To: NECPUC and NESCOE

From: Eric Johnson, Director, External Affairs, ISO New England

Date: January 22, 2016

Subject: *How Energy Storage Can Participate in New England's Wholesale Electricity Markets*

Interest in energy storage technologies is growing in New England and project developers, policymakers and others are examining how these technologies can participate in the wholesale electricity markets. ISO New England developed the attached paper to explain the characteristics and requirements of the various wholesale markets in which storage devices can compete today.

This paper outlines the opportunities available to energy storage technologies to be compensated in the wholesale energy markets for providing services needed for a reliable, efficient, and competitive power system.

While this paper provides a general overview, it does not contemplate all possible energy storage technologies and is not a substitute for the applicable tariff sections. Project developers and other interested parties are encouraged to contact the ISO to discuss market opportunities as well as operational requirements because every energy storage project is unique.

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How Energy Storage Can Participate in New England's Wholesale Electricity Markets

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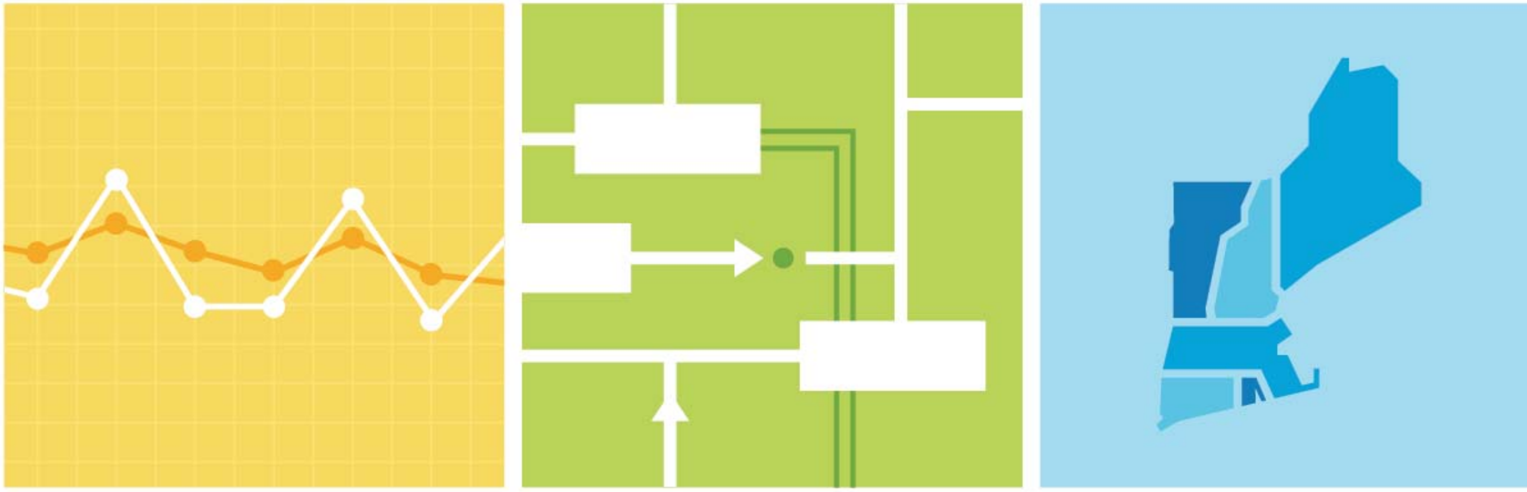


Introduction and Background

New England has a long history of operating the bulk power system with large-scale energy-storage resources. As smaller-scale energy-storage resources emerge in the marketplace, it is imperative that the energy-storage community and policymakers understand how the region's wholesale electricity markets provide opportunities for compensating emerging energy-storage technologies for providing services needed for a reliable, efficient, and competitive power system.

This paper explains how energy-storage resources currently can participate in the wholesale electricity markets and provides an overview of the characteristics and requirements to participate in various markets. For purposes of this paper, grid-scale energy-storage resources are assumed to be large enough to be able to receive and respond to economic dispatch instructions from the ISO. Smaller resources, less than one megawatt (MW), are not part of the ISO's economic dispatch but can still sell energy and capacity into the market as settlement-only resources, or alternatively, they can operate behind the customer meter, beyond the visibility of the ISO, and outside of the wholesale markets.

In New England, the existing grid-scale energy storage is in the form of pumped-storage hydropower (explained below in more detail). Two large pumped-storage hydropower facilities built in the 1970s can supply almost 2,000 MW of capacity within 10 minutes. These resources were developed to provide fast-response capability in the event that a nuclear power plant tripped off line.

The Independent Role of ISO New England

ISO New England (ISO) is independent of the participants in the wholesale markets and operates nondiscriminatory and competitive electricity markets for all types of resources. These wholesale markets are intended to provide a level playing field for all resources, and the ISO welcomes any and all technology types that can meet the specific requirements for each market. As new technologies emerge, the ISO will continue to evaluate market design and operating tools with the objective of ensuring that the needs of the system are met in the most efficient manner.

As the entity responsible for ensuring the reliability of the region's power grid, the ISO must have enough resources available to satisfy the real-time demand for electricity and provide backup power, or reserves, in the event that any combination of power plants or transmission lines becomes unavailable. Energy storage has played a role in helping the region meet electricity demand reliably and will continue to do so.

Storage as a Tool to Efficiently Ensure Reliability

Grid-scale electricity storage (sometimes referred to as "utility-scale" storage) can provide capacity and energy to the system by helping regional system operators meet demand when other power generating sources or imports are not available or are uneconomic. Grid-scale storage assets can also provide reserves and frequency-regulation service to grid operators. While most new storage technologies provide rapid response, they are usually relatively small and have to be recharged frequently; however, advanced technologies are being developed and tested that offer the promise of utility-scale storage options for grid operators.

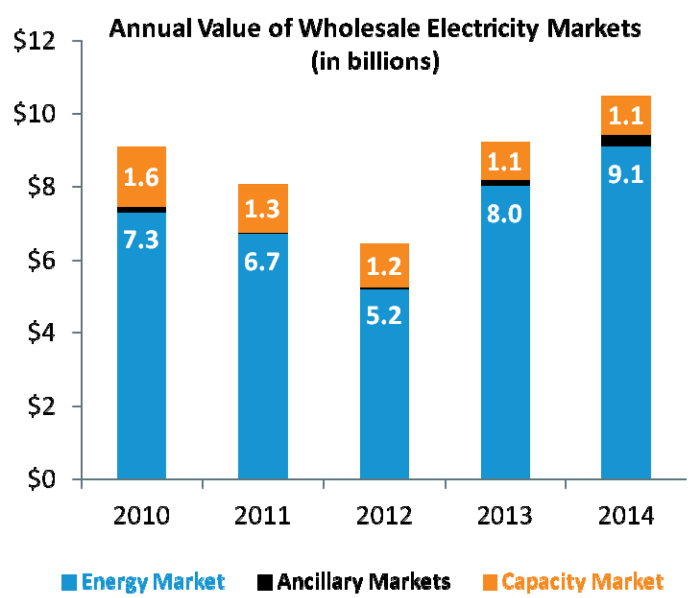
Emerging energy-storage technologies are commonly envisioned to be the resource of the future to help balance renewable energy resources, such as wind or solar power, especially as variable resources reach higher penetration levels. Today, the regional grid itself provides the flexibility to balance variable resources through a combination of energy storage from pumped-storage hydropower, the flexibility of the generation fleet to ramp up and down, and the power system's ability to move power across the region's transmission ties with neighboring power systems.

To maintain system reliability, the ISO must have visibility of discrete supply and energy-storage assets and not simply the net output of a combination of these resources. By knowing when the power being supplied to the grid is sourced from a generator or a storage device and understanding the physical characteristics of each resource, the ISO can develop more accurate production schedules for all resources participating in the wholesale market to reliably and economically meet electricity demand. Additionally, the ISO must know when storage resources are either taking power from the grid and charging or are depleting their storage and putting power onto the system.

For storage to be a useful reliability tool, the ISO will need to know the amount of power and the maximum duration and availability of every grid-scale storage device on the bulk power system so that it can optimally use these assets to meet demand reliably and at minimum cost.

New England's Comprehensive Array of Wholesale Electricity Markets

In addition to its roles as the operator of the region's high-voltage power grid and long-term system planner, the ISO is responsible for designing, administering, and overseeing the region's competitive wholesale electricity markets. This interrelated suite of markets—energy, capacity, and ancillary services—ensures the constant availability of competitively priced electricity for the region's 14 million residents and is the foundation of the region's reliable power system.



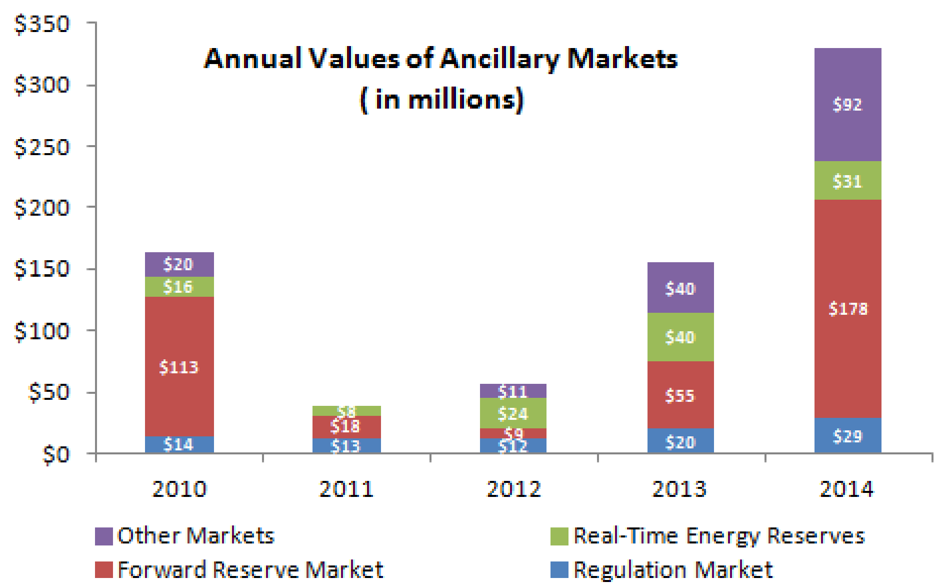
With a cumulative annual value ranging between $5 billion and $14 billion, the competitive markets represent opportunities for innovative technologies to provide the services needed for a reliable power system.

The region's major competitive wholesale electricity markets are as follows:

- *Energy Market*: The core product bought and sold in the wholesale markets is electrical energy. Power plants generate and sell electric energy into the wholesale market where competitive suppliers, utilities, and end users can purchase the power they need day ahead or in real time to serve retail demand. Some resources participating in the real-time energy market are also compensated for providing reserves—operating in a ready-to-respond state to supply electric energy or reduce demand in real time if needed to preserve system reliability.
- *Forward Capacity Market*: New England's long-term capacity market ensures that the region has sufficient resources to meet the future demand—three years into the future. The

capacity market compensates resources for their commitment to perform during stressed system conditions.

- *Regulation Market*: This market compensates resources that respond instantaneously to instructions from ISO New England to increase or decrease output to balance frequency and interchange on the regional power system.
- *Forward Reserve Market*: This market compensates resources for keeping capacity in reserve and available to provide electric energy within 10 or 30 minutes, which assures the New England system is able to withstand adverse power system events, such as large-scale and unexpected transmission or generation outages.



Energy-Storage Participation in the Wholesale Electricity Markets

Energy storage is unique because many of these technologies operate both as a supply resource and a load resource. ISO market rules offer a very flexible framework to accommodate this uniqueness; storage assets can participate in the wholesale market as a generator, load, or both.[1] A pumped-storage hydro unit, for example, is modeled as: (1) a load for when it pumps water up into the reservoir (i.e., a dispatchable-asset-related-demand [DARD] pump), and (2) a generator when it releases water through the turbines to produce electricity. Additionally, these assets can currently be represented and participate in the New England electricity markets as combinations of separate assets.[2]

The chart on the following page provides an overview of ways that energy-storage devices can participate in the regional wholesale electricity markets administered by ISO New England.

[1] The ISO currently models storage facilities as both a generator asset and a load asset; each asset must be dispatched separately and not at the same time.

[2] Storage developers considering participation in a regional wholesale market should note that these markets have varying requirements with respect to duration of output.

Options for the Participation of Energy-Storage Devices in the ISO New England Markets

When Storage Device is Supplying Electricity	Market				Size Requirements and Aggregation	
	Energy	Capacity[a]	Reserve[b]	Regulation	Maximum Output	Aggregation
Load reducer/retail supplier	Avoids paying or sells at retail cost	Capacity tag[c]	No	ATRR[d]	N/A	N/A
Settlement-only generator	Real-time wholesale price taker	Yes	No	ATRR[d]	<5 MW	N/A
Generator	Real-time and day-ahead wholesale price setter	Yes	Yes	Yes[e]	≥1 MW	Case by case, per OP 14[f]
When Storage Device is Consuming Electricity	**Market**				**Size Requirements and Aggregation**	
	Energy	**Capacity**	**Reserve**	**Regulation**	**Size**	**Aggregation**
Retail load	Retail price payer	Capacity tag[c]	No	ATRR[d]	N/A	N/A
Asset-related-demand (ARD)	Real-time and day-ahead wholesale price payer	Capacity tag[c, g]	No	ATRR[d]	≥1 MW	Yes
Dispatchable-asset-related demand (DARD)	Real-time and day-ahead wholesale price setter	Adjusted capacity tag[c, g, h]	Yes[b]	Yes	≥1 MW	Yes
Demand Response	**Energy**	**Capacity**	**Reserve**	**Regulation**	**Size**	**Aggregation**
Demand-response resource (DRR)[i]	Real-time and day-ahead wholesale price setter	Yes	Yes[b]	ATRR[d]	≥100 kW	Yes[j]

(a) Developers seeking to participate in the capacity market should refer to the FCM participation guide at http://www.iso-ne.com/markets-operations/markets/forward-capacity-market/fcm-participation-guide.

(b) NERC requires 1-hour sustainability to provide operating reserves.

(c) A capacity tag is the energy consumption of an individual customer or group of customers represented as a percentage of total New England energy consumption during the hour of the annual system coincident peak in the year prior to the capacity commitment period. Capacity tags are used to allocate FCM costs (e.g., a group of customers with a 5% capacity tag will be allocated 5% of total FCM cost).

(d) ATTR refers to an alternative-technology regulation resource, which can consist of an aggregation of sites across the system that sums to at least 1 MW.

(e) A generator must be 10 MW or greater to provide regulation service.

(f) OP 14 refers to the ISO's Operating Procedure #14, *Technical Requirements for Generators, Demand Resources, Asset-Related Demands, and Alternative-Technology Regulation Resources* (November 16, 2015), http://www.iso-ne.com/static-assets/documents/rules_proceds/operating/isone/op14/op14_rto_final.pdf.

(g) The capacity tag is zero for ARDs and DARDs exclusively related to ATRRs following automatic generation control (AGC) dispatch instructions.

(h) A DARD's capacity tag will be set to a minimum consumption limit (firm load), which would be zero for a storage asset.

(i) The full implementation of demand response into the energy market is scheduled for June 1, 2018; however, a legal case is pending before the United States Supreme Court (EPSA v. FERC) pertaining to demand-response participation in the wholesale energy market (see http://www.justice.gov/sites/default/files/osg/briefs/2015/01/28/ferc_v._epsa_app.pdf).

(j) DRRs allow for aggregation, except for an individual facility providing ≥5 MW. A single facility providing ≥5 MW can be a DRR, but it must participate individually and cannot be aggregated with others.

How Certain Categories of Storage Devices Are Participating in Regional Wholesale Markets

Below is a general description of some storage technologies and the opportunities for these resources to participate in the regional wholesale electricity markets. This is not an all-inclusive list of storage technologies.

Large-Scale Pumped-Storage Hydro

New England has two large pumped-storage hydro power facilities that can quickly start, stop, or ramp up or down and maintain output and loading levels. These resources represent about 5% of the region's installed generating capacity—and can be at full output from an off-line state usually within 10 minutes. Electricity is used to pump water up to a reservoir on top of a mountain. When power is needed on the grid, the water in the reservoir is released down the mountain through a penstock and flows through turbines that generate electricity.

Generally, these facilities use electricity from the grid when prices are low to pump water up to the reservoir and then release the water and generate electricity when prices are high or when electricity is needed quickly to respond to sudden changes in system conditions. When prices are low again, the water is pumped back up the mountain, refilling the reservoir so that water is available in storage to be used for power generation. Pumped-storage facilities are extremely flexible, robust, and quick-responding resources that can participate in the energy, capacity, reserve, and regulation markets. In terms of grid operation, large-scale pumped-storage can provide various wholesale products for a sustained period.

Flywheels

In a flywheel device, a motor draws energy from the grid to accelerate a rotating flywheel and store kinetic energy. When the grid needs short-term back-up power, the flywheel can become a supply resource. Inertia allows the rotor to continue spinning, and the stored kinetic energy is converted to electricity and discharged back to the power grid. Flywheels can respond quickly to system needs, but the largest facilities to date are still relatively small and cannot sustain output or loading for long durations.

Flywheels can be connected directly to the high-voltage transmission system and can participate in the wholesale energy, capacity, and regulation markets. For example, for almost a decade, a flywheel system provided frequency regulation through a pilot project for the New England system and was compensated through the regional wholesale markets.

Batteries

A battery facility uses electricity from the grid to charge and store energy and can supply power back onto the grid by discharging its batteries. Battery facilities can respond quickly to a grid operator's instructions, and can balance variations in demand to regulate power system frequency. However, the output or loading cannot be sustained for long durations.

Batteries have the potential to operate in many different configurations, including being in front of or behind the meter. Depending on their configuration, batteries can participate in the energy market, which co-optimizes reserves in real-time, and the forward-reserve, capacity, and regulation markets.

Compressed Air

Electricity is used to compress air and store it underground or in tanks. In a typical configuration, the compressed air is released and mixed with natural gas into a combustion turbine, which increases the efficiency of the generator. Similar to the water associated with a pumped-storage hydropower resource, the air is compressed and stored when electricity prices are low and is generally released and included in the combustion process at times of high electricity prices. An advantage of compressed air and pumped-storage hydro is that due to their ability to store large amounts of energy, they typically use less-expensive power when demand is low and generate electricity during times of high demand when electricity prices are highest.

These resources can participate in the energy, capacity, reserves, and regulation markets. They also can be a demand-side asset to lower energy bills and reduce future capacity charges by lowering peak demand for the end-use customer.

Electric Vehicles

Another storage technology utilizes the batteries of electric and plug-in hybrid electric vehicles. When connected to the grid, electric vehicles can provide regulation service by modulating their charging and discharging patterns. Owners of these vehicles can charge their batteries for transportation usage when electricity prices are low and can provide power to the grid during peak demand periods. These devices can be connected directly to the grid and can participate in wholesale markets, or they can be behind the end-user's meter, helping the customer lower retail bills and lower peak demand and, in the process, mitigate future capacity costs.

Other Requirements and Procedures

While storage devices can participate in the wholesale markets, they must adhere to other requirements and procedures to participate in the markets. Certain processes set out in the ISO's governing documents may be triggered to establish the appropriate interconnection and transmission services depending on the storage technology type.

Interconnection and transmission service requirements are a function of the location to which a storage device will be interconnected (i.e., in front of or behind the meter), how it will operate (i.e., supply, load) and how it plans to participate in the markets (i.e., generator, load, or both).

Interconnection Procedures

ISO New England's *Open-Access Transmission Tariff* (OATT) sets out the processes for interconnecting generating facilities (devices for production or storage for later injection of electricity) to the regional transmission system.[3] Schedule 22 of the tariff contains the interconnection requirements for large generating facilities greater than 20 MW. Schedule 23 contains the interconnection requirements for smaller facilities 20 MW or less. The interconnection process has four key phases, including the interconnection request phase, interconnection studies phase, interconnection agreement phase, and the construction and commercialization phase.

Not all generator interconnections are subject to either Schedule 22 or 23. Generator interconnections not subject to these sections of the tariff are instead subject to applicable state

[3] The ISO's OATT is Section II of its *Transmission, Markets, and Services Tariff*. The OATT is available at http://www.iso-ne.com/participate/rules-procedures/tariff/oatt.

tariffs, rules, or procedures regarding generator interconnections administered by the electric distribution companies.

In addition to the interconnection procedures, generator additions and modifications are subject to review under Section I.3.9 of the ISO's *Transmission, Markets, and Services Tariff*.[4] Section I.3.9 sets out the process for reviewing additions and modifications to the system to ensure that the changes do not have an adverse impact on the regional power system administered by the ISO.

Transmission Service

Storage technologies operating and registering as load may need to request regional or local transmission service, depending on the type of facility to which it is interconnecting. The ISO administers regional transmission service for use of the regional bulk power system comprising transmission with voltages of 115 kilovolts (kV) or above.

Contact the ISO

While this paper provides an overview of available markets for storage, it is important that developers of storage devices talk directly with the ISO to gain further information and understanding about the operational and market requirements, as well as potential opportunities, for participating in the ISO's wholesale electricity markets.

[4] The ISO's *Transmission, Markets, and Services Tariff* is available at http://www.iso-ne.com/participate/rules-procedures/tariff.