# The State of Storage

## Energy Storage Resources in New York's Wholesale Electricity Markets

A Report by the New York Independent System Operator

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# Abstract

As the grid evolves, Energy Storage Resources (ESRs) contribution to maintaining a reliable and cost effective grid is expected to grow. ESRs such as pumped hydroelectric generators, flywheels, and batteries can supply electricity to the grid to meet demand, and can withdraw electricity from the grid to alleviate excess supply. ESRs can promote more reliable and efficient operation of the electric grid, particularly when paired with intermittent renewable generation. ESRs can participate in the New York Independent System Operator, Inc. (NYISO)-administered energy, ancillary service, and capacity markets in certain limited participation models (*e.g.,* Limited Energy Storage Resource[a] (LESR), Energy Limited Resource (ELR), and demand response programs).

Here at the NYISO, we continue to look for better ways to integrate ESRs into New York's wholesale electricity markets and harness the value that ESRs can bring to the grid. The NYISO looks to create a new participation model for ESRs.

The *Energy Storage Integration Phase* will create a new ESR participation model that captures unique storage characteristics.

The second phase, *Energy Storage Optimization*, looks to more efficiently utilize ESR services taking into account the resource's energy constraints over the course of a day. In the second phase, ESR operators may grant the NYISO permission to maximize the ESR's potential instead of submitting conventional DAM or RTM offers.

The third phase, *Renewable and Storage Aggregation* will analyze the pairing of ESRs with intermittent resources.

The NYISO is currently engaged in developing a new market design concept that reflects ESR technological advancements and policy development to allow wholesale grid operators and ESR managers to take better advantage of ESR capabilities. This Report will describe the technical, regulatory, and market landscape for ESRs and the NYISO's proposed full market participation model.

[a] Capitalized terms not defined in this paper have the meaning defined in Section 1 of the NYISO's Open Access Transmission Tariff (OATT) and Section 2 of the Market Administration and Control Area Services Tariff (MST).

## Executive Summary

In New York, there is both a wholesale and a retail market for electricity. Generators participating in the wholesale markets offer to sell power to Load Serving Entities (LSEs). LSEs purchase electricity at wholesale rates and sell electricity in the retail market to end-use consumers, for instance homes or businesses, typically at standard rate isolated from real-time system conditions. The wholesale market schedules supply to meet end-use demand. The NYISO oversees competitive wholesale electricity markets for energy, ancillary services, and capacity to maintain electric system reliability at the lowest price to consumers. ESRs are resources that can help the NYISO balance supply and demand in a reliable and efficient manner due to their flexibility to consume or supply electricity.

**Energy**

The amount of electricity a generator produces over a specific period of time, measured in megawatt-hours (MWh).[2]

**Ancillary Services**

Ancillary services are the speciality services and functions provided to the grid that facilitate and support the continuous flow of electricity to meet demand. Examples include regulation service, operating reserves, voltage support, and black start capability.

**Capacity**

The ability to generate or transmist electrical power, or the ability to control demand at the direction of the NYISO, measured in megawatts (MW).[3]

Energy storage is defined by the Federal Energy Regulatory Commission (FERC) as "a resource capable of receiving electric energy from the grid and storing it for later injection of electricity back to the grid regardless of where the resource is located on the electrical system."[1] Examples include, among others, pumped hydroelectric storage, compressed air energy storage, flywheels, and batteries.

Storage can be located either in front of the meter (FTM) or behind the meter (BTM). FTM storage units are "in front" of a distribution utility's retail meter, meaning that the units generally transact solely in the wholesale markets. In contrast, BTM units are typically limited to retail transactions, although there are some NYISO participation models that allow eligible BTM facilities to be compensated for load reduction in the wholesale markets. A few different phrases can be used to convey this distinction (wholesale versus retail; federal versus state jurisdiction; distribution versus transmission; etc.), but for simplicity, this Report will describe ESRs as FTM or BTM.

Under the participation model contemplated by the NYISO's DER Roadmap,[4] ESRs 20 MWs or less (whether FTM and BTM) will be allowed to aggregate with other non-ESR distributed energy resources (DER) in order to facilitate wholesale market participation; minimum aggregation size for the DER participation model will be 0.1 MW. Separately, FTM ESRs less than one MW will be allowed to aggregate with similar ESRs in order to facilitate wholesale market participation under the ESR participation model; minimum aggregation size will be 0.1 MW. The NYISO describes the ESR participation model futher in this Report.

This Report focuses on FTM ESRs with a capability of 0.1 MW or more that want to participate in the NYISO-adminsitered wholesale markets. The Report will:

- Highlight the advantages ESRs can provide to the wholesale market;
- Identify storage technologies that currently participate in the NYISO administered wholesale markets as well as certain technologies that may participate in the future;
- Explain the NYISO market models under which storage currently participates;
- Describe New York State policies, like Reforming the Energy Vision and the Clean Energy Standard, which are opening new opportunities for ESRs;
- Identify barriers to ESRs' full market participation;
- Describe the NYISO's current ESR market design proposal; and
- Outline the NYISO's anticipated timeline for integration, development, and deployment of a new market participation model for FTM ESRs sized 0.1 MW and above.

## Capabilities of ESRs

ESRs could offer various services into the NYISO markets. The NYISO oversees a Day-Ahead Market (DAM) and a Real-Time Market (RTM). The NYISO schedules energy, regulation, and operating reserves in the DAM and RTM. The NYISO also administers a seasonal (summer and winter) capacity market. Capacity for each six month Capability Period is sold in a six-month strip auction, a monthly auction (all remaining months in the Capability Period), and a spot market auction (prompt month).

### Distributed Energy Resource (DER)

FERC defines a Distributed Energy Resource (DER):

> **"A source or sink of power that is located on the distribution system, any subsystem thereof, or behind a customer meter."**[5]

The NYISO's definition of DER continues to evolve, but generally could be described as :

> **"A Supplier that participates in an aggregation using a combination of various technologies including Demand Side Resources, energy storage resources, Generators, and Intermittent Power Resources."** [6]

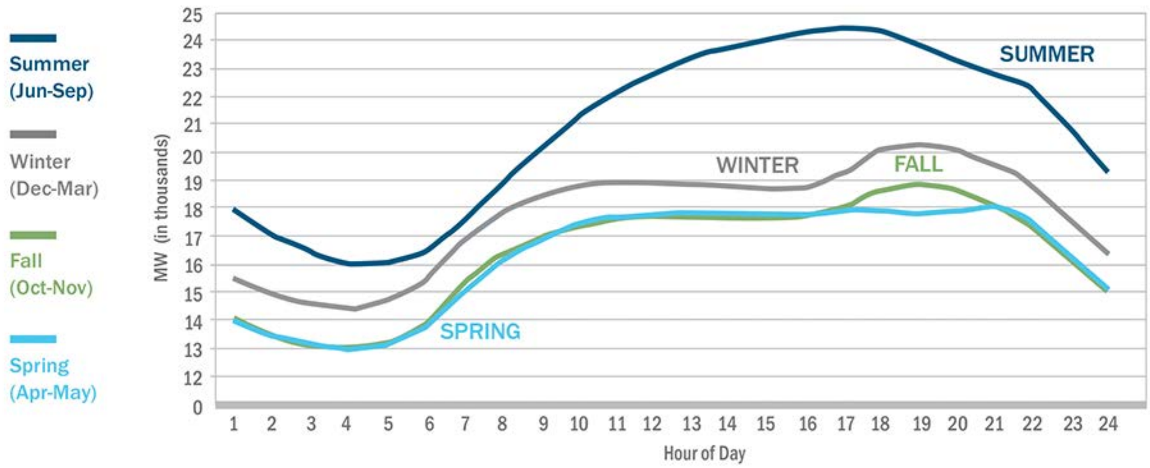
While some storage may be considered DER, not all DER are storage. Examples of DER in the wholesale market include aggregated residential solar panels or an industrial complex's natural gas generator that reduces peak demand. The NYISO is creating a new participation model for DER which will leverage many of the capabilities found in the market participation model developed for storage. The NYISO is aware of synergies existing between FTM and BTM storage programs, and looks to share concepts when warranted.

### Energy

ESRs' ability to shift load as a consumer when load is low and as a supplier when load is peaking, can help grid operators handle peak demand, manage the variability of intermittent resources, and potentially defer transmission upgrades in some instances.

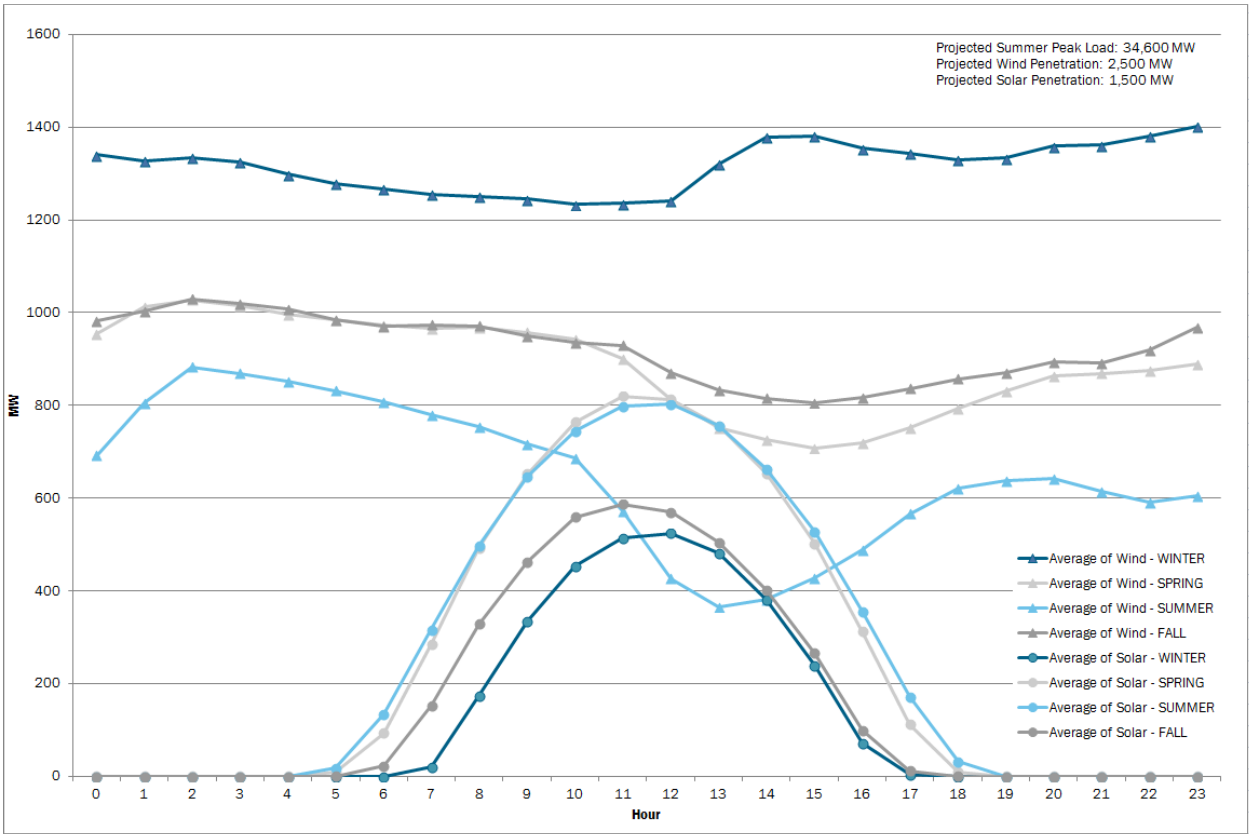
Electricity demand is not constant. Peak demand is the maximum amount of electricity consumed during a one-hour period for a particular time and location. [7] Sufficient supply must be procured to meet peak demand. The NYISO measures daily, seasonal, and annual peak demand. Figure 1 shows a typical demand curve for New York. Demand is low around 4 AM, rises around 7 AM, and peaks around 4 PM. This mirrors when people sleep, go to work, and head home for the evening. ESRs could help the NYISO manage daily peak demand in the energy markets by storing excess supply to deploy during greater demand.

**Figure 1: Daily, Seasonal Load Trends in New York, 2016**



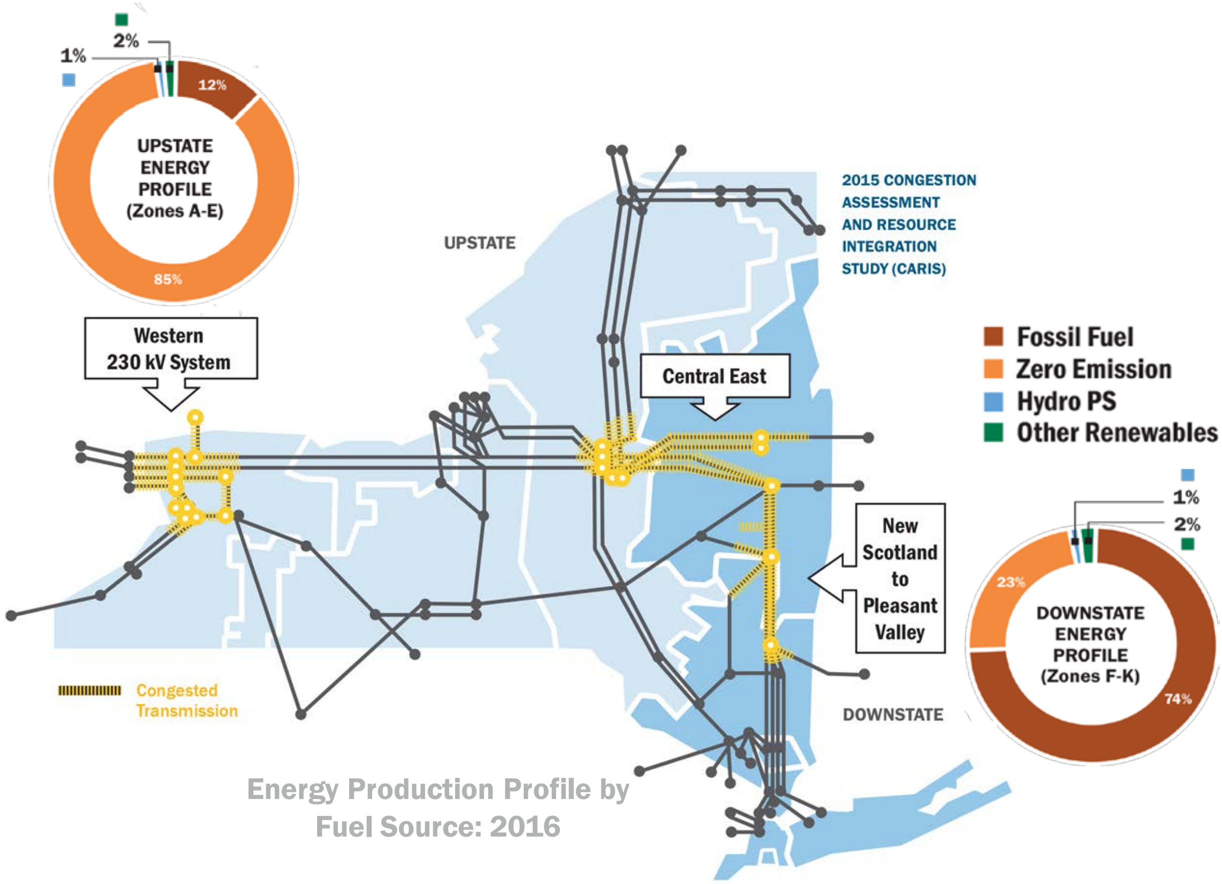

ESRs can also help the NYISO manage increasing levels of intermittent renewable energy. The energy markets have only a limited ability to dispatch intermittent resources and usually schedule the resources based on the projected availability of the resource's fuel (*e.g.,* sun and wind). The energy markets look to curtail output of intermittent resources at times when output from these resources are not economic due to transmission constraints, or when there are potential reliability concerns due to mismatches of supply and demand. Curtailment of wind resources at the NYISO is accomplished economically – wind plant operators identify price points at which they are willing to reduce output. ESRs, like other fully dispatchable resources, can timely respond to economic signals to help manage the variability of intermittent resources. Absent system constraints like congested transmission, storage could "firm" renewable energy by saving excess production or by supplementing injections during underproduction. Wind power production typically peaks at night and solar power around midday (Figure 2). Storage resources could purchase this energy to sell hours later. ESRs could support greater renewable energy penetration while maintaining grid reliability.

Figure 2: Projected Wind & Solar Hourly, Seasonal Generation in 2019 in New York




Over 80% of New York's high voltage transmission lines are over 30 years old.[8] Transmission infrastructure upgrades over the next 30 years could cost upwards of $25 billion.[9] Downstate (Long Island, New York City, and the Hudson Valley, otherwise known as zones F-K) consumes 66% of the states' electricity but generates 53%.[10] Existing transmission infrastructure may not be sufficient to deliver new renewable energy from northern and eastern New York to the large load centers of New York City and Long Island because of congested transmission lines. Figure 3 illustrates how the locations for renewable energy installation and large load centers are separated by transmission constraints. ESRs could enable further penetration of renewable resources by storing renewable energy for delivery when the transmission system is not constrained. Additionally, as the edge of the grid becomes more dynamic, ESRs located downstream of the transmission constraints could improve the ability for grid operators to manage congested transmission lines.

**Figure 3: Sources of Energy Production and locations of Transmission Constraints**




## Capacity

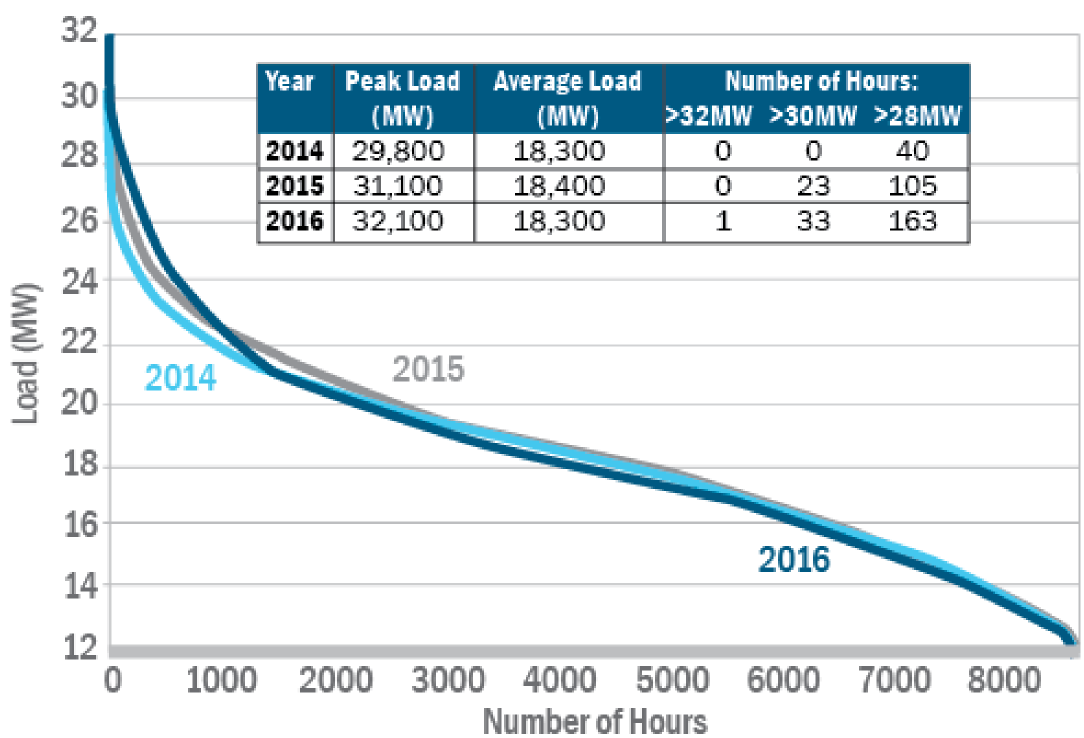
The NYISO peak demand was 33,075 MW in summer 2016 versus 24,164 MW in winter 2016.[11] Typically, demand is greater in the summer than in the winter because of the load from air conditioning. Annual peak demand typically occurs on a summer afternoon and is about twice as great as average load (See Figure 4).[12]

**Figure 4: Peak versus Average Load**

| Year | Actual Peak (MW) | Average Hourly Load (MW) |
|---|---|---|
| **2006** | 33,939 | 18,520 |
| **2007** | 32,169 | 19,103 |
| **2008** | 32,432 | 18,854 |
| **2009** | 30,844 | 18,126 |
| **2010** | 33,452 | 18,665 |
| **2011** | 33,865 | 18,645 |
| **2012** | 32,439 | 18,538 |
| **2013** | 33,956 | 18,666 |
| **2014** | 29,782 | 18,272 |
| **2015** | 31,139 | 18,443 |
| **2016** | 32,076 | 18,306 |

As highlighted in Figure 5, the annual average hourly load was 18,300 MW in 2016.[13] There was about one hour in the year where load was greater than 32,000 MW; 33 hours in the year where load was greater than 30,000 MW; and 163 hours in the year where load was greater than 28,000 MW.[14]

**Figure 5: Load Duration Curve**



Reliability requirements applicable to the New York Control Area require the grid be designed to meet annual projected peak load, plus a minimum reserve margin requirement to account for unanticipated generator or transmission outages. This margin, called the Installed Reserve Margin (IRM), secures generation capacity beyond the forecasted peak demand to meet a contingency. The IRM, determined by the New York State Reliability Council in conjunction with the NYISO, is 18% for 2017-2018.[15] The maximum capacity procured for a given Capability Period is not needed for a vast majority of the hours in that Capability Period. Maintaining sufficient resources to meet yearly peak demand can be costly, not only because these peaking resources are paid for their capacity, but also because if called upon, are paid for energy produced, which is typically more expensive. Additionally, it is expected that with large amounts of renewable resource penetration the IRM would increase, possibly substantially, to maintain system reliability. ESRs could help meet annual peak demand in the energy market, and if eligible to provide capacity, ESRs could be used to meet IRM requirements. Furthermore, if ESRs improve system reliability – perhaps after significant ESR penetration – future IRM requirements may not increase as dramatically with large renewable resource penetration.

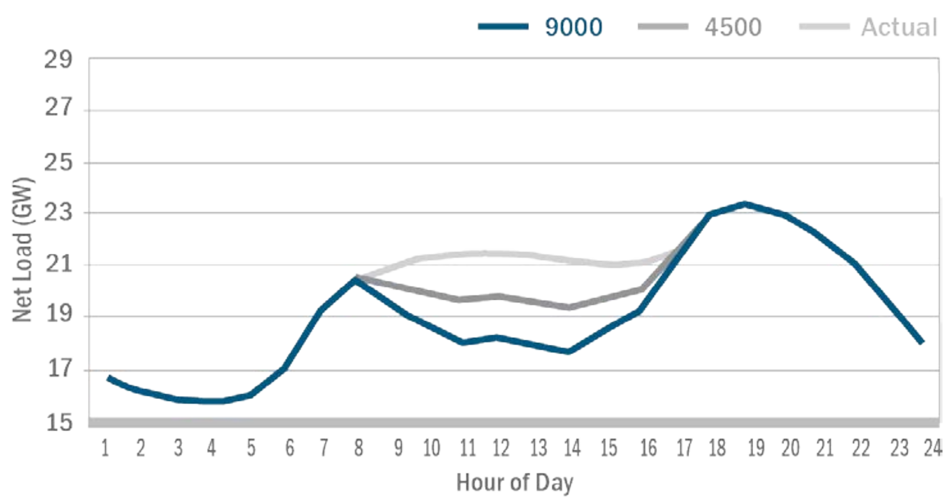
### Regulation Service

Every six seconds, the NYISO may request eligible resources to ramp up or down to maintain a balance of supply and demand as well as grid frequency at 60 hertz (Hz). Today, some ESRs provide frequency regulation service.

Intermittent resources like wind and solar power plants can change output because of the variability of the wind and the sun throughout the day, but such changes are not always fully controllable by system operators. The potential effect of solar penetration on the daily load curve, more severe during the winter, is shown in Figure 6. As explained in the NYISO's 2017 Power Trends, "[at] increasing levels of behind-the-meter solar installations, the net load that must be met with centrally dispatched generation during a typical winter day begins to feature sharper peaks that would require generators to move up or down more quickly than currently experienced on the system."[16] Notably, at 9,000 MW of solar installation, the solar resource production begins to decline long before system demand peaks for the typical winter day, exacerbating the ramping effect.

Based on results from the NYISO's solar preliminary integration study, the NYISO estimates that existing Regulation Service requirements will be sufficient to balance the variability of new wind and solar resources up to the point where solar penetration exceeds 1,500 MW of installed capacity, or installed wind capacity grows to exceed 2,500 MW. Beyond these penetration thresholds the study suggests that "minor upward revisions of the regulation requirements could be warranted," notably in the spring, fall, and winter periods. During the summer, system load and solar production generally track each other more closely than during the other seasons, lessening the need to increase Regulation Service requirements. At the highest penetration levels examined by the study (9,000 MW solar, 4,500 MW wind), there will be additional upward pressure on Regulation Service requirements, but grid operators should be able to manage such increases within existing market rules and existing system resources. However, the study notes that it will be important to monitor the system's capability to serve its regulation and ramping needs as wind and solar penetration increases and displaces conventional thermal generation. In particular, the study recommends that the NYISO periodically assess the potential for storage technologies to mitigate the need for higher levels of regulation.

**Figure 6: Effect of Increasing Solar Generation on Net Load- Typical Winter Day**




Ramp rate refers to how quickly a generator can change its output. The increasing penetration of limited-control, intermittent solar and wind resources will increase the demand for generators that can quickly ramp generation up or down for longer periods of time.

Ramp support is currently procured through the energy market, as the Real-Time Market software looks ahead at least an hour to ensure adequate ramp support exists. Existing regulation service, used to manage fluctuations on a six-second basis, could satisfy reliability concerns under system conditions with maximum 1,500 MW of total solar resources or maximum 2,500 MW of total wind resources.[17] However, in the coming decades with greater renewable energy penetration, additional ramp support may warrant consideration as a competitive product separate from the energy or regulation markets.

ESRs, such as flywheels and batteries, could provide ramp support to both renewable and conventional resources. For example, ESRs could support system load when solar generation tails off in the evening.

### Operating Reserves

Operating reserves exist in the event of unplanned events that jeopardize system reliability. Currently, the NYISO procures 2,620 MW of operating reserves for New York, which is twice the capacity caused by the most severe contingency under normal transfer conditions, as required by the New York State Reliability Council rules.[18] New York has locational and categorical reserve requirements.[19] There are three classes of reserves: 10 minute synchronous, 10 minute nonsynchronous, and 30 minute reserves (which includes both synchronous and nonsynchronous resources). Synchronous (spinning) reserves are running in time with grid frequency. Nonsynchronous (nonspinning) reserves must be started and matched to grid conditions. The 10 or 30 minute label is the amount of time allowed for a resource to convert the reserve power into consumable energy for the grid. Depending on its characteristics, an ESR could provide reserve services. Or, when coupled with an ESR, a 30 minute-start natural gas turbine may be able to provide 10-minute reserves; the ESR would provide the short-term output until the turbine finished start-up.

### Voltage Support

Reactive power, measured in volt-ampere reactive (VAR), supports all transactions on the New York State transmission system. If there is insufficient reactive power, the system voltage can drop, and vice versa.[20] Voltage is an important attribute of a robust grid that ensures the grid remains efficient and stable. Without the proper management of voltage, electricity wouldn't be as reliable and in some cases large voltage fluctuations may damage end-use equipment like running air conditioning or keeping food stored in refrigerators. Voltage support service (VSS) is currently an NYISO program for qualified resources that can inject and absorb VARs which supports the system voltage. Eligibility to provide VSS is determined via a NYISO test procedure. VSS Suppliers are compensated as described in the NYISO's Services Tariff. The ability of ESRs to provide voltage support to the bulk power system is dependent on the technology used and the resource's location on the transmission or distribution system.

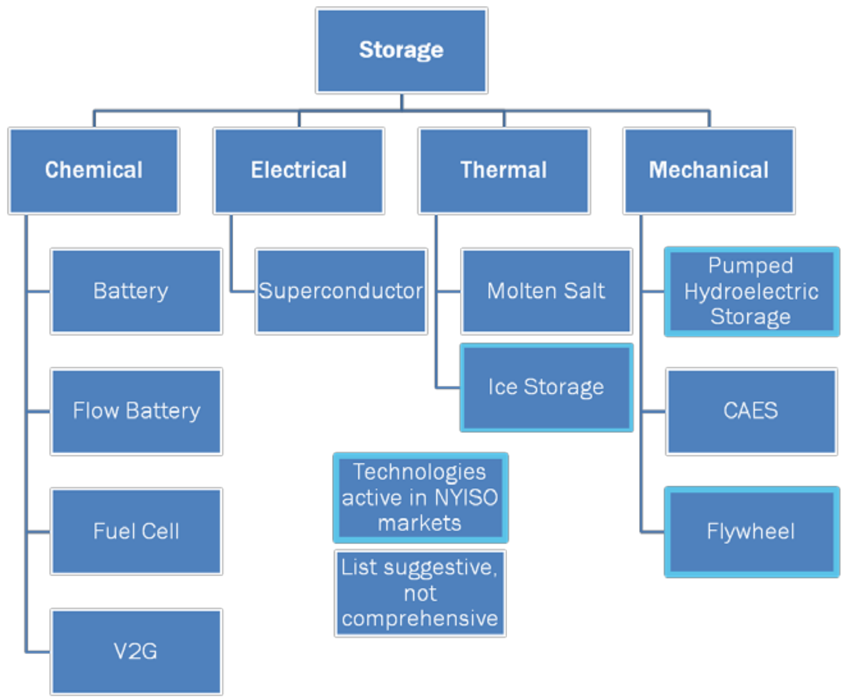
### Black Start

Resources that provide black start service are those that can help restart the grid in the event of a blackout. These resources are selected by the NYISO and are compensated for costs incurred. Today, large pumped hydroelectric units are eligible to provide black start service. Currently, the NYISO has sufficient black start capability to meet the applicable requirements.

## Types of Storage

As seen in Figure 7, there are many different storage technologies that may provide future value to the wholesale markets.

**Figure 7: Types of ESRs**




### Pumped Storage

When electricity prices are low, a pumped hydroelectric storage facility uses electricity to pump water from a lower reservoir to a higher reservoir. When prices are high, the unit releases the water to flow past a turbine to generate electricity. Pumped storage facilities must take advantage of price differentials.[21] In New York, pumped storage can participate in the energy, capacity, and ancillary service markets.

As of 2016, two pumped hydroelectric storage facilities participated in the NYISO wholesale markets. New York Power Authority (NYPA) owns four turbines at Blenheim-Gilboa that have a joint nameplate capacity of 1,160 MW. [22] The units jointly generated 371,300 MWh in 2016. [23] NYPA also owns a pumped storage facility at Lewiston that has nameplate capacity of 240 MW and generated 464,300 MWh in 2016.[24] The Lewiston units are part of the Niagara complex.

The pumped storage units accounted for 3.6% of summer 2016 capability (MW) and 3.4% of winter 2016 capability (MW).[25] Pumped storage accounted for .6% of annual net energy in 2016. [26] Pumped storage is not predicted to significantly increase across New York State because of limits as to where it can be located.[27]

### Flywheels

Flywheels store and produce electricity as kinetic energy using a large spinning mass. Today, a 20 MW flywheel offers regulation service in the NYISO DAM and RTM.

### Other

As of 2016, no other FTM storage technologies, summarized in Figure 8, were deployed in New York State's wholesale electricity markets. Figure 9 gives a summary of the services that ESRs could potentially offer; the figure is suggestive, neither comprehensive nor exclusive.

**Figure 8: Potential Storage Concepts in New York**

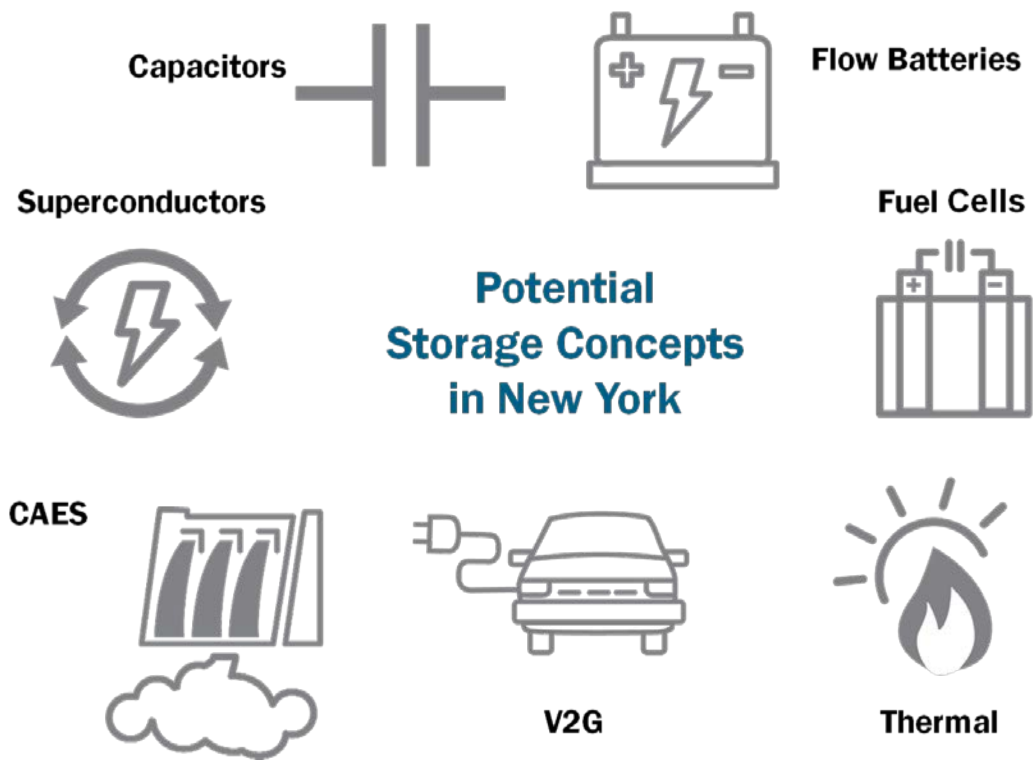


**Figure 9: Storage Resources Potential Services**

| | | Pumped Storage | CAES | Batteries | Flow Batteries | Flywheels | Fuel Cells | Supercapacitors | V2G | ESR Aggregations |
|---|---|---|---|---|---|---|---|---|---|---|
| | Energy – DA | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| | Energy – RT | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| | Capacity | ✓ | ✓ | ✓ | ✓ | | ✓ | | | |
| Ancillary Services | Voltage Support | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Regulation | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Operating Reserves | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |

**Compressed Air Energy Storage (CAES)**

CAES resources use electricity to compress air in a storage tank or cavern. As the air is released, it is expanded and heated to make a natural gas turbine more efficient. A CAES unit can improve the efficiency of a natural gas turbine by 30%.[28] CAES-supported natural gas turbines can provide energy, capacity, voltage support, operating reserves, regulation, and black start service.

**Vehicle to Grid (V2G)**

Under a V2G concept, Electric Vehicles (EVs) could serve as storage. Aggregated EVs could charge when electricity prices are low and return electricity to the grid when prices are high. V2G is in the research and development stage now, and must address issues like EV warrantees, aggregation requirements, and infrastructure.

### Electric Vehicles (EVs)

New York State's ambitious carbon reduction goals may encourage other sectors like transportation or industry to electrify. Gasoline prices, fuel efficiency standards, declining battery costs, and government subsides, amongst other factors, may encourage high penetration of EVs. EVs could increase electricity demand. The NYISO published a report[29] in 2009 on the potential impact of plug in hybrid EVs.

Under the REV proceedings, New York State Electric & Gas, Central Hudson Gas & Electric, Rochester Gas & Electric, Orange and Rockland, National Grid, and Con Edison will jointly develop an EV Readiness Framework by 2018.[30] Utilities will also conduct individual research studies to analyze the potential consequences of EVs.[31]

#### Thermal

Thermal storage technology takes advantage of the energy embodied in heat exchanges. There are a number of different thermal storage technologies. Sensible heat storage technology uses a medium (like water or rock) to exchange heat without the use of phase changes or chemical changes.[32] Examples include pumping heated or cooled water into aquifers or manmade boreholes, or circling water around an insulated pit filled with gravel.[33] Latent heat storage involves phase changes, like when cheap electricity is used to create ice that later cools the building. Newer thermochemical storage use chemical reactions.[34] Such exchanges are lesser developed.

> **Con Edison Refrigeration**
>
> Con Edison has paired with Axiom Energy in a $5 million, 1.5-2 MW/ 6-8 MWh project that will freeze salt water in onsite tanks for refrigeration in grocery stores in Brooklyn and Queens.[35]

#### Batteries, Flow Batteries, Fuel Cells, and Supercapacitors

Batteries exchange energy between a chemical and an electrical state. There are many different types of batteries: lead-acid, sodium-sulfur, sodium-ion, sodium nickel chloride, nickel cadmium, nickel metal hydride, [36] zinc-bromide, and others. [37] Lithium ion batteries are found in car batteries and consumer electronics. Flow batteries are batteries with liquid electrolytes separated by a membrane[38] and can be instantly recharged if the liquid electrolytes are exchanged.[39] A fuel cell converts hydrogen and oxygen into water and energy. A supercapacitor is two conductors separated by an insulated layer that has close to zero resistance when cooled below a critical temperature. Batteries, flow batteries, fuel cells, and supercapacitors could participate in the wholesale markets.

## New York State Policy

New York State is a leader in reforming electricity markets to reflect the full value of clean energy resources, and to animate consumer-based participation in markets through the integration of DER. A notable driver behind many of the state's energy policies is the desire to improve resiliency, promote efficiency, and reduce carbon dioxide emissions. New York State is aggressively pursuing policies that encourage carbon dioxide emissions reductions. The 2015 New York State Energy Plan[40] looks for the following:

- Reduce the energy sector's (power, industry, buildings, and transportation) GHG emissions 40% from 1990 levels by 2030, translating to a 80% reduction by 2050
- Decrease energy consumption in buildings 23% from 2012 levels by 2030
- Generate 50% of electricity consumed within New York from renewable energy by 2030

### REV, Con Edison, and Storage

Con Edison serves New York City and Westchester County – two large load centers within New York State. Con Edison is working on storage projects that follow REV objectives.

**Storage on Demand**

With NRG Energy, Con Edison will deploy a one MW/four MWh mobile unit comprised of two batteries and switchgear.[43]
Con Edison will fund the mobile unit.

**Commercial Battery Storage**

Con Edison has partnered with GI Energy to pilot a 4.2 MW/ 4.4 MWh of FTM battery storage across four customer host sites in an effort to defer transmission upgrades.[44] Con Edison will pay customers a quarterly payment to host an ESR on their property. Con Edison hypothesizes that consumers will prefer this straightforward payment option over various market involvements.

**Clean Virtual Power Plant**

This virtual power plant is a $15 million partnership between Con Edison, Sunverge, and SunPower.[45] The 1.8 MW/ 4 MWh virtual power plant is an aggregation of .007-.009 MW solar panels, and of .006-.0194 MWh lithium-ion batteries installed on about 300 homes.

Two policies that support the State Energy Plan's goals are Reforming the Energy Vision (REV)[41] and the Clean Energy Standard (CES).[42]

The Clean Energy Fund is a 10 year (2016-2026), $5 billion dollar initiative to help advance REV objectives.

### Reforming the Energy Vision

REV looks to achieve the transformation from Figure 10 to Figure 11 by evolving the role of a distribution utility into that of a distributed system platform (DSP). Distribution utilities under this new DSP model should help consumers turn into "prosumers," or parties that act as both producers and consumers of electricity. DSPs should incorporate DER, energy efficiency, and demand reduction into their system planning processes. DSPs should also identify "non-wires alternatives" to traditional infrastructure investment plans.

Utilities cannot own DER, with a few exceptions.[46] Utilities submitted individual Distributed System Implementation Plans (DSIPs) to the Public Service Commission (PSC) to show how they will become DSPs on June 30, 2016. Utilities jointly submitted a Supplemental DSIP by November 1, 2016 to address commonalities.

In response to these submissions, the PSC ordered that by December 31, 2018, utilities must have at least two energy storage projects attached to a distribution substation that offer at minimum two distinct services (like energy, regulation, or capacity).[47]

**Figure 10: Today's Power Grid**

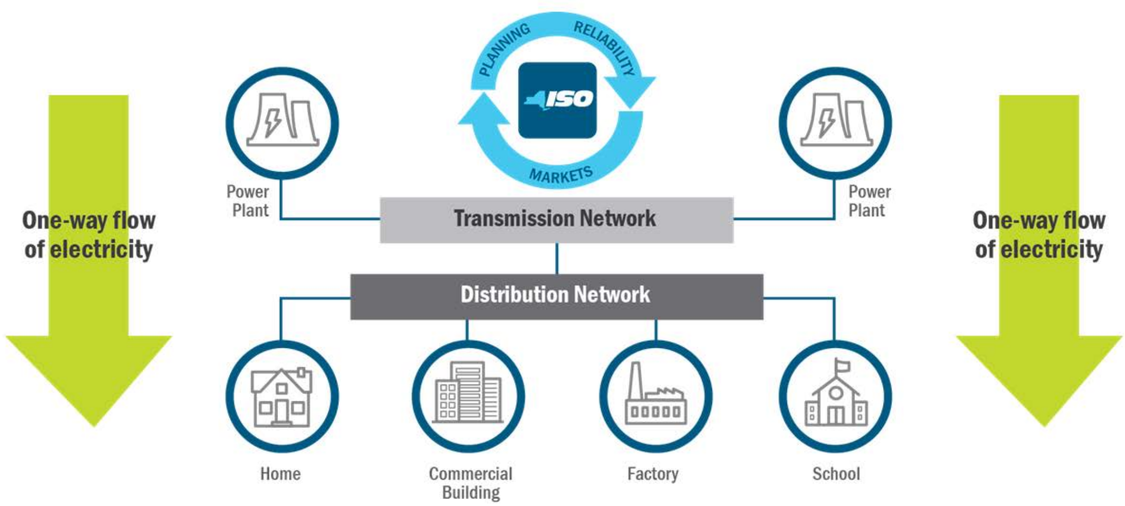
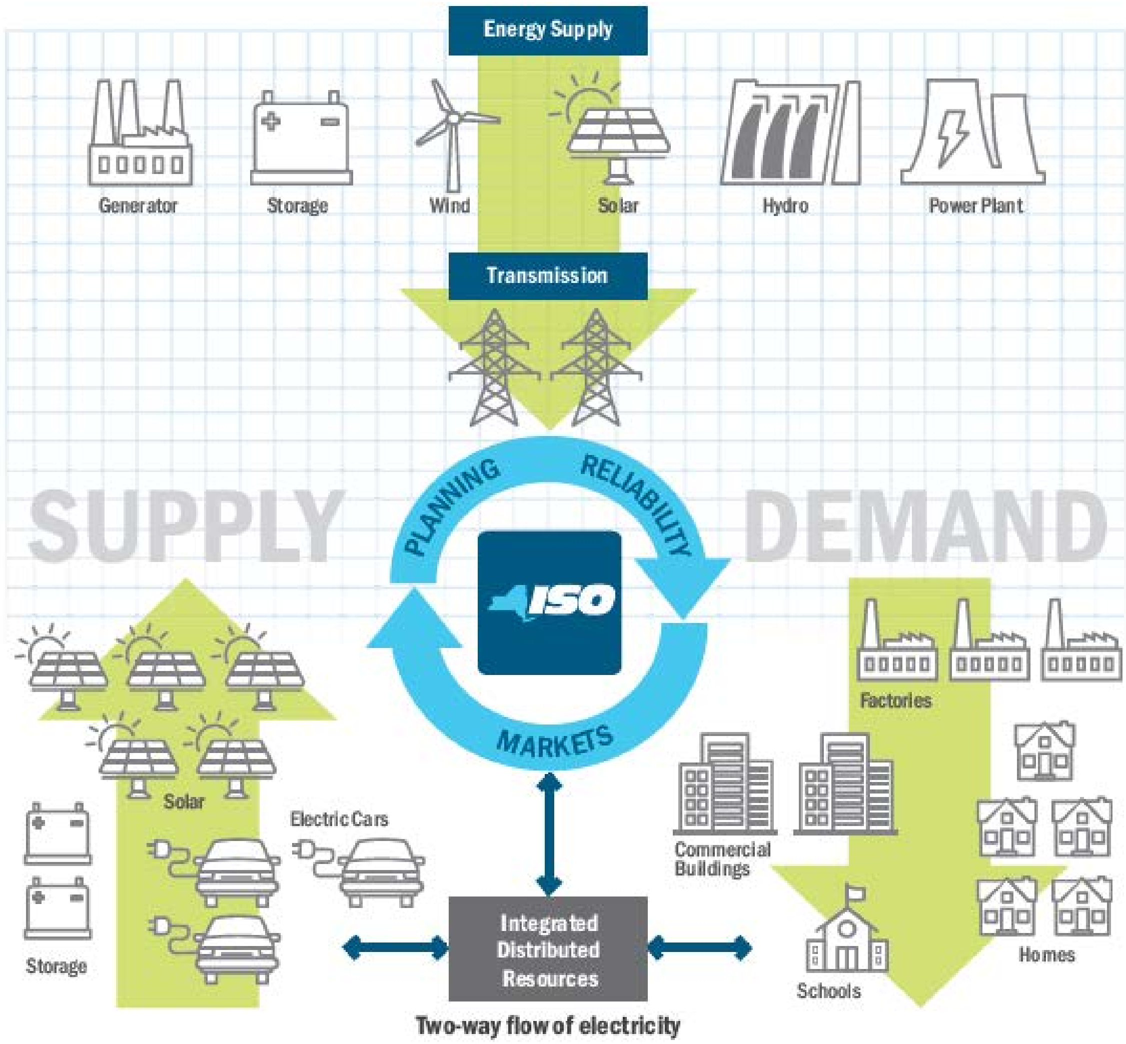


**Figure 11: Tomorrow's Power Grid**




## CES

The CES codifies the State Energy Plan goal of meeting 50% of electricity use with renewable energy by 2030. The goal will be met through the use of a credit system. Each load serving entity (LSE) must procure a certain percentage of their total load from renewable energy sources, accounted through renewable energy credits (RECs). The percentage of load served with renewable energy increases yearly to meet the 50% by 2030 goal. RECs set a price floor for renewable energy, and are compatible with the NYISO's competitive market structure because risks for revenues remain with developers.

Additionally, under the Clean Energy Standard, LSEs must procure a certain percentage of their load from nuclear plants, accounted through zero-emission credits (ZECs). ZECs also set a price floor. ZECs do not count towards the 50% renewable energy by 2030.

Storage, with the exception of fuel cells, is not classified as renewable energy resources under the CES and, thus, is not eligible for RECs.[49]

### NY-BEST

NY-BEST is a public-private coalition of organizations interested in storage. Created in 2010, NY-BEST had more than 150 members in 2016. In its 2016 Energy Storage Roadmap for New York's Electric Grid, NY-BEST advocates for a 2,000 MW of storage mandate by 2025 that increases to 4,000 MW by 2030.[48]

### NYSERDA

To date, the New York State Energy Research and Development Authority has offered the following grants concerning storage:

- **$6.3 million for Energy Storage Technology and Product Development** to reduce ESR hardware costs, to improve performance, and to provide different services.
- **$15.5 million for Demonstrating Distributed Energy Storage for 'Stacking' Customer and Grid Values** to demonstrate that storage can provide value stacking, or different types of wholesale and retail services like energy, capacity, and ancillary services.
- **$8.1 million for Reducing Distributed Energy Storage Soft Costs** to reduce costs not related to materials or labor (like permitting, insurance, taxes, etc.) associated with distributed energy storage .025% per MWh by 2019 and .033% per MWh by 2021 (compared to a 2015-2016 baseline of $.220 per MWh).

### Storage Mandate

New York State legislation (S.5190/A.6571) instructs the PSC to create storage procurement targets for 2030. Governor Andrew Cuomo signed the legislation into law on November 29, 2017.

### New York City's Target

In September 2016 Mayor Bill de Blasio announced a New York City energy storage target of 100 MWh by 2020. New York City is the first city in the U.S. to set a storage target.[50]

### Policy and Markets

The goals in the New York State Energy Plan, implemented through REV and the CES, are changing the electricity sector. ESRs are useful contributors to REV and CES objectives, and must be able to compete with their full market potential to ensure low cost, reliable electric supply for consumers.

## Other States

Other states are looking to integrate storage into the wholesale electricity markets. Three states have adopted energy storage mandates.

### California

California approved the United States' first energy storage mandate. Building from Assembly Bill 2514 (2010), in October 2013 the California Public Utilities Commission agreed that the three investor-owned utilities (Southern California Edison, Pacific Gas & Electric, and San Diego Gas & Electric) must have 1,325 MW of storage procured by 2020 and implemented by 2024.[51] For other electricity providers, up to 1% of 2020 peak load must be met with storage resources procured by 2020 and implemented by 2024.[52] Up to 50% of storage can be utility-owned, and each year there are mandatory requirements for both MW acquisitions and interconnection location (transmission, distribution, or customer).[53]

ESRs can participate in the California ISO as non-generator resources[54] or regulation energy management resources .[55] There are obligations for those resources that receive resource adequacy payments.[56] Somewhat similar to NYSERDA, the California Energy Commission funds storage resource though an Electric Program Investment Charge.[57]

### Oregon

House Bill 2193, passed in 2015, required Portland General Electric and PacifiCorp to jointly have 5 MWh of functioning storage by 2020.[58]

### Massachusetts

In May 2015, the Massachusetts Energy Storage Initiative allocated $10 million dollars for studies and demonstration projects.[59] The resulting *State of Charge Report* recommended that 600 MW of new storage resources should be installed by 2025 to save ratepayers $80 million annually.[60] The report noted that 1,766 MW of new advanced storage technologies (resources other than pumped hydroelectric storage) would cost $970 million-$1.35 billion but yield $2.3 billion in benefits for Massachusetts and $250 million in benefits for surrounding states. These benefits are due to lower peak demand, transmission and distribution deferrals, lower greenhouse gas (GHG) reduction compliance costs, reduced renewable energy integration costs, generation capacity deferrals, increased grid flexibility, and generally lower electricity prices.

Governor Charlie Baker signed House Bill 4568 in August 2016. The bill asked for 1,600 MW of offshore wind, 1,200 MW of new hydropower and other renewable resources, and directed the State Department of Energy Resources (DOER) to decide whether or not to set storage targets.[61] In December 2016, the DOER decided to move forward with a storage mandate.[62] In June 2017, the DOER decided that utilities should procure 200 MWh of storage by January 2020.[63]

In the New England wholesale electricity markets, ESRs can supply electricity as settlement-only generators[64] or generators, and can consume electricity as assets related demand products (both dispatchable and nondispatchable). Additionally, ESRs can also participate as demand response, and can offer regulation service as alternative technology regulating resources.[65]

## Federal Policies

In 2009, the NYISO was the first of the ISO and RTOs to develop rules that allowed limited energy storage resources (LESR) supply regulation service. The NYISO's innovative approach included a process where the LESR's state of charge is managed by the NYISO's real-time energy market software. A few years later in 2011, FERC issued an order known as "pay for performance" that would benefit fast ramping resources like ESRs by requiring regulation service payments to compensate for the amount of up and down ramping that is actually incurred by regulation service providers.

More recently, on November 17, 2016, FERC issued a Notice of Proposed Rulemaking (NOPR) to encourage the removal of barriers to ESRs and DER integration in the wholesale markets.[66] FERC wants Independent System Operators and Regional Transmission Operators to pursue the following: [67]

- Create participation models that allow storage resources to provide all the services that they are physically able to in the wholesale markets;
- Identify necessary scheduling parameters to let storage and DER participate in the market;
- Allow these resources to set market clearing price; and
- Establish a minimum size requirement no greater than 0.1 MW.

The NYISO submitted its NOPR comments on February 13, 2017.[68] The NYISO will develop its market design to be consistent with the FERC's proposed rules.

## Offer All Services

Unlike other resources that participate in the wholesale markets, ESRs must buy electricity in order to sell electricity and provide market services. ESRs therefore obtain the greatest value from buying energy in low-cost intervals and reselling it during high-priced intervals. The buying and selling of electricity could be done over the larger course of the day through DAM participation or over shorter time periods through RTM participation. Currently, there is no market model in New York that would allow ESRs to change from producers to consumers intra-hour. Keeping in the spirit of the FERC NOPR, the NYISO will address this gap in its new ESR participation model.

Some ESRs may be able to inject maximum output for more than one hour, but less than four hours. Currently, these resources cannot offer energy because they do not meet the minimum ELR requirements. In its new market participation model, the NYISO will remove this barrier.

## Scheduling Parameters

Generators typically offer the following parameters with their energy market supply offers:

- Minimum run time (hrs)
- Minimum down time (hrs)
- Maximum stops per day
- Start up time (hrs) and cost ($)
- Market Choice (DAM versus RTM)
- Date, number of hours offer pertains to, and expiration offer date/time (DAM only)
- Response rate (MW/minute) for normal, emergency, and regulation modes
- Minimum generation (MW and a $/MWh)
- Upper operating limit for normal and emergency situations

However, as FERC highlighted, these offer parameters may not be applicable to ESRs. FERC recommended some parameters that should be included in the new participation model for ESRs: state of charge, upper charge limit, lower charge limit, maximum energy charge rate, and maximum energy discharge rate.[69] FERC also proposed some optional parameters: minimum charge time, maximum charge time, minimum run time, and maximum run time.[70]

## Set the Clearing Price

The NYISO believes that ESRs should be eligible to set energy, capacity, and ancillary service prices. For setting LBMPs, the NYISO includes all Fixed Block and dispatchable resources that are willing to follow NYISO commitment and dispatch instructions as eligible to set price. Allowing ESRs to set price will encourage wholesale market competition between ESRs and other technologies which results in lower costs for consumers.

### Size Requirement

While SCRs have a 0.1 MW minimum requirement, DSASP participants, ELRs, and LESRs have a one MW minimum requirement. Storage developers have expressed interest in reducing the minimum offer requirement to less than one MW. The NYISO is devising aggregation concepts that will assist small ESR participation in the wholesale market and continues to review the impact minimum offers of less than one MW has on the dispatch process and commitment evaluation. Dependent on the outcome of the NYISO evaluation, the FERC NOPR and stakeholder feedback, the NYISO may reduce the minimum offer level to 0.1 MW.

### Implications for New York

Current models, like ELRs, LESRs, DSASP, and SCRs do not fully capture the services that storage can offer to the market. The NYISO therefore looks to create a new market participation model to allow ESRs to offer all potential services and be eligible to set market clearing price through appropriate scheduling parameters and size requirements.

## Wholesale Market Participation Models

NYISO currently allows energy storage resources to participate as ELRs, LESRs, or in demand response programs. ESRs are eligible for four demand response programs: DSASP, SCRs, DADRP, and EDRP. However, the majority of resources participate in either the DSASP or SCR program. Relevant models are summarized in Figure 12.

### ELR

An ELR is defined by the NYISO as a "resource that, due to environmental restrictions on operations, cyclical requirements, such as the need to recharge or refill, or other non-economic reasons, is unable to operate continuously on a daily basis, but is able to operate for at least four consecutive hours each day."[71]

In other words, ELRs receive capacity payments, and can operate at the level represented by their capacity obligations for some but not all of the day because of limiting factors like ambient air temperature, pondage levels, or emissions constraints.

ELR examples include pumped storage facilities or generators with output constricted by pollution limits. ELRs must be capable of maintaining one MW of injection for a minimum four consecutive hours, are not permitted to aggregate, and have their energy withdrawls offer as negative MW value generation offers. [72]

### LESR

LESRs are resources that cannot inject maximum output for an hour. Unlike other generators, LESRs exchange a state of charge signal with the NYISO.[73] Examples of LESRs may include flywheels, batteries, flow batteries, fuel cells, or supercapacitors.[74] LESRs must be at least one MW and cannot be aggregated across different locations.[75] LESRs offer regulation service into the market. Like other regulation providers, LESRs are compensated for regulation capacity and regulation movement. However, for the energy component, LESRs have a unique settlement process-- LESRs settle hourly based on net injection/withdrawal at the hourly LBMP. The net injection assumes perfect execution and is not currently subject to performance review.[76] Like other regulation service providers, LESRs must buy out of their DAM schedule if unable to deliver the service in real time. LESRs are compensated through a Day Ahead Margin Assurance Payment (DAMAP) if the NYISO dispatches the LESR away from its DAM schedule for reliability reasons. [77]

### DSASP

The DSASP is an offer-based demand-side ancillary service program. The one MW requirement can be met by aggregation within a load zone.[78] DSASP resources offer into the NYISO regulation or operating reserves markets. DSASP resources must be able to respond to six-second basepoints. Like other Ancillary Services providers, DSASP resources must buy out of their DAM schedule if unable to meet it in real time.

### DADRP

Participants offer load reduction to compete with generator offers in the energy DAM. If unable to curtail as scheduled, the participant is charged the higher of the DAM or RTM price for the scheduled reduction amount. [79]

### SCR

SCRs are demand-side resources that may be called upon by the NYISO to reduce at least 100kW of load for grid reliability purposes. [80] It is expected that SCR's reduce its load for at least four consecutive hours. This requirement can be met by aggregating individual resources within a load zone. SCRs receive both capacity and energy payments. SCRs receive capacity payments from NYISO auctions or from bilateral contracts. Energy payments are settled when the NYISO calls upon the SCRs to reduce load.

### EDRP

Like the SCR program, EDRP participants reduce load when called upon by the NYISO in response to a reliability event. However, all load reductions are voluntary, and participants are not penalized for underperformance and are paid for measured energy reduction at a rate of minimum $500/MWh or the actual LBMP, if higher.

**Figure 12: Storage Participation Models**

| Existing ESR Participation Models | DSASP | DADRP | SCR | EDRP | ELR | LESR |
|---|---|---|---|---|---|---|
| **Market Services** | Regulation, operating reserves | Energy | Capacity (energy when called) | Energy | Energy, capacity, regulation, operating reserves | Regulation |
| **Description** | Economically offer ancillary services in day-ahead and real-time markets | Economically offer to curtail load in day-ahead market | Load reduction during reliability events | Voluntary load reduction during reliability events | Economically offer energy and ancillary services in day-ahead and real-time markets | Economically offer regulation in day-ahead and real-time markets |
| **Minimum Size (MW)** | 1.0 | 1.0 | 0.1 | 0.1 | 1.0 | 1.0 |
| **Aggregation** | Yes, within load zone | Yes, within load zone and load serving entity | Yes, within load zone | Yes, within load zone | No | No |
| **Time Component** | Depends on offer | Depends on offer | Must be able to run maximum output for 4 consecutive hours | Guaranteed 4 hour run time when called | Must be able to run maximum output for 4 consecutive hours | Cannot sustain maximum injection/ withdrawal for longer than one hour |
| **Payment** | Subject to offer floor; paid reserve or regulation market clearing price | Subject to offer floor; paid energy clearing price | Capacity payments through NYISO auctions or bilateral contracts; energy payments based on performance and LBMP with guaranteed cost recovery | Paid for energy reduction at minimum rate of $500/MWh or actual LBMP if greater | Capacity payments through NYISO auctions or bilateral contracts; paid energy and ancillary service clearing price | Regulation market clearing price; energy settled at hourly LBMP for net output |
| **Program Start Year** | 2008 | 2001 | 1999 | 2001 | 2001 | 2009 |
| **MW enrolled (2016)** | >110[81] | 0 | >1,150[82] | >25[83] | >1,400[84] | >20[85] |

# Proposed Wholesale Market Participation Model

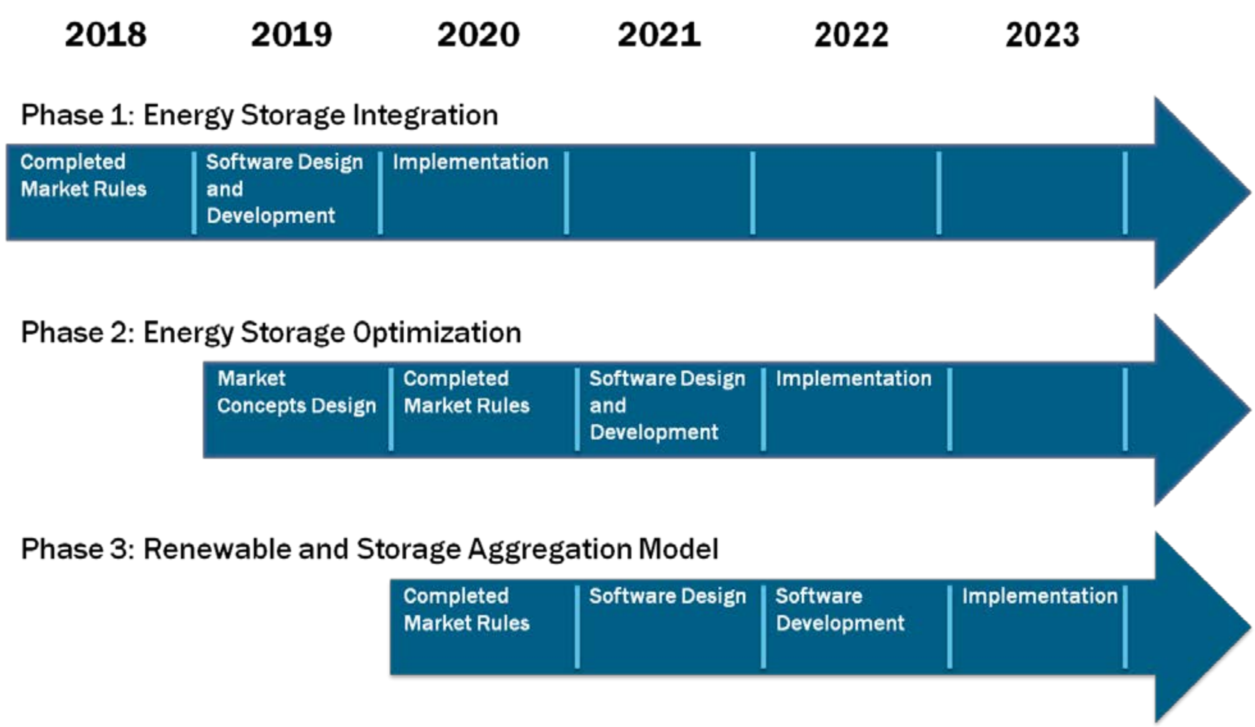
The NYISO looks to create a new participation model for ESRs. A timeline is given in Figure 13.

The *Energy Storage Integration Phase (2017-2020)* will identify parameters important to include in an ESR offer and create a new ESR participation model.

The second phase, *Energy Storage Optimization (2019-2022)*, looks to more efficiently utilize ESR services taking into account the resource's energy constraints over the course of a day. In the second phase, ESR operators may grant the NYISO permission to maximize the ESR's potential instead of submitting DAM or RTM offers.

The third phase, *Renewable and Storage Aggregation (2020-2023)* will analyze the pairing of ESRs with intermittent resources.

**Figure 13: NYISO ESR Timeline**




### Phase 1: Energy Storage Integration (2017-2020)

The NYISO proposes that ESRs will submit a single offer that reflects the resource's physical constraints. The alternative is for the ESR to self-determine when to perform as a generator or as a load by offering separately on an hourly basis. If an ESR had to offer as a generator or as a load, the

ESR not only must predict what hours to discharge and charge, exposing the ESR to risk, the ESR also would not be able to maximize the use of its flexibility during large intra-hour price variations. A single offer model allows ESRs to respond to economic signals and change between withdrawing and injecting electricity within an hour.

#### Proposed Energy Offer Curve

A potential ESR offer curve is given in Figure 14. The ESR would charge, or act like a load, when the LBMP is equal to or below the ESR bid to buy energy; the corresponding MW quantity would be represented as a negative generation offer. The ESR would inject energy, or act like a generator, when the LBMP is equal to or higher than the ESR offer to sell energy. The NYISO proposes that large and aggregated FTM ESRs will settle at 5-minute nodal LBMPs for both charging and discharging.

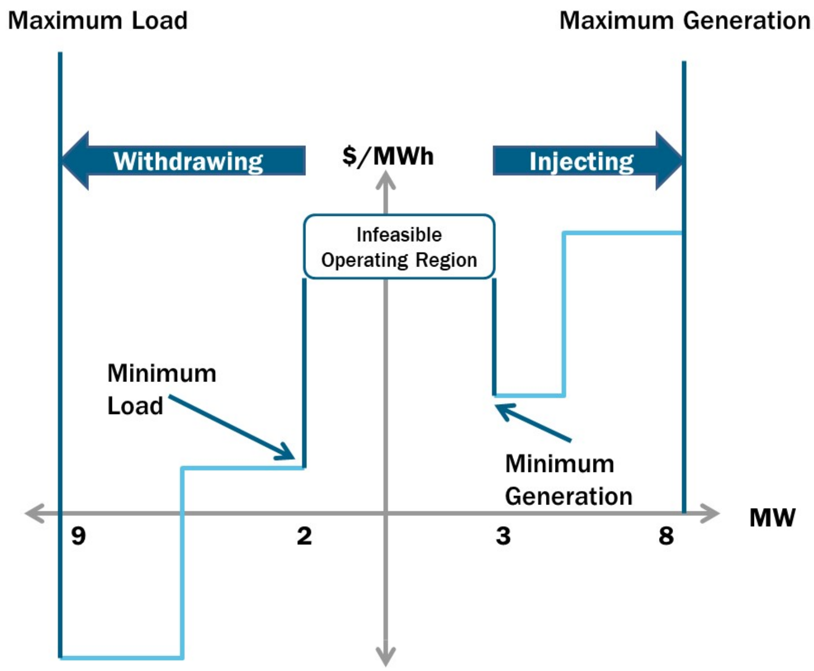
#### RTC versus RTD

The NYISO is committed to creating a storage participation model that takes greater advantage of the services that ESRs can provide, while working smoothly with the grid operating system software.

The NYISO handles the real time energy markets using two tools: real time commitment (RTC) software, which gives a 2.5 hour look-ahead optimization parceled into 15 minute intervals, and real time dispatch (RTD) software, which gives approximately 1 hour look-ahead optimization with a five-minute interval and remaining advisory 15 minute intervals. RTC posts advisory LBMPs, schedules external physical transactions, and can quick start reliability units. RTD balances the RTM with available on-line resources, creates the real-time binding dispatch schedules for internal resources, and produces the RTM settlement LBMPs.

Depending on ESR characteristics, RTC or RTD would signal to the ESR when to charge or discharge. For ESRs with a transition time or non-operating region, RTC would determine and commit accordingly whether the ESR should charge or discharge, based on projected LBMPs and parameters like minimum run time. If the ESR did not have a transition time or non-operating region, the ESR could charge or discharge based off RTD signals.

**Figure 14: ESR Offer Curve**




### Phase 2: Energy Storage Optimization (2019- 2022)

ESR dispatch is constrained by energy level. Some ESRs will be interested in managing the ESR's energy level for themselves. Others may wish for the NYISO to do so. Under *Phase 1: Energy Storage Integration*, resource managers will predict when the ESR should charge or discharge. Under *Phase 2: Energy Storage Optimization*, if the resource manager opts to allow the NYISO to manage the ESR's energy level, the NYISO will use its software to economically schedule charge or discharge cycles over a period of time for the ESR.

The NYISO has found in previous studies that offers with parameters that reflect daily energy level constraints tend to reduce generators' total production costs. Without an energy-constrained offer, an ESR must predict which hours to include a cost-adder within its offer; this cost-adder is the amount necessary to compensate for energy-constrained costs. In an offer that reflects energy constraints, the resource does not have to estimate energy-constraint cost-adders over a series of hours. In Phase 2, the NYISO hopes NYISO-determined deployment of the ESRs will not only lower generators' production costs, but also improve market efficiency.

### Phase 3: Renewable and Storage Aggregation Model (2020-2023)

As future REC procurement requirements are considered and other incentives for improving the capacity factors of renewable resources continue to evolve, several developers and market participants have expressed interest in aggregating storage resources with renewable energy resources to "firm" the variable resources into a controllable, dispatchable unit. The NYISO will consider the necessary model, software, and tariff changes needed to allow ESR to both firm renewable energy behind the meter and to offer other ancillary services.

### Potential Phases

The NYISO is considering other potential project phases surrounding energy storage resources.

#### Capacity Markets

ESRs will need a participation model for the capacity market. It is envisioned that FTM storage and DER will function under similar models in the capacity market. Consideration of the capacity market model for FTM or aggregated ESRs will begin in 2018.

#### Pilot Programs

One of the pillars of the DER Roadmap is the NYISO Pilot Program. Smaller ESRs that are classified as DERs can be, depending on circumstances, eligible to participate under this DER Pilot program. There is no plan to create a separate pilot program solely for ESRs.

#### Dual Participation

Some MPs have expressed interest in participating in the wholesale market and the retail market. As an example, an ESR may want to contract as a Non-Wire Alternative under a distribution utility during the summer and offer into the wholesale market during the other seasons. As part of the *DER Roadmap* efforts, the NYISO looks forward to working with MPs to gather input about dual participation in retail and wholesale markets. Resources will not be compensated for the same service twice.

## Conclusion

The NYISO is creating a new wholesale market participation model for large and aggregated FTM ESRs. ESRs are able to act like both generators and load, and can provide different services into the energy, capacity, and ancillary service markets. ESRs may prove especially important for integrating high levels of intermittent resources. The current market models of ELRs, LESRs, DSASPs, and SCRs may not provide enough flexibility for ESRs to offer all available services into the wholesale markets. The NYISO looks to identify parameters to create a new wholesale ESR participation model in Phase 1, optimize ESR system deployment in Phase 2, and explore aggregations with intermittent resources in Phase 3. As the NYISO continues to align its markets with federal and state policy objectives, a new ESR market participation model will help maximize the economic and societal benefits of storage.

# Appendix

**Figure 155: Abbreviations**

| Abbreviation | Meaning |
|---|---|
| **BTM** | Behind The Meter |
| **CES** | Clean Energy Standard |
| **DADRP** | Day-Ahead Demand Response Program |
| **DAM** | Day Ahead Market |
| **DAMAP** | Day Ahead Margin Assurance Payment |
| **DOER** | Department Of Energy Resources (Massachusetts) |
| **DSASP** | Demand Side Ancillary Service Program |
| **DSIP** | Distributed System Implementation Plan |
| **DSP** | Distributed System Platform |
| **EDRP** | Emergency Demand Response Program |
| **ELR** | Energy Limited Resource |
| **ESR** | Energy Storage Resource |
| **EV** | Electric Vehicle |
| **FERC** | Federal Energy Regulatory Commission |
| **FTM** | Front of The Meter |
| **GHG** | Greenhouse gas |
| **Hz** | Hertz |
| **LBMP** | Locational Based Marginal Pricing |
| **LESR** | Limited Energy Storage Resource |
| **LSE** | Load Serving Entity |
| **MP** | Market Participant |
| **MW** | Megawatt |
| **MWh** | Megawatt-hour |
| **NOPR** | Notice of Proposed Rulemaking |
| **NYISO** | New York Independent System Operator, Inc. |
| **NYPA** | New York Power Authority |
| **PON** | Program Opportunity Notice |
| **PSC** | Public Service Commission |
| **REC** | Renewable Energy Credit |
| **REV** | Reforming the Energy Vision |
| **RFP** | Request for Proposals |
| **RTC** | Real-Time Commitment |
| **RTD** | Real-Time Dispatch |
| **RTM** | Real-Time Market |
| **SCR** | Special Case Resource |
| **ZEC** | Zero Emission Credit |

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