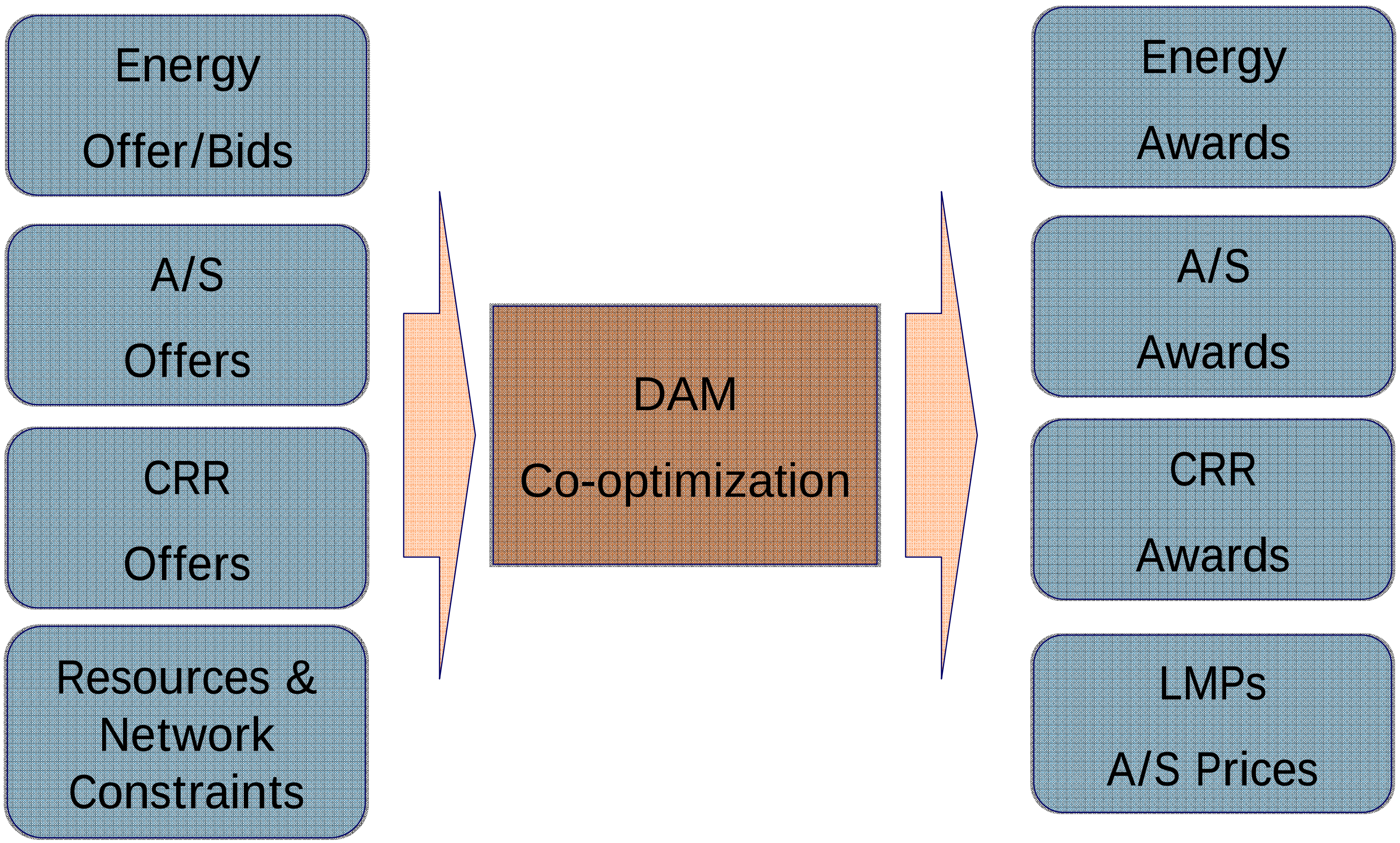
- UPLAN uses marginal cost based generator offers and opportunity cost based offers for A/S, storages and other secondary resources to determine LMPs.
- UPLAN minimizes generator startup, shutdown, and operating costs including transmission losses. In this simulation wind is given dispatch priority over other generation technologies
- UPLAN is also suitable for modeling real-time grid operations and market interactions with all resources.



1. UPLAN Network Power Model

http://www.energyonline.com/products/uplane.asp

Approach
Day-ahead Market (DAM)



Approach – UPLAN Storage Simulation

- UPLAN generates one year of hourly nodal prices at the bus where storage is located
- Optimization of hourly storage operation is done using linear programming
  - Maximize monthly net income which equals revenue minus charging cost, fuel cost, and emission cost
  - Subject to the following
    - Maximum charging rate
    - Maximum discharging rate
    - Maximum Storage capacity
    - Minimum inventory level
    - Discharge efficiency
- The scheduled hourly charging MW is treated as load and added to the storage bus
- The scheduled hourly discharging MW is treated as the storage maximum available capacity in the unit commitment and dispatch.

Analysis of Energy Storage Systems to Address Regional Wind Penetration in NYISO and ERCOT

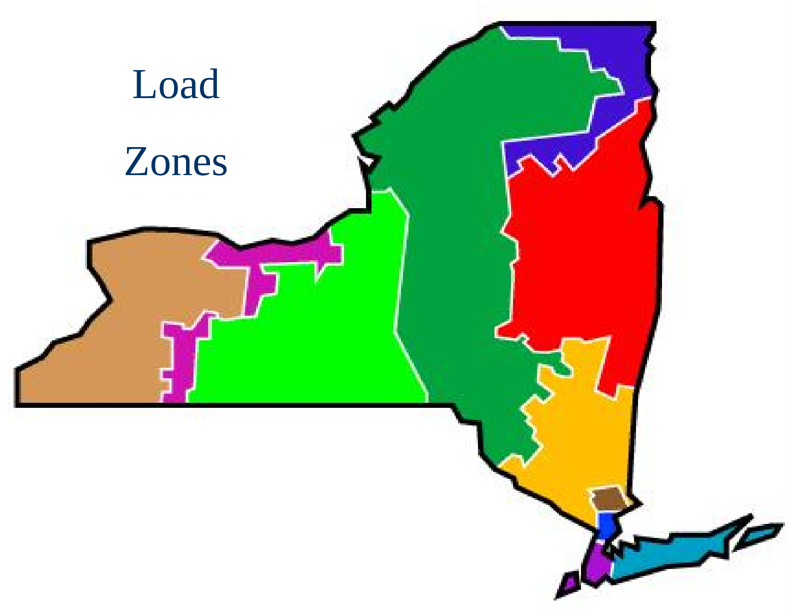
EXECUTIVE SUMMARY
Introduction
Approach and Methodology
NYISO Case Study
ERCOT Case Study
Appendix

NYISO Introduction

- The New York Independent System Operator (NYISO) operates the high-voltage transmission network of New York State. It also administers and monitors the Day Ahead and Real time wholesale electricity markets. The NYISO is responsible for the reliable operation of New York's nearly 11,000 miles of high-voltage transmission and the dispatch of over 500 electric power generators. The NYISO also administers bulk power markets in New York State.

- NYISO manages the electric grid and the wholesale electricity market in all the Load Zones in New York State.

A map of the load zones and some illustrative zonal prices are displayed in the page (Source GDF Suez)



eal Time Prices *

North 42.30	Mohawk Valley $41.80	Central $40.00
Genesee $38.65	West $33.15	Capital $43.22
Hudson Valley $44,15	Millwood $44.15	Dunwoodie $44.15
NY City $46.30	Long Island $47.62	

NYISO Introduction

NYISO coordinates the continuous buying, selling and delivery of wholesale electricity through the Energy Market. It also coordinates import/export of energy to and from the neighboring ISOs such as PJM, ISO-NE, Ontario and MISO. NYISO balances the needs of suppliers, wholesale customers and other market participants and monitors market activities to ensure open, fair and equitable access.

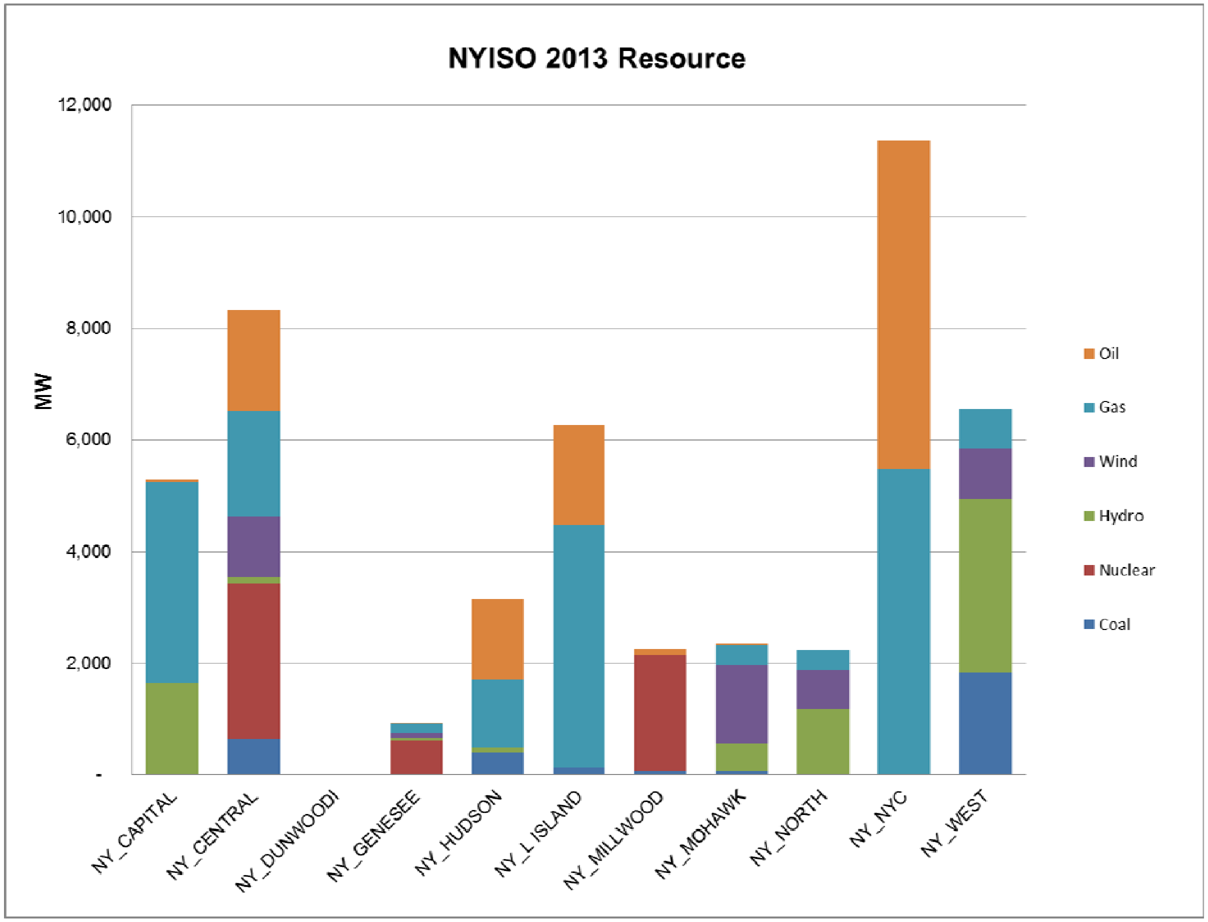
The market uses locational Based Marginal Pricing (LBMP) that reflects the value of the energy at the specific location and time it is delivered. When low cost energy cannot flow freely across the Grid due to transmission congestion, more-expensive local electricity is generated in order to meet that demand. As a result, the LBMP is higher in those congested locations.

The Energy Market consists of Day-Ahead and Real-Time markets. The Day-Ahead Market is a forward market in which hourly LBMPs are calculated for the next operating day based on generation offers, demand bids and scheduled bilateral transactions.

The Real-Time Market is an imbalance market in which the imbalances are cleared at five-minute intervals based on actual grid operating conditions. Real-time prices are available.

NYISO Base Case Results
Generation Capacity

- Includes generation capacity from 2010 Gold book published by NYISO.



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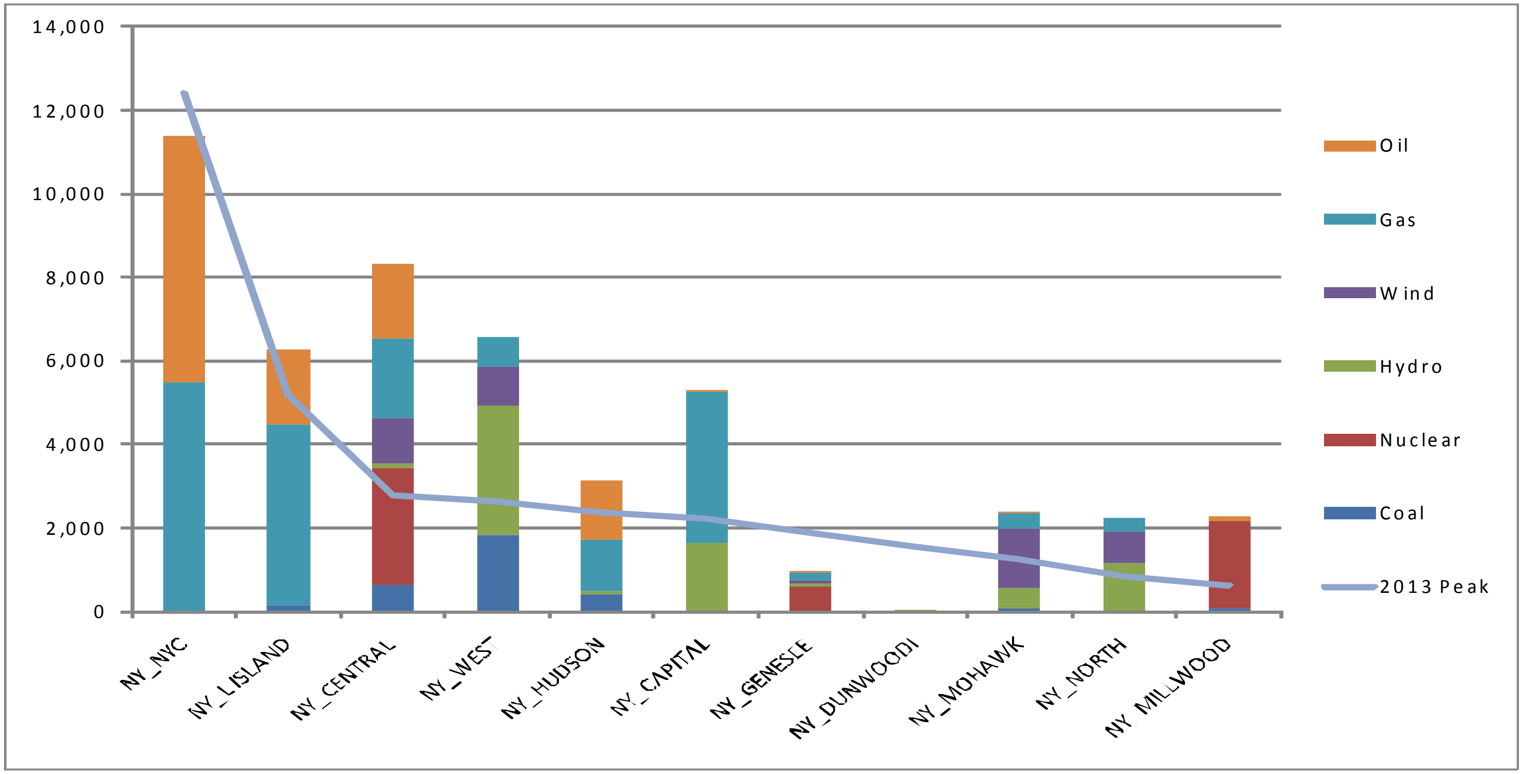
NYISO Base Case Results
Load Resource Balance

- 2013 load projections by NYISO



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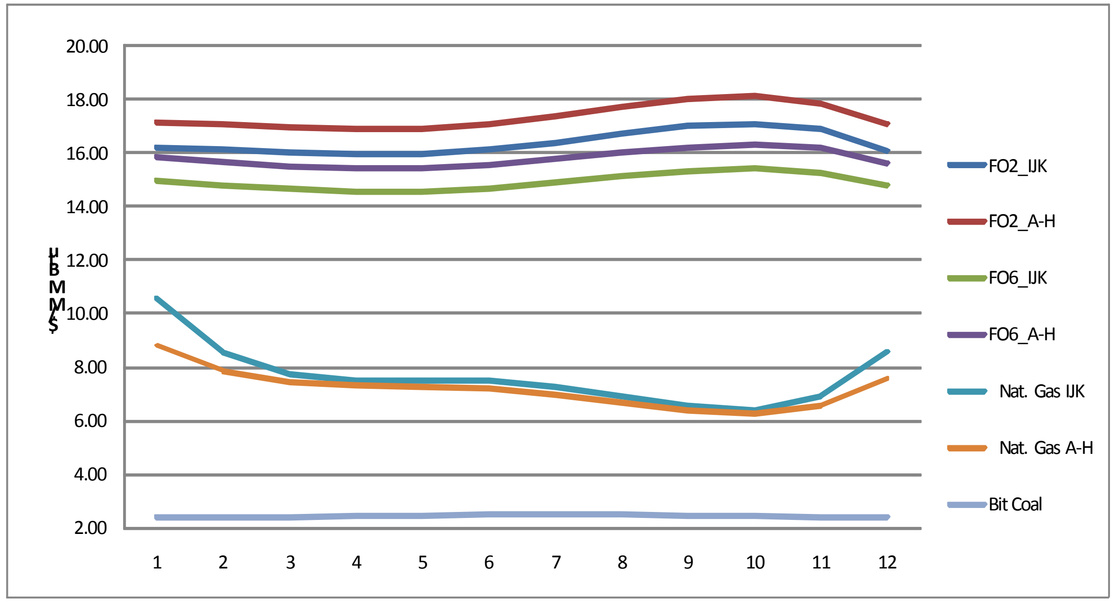
NYISO Base Case Results Transmission

- Power flow case
  - 2013 NYISO Wind study case that reflects the future system
- Thermal constraints – supplied by NYISO
  - interface definitions and transfer limits
  - contingencies
  - monograms

4,250 MW Wind Case		
Interface Name	**Maximum Transfer Limit**	**Minimum Transfer Limit**
Captial to Husdon	4200	-900
CENTRAL EAST	2800	-900
ConEd - LIPA	2166	-500
Cross Sound Cable	330	0
Dunwoodie (I) to Long Island (K)	1265	-500
Dunwoodie (I) to NYCity (J)	3700	-1000
DYSINGER EAST-OP	2550	-99999
IMO-NYISO	2000	-2000
ISONE-NYISO	1400	-1700
LI - ISONE	450	-450
MILLW-SOUTH-OP	9999	-99999
MOSES SOUTH-OP	2500	-99999
Neptune HVDC	665	0
NIAGARA TIE	1700	-1700
NYISO-HQ	1050	-1500
NYISO-IESO	2500	-2500
NYISO-PJM	2500	-2500
Ontario North - NYISO	0	0
PJM East - NYISO	2500	-2500
PJM West - NYISO	2000	-2000
TOTAL EAST	6400	-99999
UPNY Seny-OP	5800	-99999
UPNY-ConEd-OP	4800	-99999
Volney East-OP	4400	-99999
WEST CENTRAL-OP	1425	-99999

NYISO Base Case Results
Commodity Prices

- 2013 Commodity Prices ($/MBtu)
  - Natural Gas (A-H, IJK) =7.19, 7.67
  - Light Oil (A-H, IJK) = 17.34, 16.37
  - Heavy Oil (A-H, IJK) = 15.79, 14.91
  - Coal = 2.44
- Emission allowances ($/ton)
  - CO_2 = 4.90 $/ton
  - SO_2 = 39.97 $/allowance
  - NO_x = 465.44 $/allowance
- Sources: NYISO inputs



1) The Clean Air Interstate Rule (CAIR) has been assumed and CAIR requires participating states to submit 2.0 allowances per ton of SO2 emission starting in 2014.

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NYISO Base Case Results Generation

- Wind generation meets 6% of total system demand in 2013 (4,250 MW case)
- Emission cost: $ 265 M
- System wide congestion cost: $ 916 M[1]
- Total production cost: $ 7.5 B

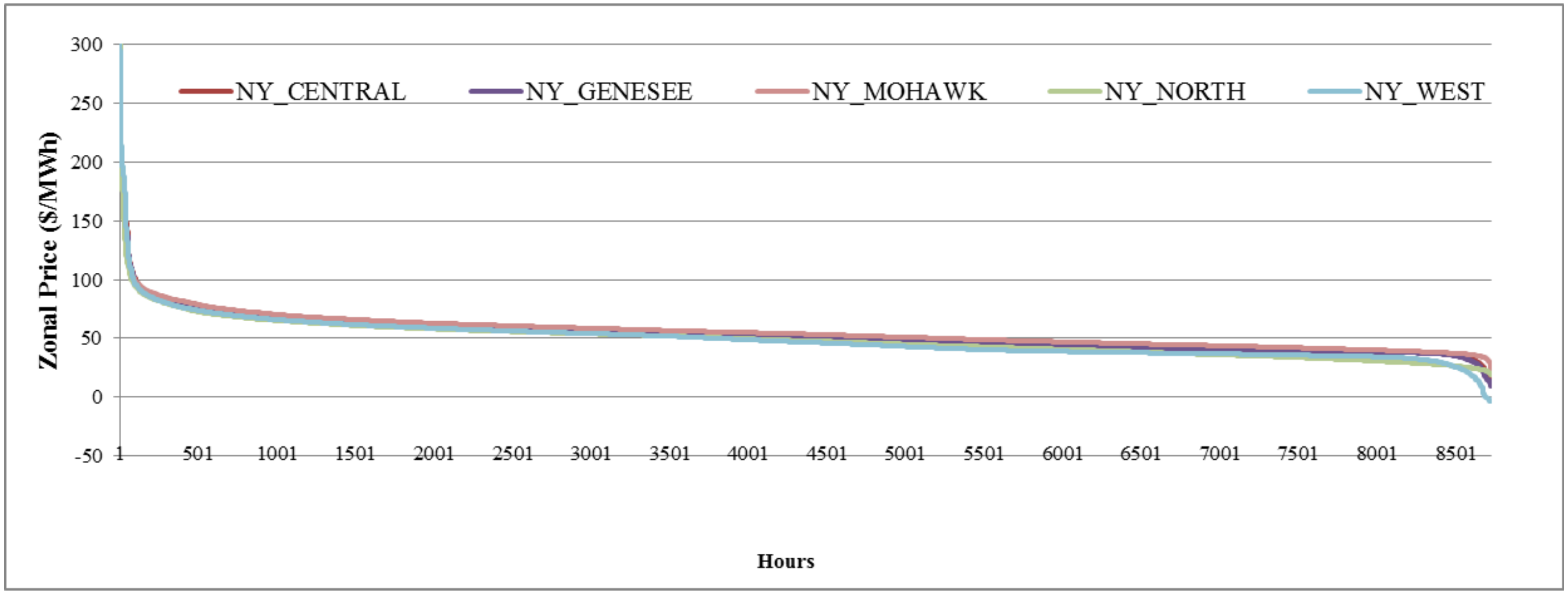
4,250 MW Wind Case Generation Results (GWh)	
Category	**Generation (GWh)**
Coal	21,358
Gas	58,512
Hydro	29,808
Nuclear	47,080
Oil	1,118
Wind	10,910
Grand Total	168,787
Other Results	
Total Demand (GWh)	168,712
Renewable Total	10,910
Renewable Percent	6%
Co2 Emissions (Mmetric Tons)	55
Co2 Adder ($/Mmetric Tons)	4.80
Congestion Cost (M$)	916.21
Total Variable Production Cost (M$)	7,523

CO_2 adder in the table above is in $ per metric ton

1) Congestion cost is equal to the load payments minus generator revenues for the New York system.

NYISO Base Case Results
Zonal Price Duration Curve

- Increased wind and transmission congestion cause higher LBMP spreads between the zones



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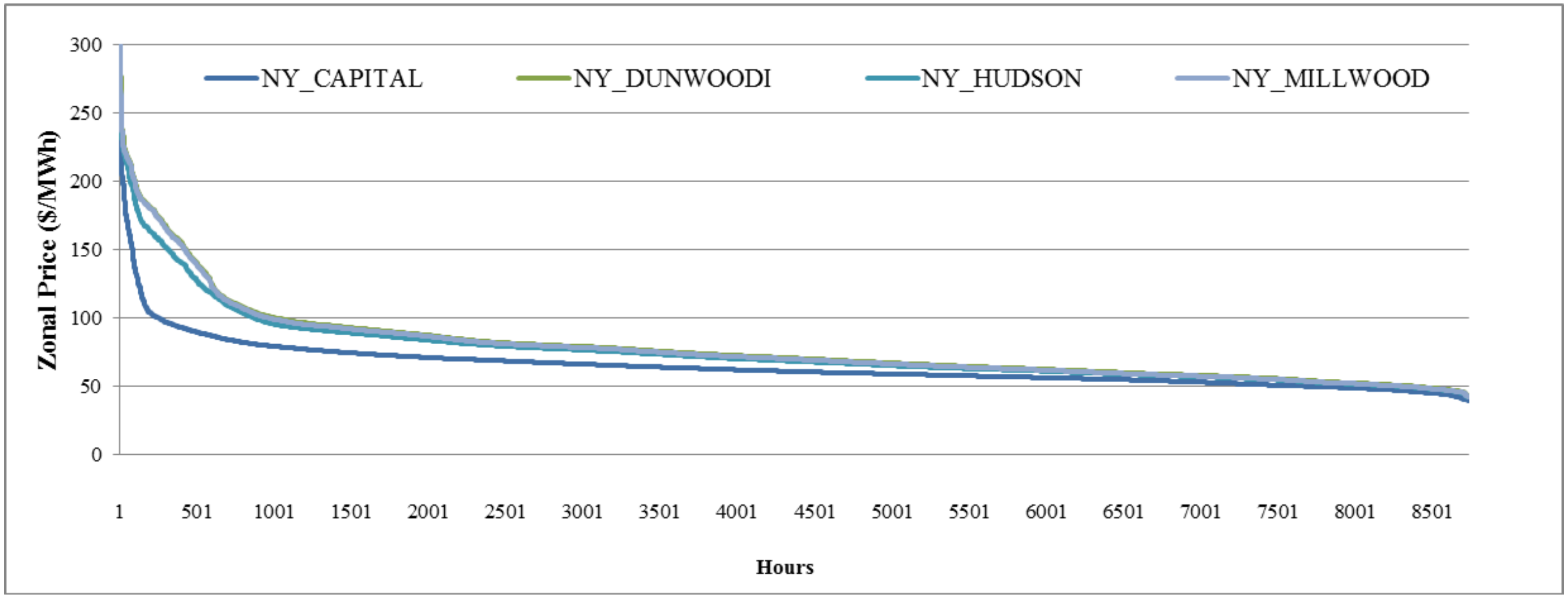
NYISO Base Case Results
Zonal Price Duration Curve

- Increased wind and transmission congestion cause higher LBMP (same as LMP) spreads between the zones



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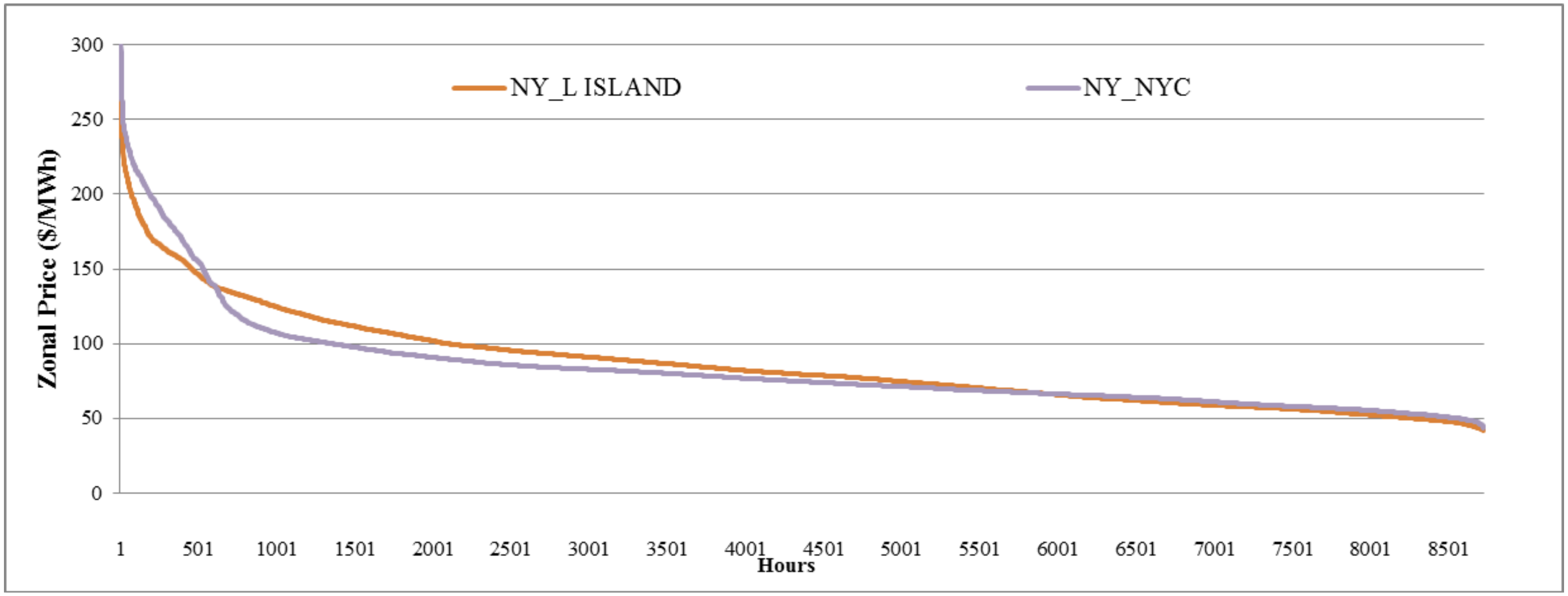
NYISO Base Case Results
Zonal Price Duration Curve

- Increased wind and transmission congestion cause higher LBMP spreads between the zones



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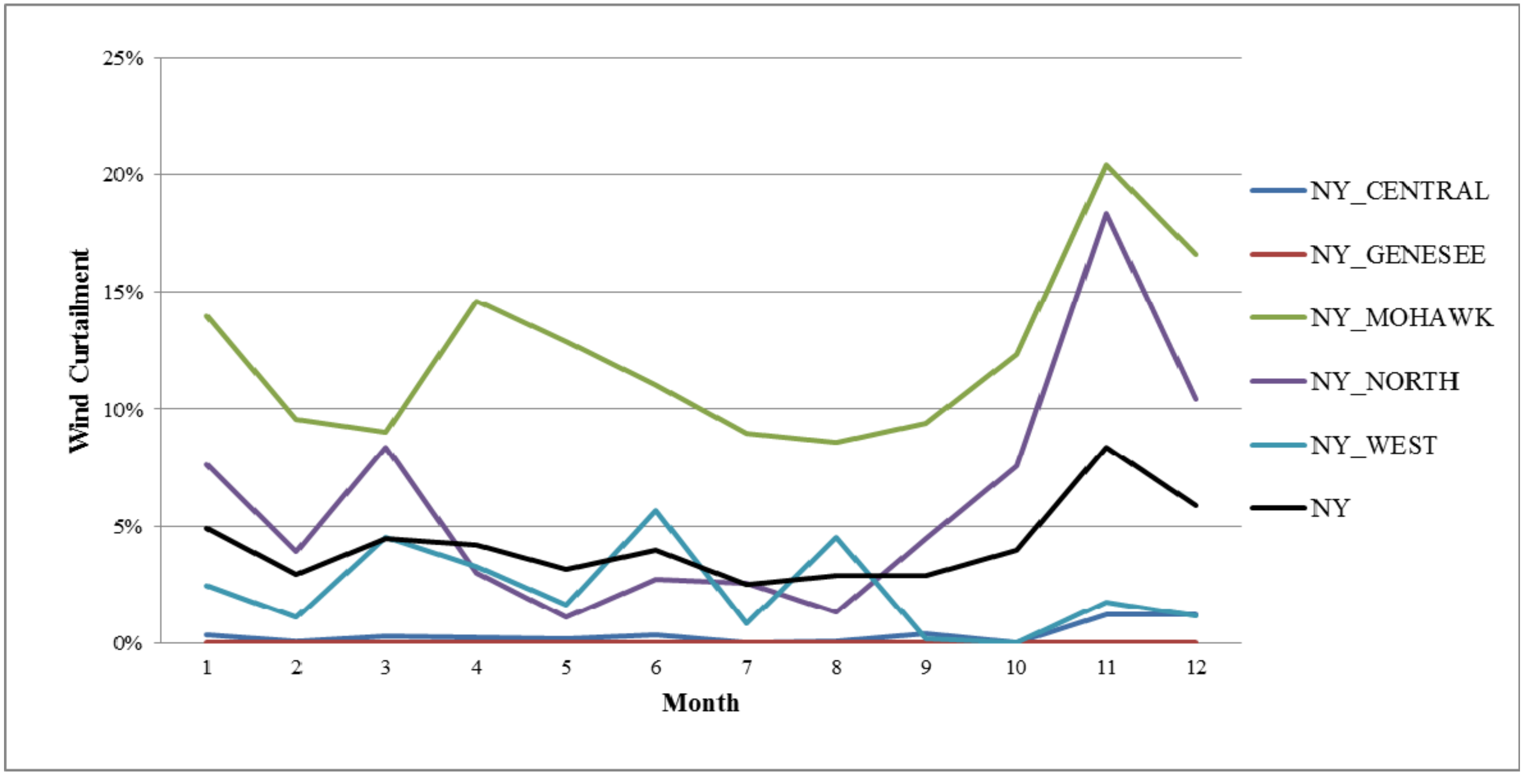
NYISO Base Case Results
Top Congestion Events

- Storage can be located to mitigate transmission bottlenecks that curtail wind generation

Constraint Name	From Bus	To Bus	Percent Congestion (%)	Origin of Congestion
DUNWREAC	DUNWODIE	REAC71	86.0	System
MALOWILL	MALONE	WILL 115	49.5	Wind
COFFLYME	COFFEEN	LYMETP	40.6	Wind
PLTVLEED	PLTVLLEY	LEEDS 3	49.7	System
DELHDEL	DELHI115	DEL T115	27.6	Wind
FARR1065	FARRAGUT TX9	FGT_X9	17.0	System
GOUDOAKD	GOUDY115	OAKDL115	20.9	System
GRENKENT	GRENWOOD	KENTTAP	14.1	System
FRASGILB	FRASR345	GILB 345	19.3	System
ALPSREYN	ALPS345	REYNLD3	14.1	System
CNDG447	CNDGUA_T	CNDGUSTR	10.3	Wind

NYISO Base Case Results
Wind Curtailment

- Zonal wind curtailment due to transmission congestion (mainly 115 kV lines)



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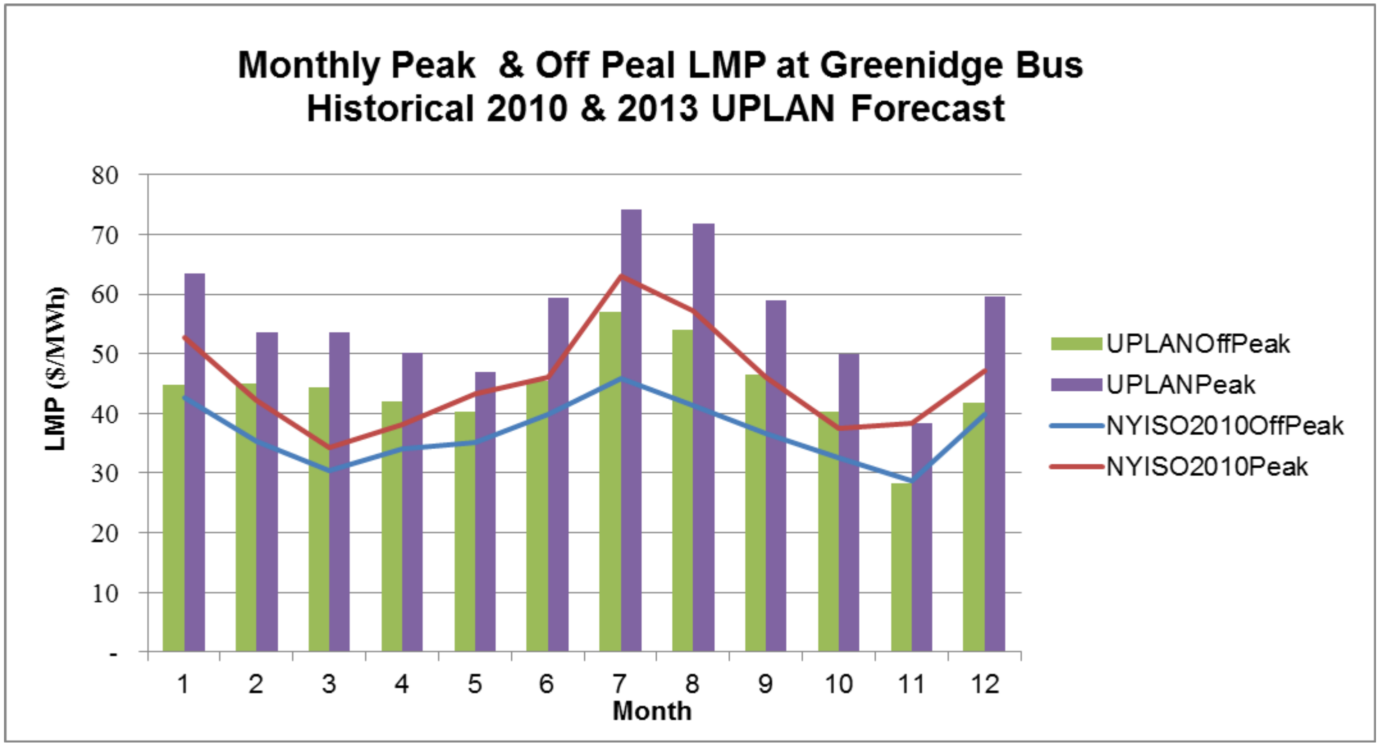
NYISO Base Case Results
Monthly prices at Greenidge Bus

- Monthly Peak & Off Peal LMP at Greenidge Bus
- Annual average arbitrage between Peak and Off Peak hours is 8.5 $/MWh



NYISO Storage Case Inputs Assumptions Compressed Air Energy Storage (CAES)

- Characteristics of CAES technologies

Operating Parameters	CAES	CAES (No Fuel)
Generating Capacity	150 MW	150 MW
Compressor load	150 MW	150 MW
Heat Rate (LHV)	3700 Btu/kWh	-
Ramp Rate	20% /min	50% /min
Energy factor (MWh consumed for compression/ MWh generated)	0.70	1.5
Discharge hours	30 hrs	8 hrs
Working Storage Capacity	4,500 MWh	1,200 MWh
Variable O&M **Fixed O&M**	$ 4 / MWh $ 7/ kW-yr	$ 4 / MWh $ 6/ kW-yr
Total installed capital costs	$ 1000 / kW	$ 1100-1400 / kW
Ability to provide ancillary Services	Regulation up and regulation down; Spinning reserve; non spin reserve; replacement	Regulation up and regulation down; Spinning reserve; non spin reserve; replacement

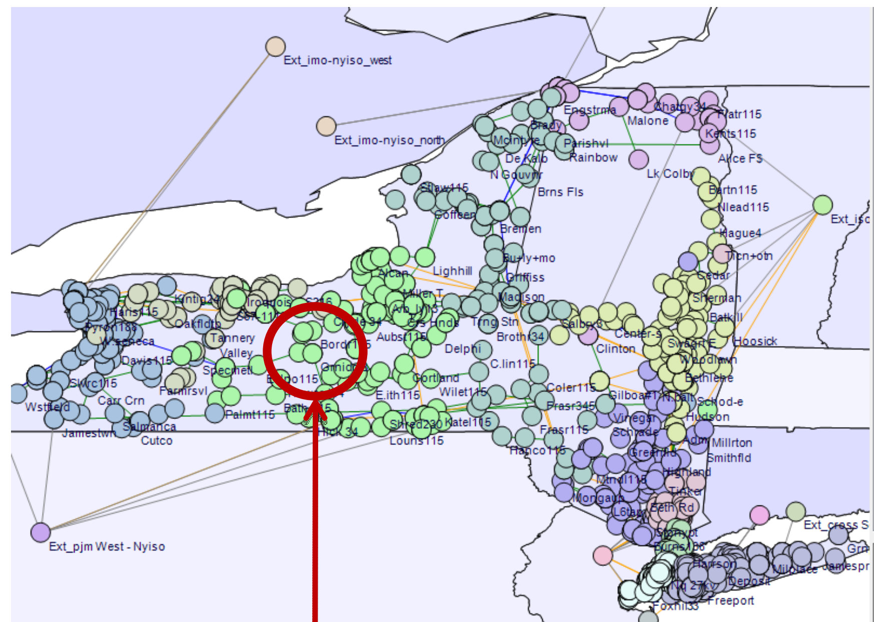
NYISO Storage Case Inputs Assumptions
Bulk Battery

- Characteristics of Battery technologies

Operating Parameters	Bulk Battery	Distributed Battery
Size (per battery)	150 MW	1 MW
No. of batteries	1	400
Energy Efficiency ac/ac	0.8	0.85
Storage capacity	900 MWh	2 MWh
Pumping Size	150 MW	1 MW
Discharge hours	6 hrs	2 hrs
Total installed investment Costs	$ 1200 - 1500 / kW	$ 1200 - 1500 / kW
Variable O&M **Fixed O&M**	-	-
Ability to provide ancillary services	Regulation up and regulation down; Spinning reserve; non spin reserve; replacement	Regulation up and regulation down; Spinning reserve; non spin reserve; replacement

NYISO Storage Case Inputs
Site information for CAES Plant

- Storage Plant Site: Greenidge, NY
- Technologies modeled:
  - CAES
  - Bulk Battery
- Plant size: 150 MW
- Each storage technology modeled at the same site in separate UPLAN scenarios
- Distributed batteries modeled at nodes
  - Metric used: average daily Peak/Off-Peak LMPs



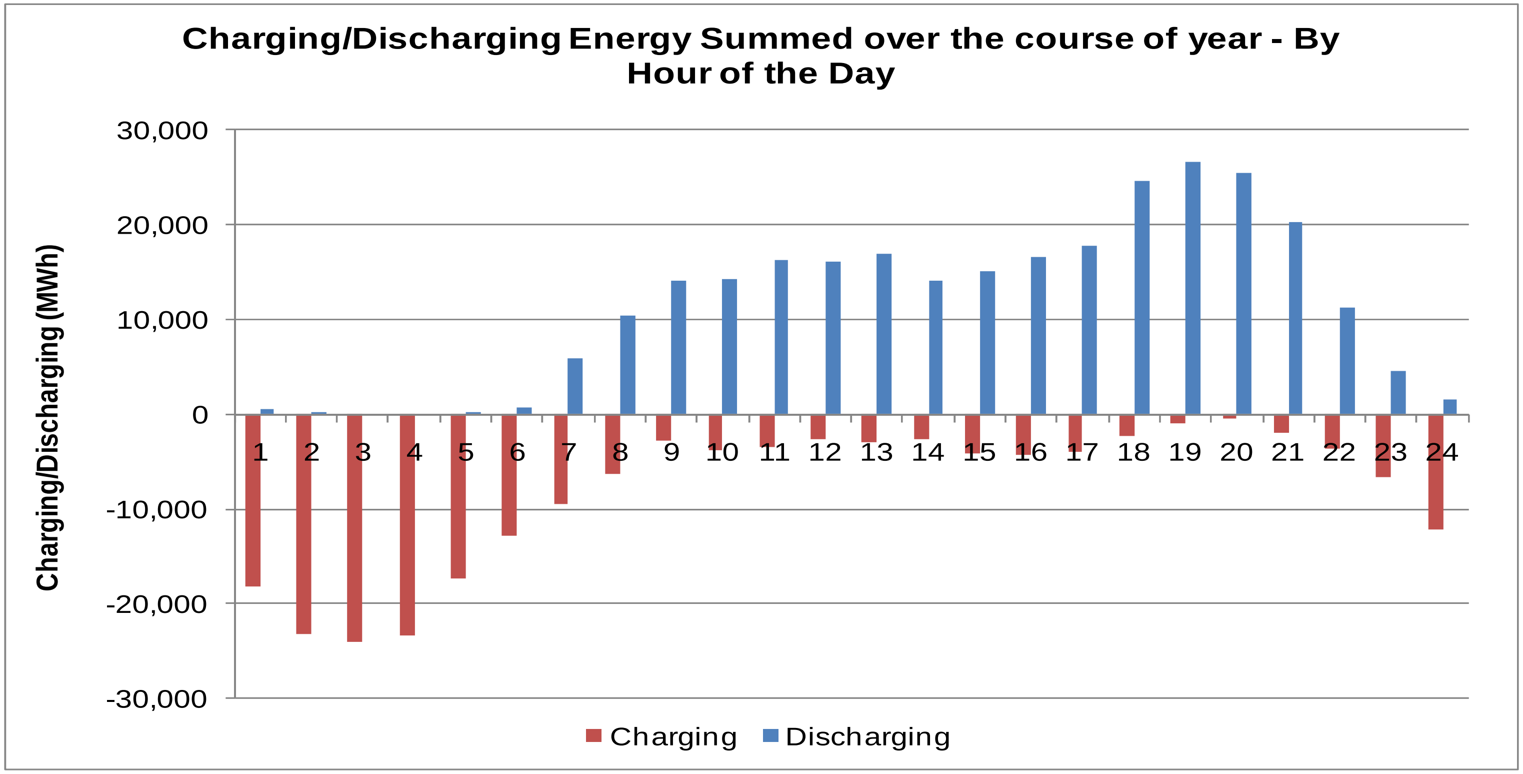
<u>LOCATION OF CAES & Bulk Battery UNIT(s)</u>

SENECA GENERATING FACILITY

Located on Greenidge Station, NY

NYISO Storage Case Results
Compressed Air Energy Storage - DAS

- Operational behavior of CAES – charging during off-peak hours and discharging during peak hours
- Total Charging hours – 1305, Discharging hours – 1845
- CAES is dispatched either as load or generation about 21% percent of the year



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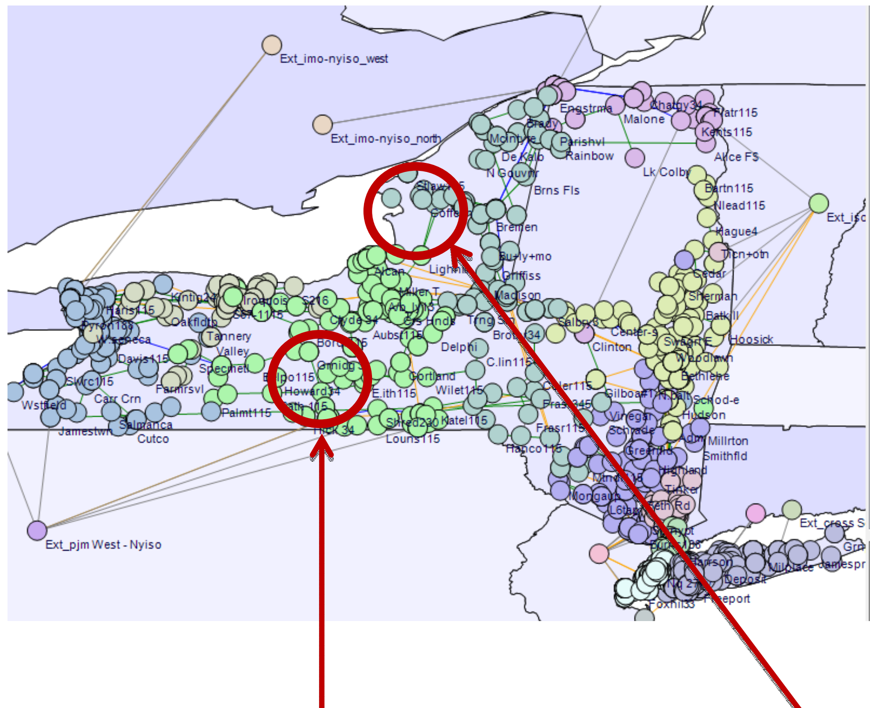
NYISO Storage Case Inputs
Site information for Bulk Battery

- Storage Plant Site: Greenidge, Meyer, and Coffeen, NY
- Technologies modeled:
  - Bulk Battery
- Plant size: 150 MW



LOCATION OF Bulk Battery UNIT

GREENIDGE & MEYER GENERATING FACILITIES

Located on Meyer Station, NY

LOCATION OF Bulk Battery UNIT

COFFEEN GENERATING FACILITY

Located on Coffeen Station, NY

* Results for Meyer and Coffeen Street Batteries have not been reported, except when mentioned

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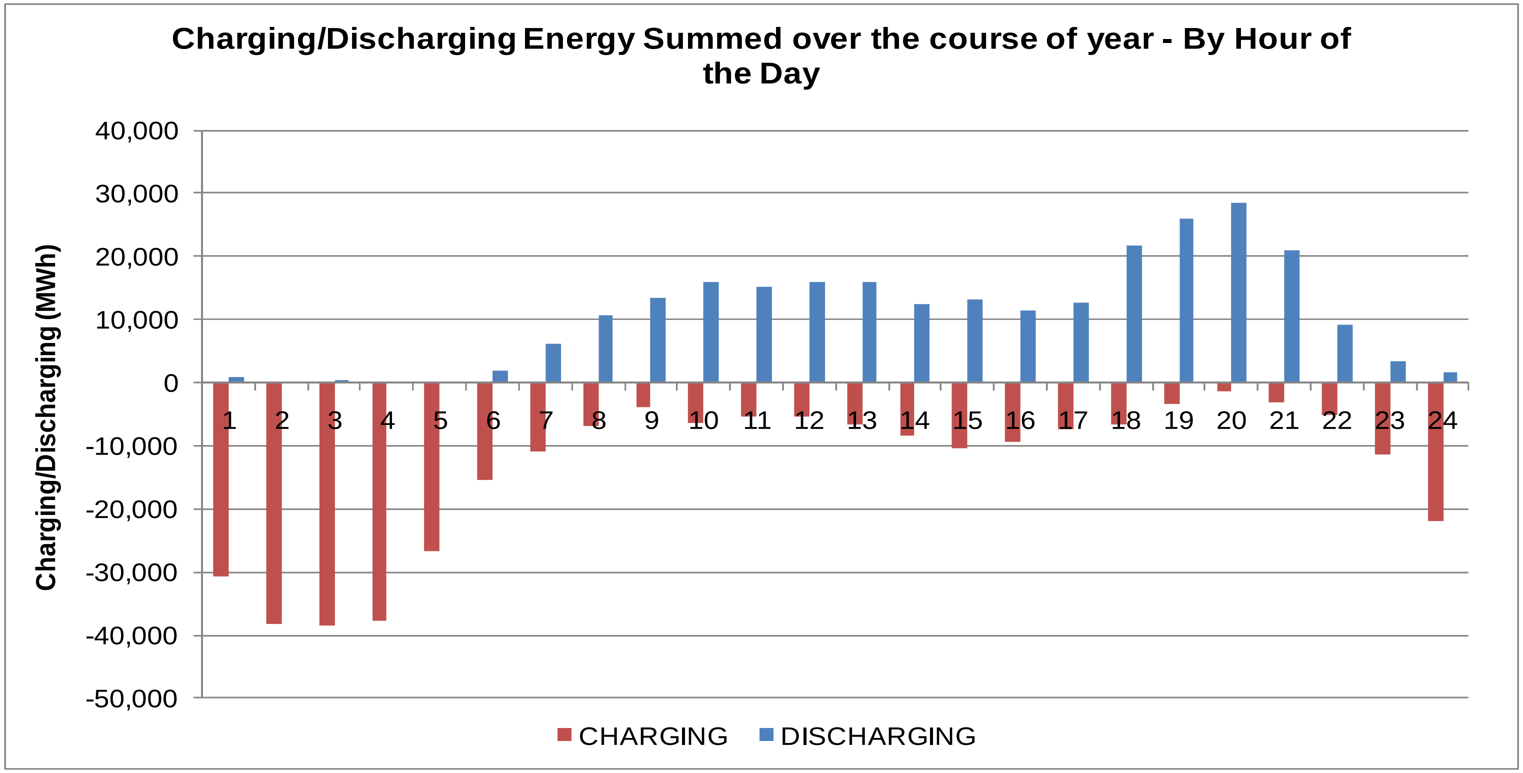
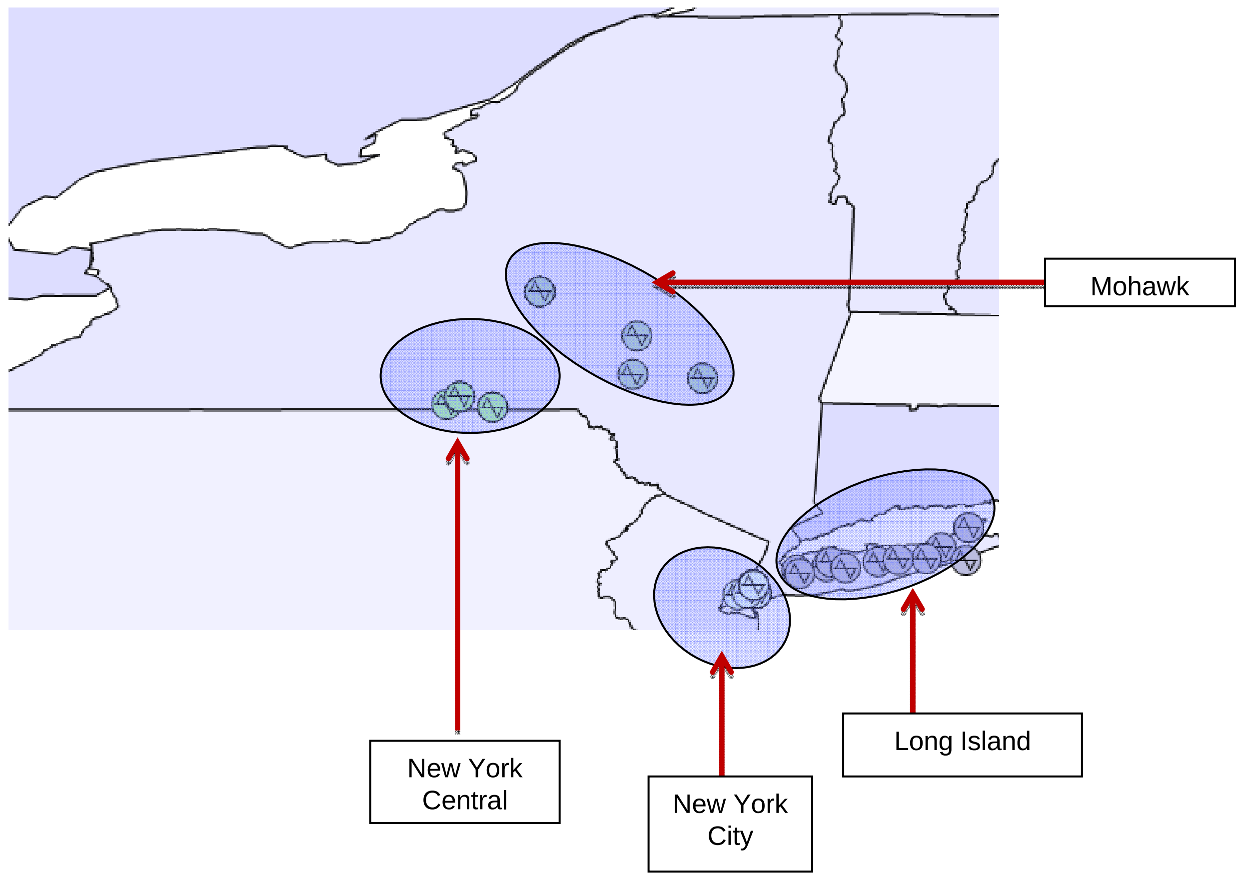
NYISO Storage Case Results
Bulk Battery Storage

- Operational behavior of Bulk Battery - charging during off-peak hours and discharging during peak hours
- Total Charging hours – 2213, Discharging hours – 1820
- Bulk Battery is dispatched either as load or generation about 19.57% percent of the year



NYISO Storage Case Inputs
Site information for Distributed Batteries

- Storage Plant Site: NY – Central, Mohawk, New York City, Long Island
- Technologies modeled:
  - Distributed Battery
- Plant size: 1 MW each
- Metric used: average daily Peak/Off-Peak LMPs



* The map does not contain all the modeled batteries

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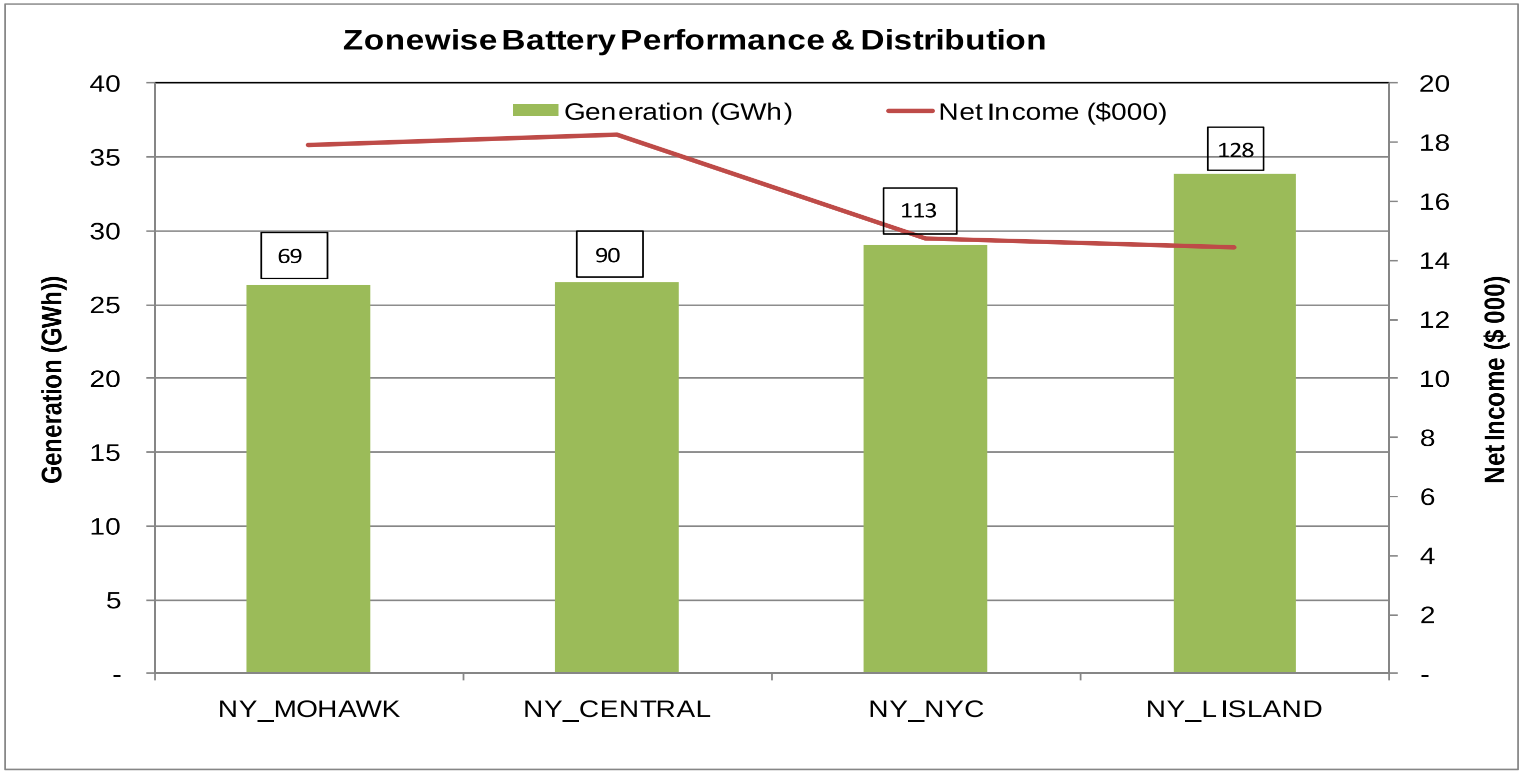
NYISO Storage Case Results
Distributed Battery Storage

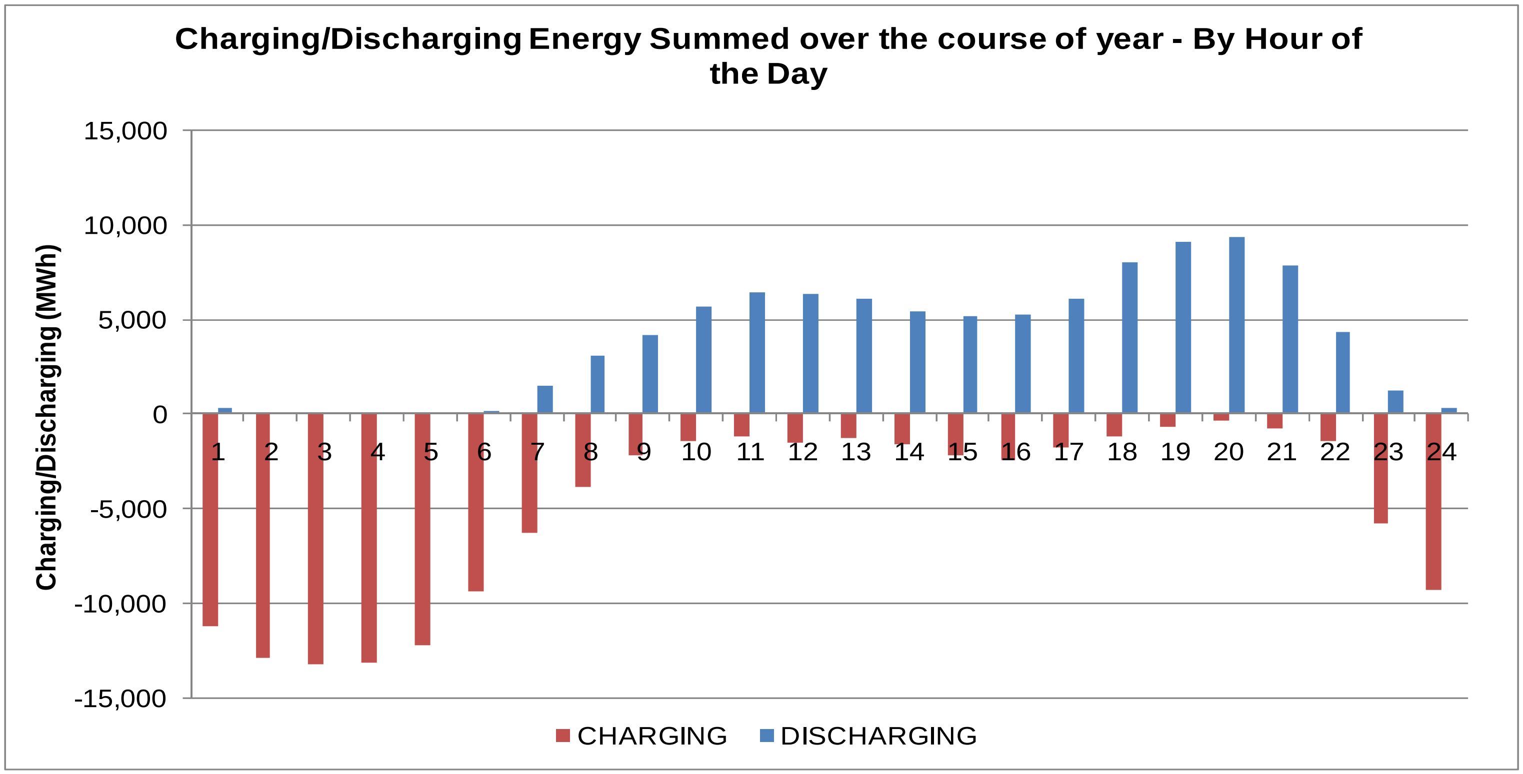
⇨ Metric used for siting batteries: Average Daily Peak LMP – Off-Peak LMP at all demand nodes



* ☐ Number of 1 MW distributed batteries in each NYISO zone

NYISO Storage Case Results
Distributed Battery Storage

- Operational behavior of Distributed Batteries - pumping during off-peak hours and generating during peak hours
- Depending on the zone, total pumping hours range between 334-385, generating hours range between 337-376
- Distributed batteries are dispatched as load or generation about 3.3% percent of the year



* Non coincidental pumping and generation

NYISO Storage Case Results
Distributed Battery Storage

⇨ Storage Performance for Distributed Batteries

Zone	# Units	# Charging hours Average (hrs)	# Discharging hours Average (hrs)	Capacity factor (%)	Energy Rev. ($ M)	A/S Rev. ($ M)	Net Income ($ M)	Societal benefit ($ M)
NY_MOHAWK	69	4259	3863	4.35	1.54	1.14	1.71	8
NY_CENTRAL	90	3400	3165	3.37	1.59	1.3	1.83	
NY_NYC	113	3564	3393	2.93	3.34	0.56	1.47	
NY_L ISLAND	128	5366	5062	3.02	3.46	0.57	1.44	

NYISO Storage Case Results Summary - 2013

	CAES ($ million)	Bulk Battery ($ million)	Distributed Battery ($ million)
Producers' Benefits	-46.8	-23.5	-12.3
Consumers' Benefits	46.5	31.4	20.7
Total NYISO System Benefits	-0.3	7.9	8.4

The percent change in System Benefits is very small compared to total system cost of $7 billion. Low societal benefits are also due to increases transmission losses.

* Production cost savings/Net Societal Benefit = Change in NYISO system-wide generator production costs + purchase costs - sales revenues

Producer Surplus = Generator Revenues – Generator Costs

Consumer Surplus = Demand Bids – Demand Payments

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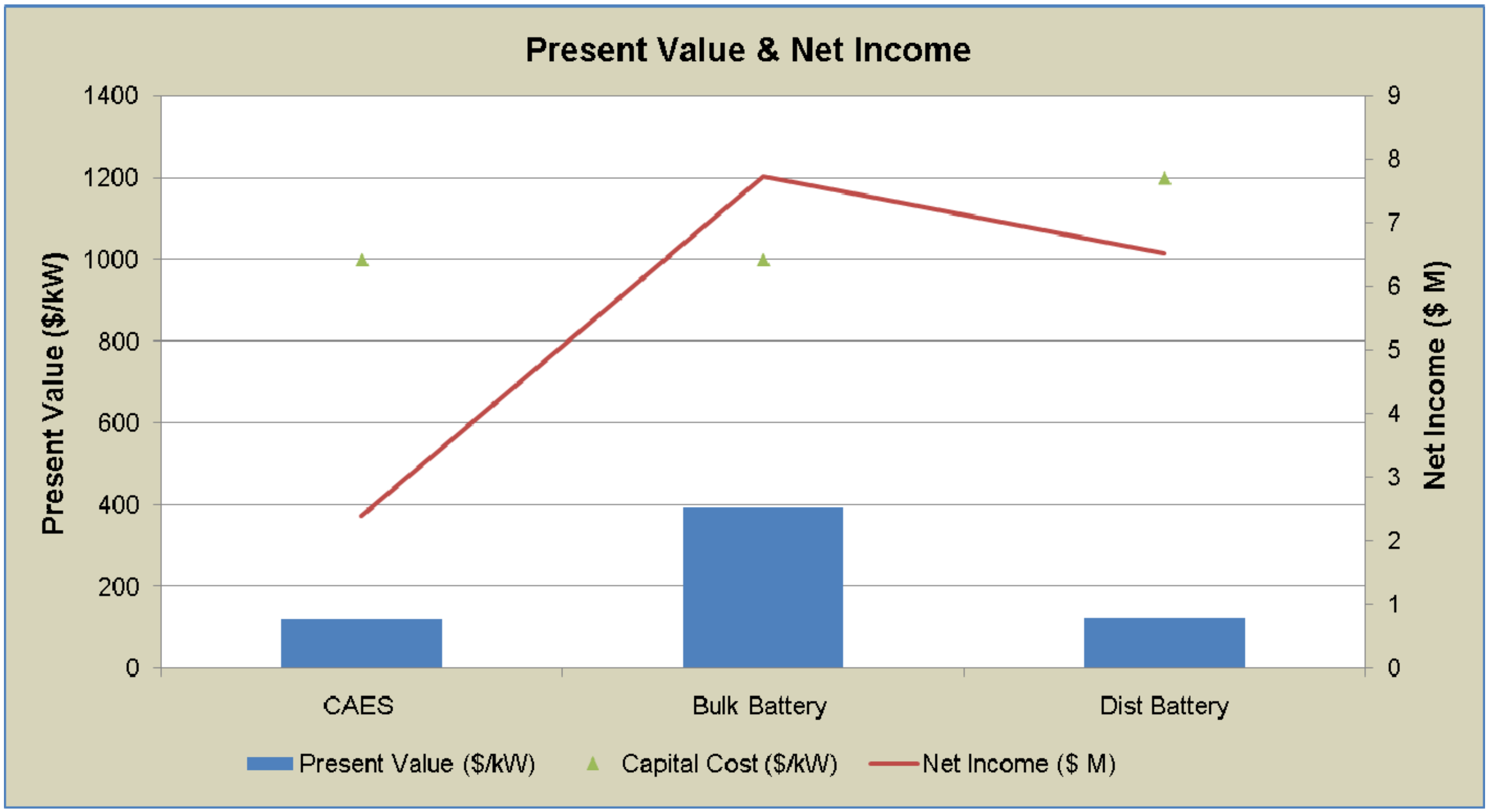
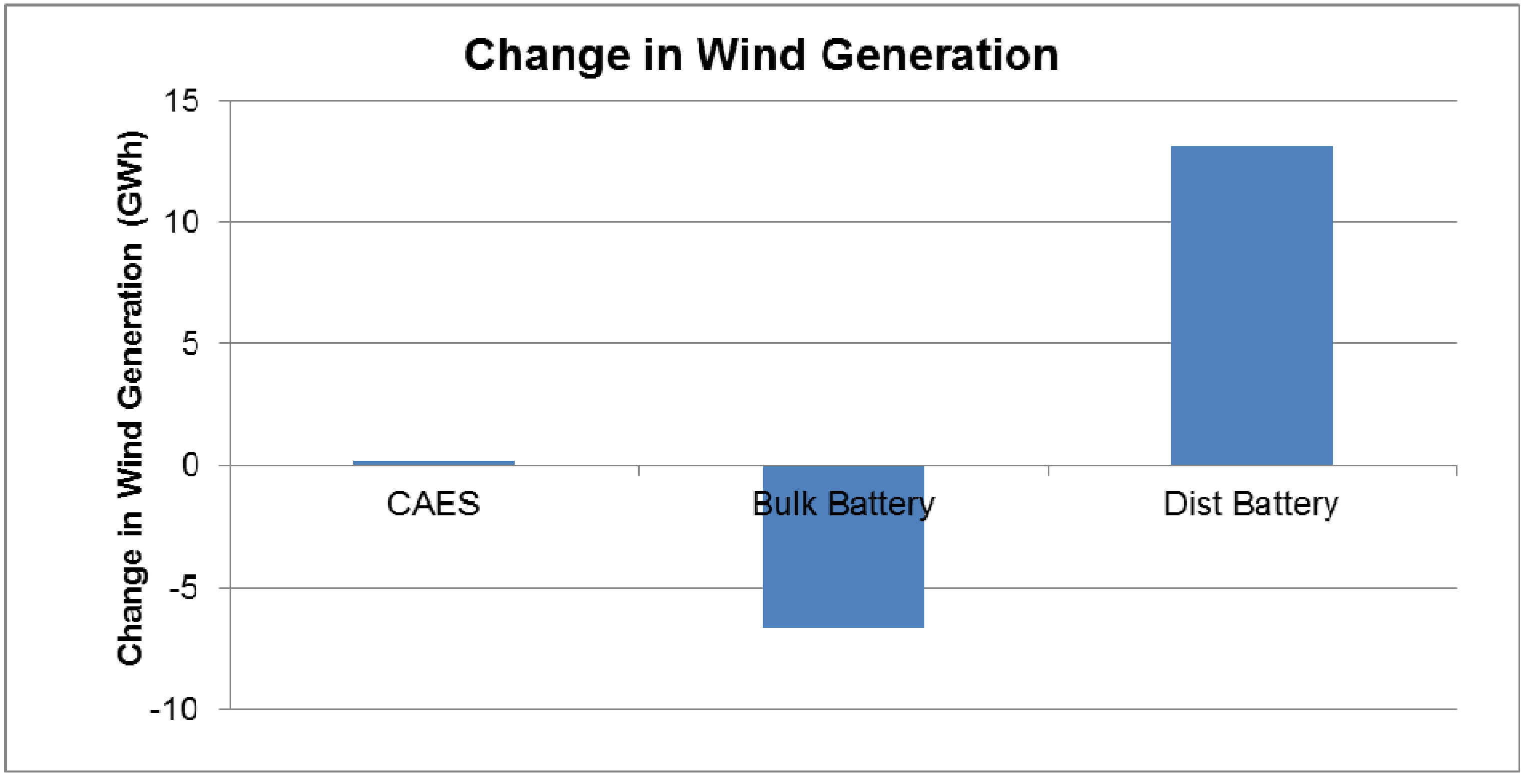
NYISO Storage Case Results Summary - 2013

Owner Benefits for all the storage Technologies



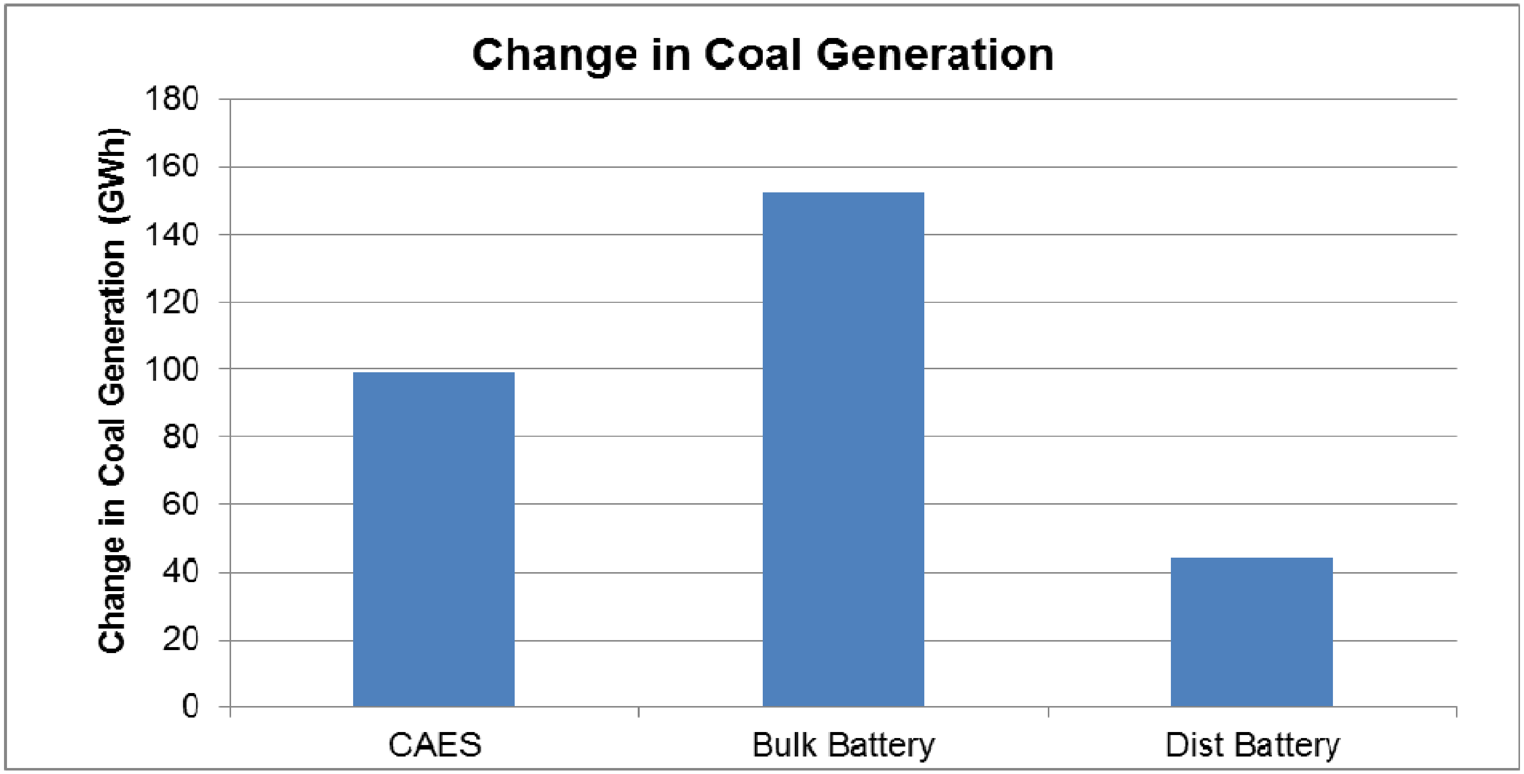
NYISO Storage Case Results
Impact on Wind Generation - 2013

- Distributed batteries increase wind generation.
- CAES and Bulk Battery have limited impact on wind generation



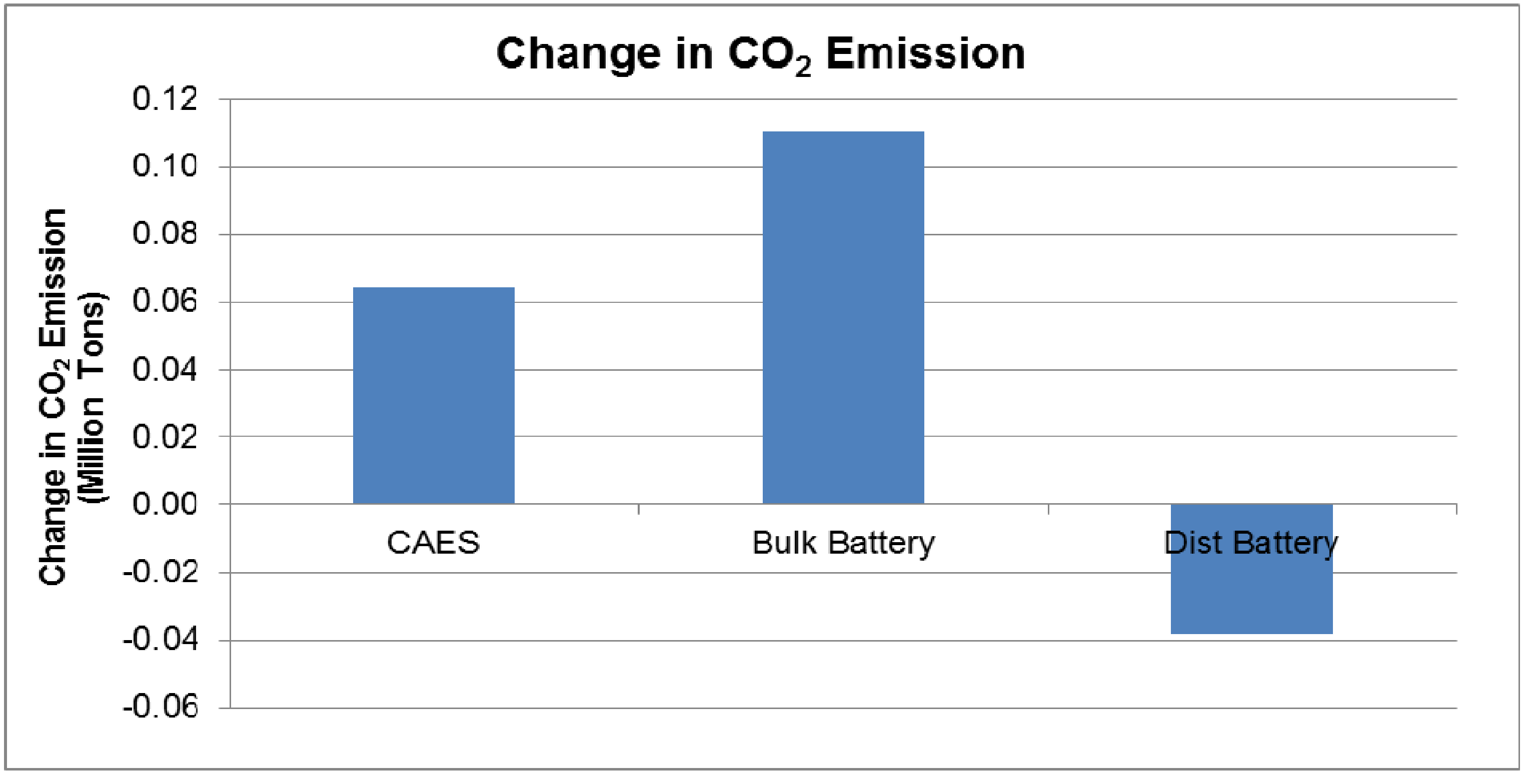
NYISO Storage Case Results
Impact on Coal Generation - 2013

- Coal generation increased in all the storage scenarios



NYISO Storage Case Results
Impact on CO_2 Emissions

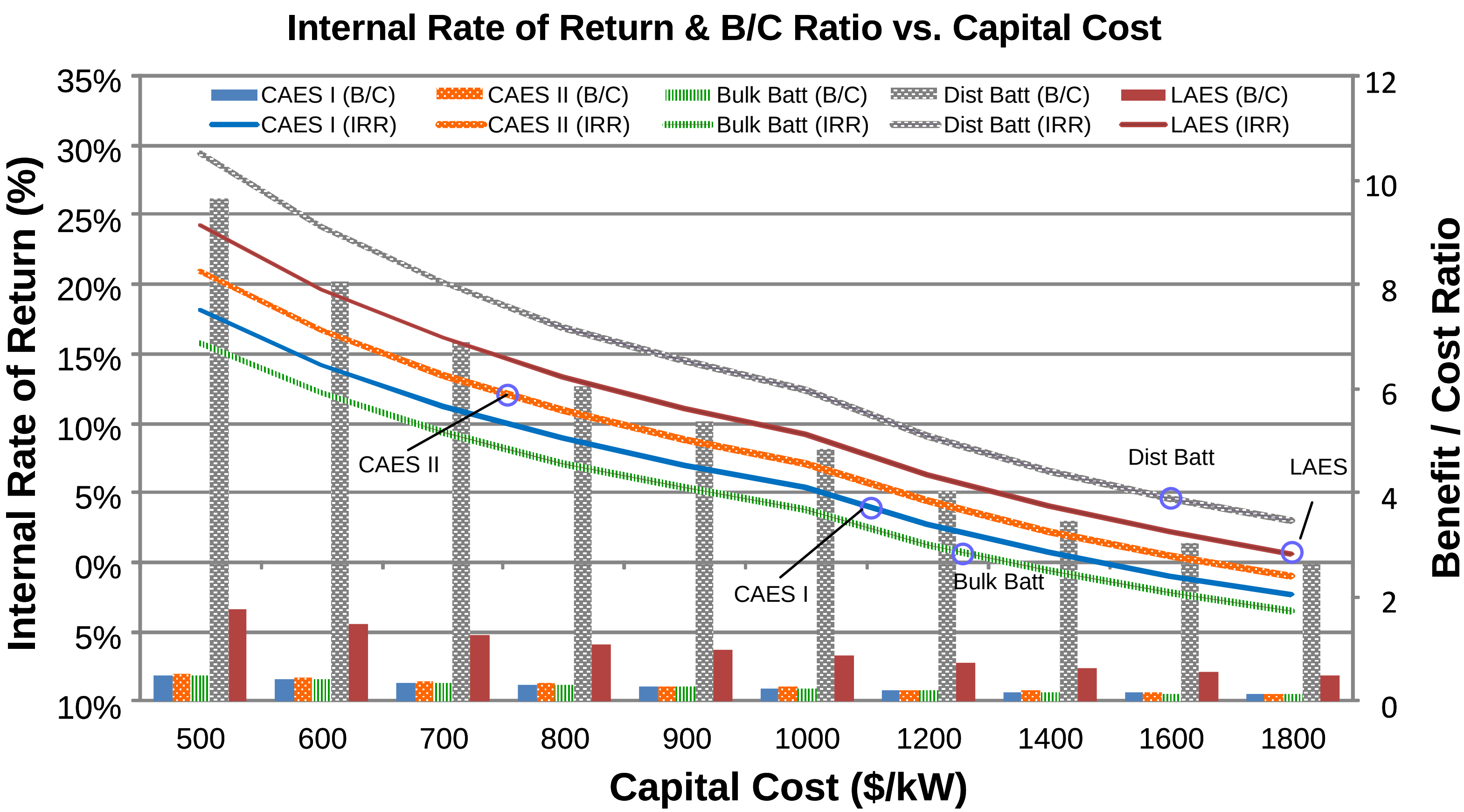
- CO_2 emissions increase by 0.064 M Tons and .11 M Tons with CAES and Bulk battery
- CO_2 emissions decrease by 0.038 M Tons with Distributed batteries



Analysis of Energy Storage Systems to Address Regional Wind Penetration: Case Studies in ERCOT

ERCOT Case Study - Background

Introduction: 2009 EPRI Study investigated storage options in ERCOT (Ref- EPRI:1017824, 2009)



The 2009 study examined the role and value of CAES, bulk Battery, Distributed Battery (Dist Batt) and Liquid Air energy Storage Systems (LAES)

Electric Reliability Council of Texas (ERCOT) Assumptions and Project Scope

To analyze the economic and system benefits of operating a hypothetical Advanced Battery Storage system in the ERCOT market, with special interest in its revenue earning potential from energy and regulation services and estimating the benefits from life expectancy of battery system.

Case Study Objectives:

- Evaluate the extent to which batteries can increase the efficiency of electric system (Benefit and Cost). Purpose of this study is to learn how battery analysis has to be performed taking into account it's charging and discharging characteristics; cycle life vs. depth of discharge profile.
- Increase in the life cycle of the battery is equally important as the cost and revenue.
- Valuate net present value of battery storage at various life cycles
- Calculate the economic benefits from participation in energy and ancillary service (A/S) markets
- Estimate the revenue streams earned
- Assess challenges and opportunities for battery storage to provide ancillary services

Sequential Battery Life Optimization and Maximizing Energy and A/S Revenues

- Energy, A/S revenue and battery life optimization
  - Battery life is optimized sequentially, energy and A/S first, then battery life
  - Battery bids to energy and ancillary service markets
  - To optimize battery revenue and life, battery bids to AS for frequent shallow charge/discharge
  - Both battery life and revenue are optimized

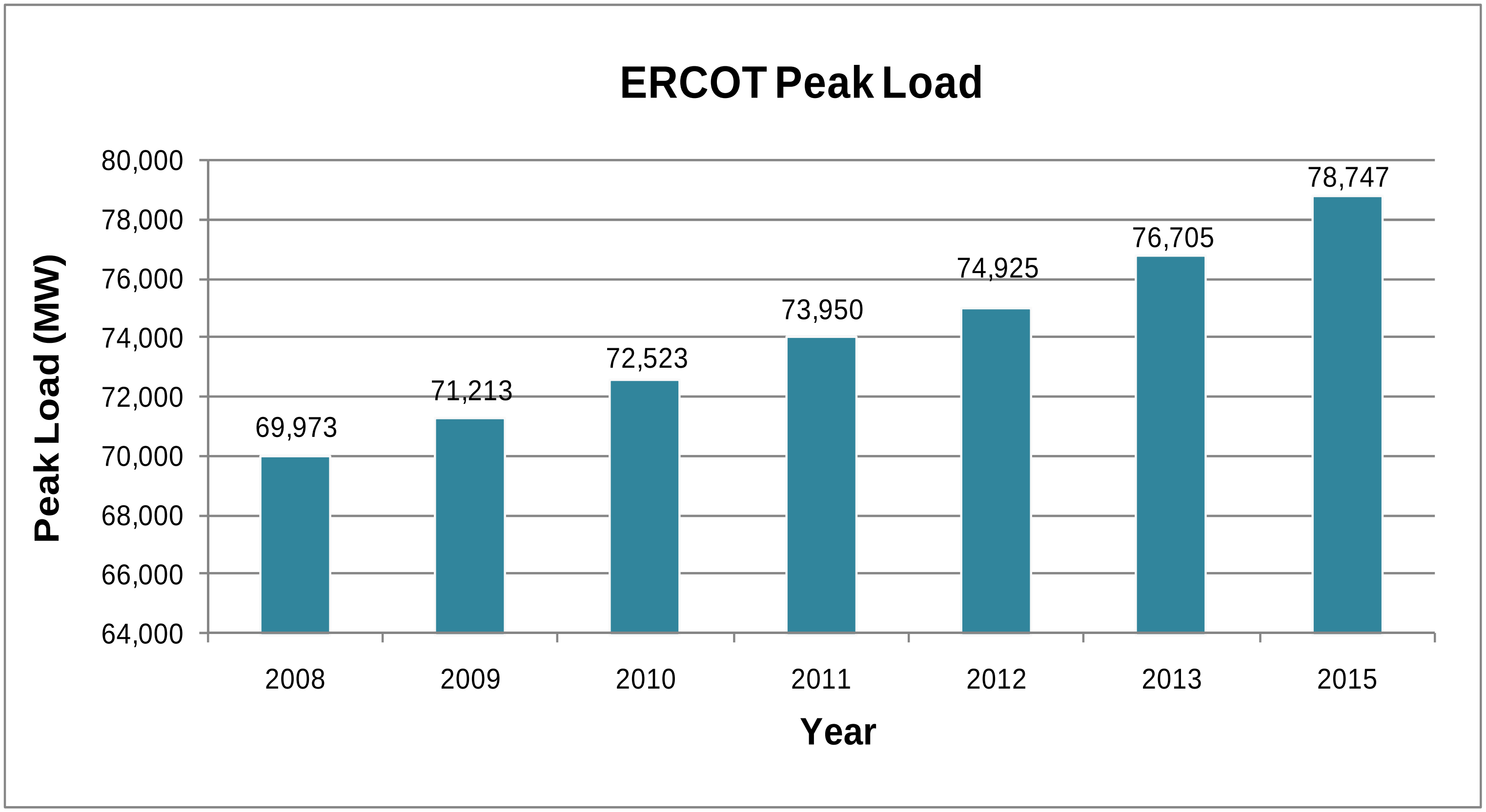
ERCOT ISO Battery Case Study
Approach and Assumptions

- Develop a database for the current infrastructure of ERCOT ISO
  - Load
  - Generation
  - Transmission Topology
  - Fuel Costs
  - Contingencies

- Develop a Base Case to include CREZ Scenario 2 generation, transmission as well as wind expansion
- Simulate the Base Case for CREZ Scenario 2 to produce a detailed forecast of ERCOT prices and unit operations
- Develop a mixed integer program to simulate the operation of battery. Determine the revenue from energy and ancillary services, inventory levels, state of charge of battery (SOC), and life cycle.
- Develop a series of cases with different levels of SOC and evaluate the impact of revenue and cost over the life cycle
- Analyze and quantify additional transmission benefits to the system that may occur due to increased capability of the grid to carry and distribute additional wind

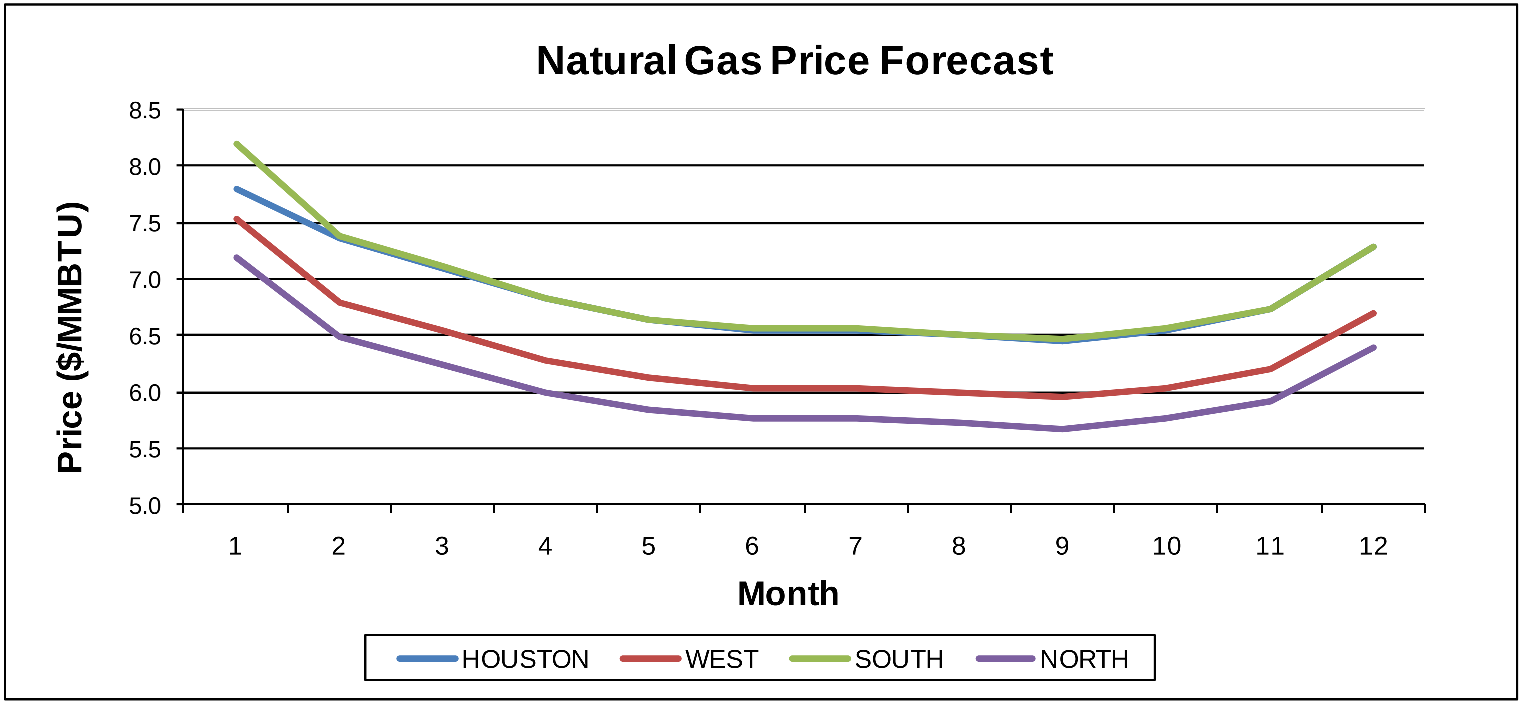
ERCOT ISO Assumptions
Load Forecast – CREZ Scenario 2

- The Scenarios were simulated using UPLAN and Post-CREZ scenario for 2015
- ERCOT Load for year 2015 is based on the Load Forecast Report by ERCOT



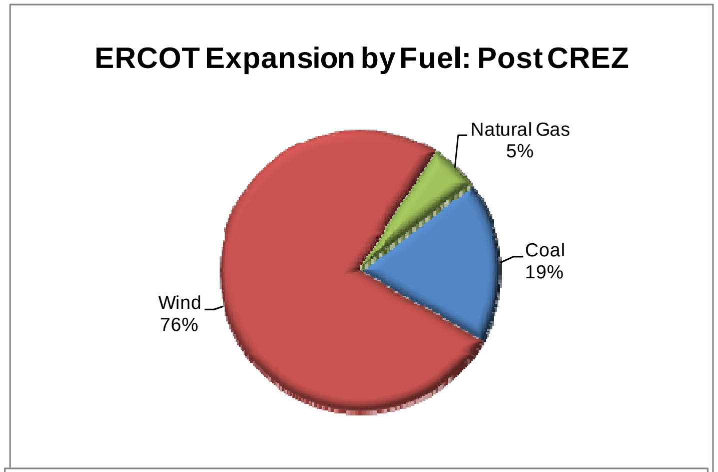
ERCOT ISO Inputs
Natural Gas Prices - Assumptions

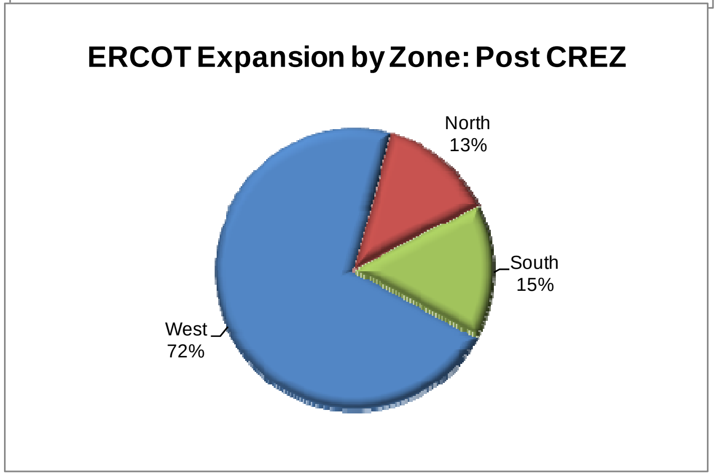
- Natural Gas Price Forecast for 2015 is based on LCG Forecast



ERCOT ISO Inputs Assumptions Generation

- Wind expansion plan was based on CREZ Scenario 2
  - Wind interconnection requests ~ 40,000 MW
  - New CREZ Wind – Scenario 2 ("Hybrid" 18.5 GW)
    - Panhandle A (3191 - MW)
    - Panhandle B (2393 - MW)
    - McCamey (1859 - MW)
    - Central (3047 - MW)
    - Central West (1063 - MW)





ERCOT ISO
Battery Modeling Assumptions

- UPLAN co-optimizes energy and A/S based on ERCOT day-ahead market (DAM). DAM is a daily co-optimized market for energy and ancillary service capacity.
  - Simulation year - 2015
  - The financial settlement of the battery is based on bids in the day-ahead market
  - During discharge the battery receives nodal price (LMP)
  - During charging battery pays zonal price
  - Regulation prices are determined by system-wide co-optimization

ERCOT ISO
Battery Revenue Optimization

- Energy and A/S revenue co-optimization
  - Run UPLAN market model and develop LMP in the battery node and zonal prices at battery zone
  - Using mixed integer programming (MIP) the operation of battery is maximized
  - Battery bids to energy and ancillary service markets
  - To optimize battery revenue and life, battery bids to AS for frequent shallow charge/discharge
  - Both battery life and revenue are optimized

ERCOT ISO
Battery Life Optimization

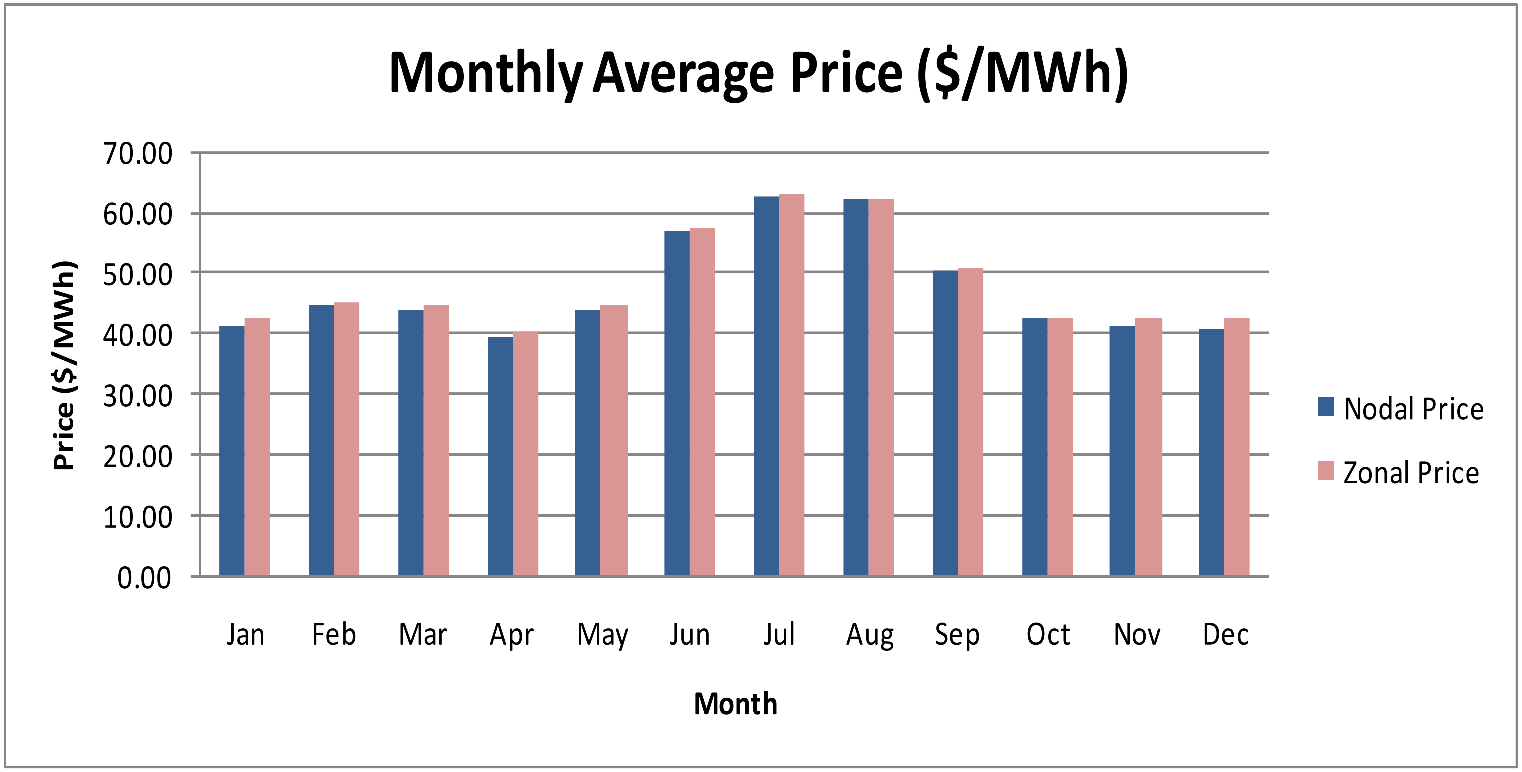
- UPLAN modeling assumptions used for this example of battery revenues and life expectancy.
  - Battery participates mainly in the day-ahead ancillary service markets
  - Inputs to the battery optimization model
  - Energy and A/S price curves from UPLAN
  - Battery assumptions
    - Storage Size
    - Charging/discharging size, efficiency, and storage size
    - Battery bids to A/S every hour at its maximum available capacity
    - Charging/discharging size

ERCOT ISO
Battery Life Optimization

- In this study we evaluate the performance of advanced battery located at a wind farm in ERCOT. The study includes the revenue over lifetime of the battery. Since, the lifetime of battery depends on number of cycles it goes through in its lifetime. The study also includes prolonging the battery life.
- Battery life is optimized sequentially, energy and A/S first, then battery life
- Batteries earn most of the revenue from AS, which has to be scheduled in DA. To take advantage of the DA prices, however actual dispatch takes place in the RT and to enhance the life cycle, one has to stick to the average so that life is maximized. Hence there is a gap between DA and RT scheduling. Hence the protocols need to consider this.
- Life Time optimization
  - Battery operates to provide mostly Regulation Up and Regulation Down.
  - To increase the lifetime, the inventory level is maintained within narrow range by controlling the net change within charge and discharge, close to battery efficiency.
  - Losses are replenished by energy purchases.

ERCOT ISO
Battery Zonal and Nodal Prices Analysis

- Monthly average zonal and nodal price summary (2015)



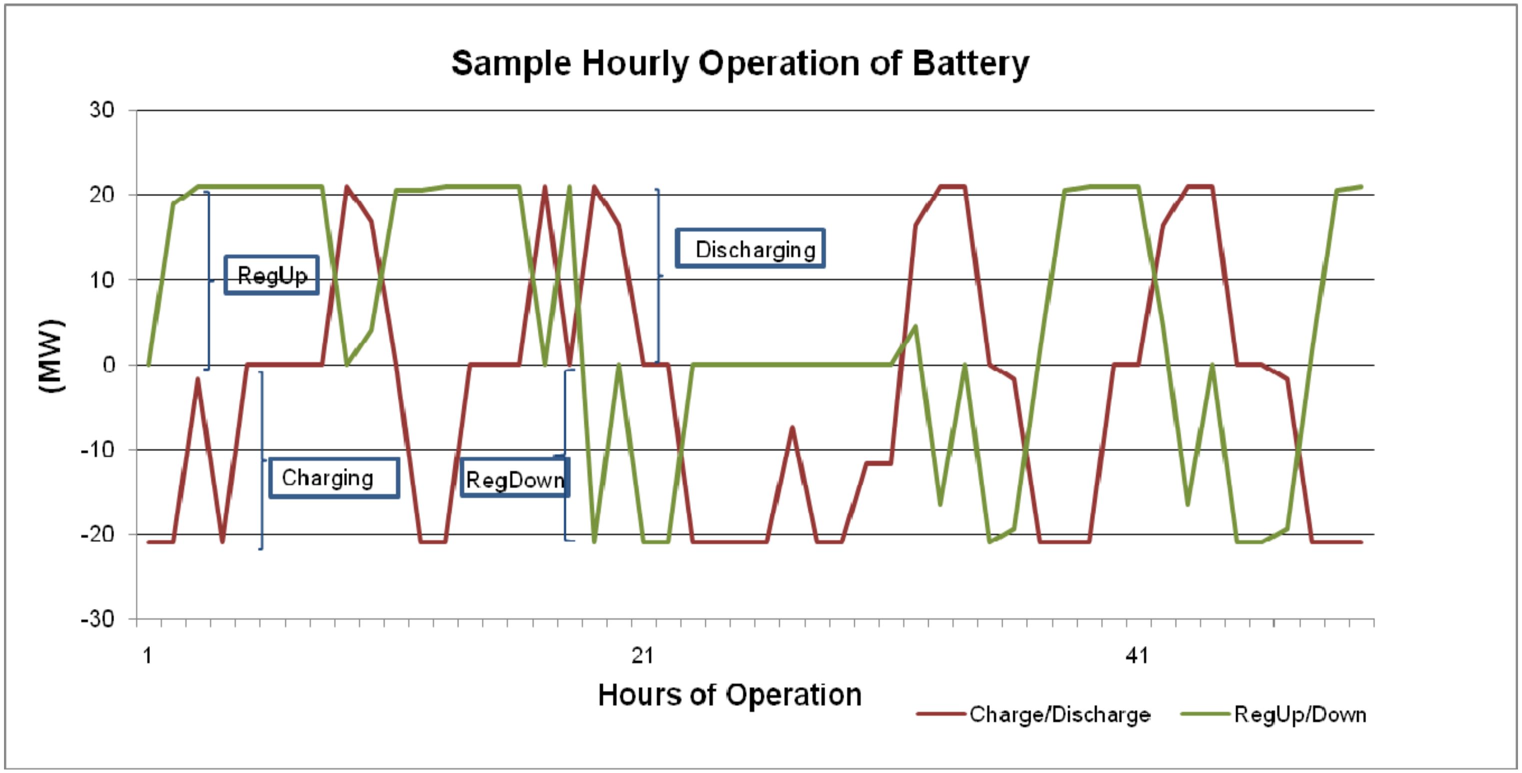
ERCOT ISO
Battery Characteristics

- For this case study an advanced battery was assumed with the following characteristics
- Delta State of Charge (SOC) and Life of the battery were optimized

Characteristic	Battery 25 MW/50 MWh
Net Battery Charge and Discharge Capacity (MW)	25
Optimal Delta SOC	80%
Charge/Discharge Time (hr)	2
Roundtrip ac - ac Efficiency (%)	90%
Capital Cost ($/kW)	800-1200
Fixed O&M Cost ($/kW-Yr)	$1.00
Variable O&M Cost ($/MWh)	$1.00

ERCOT ISO
Battery Characteristics

➩ Hourly operation of battery in various markets



ERCOT ISO
Battery Cost and Revenues

- Monthly operation of battery

Year	Post CREZ								
				Cost	Revenue				Income
Month	Unit Size (MW)	Generation (GWh)	CapacityFactor (%)	Total Cost incl. O&M cost ($1000)	Energy Revenue ($1000)	Regulation Revenue ($1000)	Regulation Down Revenue ($1000)	Total Revenue ($1000)	Net Income ($1000)
Jan	24	3.17	17.73%	109.83	200.81	76.03	41.53	318.37	208.55
Feb	24	3.25	20.14%	133.48	209.55	59.80	48.52	317.88	184.40
Mar	24	3.07	17.18%	100.58	190.99	92.11	31.67	314.77	214.20
Apr	24	2.94	16.99%	85.01	181.45	80.88	24.59	286.92	201.91
May	24	3.01	16.83%	82.55	192.47	83.77	35.31	311.56	229.01
Jun	24	2.23	12.91%	86.54	167.00	68.53	55.44	290.96	204.42
Jul	24	2.27	12.71%	101.97	177.35	70.98	60.30	308.63	206.66
Aug	24	2.17	12.17%	89.85	171.12	70.05	57.79	298.96	209.11
Sep	24	2.63	15.24%	105.38	177.58	88.58	31.74	297.90	192.52
Oct	24	2.80	15.68%	78.29	169.79	83.19	20.46	273.44	195.15
Nov	24	2.96	17.11%	107.24	183.81	93.16	30.85	307.83	200.58
Dec	24	3.64	20.38%	116.76	222.05	66.65	41.71	330.40	213.65
Annual		34.12	16.23%	1,197.47	2,243.97	933.74	479.92	3,657.62	2,460.16

Number of Cycles	548

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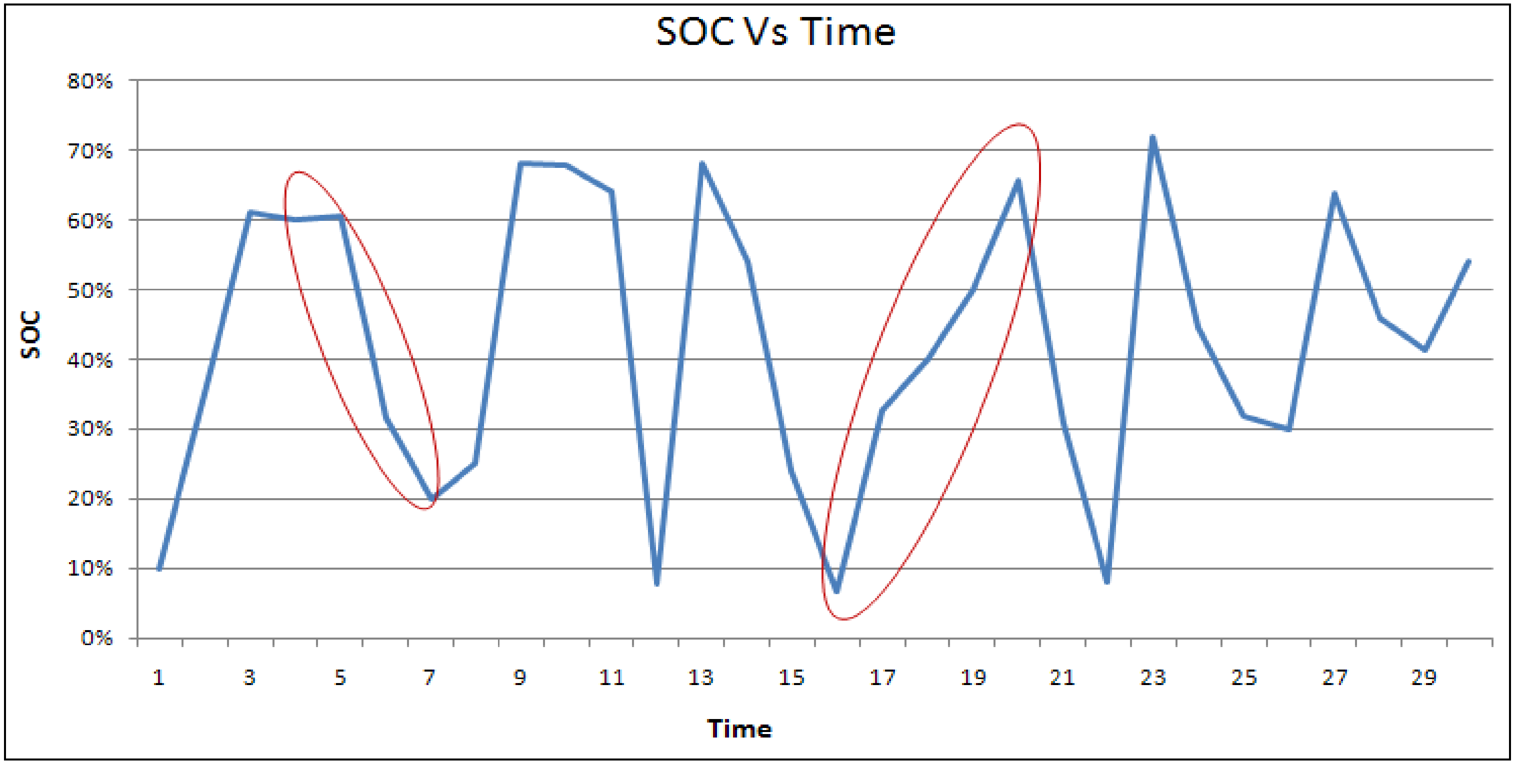
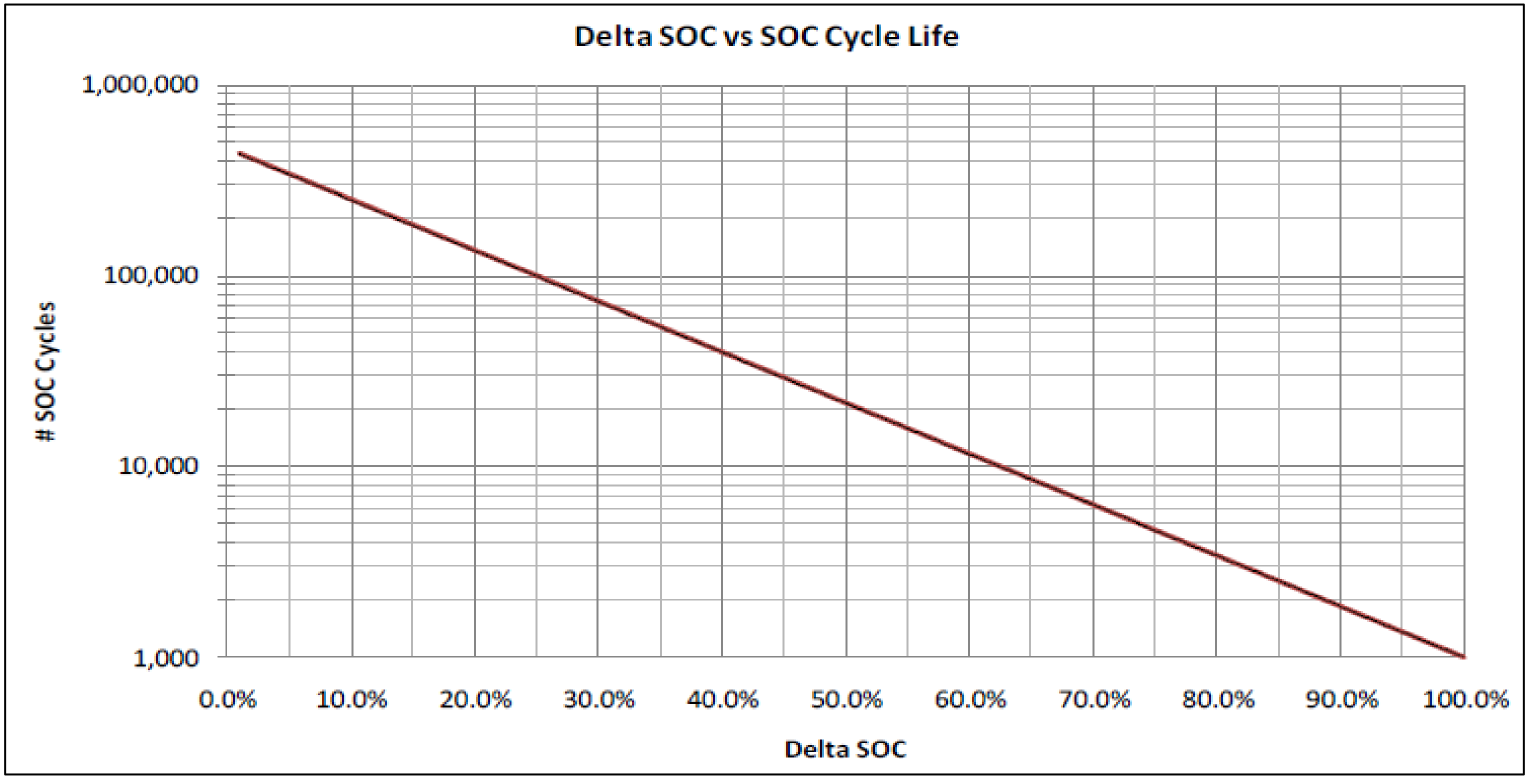
ERCOT ISO
Battery State of Charge (SOC) Cycle

- SOC cycle in ramp operation



ERCOT ISO
Assumed Battery SOC Life Cycle Profile

- Maximum number of cycles (life cycle) that a battery may last as a function change in the state of charge (Delta SOC)



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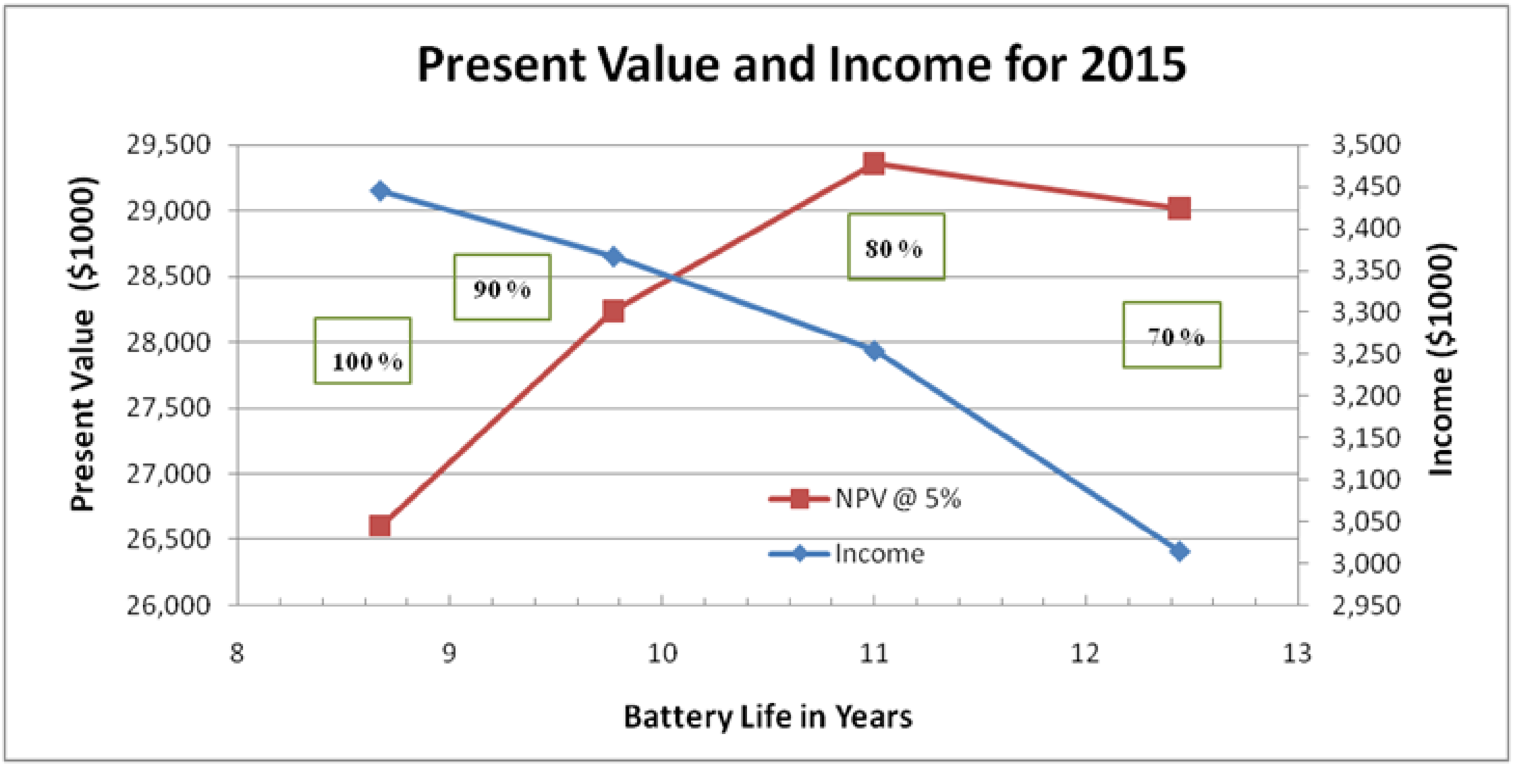
ERCOT ISO
Battery Net Present Value (NPV) and SOC

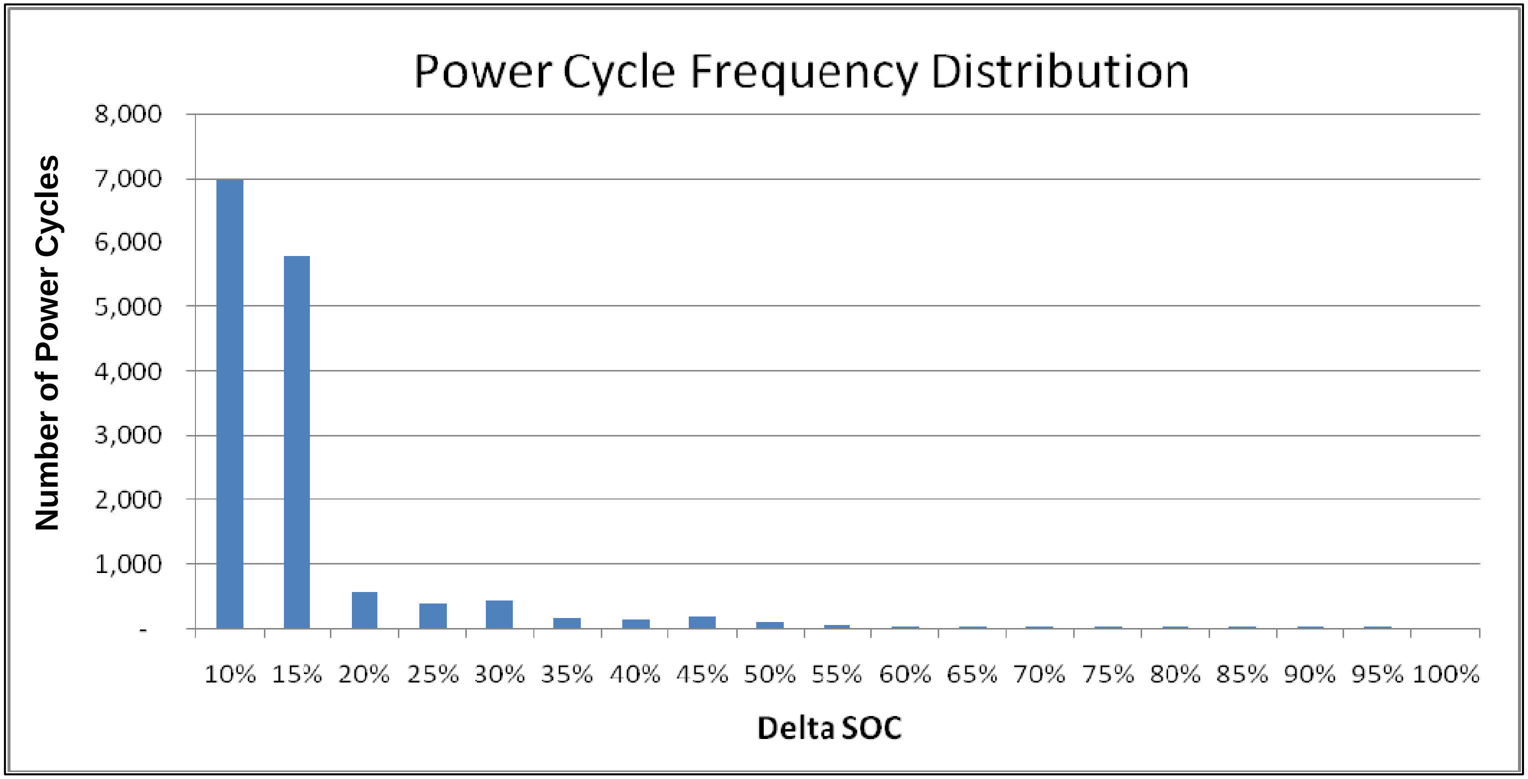
- Present value and Net Income at various battery life. The battery life depends on the operating state of charge (SOC). For example, at 80% SOC, the battery life is 11 years and Net Income is about $3.26 million with a NPV of $29.4 million over 11 years.



ERCOT Battery Storage Case Results

Number of Power Cycles vs. change in state of battery charge

Power Cycle Frequency is the number of times the SOC of the battery changed. For example, in the graph below, the battery changes its SOC 7000 times at 0 – 10% magnitude. At 10% the life of battery is approximately 250,000 cycles. Therefore, at 7000 power cycles, the unit life is estimated to be 11 years.



ERCOT ISO
Recommendations for further study

- Future Analysis
  - Potential benefit of distributed battery across the grid
  - Potential benefit for integration of other intermittent resources
  - Grid integration benefits
    - Stabilizing LMPs
    - Reducing extreme fluctuations
    - Reducing reactive support
  - Evaluate the potential of distributed Battery storage for grid security

ERCOT ISO
Challenges of Modeling Battery

- Current protocol does not support the battery integration into the ERCOT electricity grid
- Batteries pay zonal price during charging and get paid nodal price for discharged power. This introduces unfair arbitrage opportunity
- Uncertainty in market price
- Probability of being called for regulation
- Batteries are a valuable A/S resource and should be given a preferred treatment in the A/S market
- Battery operation should be optimized considering the energy component, A/S component, and life cycle
- The simulation results indicate that there is hardly any arbitrage opportunity in the energy market after A/S market participation

Analysis of Energy Storage Systems to Address Regional Wind Penetration in NYISO and ERCOT

NYISO Storage Case Results
Compressed Air Energy Storage – No Fuel

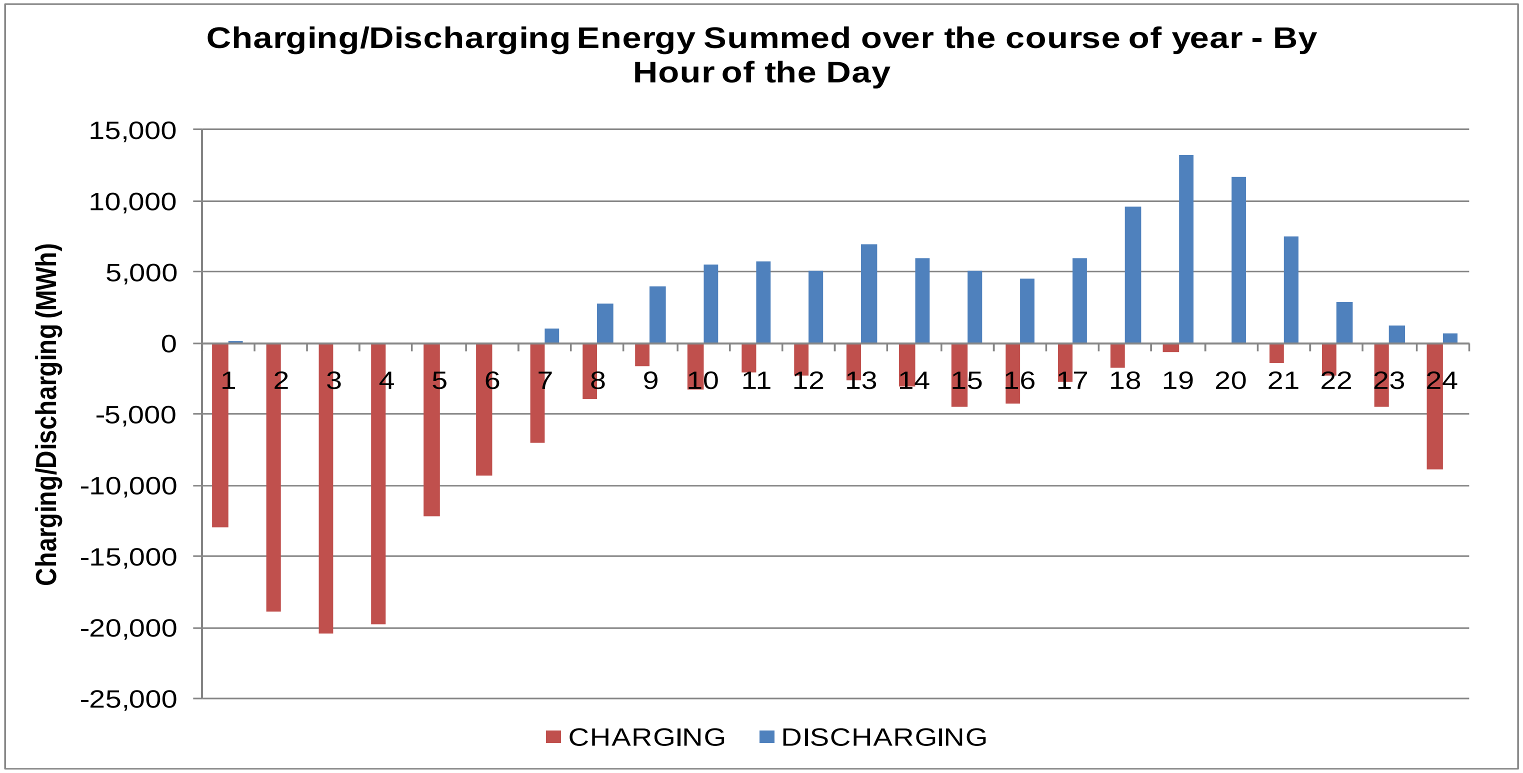
	Optimize Day Ahead Schedule (DAS)
	Compressed Air Energy Storage (CAES) – No Fuel
Energy Rev	**5.79**
Regulation Up	2.05
Regulation Down	0.69
Spin	0.03
Non-Spin	2.87
A/S Rev	**5.63**
Capacity Rev	**0.18**
Total Rev	**11.59**
Fuel Cost	6.62
VOM	0.40
FOM	9.00
Emission CO2	-
Emission NOX	-
Emission SOX	-
Total Cost	**16.02**
Net Income	**(4.43)**
Capacity Factor	**7.6%**

*All values are in $ millions

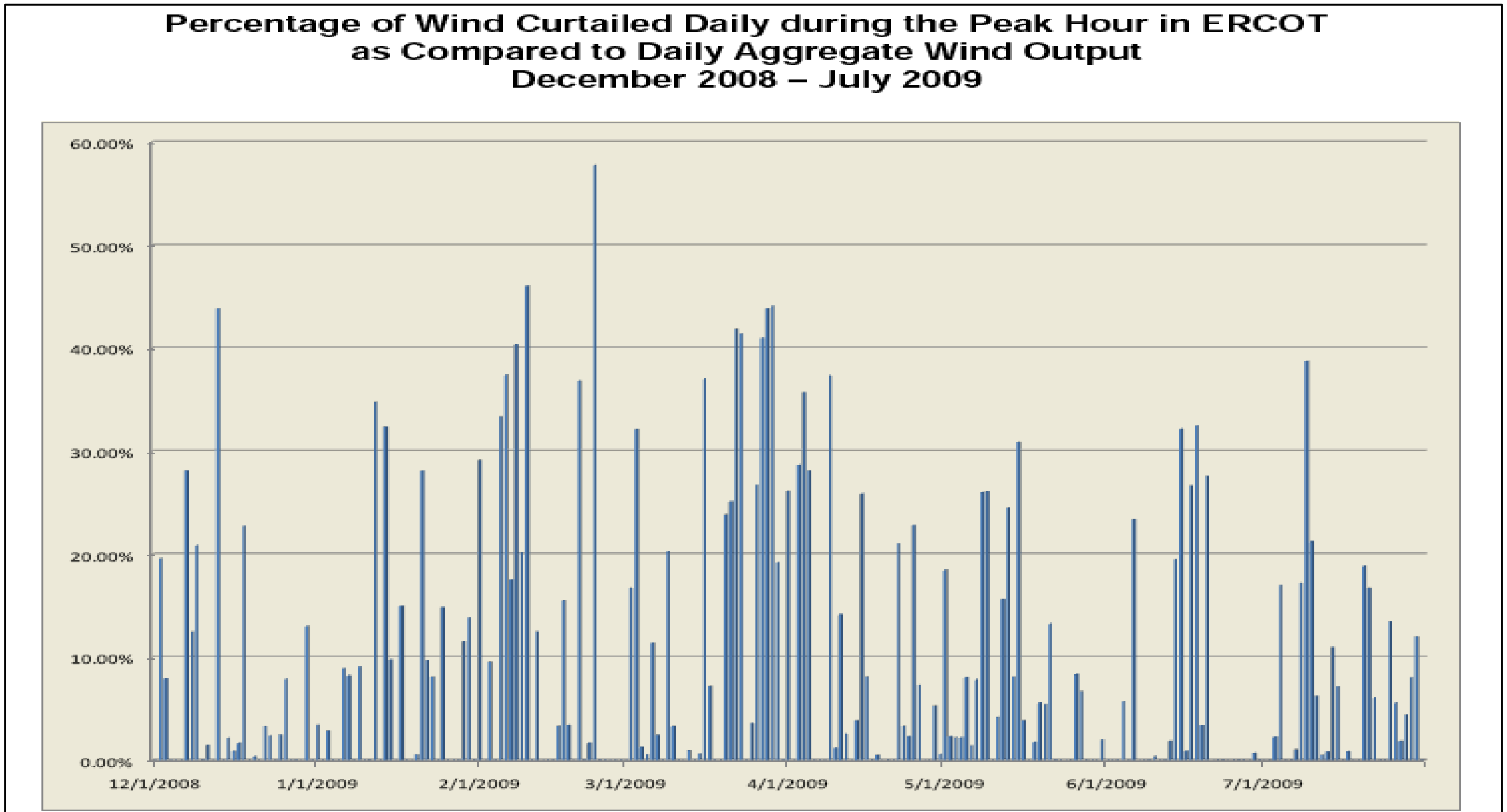
The objective of this UPLAN run was to assess the role and impact of a non-fuel CAES

NYISO Storage Case Results
Compressed Air Energy Storage – No Fuel

- Arbitrage not sufficient for the operation of CAES
- Total Charging hours – 1030, Generating hours – 720

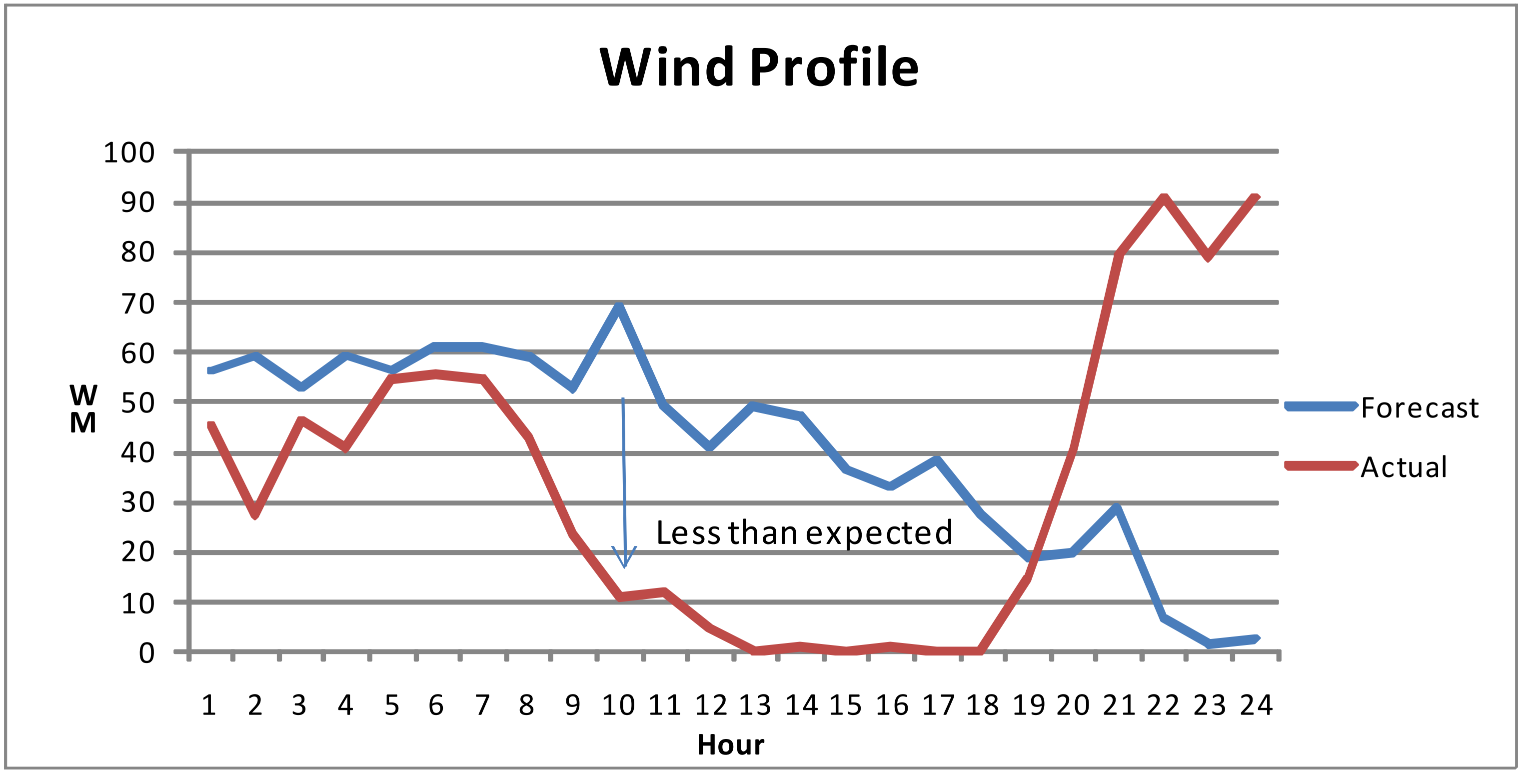


ERCOT ISO
Wind Integration Challenges

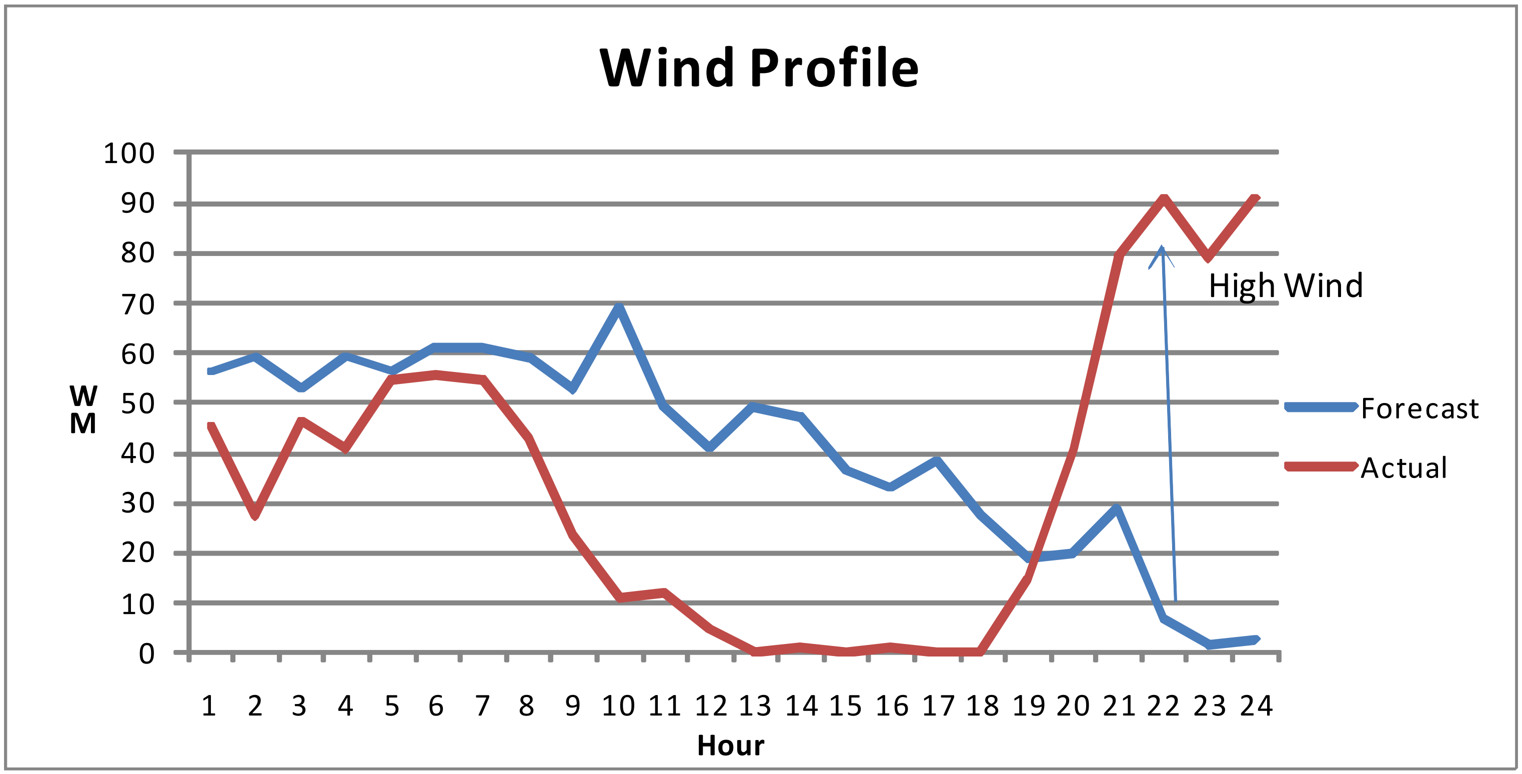


Source: Estimated from Monthly Staff Presentations to the ERCOT Board of Directors, December 2008 through July 2009.

ERCOT ISO Wind Integration
Case : Actual Wind - Less than forecast



ERCOT ISO Wind Integration
Case : Actual Wind - More than forecast



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ERCOT ISO Wind Integration Issues with Wind

- Gaining adequate transmission access to load centers, removing physical and financial disadvantages arising from the intermittency of wind generation and uncertainties in the output of the intermittent energy are some of the important challenges to meet the RPS standard.
- CAES and batteries have the potential to uniquely mitigate some of these disadvantages of wind power and provide a pathway to improved wind integration and substantially increase its economic benefit. The storage and fast "dispatchability" properties of batteries can be used to compensate for the unreliable nature of wind generation and turn it into a reliable commodity.
- To absorb the excess wind the generators may have be backed down or even shut down. Since, the base load generator takes a long time to re-start, shutting down base load generators may not be desirable for system reliability. When this happens compressor unit of CAES can create load to maintain the operation of base load. Batteries and other storage units can also absorb the additionally wind by charging the storage.

ERCOT ISO Wind Integration Issues with Wind (Cont'd)

- The high speed storage devices are particularly useful in absorbing sudden changes in the wind and to smoothen out the fluctuations.
- Wind because of its intermittent nature creates additionally A/S burden which results in high procurement prices for A/S markets. Storage devices can provide A/S and helps mitigate the high the prices.
- The inventory in storage can also be used as non-spinning reserve during the time when the units are not generating or in idle state. This is particularly for un-coupled charged and discharge cycles.
- The areas with high wind penetration are located far from the load centers. There is a need to have sufficient transmission infrastructure for wind generation to reach the load centers. In the absence of sufficient transmission, storage units can help mitigate congestion by charging during congested hours and generating electricity during non-congested hours.