

# Electric Energy Storage: Opportunities and Challenges in NY<sup>1</sup>

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## Introduction

Electricity markets are unique in their dependence on the instantaneous balancing of demand with supply. This Real Time market must be reliable and efficient to meet the needs of the market participants at fair and reasonable prices. In New York, the New York State Independent System Operator (NYISO) administers the state's wholesale energy markets and operates the high voltage electric transmission system. NY electricity market is highly diversified and complex marketplace featuring co-optimized market clearing systems for energy and ancillary services. Included in the NYISO's responsibility is the electric energy management for New York City, which is one of the world's biggest and most complex load pockets.

High energy Electric Energy Storage (EES) applications that include Installed Capacity, Energy sales, Demand Side Response and Ancillary Services, can result in major revenue opportunities or cost savings for various market participants. EPRI Solutions and Customized Energy Solutions recently conducted a detailed market analysis of EES in NY State as part of a joint NYSERDA / DOE Energy Storage Initiative. This market study was designed to identify the multiple revenue streams arising from electric energy storage, especially those benefits that correlate the characteristics of the technology with the opportunities that are available in the new energy markets as demonstrated in New York State through NYISO.

## EES for energy markets

The application of EES at the utility scale has been limited largely by the technical and economic constraints. All technologies have their advantages and disadvantages, and each may be appropriate in a niche market. Various utility grade EES technologies available today include: <sup>[1]</sup>

- Flow Batteries
  - Vanadium Redox Batteries
  - Zinc-bromine Flow Batteries
- Sodium-Sulfur Batteries
- Lead-Acid Batteries
- Nickel-Cadmium Batteries
- Flywheel Energy Storage
- Pumped Hydro Storage
- Compressed Air Energy Storage (CAES)

Although all of the technologies mentioned above are viable in a utility application, some have greater potential than others. Some general conclusions can be made about their potential in NY State:

- Very large scale pumped hydro and CAES continue to have some potential where geographic considerations allow their use. Most suitable pumped hydro sites have already been developed, but opportunities exist for CAES. Unfortunately, most prospective CAES sites in New York are in the western side of the state, where the economic case of energy storage is the weakest.
- Of the other energy storage technologies, sodium-sulfur, vanadium redox, and zinc-bromine are quickly approaching maturity in manufacturing and have shown substantial promise in recent field demonstrations. Should promised cost reductions become a reality, these technologies will be well-situated for the bulk energy storage market.

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<sup>1</sup> This project is part of the Joint Energy Storage Initiative between the New York State Energy Research and Development Authority (NYSERDA) and the Energy Storage Systems Program of the U.S. Department of Energy (DOE/ESS), and managed by Sandia National Laboratories (SNL).

- The extremely high cycle life of flywheel devices makes up for their relatively low energy density, so that they may be viable solutions for applications such as frequency regulation. Ultracapacitors and SMES devices, may also have potential in these applications, but are not yet mature enough to consider in a utility size market application.
- Lead-acid batteries are not being considered in this analysis because they are already very mature and have been demonstrated repeatedly in a utility energy storage context, with no substantial subsequent development. Utilities seem reluctant to accept lead-acid facilities because of the relatively short service life and perceived large maintenance costs. In addition, the environmental effects of large lead-acid batteries may be significant.

### **NY Electricity Markets**

The NYISO Electricity Market includes markets for installed capacity, energy, ancillary services and transmission congestion contracts. There are six ancillary services in the NYISO Market that may provide revenue opportunity for EES. These include 10 minute synchronous reserves, 10 minute non-synchronous reserves, 30 minute reserves, regulation and frequency control, voltage support and black start service. Currently, approximately 50% of the energy in New York State is traded through bilateral contracts outside of the NYISO market. For the remaining energy, approximately 45% is transacted in the NYISO Day-Ahead Market (DAM), and 5% is transacted in the NYISO Real Time Market (RTM).

### **Economic Analysis<sup>2</sup>**

We analyzed and evaluated the economic benefits of EES for following applications in New York. <sup>[2]</sup>

- 10 Hr “Energy Arbitrage”
- 4 Hr “Energy Arbitrage”
- 24 Hr “Regulation and Frequency Support”
- 2 Hr “Energy Arbitrage” and 2 Hr of “Regulation and Frequency Support”
- 2 Hr “Energy Arbitrage” and 20 Hrs of “10 minute Spinning Reserves”
- 2 Hr “Energy Arbitrage” and 20 Hrs of “10 minute Non Spinning Reserves”
- Demand Response Program participation
- Supporting Renewable Energy Sources

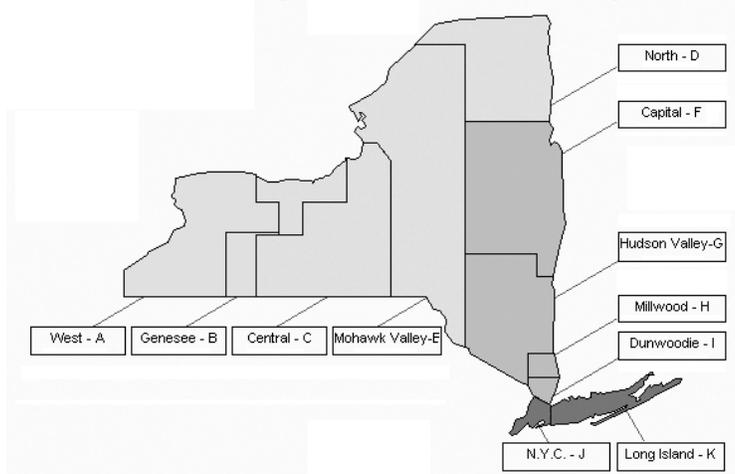
The operating periods were selected based on following criteria:

- Most of the EES technologies that can be used for the long duration energy arbitrage have efficiencies in range of 65% - 85%. Thus the ratio of Input power to output is approximately in range of 1.2 – 1.4. Assuming that these units are charged and discharged at same rate, this results in 20-40% additional charging time. Thus maximum duration of energy arbitrage considered was 10 Hrs.
- NYISO allows EES participating under Energy Limited Resources or under ICAP Special Case Resource program to receive capacity credits provided they can supply energy for 4 consecutive hours.
- We also analyzed the revenue potential for 2 Hr energy arbitrage, as a mixed operational strategy where the units will be used for both energy and ancillary services.

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<sup>2</sup> *Disclaimer: The study was conducted using NYISO published Market Data. The Market Data has been influenced by many factors throughout the startup and current operation of the NYISO. Operation and resulting price information reported in the past may not be reflective of operation and prices in the future.*

**Fig 1. NYISO Control Area (adapted from NYISO LBMP Map)**



The NYISO Control Area is divided in 11 zones, which can be grouped in 3 regions NY West, NY East and NYC region as shown below. The analysis is based on the zonal Location Based Marginal Prices (LBMP) data for 2001-04 period. Potential net revenues were also determined for all 3 regions.

**Table 1. NYISO Location Based Marginal Price distribution across zones**

| Region  | Zone          | Peak     |         |         | Off Peak |         |         |
|---------|---------------|----------|---------|---------|----------|---------|---------|
|         |               | All year | Summer  | Winter  | All Year | Summer  | Winter  |
| NYC     | Long Island   | \$65.77  | \$66.83 | \$64.69 | \$46.47  | \$46.50 | \$46.44 |
|         | NYC           | \$66.43  | \$67.22 | \$65.64 | \$44.12  | \$43.99 | \$44.25 |
| NY-East | Hudson Valley | \$55.23  | \$55.96 | \$54.50 | \$38.60  | \$37.26 | \$39.97 |
|         | Capital       | \$54.09  | \$54.11 | \$54.07 | \$38.44  | \$36.91 | \$40.01 |
|         | Dunwoodie     | \$56.13  | \$57.09 | \$55.15 | \$38.84  | \$37.60 | \$40.09 |
|         | Millwood      | \$55.32  | \$56.26 | \$54.38 | \$38.34  | \$37.06 | \$39.65 |
| NY-West | Genesee       | \$47.46  | \$46.98 | \$47.95 | \$33.91  | \$32.27 | \$35.58 |
|         | North         | \$48.07  | \$47.22 | \$48.94 | \$35.23  | \$33.41 | \$37.08 |
|         | MH Valley     | \$49.72  | \$49.16 | \$50.29 | \$35.87  | \$34.17 | \$37.60 |
|         | Central       | \$48.36  | \$47.93 | \$48.79 | \$34.65  | \$33.02 | \$36.31 |
|         | West          | \$45.40  | \$45.31 | \$45.49 | \$32.45  | \$30.98 | \$33.94 |

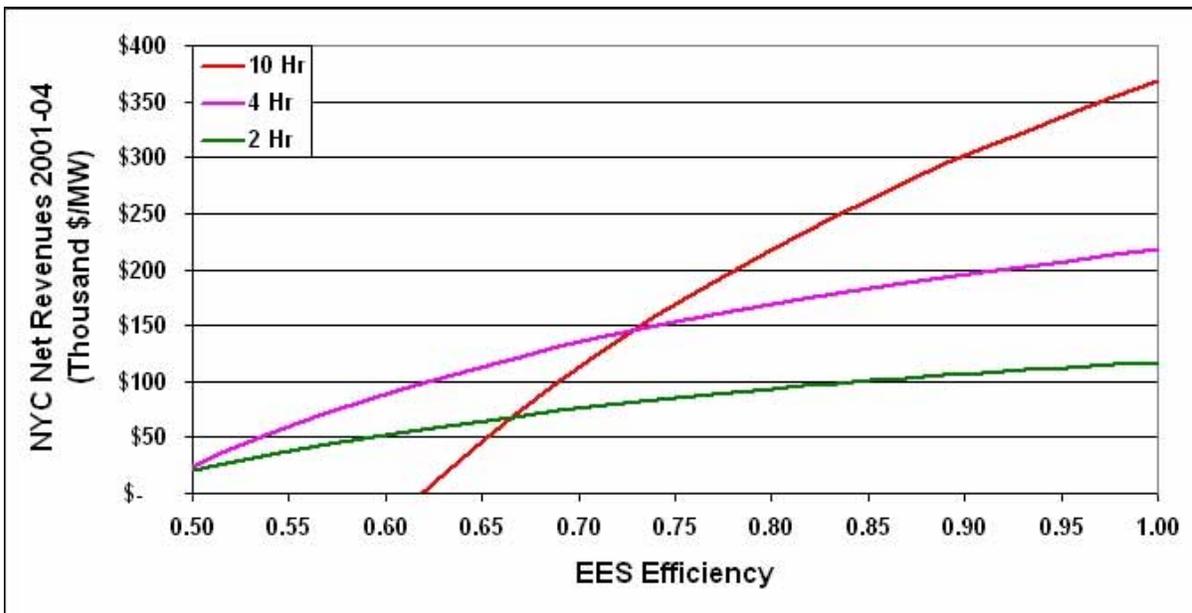
The following graph shows the expected net revenues for 2001-04 for a unit selling 1 MW power for 10 hrs in the 3 regions. It was assumed that the round trip efficiency of the EES unit was 83% while estimating the net revenues. A unit placed in NYC region would have generated net revenue of \$250,000 over the 4 year period, where as a similar unit located in the NY East and NY West regions would have earned net revenue of \$160,000 and \$125,000 respectively.

**Fig 2: Net revenue from 10 Hr Energy Arbitrage in different regions**



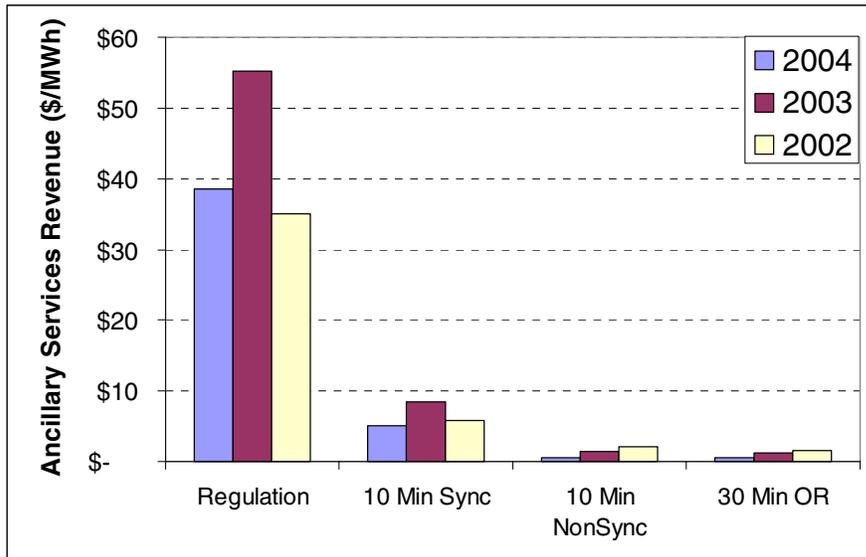
Net revenue from the energy arbitrage is highly sensitive to the efficiency of the EES. The higher the efficiency, more revenues can be generated by an EES for 10 Hr operations at same output power (e.g. 1 MW) as compared to 4 Hr or 2 Hr operations. Due to the different energy prices in 3 regions the switchover points between these 3 operations occur at slightly different efficiencies for 3 regions. Following graph shows the expected net revenue as a function of EES efficiencies in NYC region.

**Fig 3: Cumulative Net Revenues 2001-04 Vs EES Efficiency in NYC region**



For ancillary services, the NYISO area is divided in 2 regions, NY West and NY East (including NYC region). Fig. 4 summarizes the ancillary services revenues that can be expected by EES technologies providing these services for highest paying 4 hours.

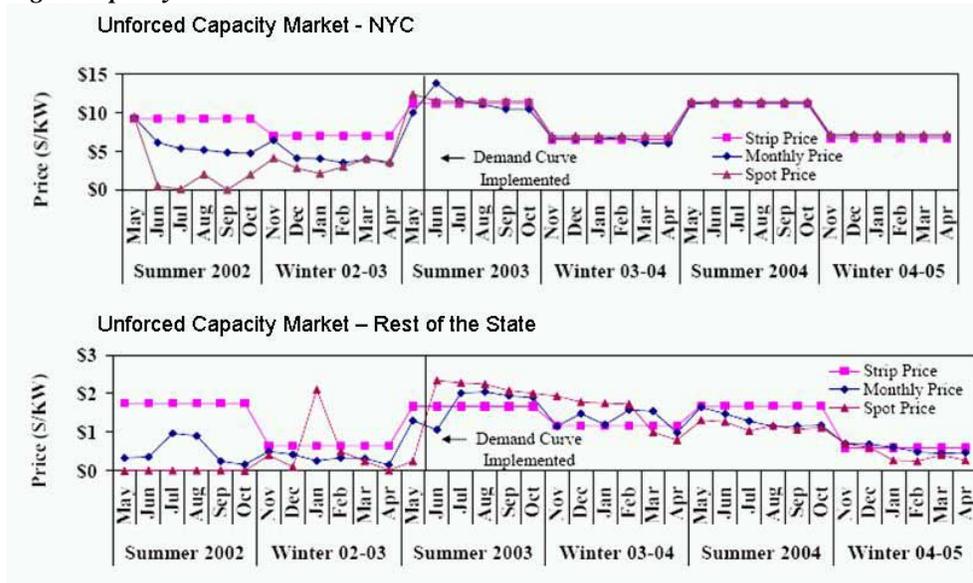
Fig 4: Ancillary services revenue for top 4 Hr (2002-04)



As seen from the chart, the regulation services offer maximum revenue potential amongst all the ancillary services. It should be noted that under current market rules, most of the EES technologies considered are not allowed to provide 10 min spinning reserves. Under NERC guidelines this service can only be provided by synchronous generators running under no load, which are synchronized to grid frequency and can respond in less than 10 minutes.<sup>[3]</sup>

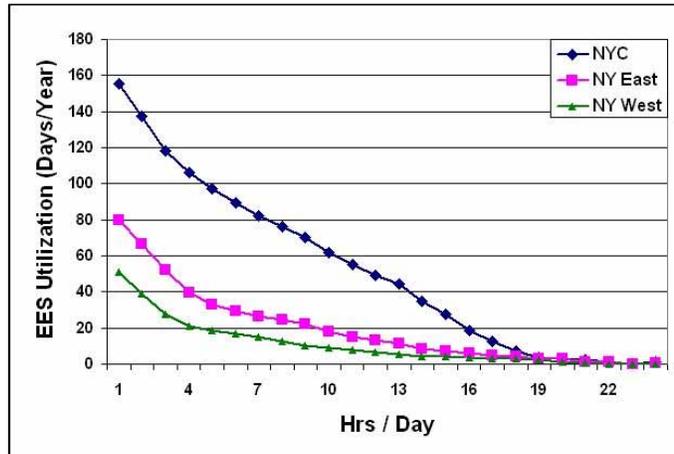
EES capable of providing at least 4 hrs of energy are eligible to receive capacity payments as an Energy Limited Resources. EES can also receive capacity revenues by participating in the Demand Side Response program as a Special Case Resource (ICAP-SCR). Due to the locational transmission and environmental constraints, EES resources located in NYC region can expect to receive attractive payments in range of \$40,000 - \$140,000 per MW-year, whereas EES resources located in rest of the state get paid much smaller capacity payments in range of \$3,000 to \$25,000 per MW-Year.

Fig 5: Capacity Revenues 2004-05<sup>[2]</sup>



**Fig. 6 DSR Potential in different regions.**

The NYISO has some of the most effective Demand Side Response (DSR) programs in the country. There are currently three demand response programs in New York State, including Day Ahead Demand Response Program (DADRP), Emergency Demand Response Program (EDRP) and ICAP SCR program. In our analysis we focused on the DADRP as it is the economic incentive program. We estimated the potential for participation in economic DSR program by calculating the number of hours in each region, when LBMP went above \$75, which is the floor price for economic DSR program. Following figure shows the potential for DSR participation in different regions. This information can be used for determining optimum size of any EES device that will be used as behind the meter resource for participating in DSR program. The graph indicates that an EES capable of delivering 4 hours of energy will be utilized for approximately 105 days in NYC region, where as a similar device will get fully utilized for only 40 and 20 days in NY East and NY West regions respectively.



Based on the technical capabilities of different EES technologies and market rules, the study investigated whether EES technologies are cost-competitive with the technologies and strategies currently in use in NY electricity markets. Following tables show the summary of the expected net revenues for different applications in all 3 regions. The estimates for average scenario for net revenue were calculated using the average revenue and cost figures from 2001-04 energy and 2002-04 ancillary services data.

**Table 2: Summary of potential net revenue for various applications in different Regions**

| Application  | Expected Net Revenue \$/MW-Yr |            |            |
|--|-------------------------------|------------|------------|
|  | NYC                           | NY East    | NY West    |
| Energy Arbitrage: 10 Hrs                           | \$ 112,772                    | \$ 22,986  | \$ 17,839  |
| Energy Arbitrage: 4 Hrs                            | \$ 134,991                    | \$ 45,841  | \$ 39,093  |
| Energy Arbitrage: 2 Hrs + Regulation: 2 Hrs        | \$ 140,094                    | \$ 46,988  | \$ 43,241  |
| Energy Arbitrage: 2 Hrs + Sync Reserve: 20 Hrs     | \$ 138,897                    | \$ 87,919  | \$ 41,240  |
| Energy Arbitrage: 2 Hrs + Non Sync Reserve: 20 Hrs | \$ 122,253                    | \$ 29,147  | \$ 24,961  |
| Energy Arbitrage: 2 Hrs + 30 Min Reserve: 20 Hrs   | \$ 121,377                    | \$ 28,271  | \$ 24,523  |
| Regulation: 24 Hrs                                 | \$ 202,969                    | \$ 202,969 | \$ 202,969 |
| Demand Response                                    | \$ 137,834                    | \$ 33,388  | \$ 24,245  |

**Technical Benefits of Energy Storage**

In addition to the economic benefits discussed above, various EES technologies also offer additional technical benefits to the operation of electric grid. Some of these benefits are listed below: <sup>[1]</sup>

- **Grid Stabilization:** EES can be used to help the transmission or distribution grid return to its normal operation after a disturbance. EES can be used to remedy three forms of stabilization: Rotor angle instability; voltage instability; and frequency excursions.
- **Grid Operational Support:** EES can also be used to support normal operations of the grid. Four types of support operations can be performed through the use of EES: Frequency Regulation Services; Contingency Reserves; Voltage Support and Black Start
- **Power Quality and Reliability:** Vast majority of grid-related power quality events are voltage sags and interruptions lasting less than 2 seconds, fact that lends to EES based solutions.
- **Load shifting:** EES can be used for load shifting though peak shaving and load leveling.

- ***Applications to Renewable Power Sources:*** Renewable power sources, such as solar or wind power, often benefit from the addition of EES. EES can absorb energy when the generated power exceeds the need, and covering the shortfall when the generated power is less than needed.

### **Conclusion**

EES technologies, capable of discharging at higher power and energy densities can offer various benefits in NYISO electricity markets. Benefits of energy storage energy arbitrage, regulation control, frequency support and demand response. In this study we tried to quantify the opportunities available for participating in these NYISO markets. The study indicates that significant opportunities are available for EES technologies to capture the market value by participating in energy, ancillary services and demand response markets in NYISO. The economics of these systems will greatly depend on it's location in the grid, capital and operating cost as well as efficiency of the EES systems. For wider acceptance of these emerging technologies in competitive electricity markets, the market participants need to understand the various value streams presented by the capabilities of EES and optimize the EES applications to tap into multiple revenue sources available in markets.

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### **References**

- [1] EPRI-DOE Handbook of Energy Storage for Transmission and Distribution Applications, EPRI, Palo Alto, CA, and the U.S. Department of Energy, Washington DC: 2003.
- [2] State of the Market report 2005, Market Monitoring Committee, NYISO
- [3] NYISO: Ancillary Services Manual: [www.nyiso.com](http://www.nyiso.com)

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